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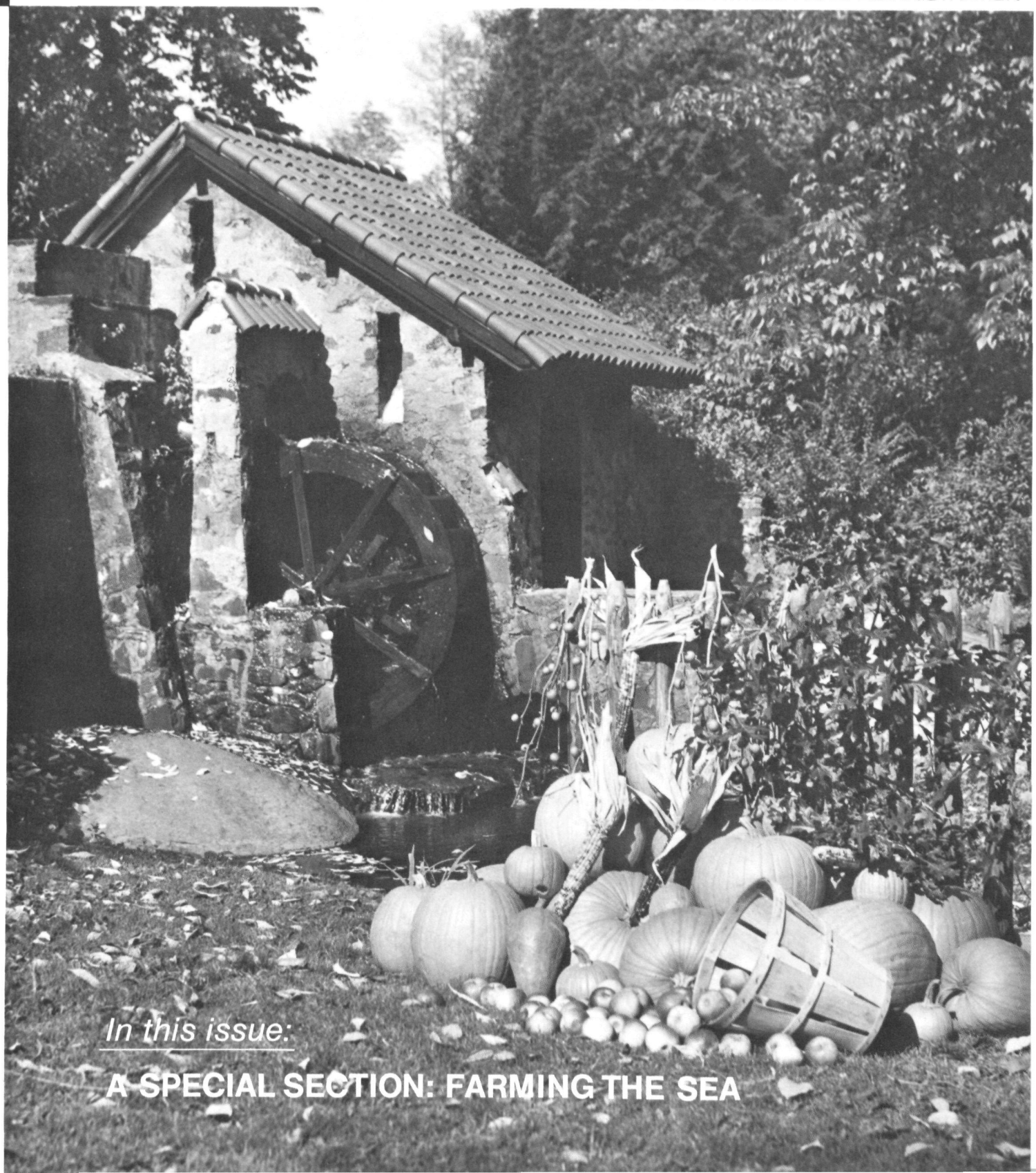

In this issue:

A SPECIAL SECTION: FARMING THE SEA

VOLUME 1
NUMBER 4

National Oceanic and Atmospheric Administration

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OCTOBER 1971
VOLUME 1 NUMBER 4

page

3. Editorial: A Coming of Age

AQUACULTURE SECTION

4. Ocean Harvests: Promise and Practicality
8. Oysters in 3-D
12. Shrimp Cocktail
15. Those Versatile Weeds From the Sea
20. Salmon—Pride of the Columbia
24. Four Thousand Years of Fishing
26. The Sterling Seal
30. The Wilkes Expedition
35. Gold Mine of Game Fish
38. Man on the Move
40. Inside Hail Alley
44. One Less Victim
46. A Feminine First
48. Ice: Traffic Stopper
52. Drought: The Land Killer
57. And Other Fish Stories
60. Where the Sea Really Begins
63. Holiday Hors D'Oeuvres
66. News From NOAA

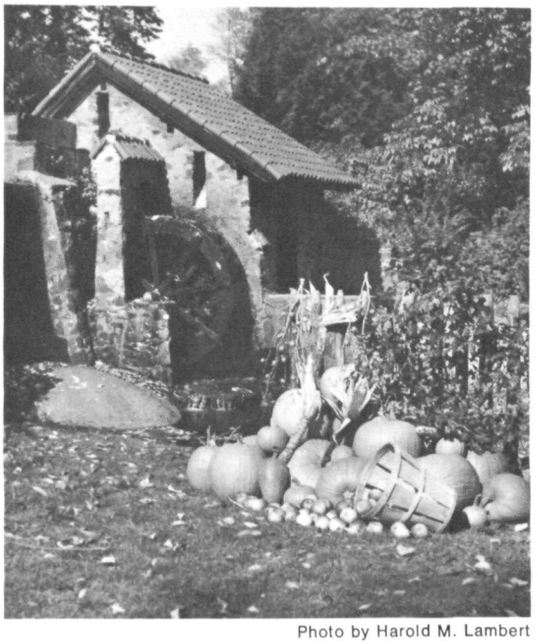

Photo by Harold M. Lambert

COVER

Autumn's harvest by the old mill stream.

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A Coming Of Age

DAVID H. WALLACE
ASSOCIATE ADMINISTRATOR
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While aquaculture has been practiced for centuries in many parts of the world, the large scale culture of aquatic animals in the United States has been confined to a few species. Shellfish have been farmed for over a hundred years in various parts of the United States. This culture has been based on utilization of marine underwater lands, either leased or privately held for the purpose of shellfish culture. The concept of private ownership of living organisms was relatively simple for oysters and clams because of their sedentary habits. This is different for fin fish and crustaceans, which often must make extensive migrations in carrying out their life cycle.

Aquaculture is now coming of age. Fresh water farming for a number of species has been perfected. Commercial fish farming is practiced effectively in the United States on a large scale for fresh water trout and catfish.

We must devote some of our energies toward sea farming in the years to come. Aquaculture has not advanced as rapidly because of the complexities of the life histories of many of the marine species. The physical, chemical and biological life requirement change drastically at each stage of development of many marine organisms from the time of spawning until the species is ready to be marketed.

Research findings are beginning to clarify the techniques necessary to cultivate such diverse species as oysters, shrimp, and salmon. The major thrust over the next several years must be to perfect our methods and to convert them into a closed system, where all factors can be controlled. In this way we can have the maximum benefits from selective breeding, predator and disease control and systematized feeding. The role of government should be to carry out the research and development on key marine species to know and understand these components. Much of this kind of research has already been carried out on mollusks by the National Marine Fisheries Service, which is now studying other species such as the shrimp. The establishment of the Sea Grant Program with a mandate to further aquaculture is already stimulating major research and development programs on all our coasts by the academic community. It becomes necessary to perfect procedures to put the new and old information together on a pilot plant demonstration basis so that the total system can be used and further developed by the private sector.

At the point when techniques have been proven for a given species the government must remove itself and encourage private enterprise to produce the commercial products. It is increasingly evident that the fisheries resources of the high seas are not unlimited or inexhaustible. If man is to meet his protein needs over the next three decades we must take the necessary technological steps now to make this possible. Aquaculture offers a major potential mechanism to produce high quality protein on a large scale to assist in meeting this obvious future need.

We cannot depend upon reproduction and growth of wild stocks for sustained production of great quantities of seafood from our water. The fluctuations in the natural environment are reflected in wide fluctuations in abundance of the species desirable for man. When we superimpose the other important uses of our estuaries which have already reduced the biological productive capacity of these waters, it becomes evident that we must modify our management techniques. Aquaculture in this context offers great promise both inshore and in the open sea. Floating and fixed platforms must be studied, evaluated and developed. Most private companies cannot afford the research and development costs involved in this concept. Government, both state and federal, must become a working partner, to move from harvesting of the wild crops in the marine waters to growing and producing domesticated animals. Aquaculture is at about the stage of development to which agriculture had evolved at the turn of the century. Research and development in agriculture enabled this country to become one of the best fed nations of the world, even with a rapidly expanding population. It is the opportunity for aquaculture to help fill a growing need for additional food over the next 30 years.

A DISTINGUISHED EXPERT TAKES A HARD, REALISTIC LOOK AT

OCEAN HARVESTS: PROMISE AND PRACTICALITY

BY C. P. IDYLL

One of the brightest and most widely held hopes is that mankind is about to emerge from a period of primitive hunting in gathering food from the sea, and to embark on a new world of fish cultivation. The idea of sea farming or "aquaculture" has quickened the imagination of the public generally and led to rosy expectations. Many of these are unlikely to be fulfilled. Sea farming probably will never replace fishing in the same way that land farming replaced hunting.

Nonetheless, aquaculture deserves to be pursued vigorously. Most parts of the world are short of food, and a large proportion of the world's population is hungry. Presently only about three percent of the calories and twelve to thirteen percent of the animal protein consumed by humans come from the sea. Considerably more food can be taken from the ocean, but for biological, technical, and economic reasons there is a definite upper limit to this quantity. For many years to come, sea farming probably will not be able to produce the large quantities of food needed to alleviate world hunger. However, the seafoods in shortest supply are those that are most highly valued, and the culture of these can be profitable.

Aquaculture is characterized by four general types of activity. The first is the old-fashioned hatchery, where large numbers of young are raised from the egg to yolksac fry or somewhat later stages, and then released to the sea with the expectation that they will increase the size of the natural population and of the commercial catch. This expectation has almost never been fulfilled. The only exception in the United States is the culture of coho and Chinook salmon in the Columbia River, as discussed in William J. McNeil's article in this special section.

The second kind of activity involves the capture of young and their transplantation to enclosures. Here they may be allowed to fend for themselves, supplemental food may be added, or the water fertilized so that natural food is increased. Most Southeast Asian aquaculture operations are variations of this type; so are the Italian *valli*, and attempts at pompano culture in the United States.

Third is production of the young from eggs and their retention in enclosures until they reach marketable size. Japanese and United States shrimp culture are examples.

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The last and most sophisticated kind of activity involves the full control of the life history of the animal. Eggs are hatched, the young are raised in ponds or enclosures, and the juveniles and older stages are fed until they reach marketable size. Brood stock is maintained by the farmer so that he has complete control of the life cycle. Only trout and catfish culture are at this level in the United States; no marine culture has reached this level here.

Some statistics of aquacultural production are dazzling. For example, it is said that an area the size of Long Island could produce three times as much mussel meat as the entire world catch of fish, if the waters were ecologically suitable. A land farmer can produce 100 pounds of beef cattle per acre on very good pasture land, while a sea farmer can produce 100 tons of shellfish on a good acre of estuary. These figures are true reflections of shallow-sea productivity, but extrapolations should be made with great caution. There are many physical, biological, and social limitations on the areas of the ocean where sea farming can take place, and biological and economic limitations on the kinds and quantities of animals that can be raised.

Only a relatively small fraction of the land area of the earth is suitable for agriculture since a great proportion is either infertile, too rocky, too cold, too steep, or otherwise unproductive. An even greater proportion of the ocean is unsuitable for aquaculture. The open ocean is relatively unproductive, is too unmanageable an environment, and is beset with knotty problems of ownership. It is unlikely that aquaculture can ever be conducted beyond the continental shelves and the total shelf area constitutes only about three percent of the ocean's surface. In most cases, it will only be possible to farm the shallower areas, probably those less than 100 feet deep. Nor are all shorelines available to the water farmer. Many are too rocky or are in cold climates. Thus, perhaps one or two percent of the ocean area is suitable and practical for sea farms.

There are also severe limitations as to the kinds of crops that can be raised in sea farms. In the first place, we can virtually eliminate the possibility of raising plants. There are no marine equivalents of wheat, corn, apples, or potatoes; the number of species of rooted plants in the sea is extremely small, and even this tiny number produce no edible grains, roots or tubers. The edible plants in the sea—the seaweeds—are equivalent to lettuce, cabbage, and the other leafy vegetables which form a minor part of our diet. And compared to lettuce and cabbage, the seaweeds are relatively unnutritious. The Japanese harvest of wild seaweed and their culture of certain favorite kinds, like *nori*, are based more on tradition than on nutrition. Seaweed aquaculture, important for reasons other than as a food source, is discussed in Robert Wildman's article in this section.

Several characteristics make marine animals suitable for farming: the animal should be capable of being raised from the egg through all its stages, and maintained in captivity until it can be harvested; the animal should be fast growing, on cheap and abundant food, preferably of plant origin; it should be possible to maintain a brood stock in captivity; the animal should be resistant to disease, parasites, and unfavorable environmental conditions; and it should have a high market value. Unfortunately, very few marine animals exhibit all or most of these characteristics. Most of the open ocean fishes—such as tuna, mackerel, and herring—require enormous quantities of food and a great deal of ocean for maneuvering. They probably could not be raised in aquatic farms, no matter how large.

Animals now being raised on aquatic farms either commercially or experimentally include oysters, salmon, trout, clams, pompano, and shrimp. All of these share one of the characteristics listed above—high value on the market. Any animal which is to be raised profitably on a commercial basis must bring in a high unit return. This fact has great significance since for the moment at least, and perhaps for many years in the future, aquaculture will be limited to production of high-priced foods for the luxury market.

While the present level of interest in aquaculture is recent, this activity has ancient roots. (A subsequent article reviews this long history.) Today, many countries including the USSR, the United Kingdom, Japan, Korea, Israel, and Taiwan are supporting active programs of research. In the United States, a considerable number of government and other laboratories are working on culture of fish and invertebrates. For example, NOAA's National Sea Grant Program sponsors research at institutions on every coast, frequently in close cooperation with work at National Marine Fisheries Service laboratories.

In general, fresh-water animals seem easier to manipulate than marine animals, and their environment easier to control. In the United States, the commercial culture of trout, catfish, and bait-fishes supports sizable industries. The 1970 pond production of catfish was expected to exceed the quantity caught from the wild by about

continued

four times, and extraordinary quantities of trout can be produced per unit of water where the conditions are suitable.

Milkfish are raised in brackish ponds and enclosures in many southeastern Asian countries, and mussels are raised in large quantities in Spain, Portugal, and other places. Yellowtail are raised in Japan in mesh cages, and in 1968 more than 27,000 tons of this species were cultivated for market. The list of animals under study in Japan includes shrimp, lobsters, clams, abalone, scallops, pompano, plaice, and other species. None of these animals can be said to be in commercial production there, except on a small scale.

In brackish water, oysters have been raised for centuries and in the United States this is the only marine species under extensive and profitable culture. The advantage of culture compared with the harvest of wild stocks is well illustrated by oysters. The 185,000 acres of leased cultivated grounds produced the same amount of oyster meat as the four million acres of uncultivated public grounds. William Shaw describes oyster culture work in a separate article.

Interest in raising shrimp is very high in the United States, and shrimp culture research is discussed in another article by Albert Sparks.

Considerable interest has also been shown in the possibility of raising pompano commercially, because this species grows rapidly in captivity, especially in cages suspended in the water. Several attempts have been made, but few pompano have been sold and no industry exists. The chief obstacle is that pompano cannot yet be raised from the egg on a large scale, and commercial operations must depend on the capture of young animals in the sea. Supplies of young fish are unpredictable and the State of Florida, where most of these exist, has placed severe limitation on the quantities that can be taken and the places they can be caught.

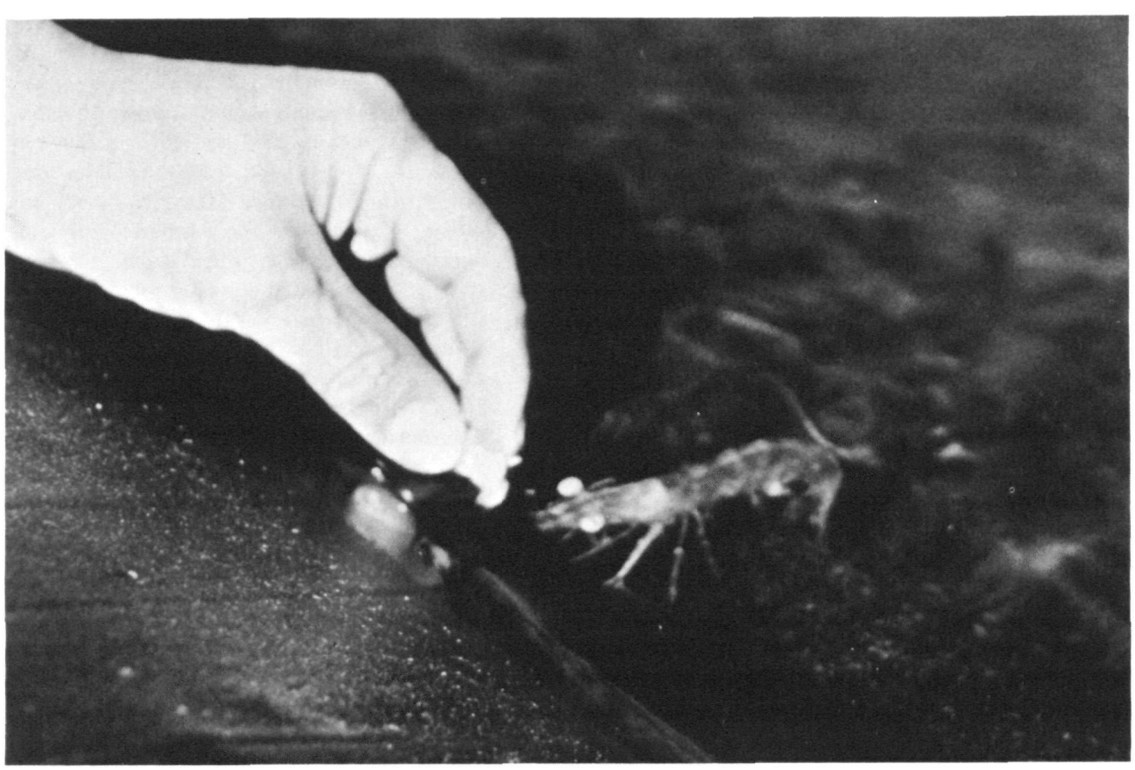
For over 80 years, attempts have been made to raise northern lobster in hatcheries, and more recently there has been the same kind of interest in the spiny lobster. Around the turn of the century, 20 hatcheries in Europe and the United States turned out northern lobster larvae for release in the sea. It was subsequently established that this was ineffective in increasing the catch. More recently, attempts have been made to maintain lobsters until they are of marketable size. At the moment, this seems to be unfeasible because of the long life of these animals—five to seven years—which makes their culture expensive in manpower and food. Furthermore, they are cannibalistic and the expense of isolating them is high. The problem with spiny lobster is even more difficult. They go through a long series of larval stages in the open sea, and the problems of duplicating their environment and the food that they require are so formidable that no one as yet has been able to bring them through their larval stages in captivity. Altogether the prospects of raising lobsters commercially are not promising.

In Great Britain and elsewhere, plaice and other flatfish have been raised successfully in the laboratory and small numbers have been carried through to marketable size. The cost of the latter operation is extremely high and economic possibilities are not good at the moment. This is partly because these animals are carnivorous and so far attempts to substitute plant food for animal food have been unsuccessful. Furthermore, artificially raised flatfish exhibit a number of debilitating abnormalities. Trials have been made to increase the wild populations with hatchery-raised plaice, but the number capable of being released are so small as to have no useful effect.

Clams, abalones, and scallops can be raised in the laboratory from the egg to juveniles. In Japan, this work has progressed considerably and in the United States *Venus* clams can be produced in large numbers up to plantable size. So far, no industry has developed from this clam culture.

It is clear, then, that not all the high expectations of marine aquaculture have been fulfilled. Many people are now disenchanted about the possibilities of establishing profitable industries. Yet it is no mystery why it has taken so long in man's history to achieve success in aquaculture. Sea farming is harder and more complicated than land farming. We still lack many of the answers which are necessary on the biological, engineering, and social levels. The Food and Agriculture Organization of the United Nations estimates that, even with the present level of technology, production by aquaculture could be increased between three and five times from the present four million tons, and greater knowledge could increase production fifteen to twenty times.

This new knowledge can only come from research. A long list of problems awaits



Shrimp takes food from the hand of a fisheries biologist in a demonstration at the University of Miami. The university maintains a major shrimp aquaculture research project with support from NOAA's Sea Grant program. Univ. of Miami photo.

attack by biologists, engineers, and social scientists. Substantial progress in even a few of these could mean considerable increases in the production of our waters.

—Studies of the biology and ecology of cultured organisms.

This research is basic to successful development of aquaculture, since it is only through full understanding of the life cycle and the environmental requirements of the cultured organisms that their reproduction and growth can be manipulated. Many aquatic animals have complicated life histories and subtle environmental requirements. Many failures in aquaculture have resulted from ignorance of these complexly interacting factors. Experiments are required on temperature, salinity, turbidity, and all other influences on the well-being of the animals.

—The search for additional species suitable for commercial culture.

Few species of aquatic animals possess the theoretical optimum characteristics listed earlier. But, of the thousands of land animals, very few have proved to be suitable for ranching or culture, so we should not be discouraged that small numbers of marine animals seem suitable. Those that are should be found.

—Development of suitable food, and research on the nutrition of cultured animals.

Many of the natural foods—such as scrap fish, squids, and ground clams—commonly used at the present are not satisfactory because they are hard to handle, or are scarce and expensive; the dependence on *Artemia* brine shrimp for feeding of young stages of many animals is another bottleneck. Substitutes for all of these are urgently required. Considerable progress has been made in developing pelletized foods, and the use of cheap materials such as fish meal, supplemented by vitamins and other nutrients, appears promising. Binding materials for the pellets constitute a high proportion of the cost, and fully satisfactory binders have yet to be found. If cheap plant food can be modified and substituted for more expensive and scarce animal proteins, this step alone might make some aquaculture operations move to the profit side.

—Studies in the economics of feeding and handling.

The cost of labor for maintaining fish and other animals is a principal deterrent to profitable operation. Some animals perhaps must be fed at frequent intervals in order to maintain proper growth, but it may turn out that a single feeding in a day will give similar results, with considerable saving in labor costs. Development of automatic and demand feeders could result in savings. The labor involved in shifting animals from one place to another and in harvesting them should also come under study. The technological skills of United States industry offer one of the principal hopes in reducing costs of aquaculture.

—Studies of the physiology of maturation and spawning.

Profits are made in some parts of the world in aquaculture operations where supplies of eggs and young are dependent on the wild stocks, but this sacrifices a principal advantage of aquaculture over fishing, which is to bypass the vagaries of nature. Intensive research is required on the physiology of reproduction and on manipulations by which it is possible to control and induce maturation. Intramuscular injections of pituitary and other hormones offer great promise for many species. Reproduction of animals is often impaired in captivity; this effect and its control requires intensive study. Only when the full life history is under control are genetic studies possible. When this has been achieved, selection for fast growth, good food conversion, hardiness, and many other desirable characteristics will be possible; hybridization may also be achieved.

—Pathology of cultured organisms.

The intensity and incidence of diseases increase markedly when animals are enclosed, and problems are intensified as densities increase. Since profitable aquaculture is unlikely except under high density conditions, much better understanding of the diseases and parasites of cultured animals must be obtained, followed by development of control methods.

—Studies of the behavior of cultured animals.

Many animals exhibit feeding rhythms which may be associated with light changes, temperature changes, or other diurnal or seasonal variations in the environment. Understanding them can be a strong advantage to the fish farmer. The kinds of food depend partly on feeding behavior. Some animals, such as eels, prefer to tear pieces off large chunks of food on the bottom; others pick up small items from the bottom or snatch their food in mid-water; still others (like yellowtails) prefer to take it at the surface. Studies of the effects of crowding are also necessary. Trout and other fishes are happy in crowded conditions and are not affected when they touch each other, but shrimp seem to stop feeding when they touch another animal. They may not resume feeding for an appreciable period of time, and growth therefore may be slowed down. In Japan and the United States, trout have been conditioned to come from considerable distances and to feed at the sound of a buzzer. This suggests the possibility of maintaining populations of fish even without cages or other enclosures if they have been suitably conditioned.

—Studies of enclosures and their management.

Cages promise to be better than ponds for some species, but size, shape, and materials need study. We have little information on the chemical and physical changes that take place in ponds that are fertilized, nor do we understand yet the best ways of supplying oxygen. Predator and competitor control is also required. For many species, it is still unclear what kinds of enclosure are most suitable. In Japan, the use of net cages has been highly successful with yellowtails, and cages are also useful for trout and other species of fish.

—Engineering studies.

Research is needed in the design and construction of ponds and other enclosures. The supply and movement of water is a major problem in successful aquaculture, and the cost of power to move water and to supply oxidation has made some culture operations in Japan and elsewhere unprofitable. The high cost of construction of ponds has been another deterrent.

—Studies of the use of heated effluents.

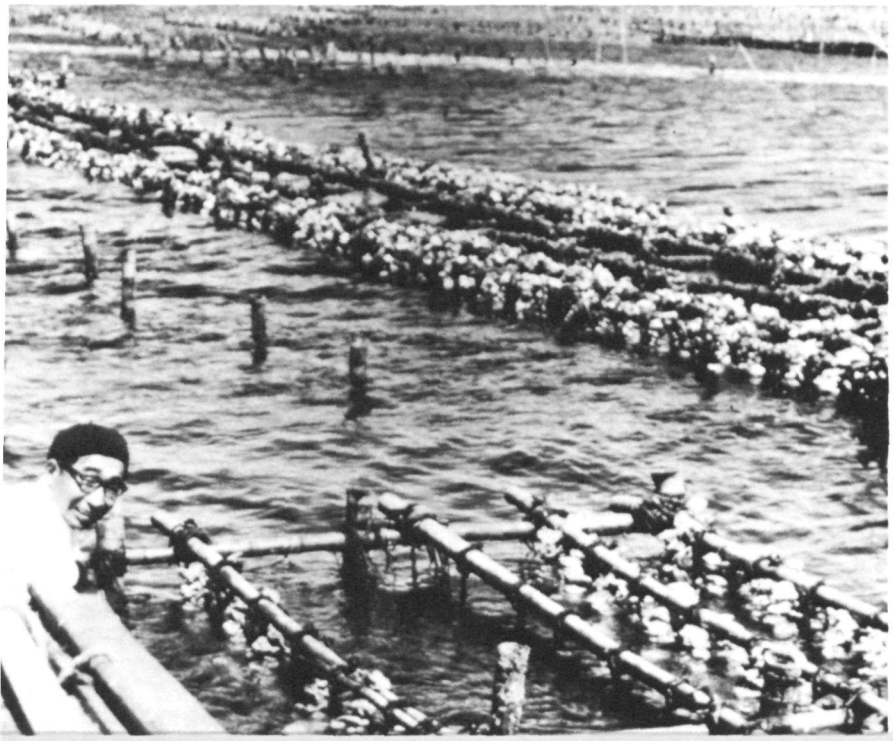
One of the attractive aspects of aquaculture is the possibility of making use of heated effluents from power plants and other industrial operations. It is inevitable that additional fossil fuel and nuclear power plants will be built over the whole coastline of the United States and elsewhere and the linking of these with aquaculture will have great social value.

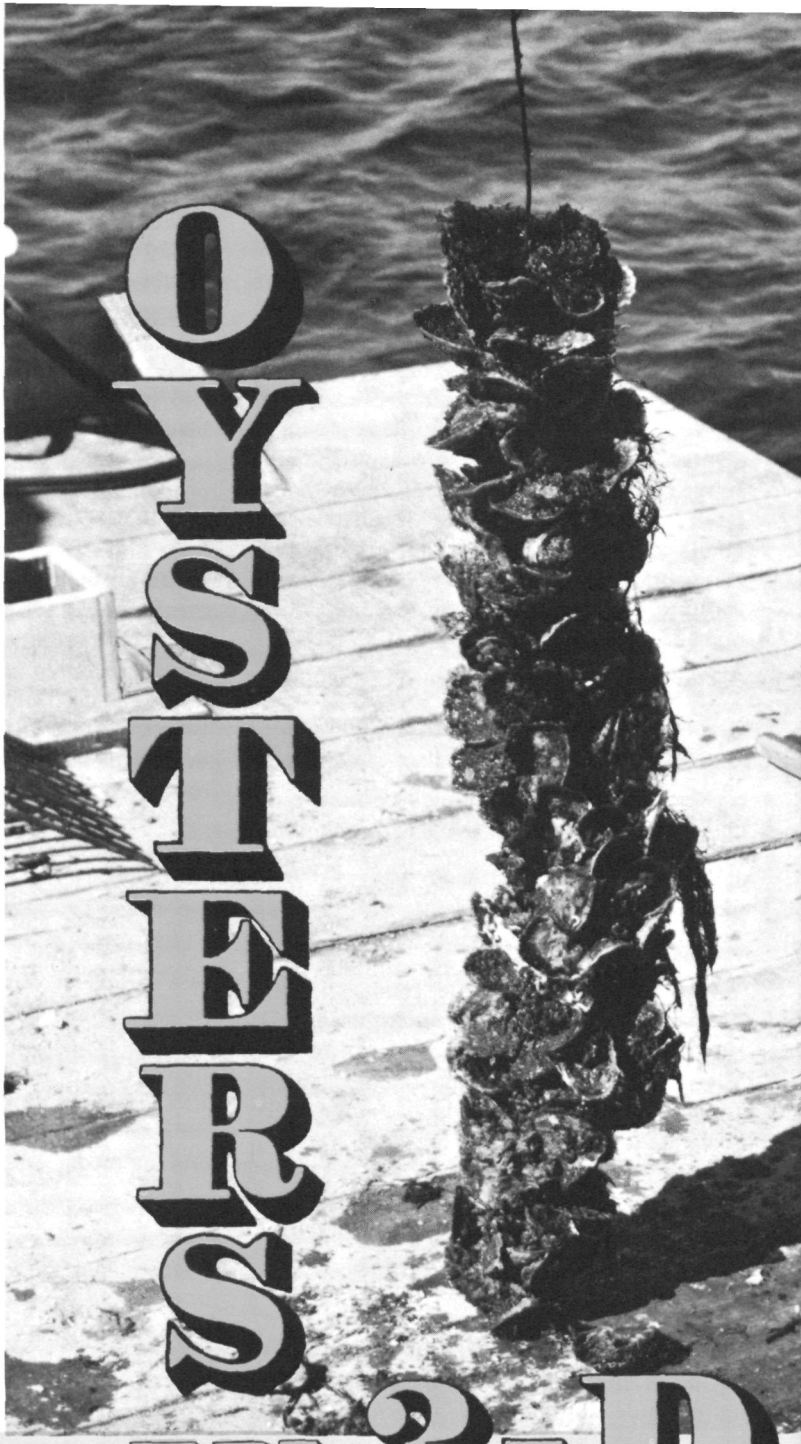
—Legal, social, and political research.

Even after all the technical and biological problems have been solved, the fish farmer sometimes faces insurmountable barriers because of social and political resistance to his activities. Edge-of-the-sea areas are highly prized, and the aquatic farmer finds himself competing with pleasure boaters, swimmers, water skiers, sport and commercial fishermen, oil and other mineral explorers, and those who seek a place to dump wastes. The fierce competition for water areas, the high cost of land at the edge of the sea, and the lack of ownership of water areas pose even greater deterrents to the development of aquaculture industry in the United States than do the biological problems. Vigorous research by social scientists is required, in order to find methods of reconciling these conflicting demands.

Formidable biological, technological, engineering, legal, and social problems still must be solved before aquaculture can become a viable industry in the United States. Yet the potential for development of profitable business and for an increase in the amount of food from the sea is great enough to justify considerable activity in commercial culture of aquatic animals. □

FARMING THE SEA





OYSTERS IN 3-D

These delicacies live in a state of suspense

BY WILLIAM N. SHAW

LANDINGS OF OYSTERS in the United States have dropped from 85 thousand tons of meat in the late 1800's to about 26 thousand tons in 1970. There are many causes for this decline but the chief one is that oysters are still hunted, not farmed.

Effective farming techniques can considerably increase oyster production. The Japanese have demonstrated this in their refinement of oyster farming. Prior to 1930, the majority of oysters in Japan were grown on the bottom and annual production was less than two thousand tons of meat. In the early 1930's, they began off-bottom or "three-dimensional" oyster culture, and it proved outstandingly successful. Today almost all of the oysters in Japan are grown in this manner, and production in 1968 was close to 41 thousand tons of meat.

Atlantic seaboard oyster farming has traditionally been two-dimensional—oysters are grown on the flat sea bottom. The best yields of oyster meats under these conditions, are approximately

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two tons per acre per year. Using their 3-D methods, the Japanese achieve up to 23.3 tons of oyster meats per acre per year.

Recognizing the Japanese achievement, the former Bureau of Commercial Fisheries in 1956 began studies at Cape Cod, Mass., on the commercial feasibility of growing oysters suspended from rafts. It was found that oysters suspended from rafts grew about twice as fast as oysters growing on the bottom. Marketable oysters were obtained in two and a half years; normally wild, bottom grown oysters take from four to five years to reach market size. This experiment also demonstrated that raft culture was commercially feasible in Massachusetts. At the time of the study, oysters sold for $11.50 per bushel. Today, oysters in the same area are worth up to $21.00 per bushel, so commercial feasibility is greater now than at the time of the study.

Three-dimensional oyster culture, originated by the Japanese in the 1930's, proved outstandingly successful. Recognizing the Japanese achievement, the Fisheries Service began studying this method in 1956 at Cape Cod, Mass.

(Opposite page, left) Racks of shells used in Matsushima Bay, Japan, for catching oyster seed. Photo by Dr. Carl J. Sindermann. (Opposite page, right) A string of oysters after suspension from a raft for 18 months in the Cape Cod oyster culture experiment. (Below, left) Section of rigid structure with oyster strings attached to staples on 4x4" boards used in NMFS studies at Oxford, Md. (Below, right) Experimental rafts at the oyster culture center on Maryland's Tred Avon River. The rafts were found to be subject to wind damage.

In 1960, we began new studies in Chesapeake Bay. In Boone Creek, a tidal pond adjacent to our Oxford, Md., laboratory, we placed a 108′ by 12′ frame, topped by 4″ by 4″ boards. From the boards, we hung 1,400 strings of seed oysters, each of which held 30 spat-laden shells separated by one-inch plastic spacers.

After two years we examined the oysters, and found that: (1) oysters near the surface grew faster than those near the bottom; (2) many oysters on the bottom portion of the strings were dead—a foot-high mound of silt and fecal wastes had accumulated under the strings which smothered the oysters; (3) oysters on strings held on a horizontal plane near the surface grew faster than those on strings held on a vertical plane.

Based on these findings, we knew that ponds with limited water exchange (the ponds under study had only 1.4-foot tidal fluctuation) would be unsuitable for growing oysters off-bottom on a commercial scale.

Further tests related to the commercial feasibility of growing oysters off-bottom in Chesapeake Bay were begun in 1968, when an off-bottom oyster culture center was established on the Tred Avon River by the National Marine Fisheries Service Biological Laboratory at Oxford, Maryland. The river appeared suitable for off-bottom culture because it had good water exchange.

Three off-bottom methods were tested—long-line, rigid structure, and raft culture.

The long-line consisted of five styrofoam floats, each sandwiched between two pieces of marine plywood and enclosed with an angle-iron frame. Each pair of floats were separated by two parallel 20-foot plastic ropes. Originally, eight-foot strings (⅛″ diameter polypropylene), bearing drilled shells laden with oyster spat and separated by three-inch plastic spacers were tied to the parallel ropes at one-foot intervals. At the end of the first year, the weight of the suspended oysters was so great that the floats were nearly submerged. Therefore, it was necessary to remove every other string, thus increasing the distance between strings to two feet. The long-line was moored with three anchors at each end.

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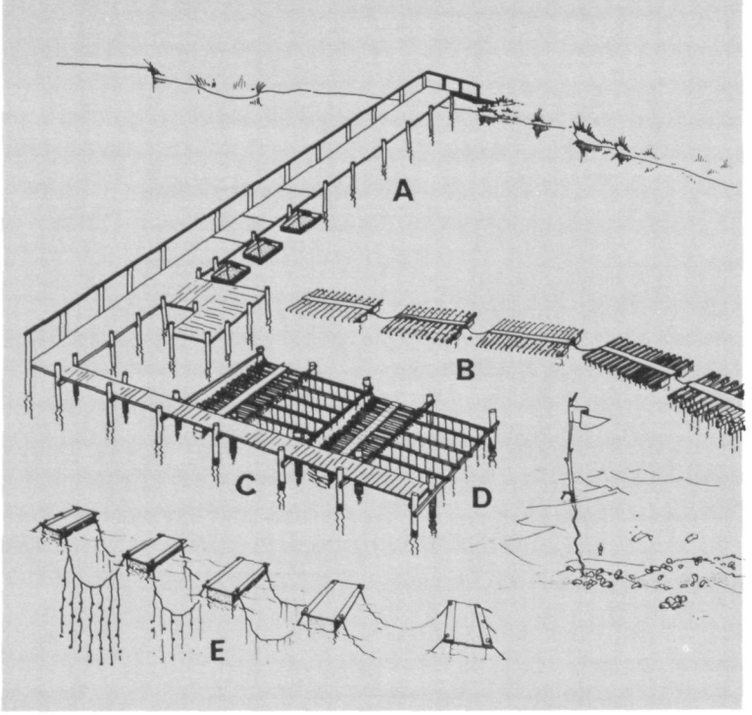
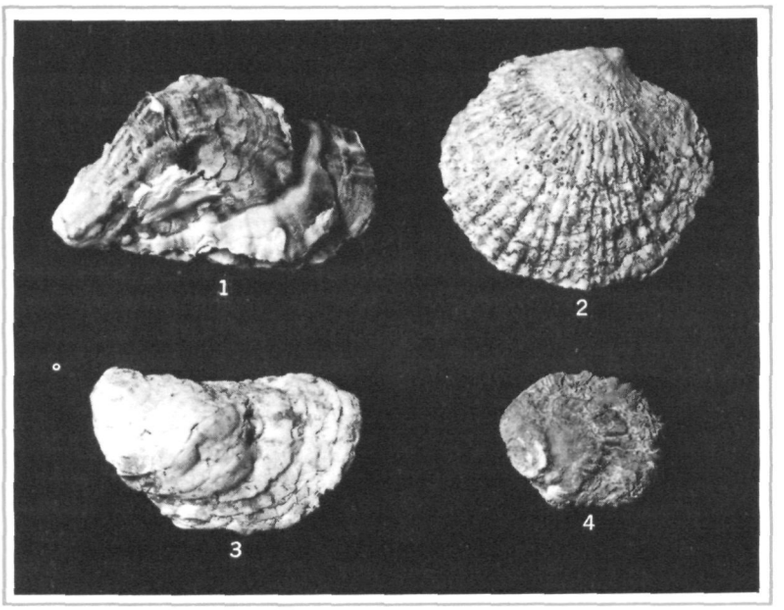
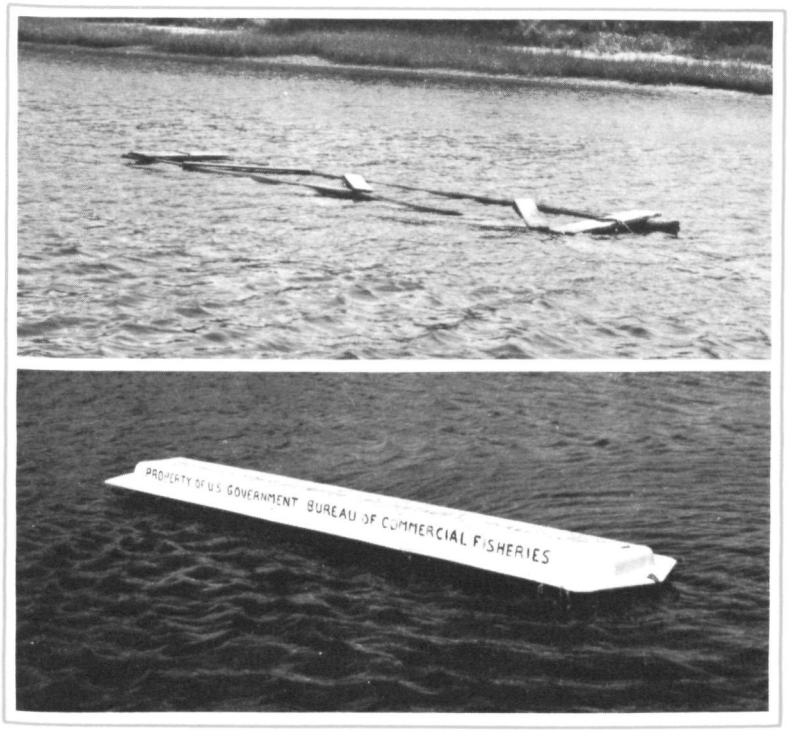


Three methods of off-bottom oyster culture have been tested by the NMFS biological laboratory in its work at the oyster culture center on the Tred Avon River. In the schematic drawing, A is the dock; B, the experimental rafts; C, rigid structure; D, strings of oysters suspended from the structure; and E, long lines suspended from floats.

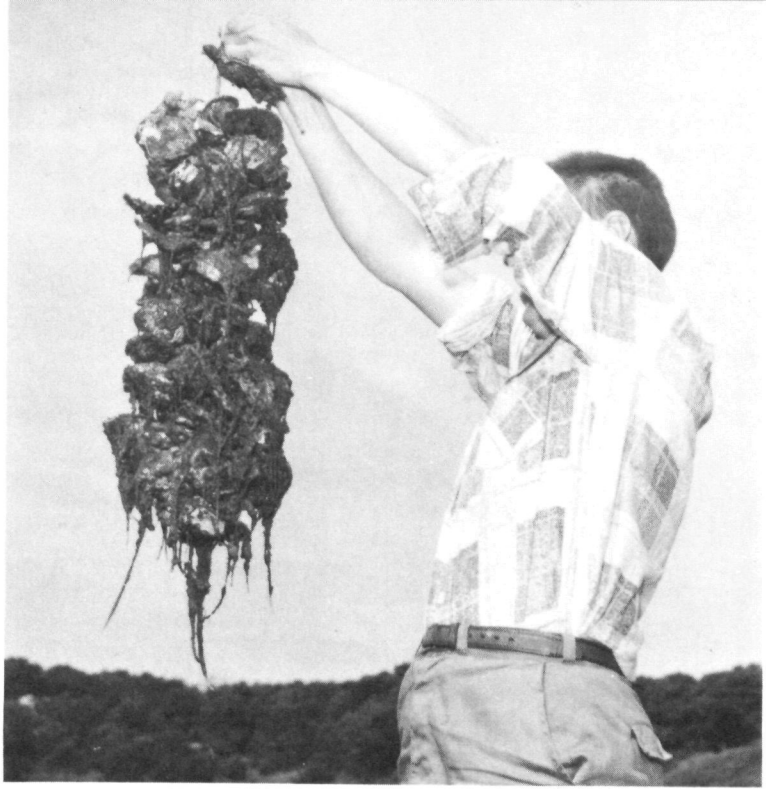


1. Japanese, or Pacific, oyster, now the principal species grown commercially on the west coast.
2. European oyster, the common oyster on the continent, which has been introduced into Maine, and is grown experimentally on the west coast. It is not yet commercially important in the United States.
3. The Eastern oyster, also known as the Chesapeake Bay oyster, Virginia oyster, and—to many children—as the "elephant's foot," is the principal commercial oyster of the U.S. east coast.
4. The Olympia oyster once was the principal species on the west coast, but population deteriorated and there is now only a small commercial fishery for this species.

Scientists checking oysters planted in a Chesapeake Bay tributary—New York Times photo.



Experimental log rafts (top) and glass-fiber rafts (below) were used in NMFS Cape Cod oyster culture tests.



String of oysters grown in experiments at Cape Cod.

The rigid structure was built at a right angle to the end of the existing laboratory dock and parallel to the 10-foot water depth at low tide. It consisted of a series of pilings 15 feet apart, joined by 2″ x 10″ boards. Resting at right angles on these boards, in every other 15-foot slot, were four 2″ x 10″ boards spaced four feet apart, with hold one foot apart, from which hung 11-foot long polypropylene ropes. Threaded on the lower 7½-feet of the ropes were spat-laden shells separated by three-inch plastic spacers.

Each raft was made of two styrofoam logs (10′ x 20′ x 9″) that were sandwiched between equal lengths of 1′ x 10′ boards. Thirteen 2′ x 4′ boards were nailed in place about a foot apart on top of the logs. Five rafts were moored on the inshore side of the structure and three rafts were moored in every other 15-foot slot in the structure. Each raft held approximately 78 seven-foot strings.

Seed oysters used in the study were donated by the Fish and Wildlife Administration of Maryland.

The purpose of the oyster culture center was twofold: (1) to show visitors interested in off-bottom culture the variety of methods by which oysters may be grown in the third dimension; and (2) to test the variety of methods for growth, meat quality, and commercial feasibility.

Several of the biological questions have been answered since the beginning of the study in 1968. The growth and meat quality of all three stocks (long-line, structure, and raft) were very similar over a two and one-half year period, and the majority of oysters were marketable at the end of this time. However, most of the strings suspended from the rafts were lost from wind damage, so this method appears less suitable for open areas. The long-line and rigid structure methods could be adapted in many areas of Chesapeake Bay.

An attempt was made to extrapolate the meat yield per acre per year from our rack culture experiments. If a total acre was placed under rack culture, similar in design to the one used in our study, a yield of 11.7 tons of oyster meats per acre per year might be realized. If one quarter of an acre is covered with racks, a more likely commercial possibility, the yield might be 2.9 tons of meat per acre per year.

With the ever-increasing threat of pollution in the United States, it is not inconceivable that many of our estuarine areas now used for growing oysters will be closed. If present bottom culture methods are maintained, oyster production will more than likely continue to decline. To utilize fully remaining good waters to their fullest potential, off-bottom oyster culture should play an important role in future shellfish management.

Numerous attempts are now being made to adjust 3-D oyster culture to local conditions in the United States. Under a NOAA Sea Grant, for example, University of Maine scientists are studying existing techniques, and will build rafts for use on the Maine coast, as well as trying to improve present methods of shucking and processing oysters.

Commercial companies, too, are growing oysters off-bottom. In New England, oysters are being grown from racks in Massachusetts and from rafts in Rhode Island. One company in Cedar Key is attempting rack culture. The two largest commercial ventures in off-bottom culture are located in California. These two companies are growing oysters from racks and each is harvesting approximately 30,000 gallons of oyster meats annually. One company in Yaquina Bay is presently growing oysters from both rafts and rigid structure. Finally an operation in Henderson Bay, Washington, is growing oysters from rafts. The success of these companies shows that off-bottom oyster culture does indeed have a bright future in the United States.

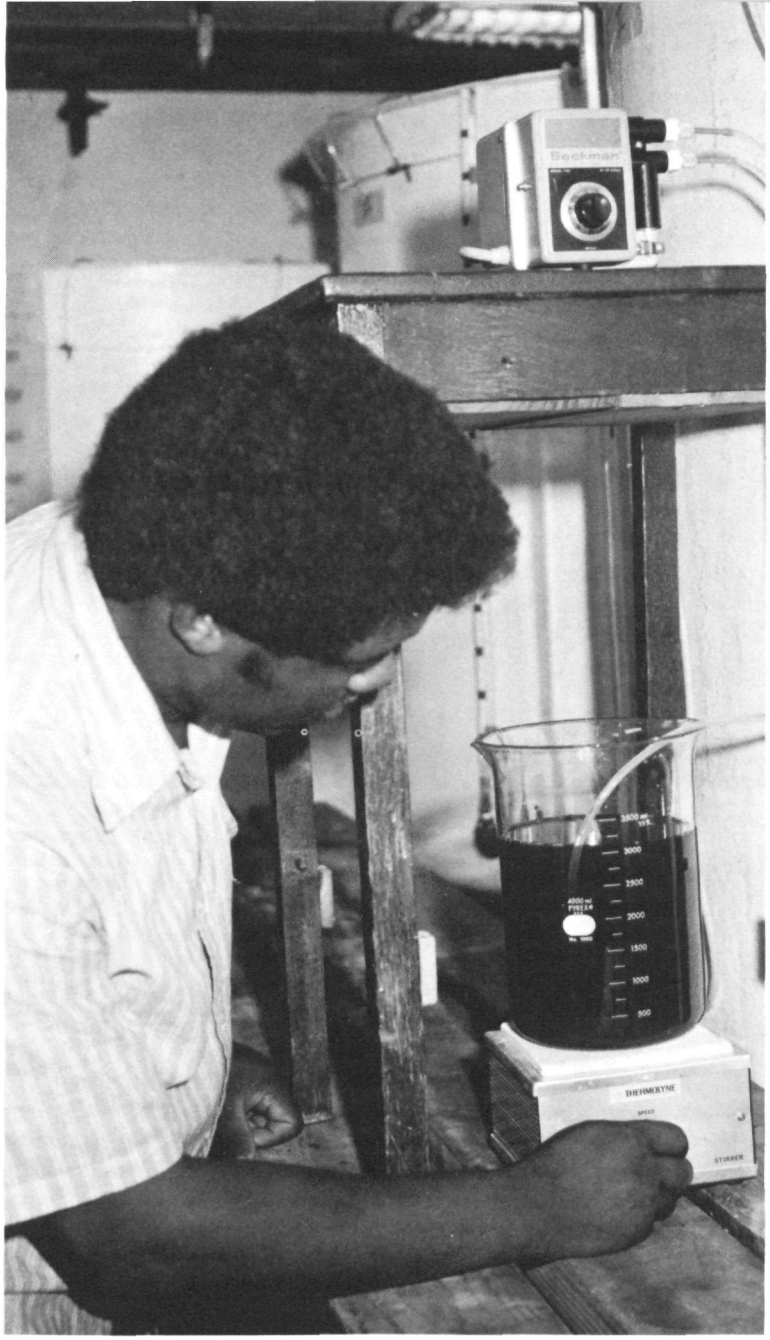
The oyster culture center at Oxford, Maryland will be maintained as a part of a cooperative program with the National Marine Fisheries Service, Division of Extension and the Fish and Wildlife Administration of Maryland. All parties interested in oyster culture will be welcome to visit the site and ask questions about the center. □

FARMING THE SEA

Of serendipity, selective breeding, diet, and some of the other things that add up to a highly cultured

SHRIMP COCKTAIL

By ALBERT K. SPARKS*



Sometimes science progresses more quickly through the failure of an experiment than through its success.

A few years ago, as part of a shrimp biology investigation, we needed information on the species composition and distribution of the larval stages of the three species of commercially important shrimp in the Gulf of Mexico off the Texas coast. To find this out, we had to culture each species, beginning with eggs from an identified gravid female, through the series of larval and postlarval stages. Ironically, when this had been accomplished, we found that the larval stages were so much alike that they couldn't be separated. So, in that sense, the experiment failed. But the valuable fallout from the effort was that we had learned how to culture the three species from egg through the postlarval stages. The foundation for our aquaculture research was laid.

It is worth noting that the United States produces more shrimp than any other nation in the world, but we also eat so much that our supply can't keep up with our demand. Since 1961, we have each year imported shrimp to keep up with the demand. During 1970, shrimp imports amounted to 219 million pounds, coming from 25 countries and accounting for almost 20 percent of the value of all edible seafood imports. During the same year, the U.S. caught 368 million pounds of shrimp, with the Gulf States accounting for almost two-thirds. So we have a great potential for shrimp farming.

Briefly, our cultural techniques consist of spawning wild caught gravid female shrimp in the hatchery and raising the offspring through the larval and early postlarval stages until they are of a size suitable for stocking. To be successful, water of sufficient quality and quantity is required, proper temperatures must be maintained, suitable food in sufficient quantity must be provided and mortalities must be minimized. Easily said—but not easily done. And our aim is to help make shrimp farming economically feasible in the United States.

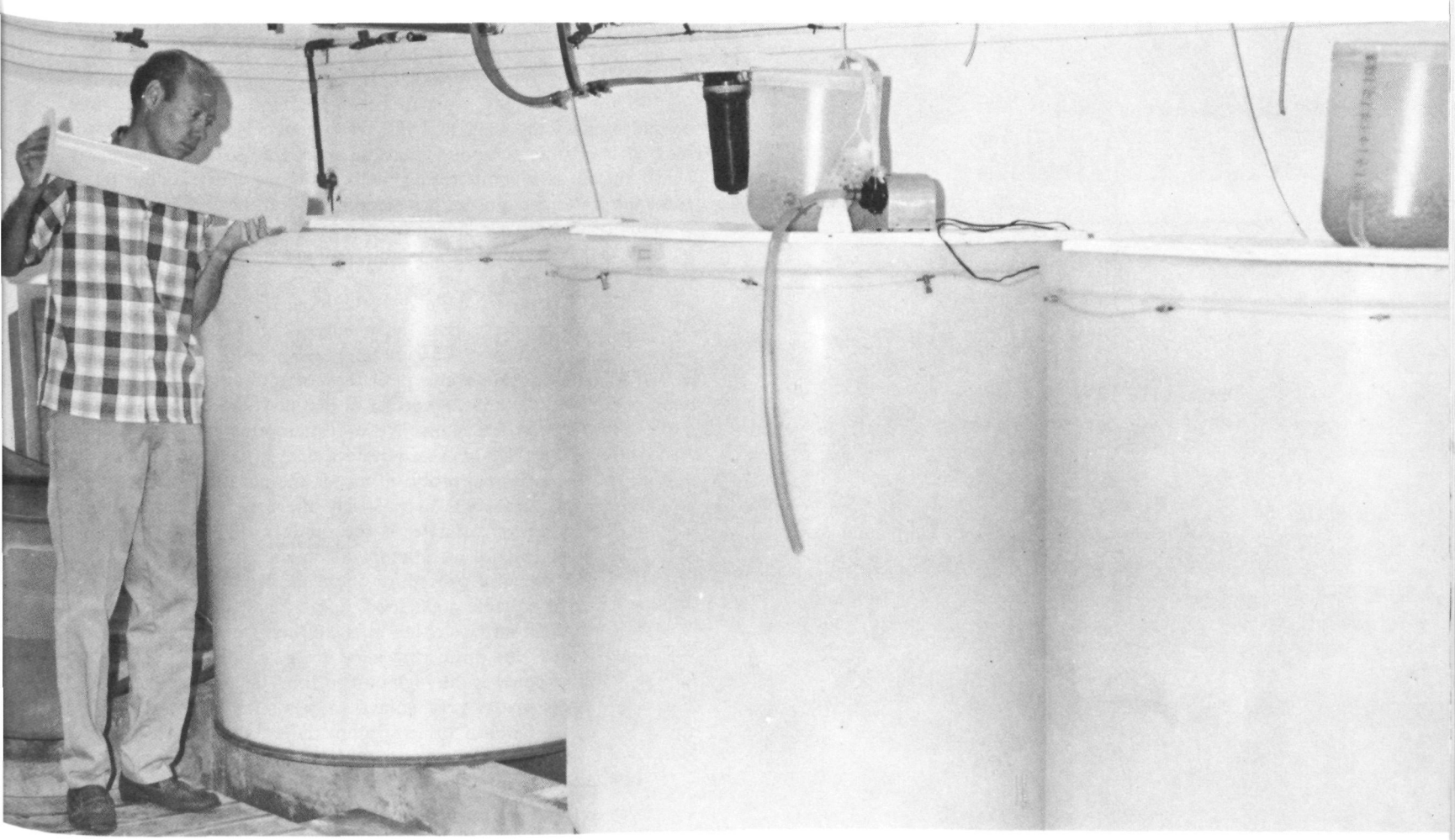
In this work we are joined by numerous other groups in the Texas Gulf area. For example, the Texas Parks and Wildlife Department has an ongoing pond mariculture program at its Marine Fisheries Research Station near Palacios. It uses postlarvae produced by us, by the Dow Chemical Company hatchery in Freeport, and by Marifarms, Inc., of Panama City, together with wild caught juveniles.

The Sea Grant Program at Texas A&M University has an active pond shrimp mariculture research program with NOAA support. Through its efforts, the first commercial pond-grown shrimp operation in Texas was undertaken by private industry. The Dow Chemical Company built a shrimp hatchery to provide postlarval shrimp for sale to prospective commercial mariculturists. As of this writing, the facility was not yet selling postlarval shrimp, but was providing them at no cost to research agencies.

In a cooperative effort by the Texas Agricultural Extension Service, Texaco, Dow, and the Brazoria County Mosquito Control District, a series of ponds was built near Angleton. The NMFS Galveston Biological Laboratory and Dow have provided postlarval shrimp for stocking. Their research is attacking the high cost of pond construction, improvement of harvest techniques, and evaluation of stocking rates and supplemental feeding.

One of the main problems we have been dealing with is sexual

* *Center Director, Gulf Coastal Fisheries Research Center, NMFS*



(Above) NMFS biologists at Galveston, Tex., have been successful in developing a prototype shrimp hatchery. In these tanks and others of varying design, biologists have reared tens of thousands of shrimp. (Left) Cultured algae are concentrated and frozen to provide food for the young shrimp.

maturation. While we have reared female shrimp from egg to adult, none have attained sexual maturity and spawned. Japanese shrimp culturists have spawned hatchery-reared shrimp, but the fecundity decreases markedly in subsequent generations. There are two aspects to this problem: it is expensive to have to depend on naturally maturing females, and you are controlled by such variables as the vagaries of weather.

Once we can consistently bring hatchery-reared female shrimp to sexual maturity, selective breeding for such desirable traits as high fecundity, increased hatchability, rapid growth, high survival rates, and suitability to hatchery and pond environments is possible. It is even conceivable that a race or breed of domestic shrimp can be developed, much like poultry, that is uniquely suited to the artificial environments of hatchery and enclosed ponds rather than the gulf and estuaries.

The second major problem is mortality. In the wild, only two of the half million or more fertilized eggs laid by each female must survive to maturity, breed, and produce a new generation for the population to be maintained. Both the promise and the challenge of shrimp aquaculture is the prospect of eliminating virtually all the mortality occurring in the natural environment by rigid control of the artificial environment of the hatchery and ponds. An obvious major cause of mortality in nature is predation, beginning with plankton feeding organisms preying on the larval stages and continuing through all stages of the life cycle. Predation can easily be eliminated in the hatchery through the use of filtered water and the use of monoculture of food organisms for the larval and postlarval shrimp. Predation in ponds can be minimized by various means such as screens on water intakes and elimination of predators by poisoning the pond prior to stocking.

We are left, then, with the problem of mortality from disease—including environmentally induced injuries, physiological malfunctions, nutritional disease, and infectious disease. Little is known of the infectious diseases of wild penaeid shrimp. We know even less of the present and potential infectious diseases of captive shrimp, but we must learn about them for two practical reasons. From experience with other animals, we know that epizootics occur only when large populations exist under crowded conditions—precisely the conditions under which we must maintain shrimp in both the hatchery and the ponds if shrimp aquaculture is to become economically feasible. Secondly, in the limited volumes of water in hatchery and pond, treatment is a practical possibility.

We are just beginning a shrimp disease research program at the Galveston Laboratory. We are beginning with studies of the normal tissue structure and the basic response to injury in shrimp—areas about which surprisingly little is known. We will then progress to the identification of the causes and effects of diseases of shrimp, including the interrelationships of water quality, nutrition, and infectious diseases.

The third major problem is nutrition, and studies on shrimp nutrition have been underway at the Galveston Biological Laboratory for several years. Although we, like many other researchers, have done numerous studies of shrimp growth and survival in ponds, our approach to nutritional studies is a laboratory one because of the impossibility of controlling or even assessing what shrimp eat in the ponds.

continued

Having the necessary amount of food available for young shrimp is a major problem. Algae, cultured in large containers, provide meals for the young or larval shrimp. Concentrated and frozen algae are thawed when needed and pumped to the shrimp by an automatic device.

In the laboratory, we can be sure of the exact amount and composition of the food that the shrimp eats. However, the possibility that organic compounds are taken directly from the water by larval shrimp is a complicating factor. If some nutrients are taken from the water, we must either determine what they are and in what quantity or develop a standard food of known composition. We have learned that commercially available artificial salts plus distilled water are not suitable, so a major effort is under way to formulate a satisfactory, completely defined diet for the shrimp.

Although we have been quite successful in developing techniques for mass culture of a diatom, *Skeletonema* sp., which serves as the food for larval shrimp until they require animal food, other species and combinations of species of diatoms are apparently better food than *Skeletonema* alons. We are attempting to develop techniques for mass culture of these other species.

A major nutritional problem, too, is the necessity of providing sufficient living algal cells at precisely the time the larvae begin feeding, requiring an estimate of the number of larvae to be fed some two weeks before we attempt to obtain gravid females. This inefficient and wasteful procedure could be avoided if we can develop a bank of suitable algal food. Some highly promising results are being obtained in developing refrigerating, freezing, and freeze-drying techniques for preserving algal food.

A major expense is the high cost of food for the late larval and postlarval stages that require animal protein. The standard food at present is newly hatched brine shrimp, the eggs of which must be purchased at relatively great expense. We have found other suitable live foods, such as mosquito larvae, but we have not yet been able to develop mass culture techniques to produce the numbers needed. The ultimate goal, of course, is to develop low cost artificial food that will produce growth rates of post-larvae comparable to those fed brine shrimp or living in the natural environment.

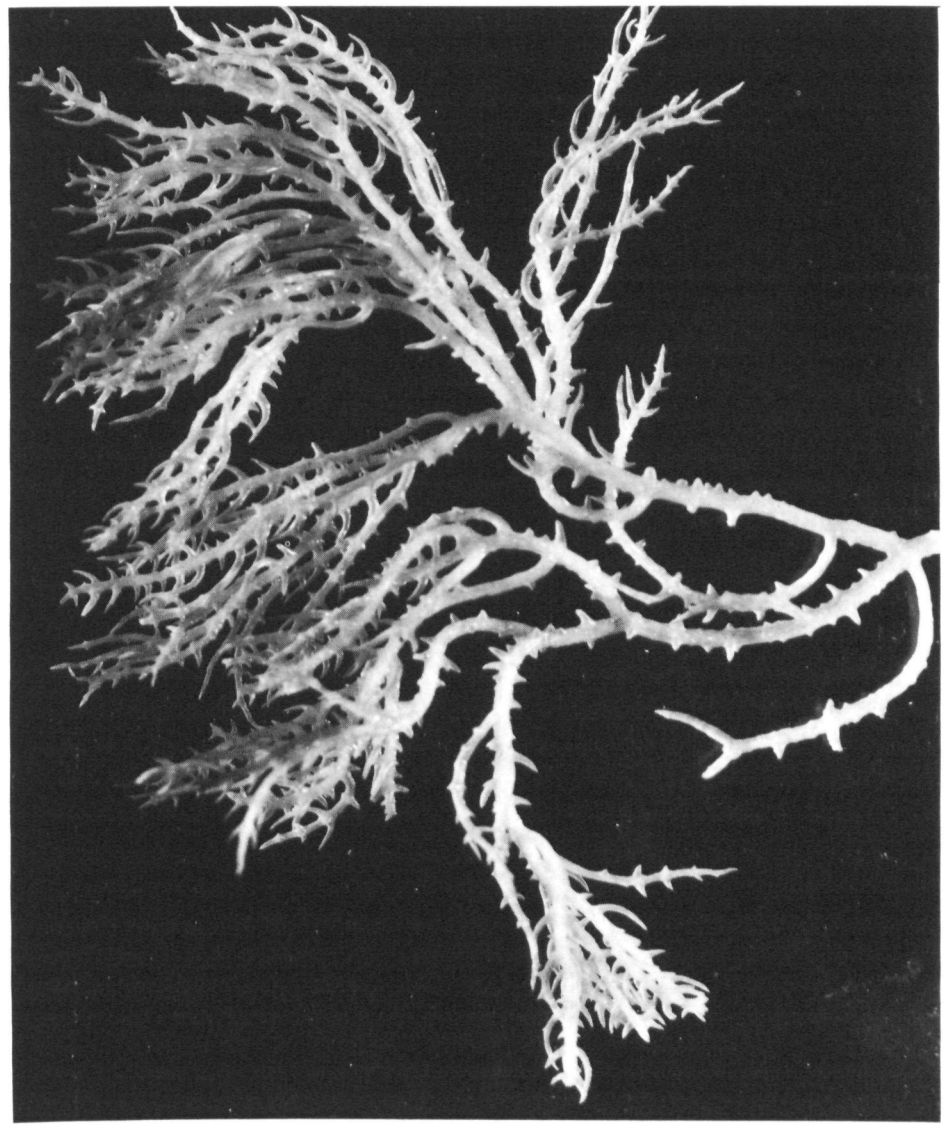
With the artificial diets tested to date, neither we nor other researchers have yet been satisfied with the growth rate of pond-cultured shrimp. Growth rate from initial stocking of 7- to 10-mm. postlarvae up to 75- to 120-mm. juveniles is usually comparable to wild shrimp, irrespective of the composition or amount of artificial food provided, but growth beyond these limits is disappointingly slow or does not occur. We have tested a number of prepared feeds and diets formulated for fish on juvenile and sub-adult shrimp under laboratory conditions. None has been nutritionally adequate even when supplemented. Nearly all the high protein feeds tested were utilized by the shrimp but none, under laboratory conditions, produced growth comparable to that observed in wild shrimp or those stocked in ponds. We are continuing our efforts to develop a pelletized food that contains all the nutritional requirements for good growth, and that the shrimp will eat.

We are also working on the improvement of hatchery techniques and design. Emphasis is placed on designing an inexpensive facility requiring a minimum labor force. Because of our research needs, we have developed hatchery techniques based on the feeding of carefully controlled amounts of monocultured algae, rather than the Japanese method of rearing mixed cultures of algae along with the larvae. Whether our method is superior for commercial operations has not been determined, but it does permit the culture of large numbers of shrimp per unit volume of water. For example, we have successfully reared them at densities of 2,000 per gallon through the protozoeal stages and 1,000 per gallon through the first postlarval stage.

We feel that numerous basic problems must be solved before shrimp aquaculture can be economically feasible. We believe that the major contribution the Galveston Biological Laboratory can make toward that goal will be through research directed to those problems. □

Had your agar, algin or carrageenan today? Yes, you have.

Those Versatile Weeds from the Sea



BY ROBERT D. WILDMAN
Office of Sea Grant

THE NEXT TIME your view down one of our beautiful beaches is interrupted by an unsightly pile of dark, decaying seaweed, remember that what is a smelly mess to you may well be someone else's bread and butter.

Several species of marine algae (seaweed) growing along our shorelines are harvested by various means for many and varied uses. Three colloids extracted from them—agar, algin, and carrageenan—are the basis of a multi-million dollar industry in the United States.

Seaweed is used in various parts of the world as food, as fodder, and as fertilizer, but in the United States its chief value is for the three colloids. Of the three, agar is undoubtedly the best known. Because of its unique combination of physical properties, it is widely used in biomedical laboratories as an all-purpose culture medium. Like algin and carrageenan, agar is also widely used in food processing as an emulsifier, stabilizer, gelling agent, or thickener.

Although agar may be extracted from at least 28 species of red seaweeds, the best known source is the alga *Gelidium*. Much of the agar used in the United States today is imported. Only one firm, the American Agar and Chemical Co. of San Diego, produces agar in the United States, from *Gelidium* that is imported from Mexico and other countries. According to a recent estimate, the total value of the 9,800 metric

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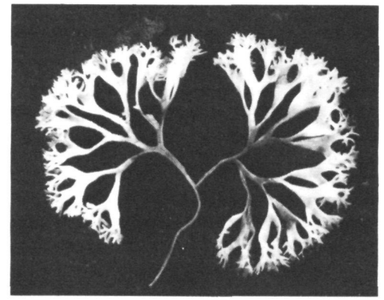
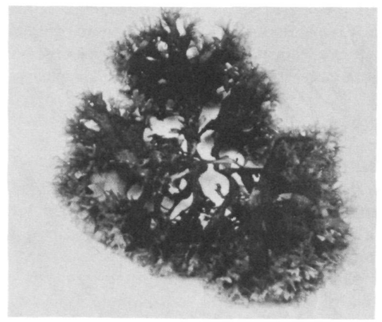
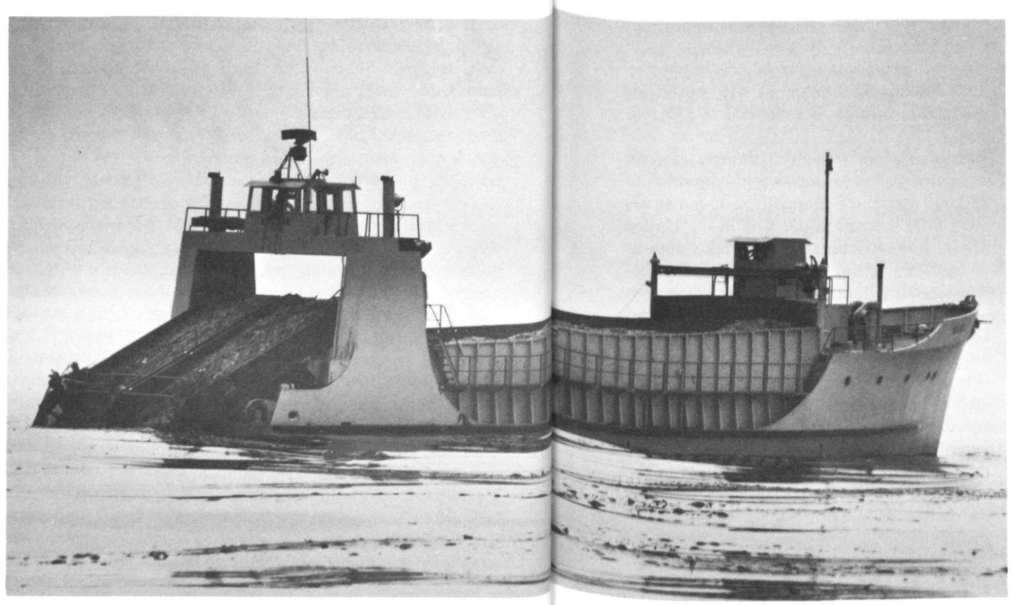
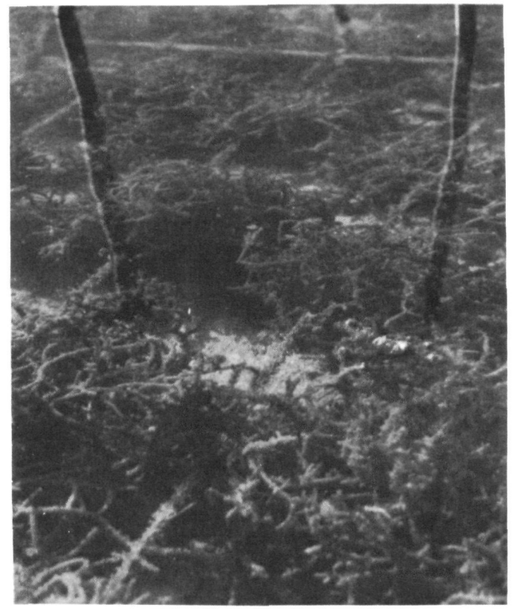


Chondrus or Irish moss is a major source of carrageenan, used in food products, pharmaceuticals, cosmetics, paints, and textile sizings. Nearly half the world's annual production of carrageenan is produced in the United States. The total value of world production is estimated at 34 million dollars. (Left) Unloading Irish moss. (Above) An individual Chondrus plant, and (below) a clump of Chondrus.

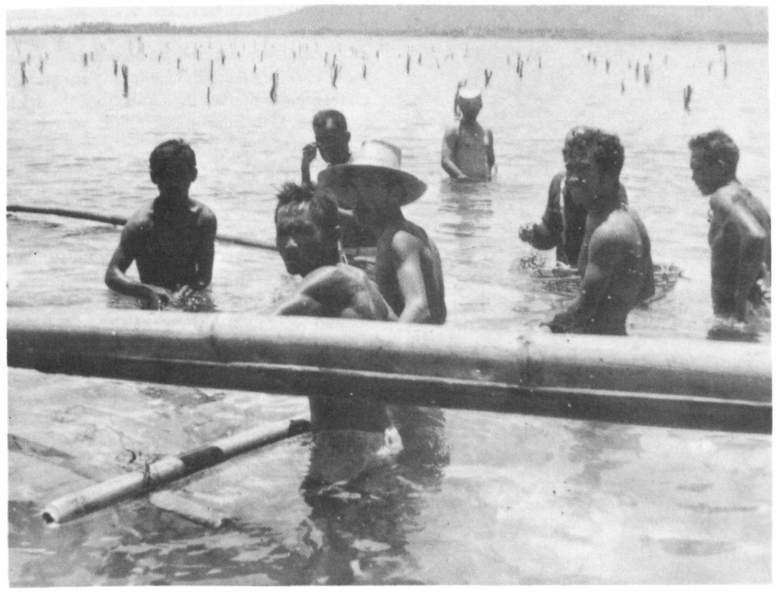


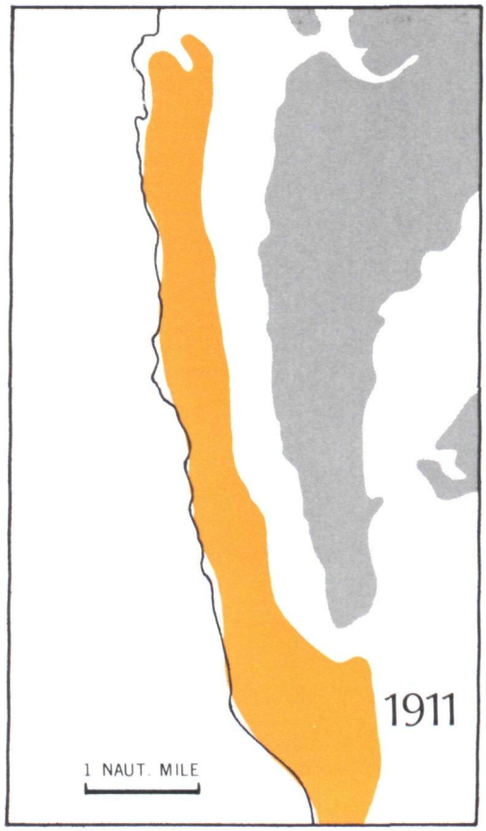
Algin is extracted from large brown algae, principally the giant kelp. (Below) The giant kelp forms interesting patterns on the surface of the ocean. (Below, right) Harvesting vessel mows the kelp just below the surface.





(Left) One of several seaweed sources of carrageenan is Hypnea Musciformis. (Above) Eucheuma growing in Indonesia. (Below) Eucheuma is harvested with nets in the Philippines.





A remarkable scientific project in California led to the recovery of many of the large kelp beds that had been rapidly disappearing. Colored areas in the charts above show the extent of the beds in 1911, 1960, and the dramatic recovery by 1969.

Eucheuma harvester in Indonesia. In many countries, seaweeds are consumed directly as food. Very little is eaten in this way in the United States, because their taste appeals to few Americans.

tons of agar produced each year throughout the world is approximately $46 million.

The second colloid, carrageenan, is also a polysaccharide extracted from red algae. Several of the red seaweeds served as sources of carrageenan, including *Chondrus* or "Irish moss", *Gigartina, Eucheuma,* and *Iridea.* Carrageenan derives its name from the Irish town of Carragheen, a major source of "Irish moss".

Carrageenan is used principally as a thickener, stabilizer, and gelling agent in food and food products, pharmaceuticals, cosmetics, paints, and textile sizings. In recent years, the carrageenan industry has grown more rapidly than that of any other seaweed product. Nearly half the world's annual production of carrageenan of 8,640 metric tons is produced in the United States. The value of the current world production is estimated at approximately $34 million.

Algin, which is the general name for alginic acid and its derivatives, is extracted from large brown algae, principally the giant kelp *Macrocystis* and *Laminaria.* The largest manufacturer of algin in the United States, the Kelco Company of San Diego, is estimated to be producing from *Macrocystis* approximately 3,900 metric tons of algin per year, at a value of nearly ten million dollars. The value of the worldwide production of algin is estimated at $35 million.

Seaweeds are consumed directly as food in many parts of the world—more than 350,000 metric tons annually in Japan alone. Very little is eaten in this way in the United States, however, because their taste appeals to few Americans. For this reason, and because of their limited nutritional value, it is unlikely that the demand for fresh seaweed for direct human consumption will appreciably increase in the United States, but other uses of seaweed may well expand. For example, seaweeds have long been used as fertilizers and have definitely been shown to promote plant growth. Although this is largely due to the minerals contained in the seaweeds, it is also thought that some of the enhanced growth results from an improvement in the soil structure by the phycocolloids, and in the growth hormones supplied by the seaweeds. Seaweed extracts have

also been credited with increasing the resistance of plants to insects and diseases.

Several extracts have shown some promise as pharmaceutical agents, including use as antibiotics, antihelminthic agents, anticoagulants, and in the treatment of intestinal ulcers.

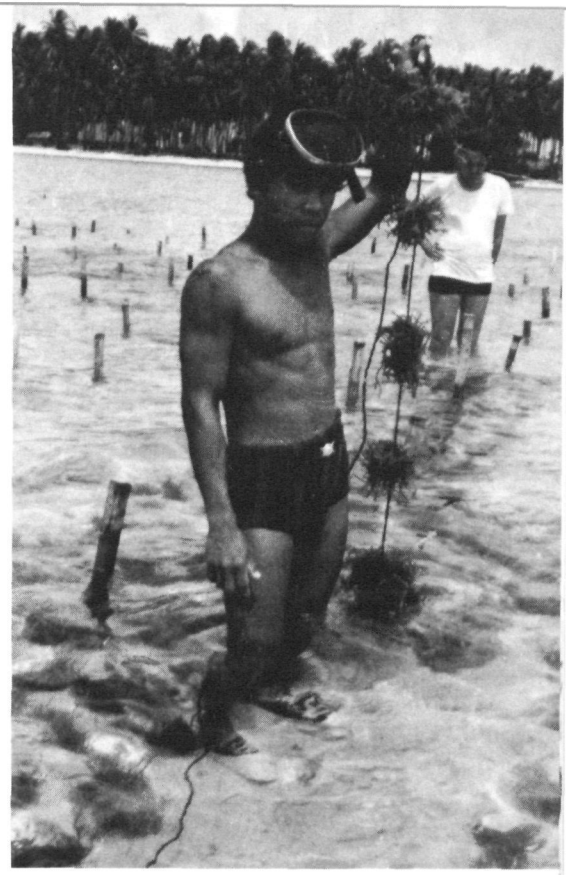
With the ever-increasing utilization of marine algae, locating reliable and economic sources of raw material has become a very real problem. Over-harvesting has eliminated certain sources; pollution now threatens others. As a result, research programs are under way in many countries to ensure a continuing supply. Japan, for instance, has for many years been developing the techniques for the culture of several species of seaweeds.

Here in the United States, a remarkable scientific and conservation project initiated in the mid-1950's in California has led to the recovery of many of the large kelp beds that were rapidly disappearing at that time. The kelp beds serve not only as the source of algin and seaweed meal, but also as a very valuable link in the marine food chains and as habitat for a variety of marine organisms, including a number of prized fish and shellfish. The research has not only identified some of the probable causes of the losses of kelp, such as overgrazing of juvenile plants by sea urchins and fish, but also has developed techniques for establishing or re-establishing kelp beds.

Initial efforts involved the transplanting of mature plants into new areas and simply anchoring them there to grow and reproduce. The project now has under development methods for establishing new kelp beds using millions of microscopic, reproductive bodies of the plant and then protecting the young plants from grazers by covering them with plastic sheets and nets. This research, now located at the California Institute of Technology, is co-sponsored by NOAA's National Sea Grant Program, the Kelco Company, Phillip R. Park Research Foundation, and three southern California counties.

At the present time, the availability of raw material sources for the production of carrageenan is also of great concern. Much of the carrageenan produced in this country is extracted from marine algae imported from many other parts of the world, and, owing to changing political climates, imports of seaweed from many countries are not considered dependable. Importation of raw materials from outside the United States also aggravates the balance of payments problem in the United States. As a result, several investigators have recently begun work under Sea Grant sponsorship looking toward increasing the sources of domestic seaweed. Biologists at the Universities of New Hampshire and South Florida are investigating the existing populations of *Chondrus* and *Eucheuma* to determine their basic biology and environmental requirements. This will help determine their availability and the amount of harvesting that might be undertaken without depletion of these stocks. In addition, a team of investigators at the University of Hawaii is developing the techniques for growing *Eucheuma* in a tropical ocean farming operation. This Sea Grant effort is also supported by the principal producer of carrageenan in the United States, Marine Colloids, Inc.

The harvest, production, and sale of seaweeds and seaweed products in the United States is now estimated at more than $30 million annually and is growing. As a result of this increasing demand, we must take precautions to avoid depleting the existing natural stocks, and initiate measures to provide additional raw material to meet our needs. With the active support of NOAA's Sea Grant Program, a number of facilities are making efforts that show definite promise of meeting these objectives. □



Philippine harvesters bring in the red seaweed, Eucheuma, a source of carrageenan.

SEAWEED

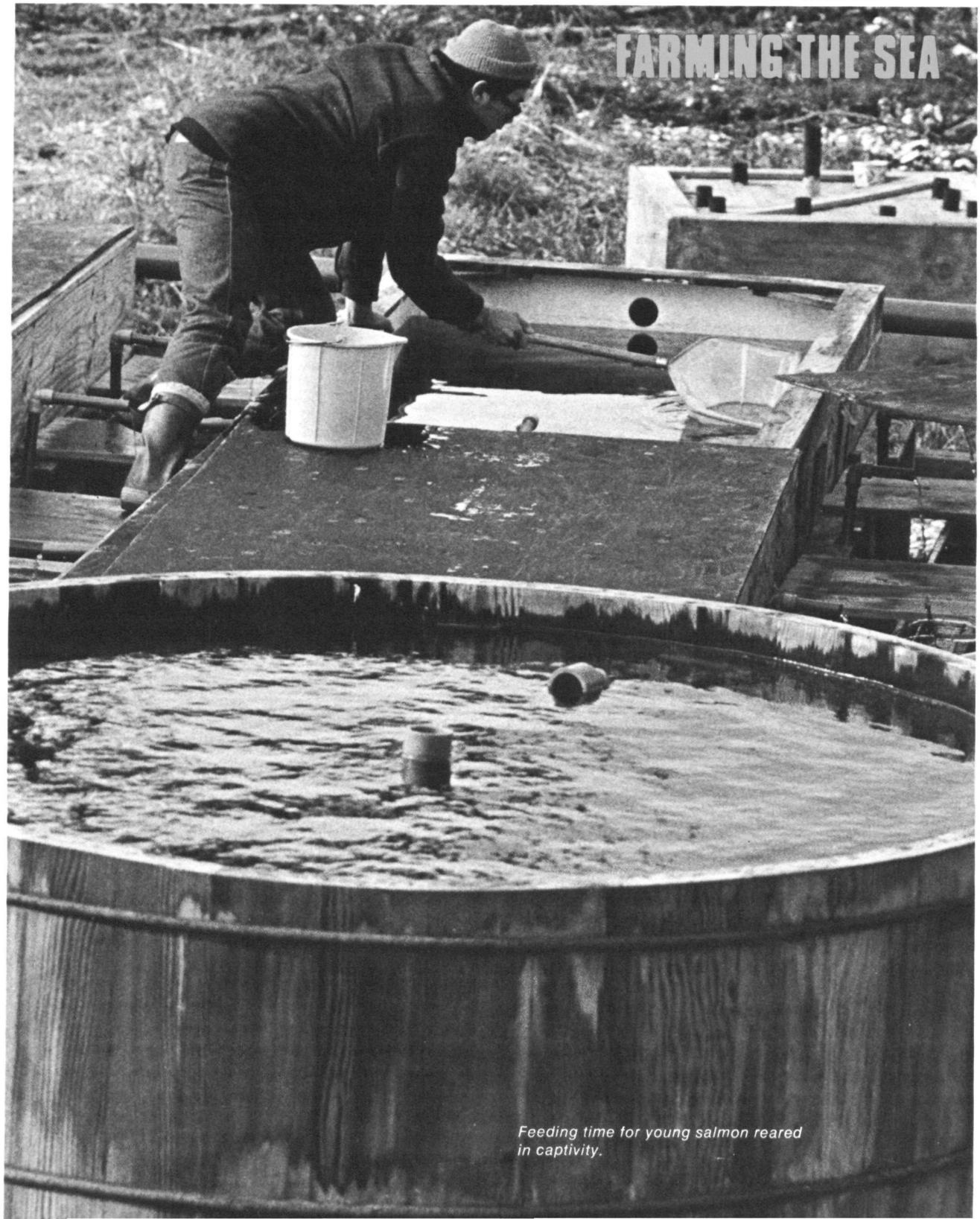
Agar, algin, and carrageenan—the three colloids derived from seaweeds—find an astonishing variety of applications in the United States. You may be benefiting from them when you use any of the following: Chocolate milk, ice cream, icings, meringues, pie fillings, fruit cakes, cheeses, mayonnaise, salad dressing, soup, canned meat, sauces, syrups, fruit juices, dehydrated mixes, confections, bread, many low-calorie and other diet foods, whip topping . . . toothpaste, hair dressing, hair sprays, cold cream, permanent wave compounds, shaving cream, sun tan lotions, hand cream . . . pill coatings, surgical dressings, dental impression compounds . . . insecticides, water-based paints . . . bacterial inoculum, plastics, cloth sizing, tobacco, oil well drilling muds, die lubricants for tungsten wire . . . clarifiers for wine and beer, casings for sausages.

Left plant measured 33 inches, styp to tip. Note proliferations and diameters of all plants. Harvested March 17, 1971, Punta San Antonio, Guaymas, Mexico.

SALMON

pride of the columbia

BY WILLIAM J. McNEIL



Feeding time for young salmon reared in captivity.

(Opposite page) At Oregon State, salmon fry are raised in experimental hatchery under the university's Sea Grant program. (Far left) Techniques for raising salmon in salt water pens are being developed by NMFS in Puget Sound. (Left) Gravel incubation tanks for salmon are being tested at Oregon State. (Below) The author, Dr. William J. McNeil, with OSU graduate student Derek Poon at the experimental chum and pink salmon hatchery.

American and Canadian fishermen caught about 700 million pounds of Pacific salmon annually in the 1930's, but the catch has declined almost 40 percent in recent years. Efforts to conserve the fish have suffered repeated setbacks, caused by degradation of freshwater habitat and overfishing. But emerging trends in salmon aquaculture plus new legislation for commercial salmon farming are encouraging signs that salmon resources can be reclaimed by artificial propagation.

Up to now, the most important task of hatcheries has been to mitigate the loss of salmon production in the Columbia River. Chinook salmon from the Columbia once dominated the coastal landings in Oregon and Washington, but construction of hydropower dams on the Columbia River removed most of their natural spawning and nursery areas from production. As a consequence, the salmon landings declined sharply, to one-third or less of their former levels. However, signs that hatchery salmon had reversed the decline were evident by 1965, and the upward trend is continuing. To date, hatcheries have been more successful with coho than with Chinook salmon, and coho have replaced Chinook as the dominant species in Oregon and Washington coastal landings.

The first Pacific coast salmon hatchery was build in northern California in 1872, and hatcheries have been highly controversial ever since. Long-term research on nutrition, diseases, genetics, physiology (including osmoregulation), and migratory behavior of juvenile salmon is now paying off in excellent returns of hatchery coho, and in some cases Chinook, salmon. This research includes long-standing projects at Oregon State and Washington now supported by NOAA Sea Grants, and NOAA's National Marine Fisheries Service. Numerous state and Canadian organizations have also had active research programs.

Hatchery methods tried with pink, chum, and sockeye salmon have generally been disappointing. These three species are important to commercial fisheries; whereas coho and Chinook are also important to recreational fisheries.

The five species differ in age and size at maturity. Chinook are the largest and longest lived. A typical Columbia River Chinook weighs between 20 and 25 pounds and is four years old at maturity. Some Chinook salmon live six or seven years and weigh between 50 and 100 pounds. Pink salmon are the smallest, averaging only four to five pounds at maturity, and living only two years from the time the egg is fertilized. Coho, sockeye, and chum are intermediate in size and typically live three to four years. All five species spawn only once, and die a few days after spawning.

Neither pink nor chum salmon require a freshwater nursery area as do Chinook, coho, and sockeye. Thus the cost of raising them in hatcheries should be much less since extensive raceways or ponds for holding and feeding juveniles are not required. Unfortunately, pink and chum hatchery fry ex-

continued

William J. McNeil is with the Department of Fisheries and Wildlife, Oregon State University

Government of Canada Fisheries photo.

Spawning channel located on the Fulton River is one of two constructed by the Government of Canada to supplement sockeye salmon stock in the Skeena River System.

perience much lower marine survival than wild fry.

In seeking suitable alternatives to hatcheries, fish culturists began in the 1950's to experiment with spawning and egg incubation channels for pink and chum salmon. Good results from the early tests prompted the Canadian government to construct several large spawning channels in British Columbia during the 1960's. They are still under evaluation, but marine survival of channel fry appears to be much higher than that of hatchery fry and may approach survival of wild fry.

A spawning channel is usually a water diversion canal with a bed of silt-free gravel for spawning. Water flow is controlled at a head gate, and spawner density is controlled at a fish weir. In most cases, the adult salmon are allowed to spawn naturally, but their numbers are carefully controlled. In some instances, fertilized eggs are planted artificially. The protected environment of the channel helps to ensure much higher fresh water survival of the embryos and larvae than would be possible in a natural spawning bed.

The application of spawning channels has been extended from pink and chum salmon to sockeye salmon in British Columbia. Sockeye use fresh water lakes as nursery areas, and spawning channels are one means to ensure that lakes are adequately stocked with fry. Spawning channels operated on the Fraser River, British Columbia, by the International Pacific Salmon Fisheries Commission have shown a very favorable benefit-cost ratio for sockeye salmon.

Successful application of hatcheries and spawning channels has opened up a third possibility—"open ocean ranching." The Japanese have carried this on successfully with chum salmon for many years. Artificial propagation of juvenile salmon has already been extended from Pacific Northwest hatcheries to British Columbia spawning channels and will probably soon be extended into Alaska both with hatcheries and spawning channels.

Coastal chum salmon fisheries began to decline in Japan before the turn of the century, and by 1910 the landings were less than one-third of their earlier levels. The Japanese began to experiment with salmon hatcheries in 1876, and numerous local, state, and private hatcheries were constructed on northern Honshu and Hokkaido Islands. In 1952, the Japanese government initiated a hatchery modernization program.

Japanese hatcheries release as many as 600 million juvenile chum salmon annually, and their hatchery system is being enlarged. The annual returns to Japanese coastal waters are estimated at about four million hatchery fish, which provide an annual coastal harvest of about 25 million pounds.

In evaluating their hatchery program, the Japanese concede that hatchery fry have a much lower marine survival than wild fry (perhaps only one-half). Yet overall efficiency favors artificial over natural reproduction by at least four times because survival of eggs and larvae is at least eight times higher in hatcheries than in streams.

Answers may soon be forthcoming to the perplexing question of why hatchery pink and chum salmon fry experience low marine survival. Laboratory tests show that salmon fry produced in standard hatchery incubators are undersized and may possess structural deformities, particularly in pink and chum salmon. The substitution of a more natural gravel substrate for the smooth artificial substrate of standard hatchery incubators is being tried as one means to correct the problem. Experimental gravel incubation hatcheries are now being field tested in Oregon by the Oregon State University Sea Grant Program, in British Columbia by the Fisheries Research Board of Canada, and in Alaska by the National Marine Fisheries Service.

In North America, salmon propagation is restricted primarily to state and federal hatcheries. However, new legislation in California, Oregon, and Washington has opened the door to limited commercial salmon aquaculture. California passed a bill in 1968 to permit a commercial anadromous fish hatchery to operate for four years on a northern California coastal stream. A bill that allows licensing of coastal streams south of the Columbia River for commercial chum salmon hatcheries became law in Oregon this past August. The Washington legislature also passed a bill in 1971 to permit commercial pen rearing of salmon in Puget Sound. A commercial firm, Ocean Systems, Inc., has a NOAA Sea Grant to demonstrate the feasibility of a commercial-sized pilot operation to raise pan-size salmon from egg to market size in enclosures on Puget Sound. The Fish Commission of Oregon and the Washington Department of Fisheries have received legislative mandates to allow salmon aquaculture and to supply sufficient seed stock to initiate commercial farming of salmon.

The pilot commercial operations in California, Oregon, and Washington will be watched with interest, because they could herald a new era in salmon aquaculture. If private hatcheries can be made to operate at a profit, with or without subsidy, new opportunities may arise to increase the availability of salmon to the common property recreational and commercial fisheries with substantial savings to the taxpayer. Furthermore, by placing salmon seed stock in the hands of private enterprise, aquaculture in floating or submerged pens or in salt water raceways or ponds becomes a possibility, once the technical problems of raising fish are solved.

Projects sponsored by the National Marine Fisheries Service and Sea Grant Programs in Oregon and Washington are examining commercial opportunities for salmon farming. Commercial firms and at least one Indian Tribal Council are working cooperatively on these projects, but the projects have not yet received high priority for funding.

The U.S. Senate Subcommittee on Oceans and Atmosphere chaired by Senator Ernest Hollings and with Senators Warren Magnuson, Ted Stevens, and Mark Hatfield in attendance, met in Seattle on July 1, 1971, to consider testimony on marine resource development, including aquaculture. Dr. Stanley Murphy, Director, Division of Marine Resources, University of Washington, noted in his testimony that ". . . the basic goal of economic diversification through development of marine resources must be the stimulation of private investment and involvement of entrepreneurship."

Lack of organized agency support for aquaculture was also emphasized in testimony before the Subcommittee. Dr. Wallace Heath, Project Director of the Lummi Tribal Salmon Aquaculture Project on Puget Sound, said:

"We have been lucky in our (Lummi) project so far, but we have not yet come off with a full-scale commercial production. There are many hazards; we know this. . . . We know we are going to have failures. "When we have those failures, there are many who are going to say, 'Ah, we told you so. Aquaculture won't work.' . . . If we succeed, they'll say, 'Ah, you made it this time, but it'll get you next year.' This is no different from any other farming operation. Try to buy insurance on next year's potato crop. It does not exist."

Dr. Heath also stated, "We do not recommend that individual proprietors enter this area unless they are well funded, because they do have to perform all of the activities that are normally performed by government (in Agriculture). . . . In the case of agriculture, . . . one turns to the Department of Agriculture, which has an annual budget in excess of $12 billion. Now when one goes into aquaculture in the sea, one must first of all provide one's own seed . . . . , you must do your own selective breeding, you must be your own veterinarian, do your own disease control, do your own engineering, do your own marketing, . . ."

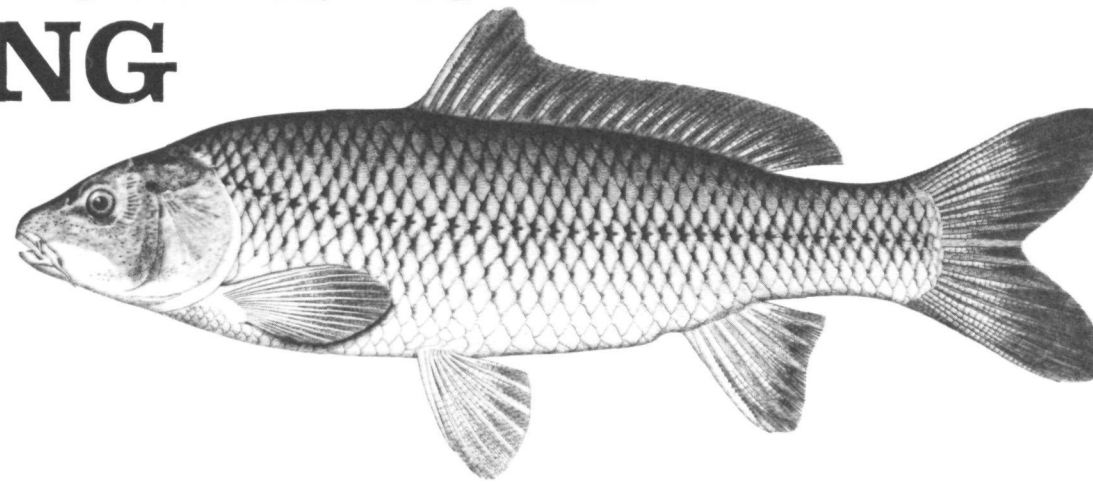
Salmon aquaculture faces many formidable obstacles, and not every venture will be successful. However, encouraging results with hatcheries and spawning channels have already stimulated new pioneering efforts with salmon farming, and an important new sea farming industry may emerge in the 1970's. □

Photo by Fish Commission of Oregon.

Raceways and hatchery building at the Bonneville Salmon Hatchery on the Columbia River. This hatchery is operated by the Fish Commission of Oregon with support from NMFS.

FOUR THOUSAND YEARS OF FISH FARMING

FARMING THE SEA



BY PHILIP R. NELSON

Carp have been cultured in China and Europe for several centuries.

AQUACULTURE, though relatively new to the United States, is one of the oldest of the applied sciences. A form of aquaculture was practiced in China as early as 2000 B.C., according to existing evidence, and a bas-relief from the tomb of Thebaine in Egypt shows the spiny rayed fish, tilapia, being taken from an artificial pond some time before 2000 B.C. In about the same period, the Japanese had learned to culture oysters.

Also called fish farming, aquaculture has been defined as the rearing of aquatic plants and animals under controlled conditions. It involves a variety of plant and animal techniques. In some highly sophisticated procedures, man exercises control over the principal environmental factors affecting the cultured species; others are simple, and control or manipulation of the habitat and the cultured animals is only minimal.

In the early stages of human society, man's existence depended upon hunting animals and gathering wild fruits and seeds. As mankind grew older and wiser, and as game became scarcer in many areas, the era of hunting and seed-gathering ended and an era of farming began. Aquaculture came later and developed slowly. Progress has been rapid in aquacultural science only during the last century, especially in the last three or four decades.

In the Orient, fish culture was born and nurtured in China, Japan, and India. Perhaps the first true system of fish farming in the ancient world—for brackish-water fish—was established in Java between 1200 and 1400 B.C., under the influence of the Hindu empire. Much later, as the Chinese traders fanned out from their mainland to establish trading posts in many of the surrounding countries and islands, carp culture was introduced. Aquaculture thus became an important source of food for the peoples of Asia and the Far East. Today, 80 percent of the more than three million tons of finfish produced worldwide comes from aquaculture enterprises established in nine countries of the Far East.

In virtually all other regions of the world, aquacultural practices did not come into being until much later—in the Christian era. Many countries never entered the field, either because there were too few fish available or because meat was too firmly entrenched as the primary source of protein. In many parts of the Near East, not only is aquaculture unknown but many of the desert nomads have never even *seen* a fish. Fish consumption is traditional, however, in Near Eastern areas which have access to coastal and river waters. (The Nile River, for instance, has for many centuries been the source of an enormous amount of seafood.)

Expanding populations in the Near East have brought great pressure to bear on agricultural land and livestock production, both of which have always been marginal at best. Interest in fishery expansion has grown, therefore, particularly in the last few decades. The introduction of aquaculture into Near Eastern countries is a fairly recent development, but one that shows promise and is expanding rapidly.

European aquaculture originated in the Middle Ages. Fish ponds were often located near monasteries to provide a ready supply of fish during Lenten periods. In Europe, carp were cultured in large quantities. Some historians say that in the Middle Ages carp were imported from the Orient via Cyprus, hence the generic name *Cyprinus;* others claim that carp and its culture were introduced into Europe from China in the 16th century. Carp culture methods in Europe were unique and developed independently of those in the Far East.

The discovery by a French monk in the 14th century of a way to fertilize trout eggs is said to have led to artificial culture of the species. In the middle and late 1700's, trout cultural practices were refined in Germany, and several fish farms were established.

Culture of other freshwater fish progressed in European countries during the 1800's, but not until 1884 was the first hatchery established for marine fish. Founded in Norway to aid the cod fisheries, the hatchery was the forerunner of others constructed elsewhere in continental Erope and in Great Britain for sole, plaice, and other species.

Aquaculture in Africa was introduced through the initiative of governments, mainly to improve the diet of local populations. Colonial administrations established fish-breeding centers that were used as models for experiments, demonstrations, training personnel, and distributing young fish (fry) to private farmers. The breeding centers did not produce fish for consumption. In certain areas, fish farms were built and operated under the supervision of government centers for the production of young fish; private farming developed under the guidance of these centers.

European settlers, large schools, missions, and private companies established African fish culture on a small number of large fish farms in the former Belgian Congo, the Rhodesias, and Mozambique, mainly to produce fish for their own use. In recent years, African aquaculture has been principally of the home-pond subsistence type, managed as

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a part-time occupation of farmers. Thousands of such home-ponds have been built.

Aquaculture is not indigenous to North America. There is no evidence that fish culture was practiced in the pre-Columbus era. Immigrants to the New World transplanted wild fish from one body of water to another as they moved inland, but fish culture as such was not developed until the 19th century.

At that time, declines in abundance of freshwater fish caused by overexploitation, construction of dams, siltation, and pollution of waters created a public demand for remedial measures. A logical solution was action to increase fish stocks through aquaculture. In the United States, the first efforts along this line included the transfer of adult fish into depleted waters to renew breeding stocks. Fertilized eggs and fry also were collected and transported to depleted waters.

Before 1866, American fish culture was concentrated primarily on brook trout. By 1870, through actions of state fish commissions, capabilities were developed for the propagation of Atlantic salmon, shad, whitefish, lake trout, yellow perch, and largemouth bass. At that time, fish culture was practiced in 19 of 37 states, as well as in the territories of Colorado and Kansas. More than 100 people were involved commercially or as a hobby.

The founders of American fish culture were wealthy and educated men, primarily those able to afford the time and expense required to develop culture techniques for brook trout, a favored sport fish. As more individuals became involved, the need for an organization of fish culturists became apparent. In 1870, at a meeting of practical fish culturists, it was resolved to form the American Fish Culturists' Association. The mission of the association was to promote the cause of fish culture, to gather information on its success, and to promote the individual interests of fish culturists.

The need for a federal fish conservation program was officially recognized in 1871 with the creation of the U.S. Commission of Fish and Fisheries. During the first nine years of the Commission's operation, 80 percent of its effort was devoted to restoring shad and Atlantic salmon and introducing Chinook salmon into new environments. Nearly all these efforts failed, either because of unsuitability of the selected environment or lack of successive large plantings of fish.

Excellent results, however, were achieved in culturing and transplanting shad. Like salmon, shad is an anadromous fish which spawns in fresh water but spends most of its life at sea. In 1873, 35,000 young shad were transplanted from the east coast and released in California's Sacramento River; between 1876 and 1880, more than half a million fry were planted. By 1884, shad was established in rivers of the Pacific Coast and eventually became an important sport and commercial species.

In 1875, the Commission took steps to pond-culture carp as a means of providing needed protein to people in rural areas. Cultural methods were available from Europe and Asia, and carp culture was a thriving and food-producing industry abroad; therefore, it seemed a logical species to introduce. The Commission raised carp to a length of two to three inches for distribution to applicants requesting fish for stocking. By raising carp to this size for distribution rather than using fry, the rate of survival was greatly increased.

The demand for carp by applicants increased from three in 1876 to nearly 10,000 in 1882. Although individuals were warned by the Commission not to stock carp in waters containing natural fish populations, enthusiasm ran high and young carp were stocked in every body of water imaginable. When it became apparent that carp were displacing more desirable species, public enthusiasm turned to disapproval, and plantings were discontinued in 1896. By that time, carp were well naturalized in public waters.

Artificial propagation of marine fish on a commercial scale originated in the New World as a result of the success achieved in rearing fresh-water fish. Because of decreases in catches of marine food-fish on the Atlantic coast, the U.S. Commission of Fish and Fisheries began an artificial propagation program in 1878. Methods were soon developed for fertilizing eggs and hatching cod, haddock, and herring. The first commercial marine hatchery was built in 1885 at Woods Hole, Mass., and two others were built in New England in 1905.

During the early years of the 20th century, marine fish hatcheries sprang up all over the world, as culturing seemed to be the best way to restore declining fish stocks. By 1917, the three east coast hatcheries liberated three billion groundfish fry. The newly hatched larvae were comparatively easy to produce but evidence of how much they added to the fisheries yield was difficult to assess. In the absence of proof that artificial propagation was beneficial, marine hatcheries lost their appeal. By the early 1950's, the movement expired.

Since then, considerable effort has been directed toward rearing marine species beyond the immediate period following hatching—from larval into juvenile stages. This required the development of suitable artificial environments and forage that would promote growth and survival of larval and juvenile fish. So far more than 20 species of marine fish and several species of mollusks have been reared from the egg to the adult form in captivity.

Eventually many more species might be reared for commercial use under controlled conditions, or raised to a size suitable for stocking in marine waters, with a reasonable expectation of survival.

Great advances have been made in the operation of salmon hatcheries during the past 20 years. Larger and healthier fish are being released as diets are improved and diseases are brought under control. The return of hatchery-reared salmon to the fishery in the Northwest now represents a favorable cost-benefit ratio.

Improved techniques for the culture of oysters, mussels, shrimp, catfish, trout, and two common marine fish have been developed in recent years. These advances have stimulated the interest of marine scientists, nutritionists, and business concerns in many countries in launching a new era of aquaculture. □

Considerable effort has been directed toward rearing marine species beyond the immediate period following hatching. (Right) Tanks used for larval and feeding research.

Before weather instruments are used in the field, they have to earn

THE STERLING SEAL

BY EDWIN P. WEIGEL

The silence was almost eerie as I stopped by the gate to photograph the sign—STERLING RESEARCH AND DEVELOPMENT CENTER.

At first all I could hear was the wind whispering over an immense expanse of neatly trimmed grass. Then a meadowlark punctuated the stillness with a high-pitched yodel. From a distance came the subdued whine of a DC-8 coasting to a landing at Dulles International Airport.

Strange setting for a laboratory, I thought. A few hundred yards down the road was a little white house. This, it turned out, was the Administration Building: an office and a conference room. William E. Eggert, Director of the Test and Evaluation Laboratory for the National Weather Service, was waiting inside.

"Everybody remarks about how much land we have out here—400 acres, all told. But it's really needed. The work being done here calls for plenty of room."

Eggert pointed to a large aerial photo on the wall of his office: "Notice we share a common fence line with Dulles Airport. Weather Service observers from Dulles drive over here twice a day to launch radiosonde balloons—once in the morning and once in the evening. That's one reason the space is needed, although their work is operational—not connected with the lab."

I asked why the balloons weren't launched at the airport.

"It's a long story," he said. "It began before Dulles was even built, back in November 1960. At that time, the Weather Bureau—now the National Weather Service—moved a unit to this site from Suitland. The move was made in part because they needed a new site for launching balloons. Apartment buildings around Silver Hill were so close that radiosondes—the instrument packages carried by the balloons—occasionally would bounce off the buildings and be destroyed.

"The move became possible when the old Central Radio Propagation Laboratory—then part of the National Bureau of Standards—moved from here to Boulder, Colorado. (Some of the Radio Propagation Laboratory is now part of NOAA's Environmental Research Laboratories.) We inherited their acreage.

"Another reason NOAA needs the space is for long-range climatological work. Almost half the 400 acres is set aside for a

Reference Climatological Station. NOAA's Environmental Data Service wants it to remain undisturbed for 200 years; they want to find out if the climate is changing."

I asked who cut all that grass. "We do," said Eggert. "If it begins to look shaggy, people driving by take notice and call their Congressmen. So we have a crew working full time every day in summer, mowing the lawn."

Eggert then sketched the history of the site and its development.

"We're still using the original buildings occupied by the Bureau of Standards people back in World War II—four small but fairly substantial buildings, plus some wooden shacks and surplus Quonset huts. All of them are way past their normal lifespan, and we're hoping for a replacement, if the budget will allow it—a building to put us all in one place.

"When the Weather Bureau first came here, there were all sorts of fascinating things left behind by the Bureau of Standards—including victory gardens. We picked up a couple of their people too. This had been one of the secret sites where optical glass for national defense was stored during the war—under armed guard 24 hours a day. Some of the guards are now part of our site-maintenance crew."

I asked about those early years, when the Weather Bureau first moved in.

"The unit here, until 1964, was called the Observational Test and Development Center. Then—with the reorganization in 1964 which created the Systems Development Office in the Weather Bureau—the site became the home of SDO's Test and Evaluation Laboratory.

I came here shortly afterward, in 1965. We then had about a dozen people. Now we have 35."

What was the guiding philosophy behind the laboratory?

"Before the reorganization, there was no real test and evaluation conducted by the Weather Bureau separately from equipment development. The people who developed the equipment tested it. All too often, when it got out into the field, the equipment failed.

"There was a lot of criticism from field units.

"So it was decided we should emulate the larger agencies, which have been doing test and evaluation for many years. The Defense Department, NASA, and the Federal Aviation Administration all have labs where they can simulate virtually all conditions to which their equipment and techniques will be subjected. They have chambers and equipment for shock, vibration, salt spray, dust, you name it. And they do destructive testing as well—literally shake an airplane to pieces.

"Well, we didn't have the money to do destructive testing but we could improve considerably over our old system. Our assignment was, and is, to make darn certain an item of equipment is suitable for field use, by testing and evaluation. We certify, first of all, that it will supply the information needed by the meteorologist, and, second, that it can be operated and maintained satisfactorily—that it is a reliable piece of equipment.

"To do this, we have two branches. One branch, composed mainly of meteorologists, certifies that the equipment or technique will provide the information needed. The other branch, mainly comprising engineers, certifies the reliability.

"For testing equipment, we have an environmental chamber—8 x 8 x 14 feet—that will give you low and high temperature, low and high humidity, winds up to 20 knots, and rainfall up to four inches an hour. And it can do these things in a variety of combinations, creating, at will, conditions of the arctic, a jungle, desert, monsoon, or what have you.

"And we have on order a chamber that will simulate a radiosonde run as the balloon rises through the atmosphere. This one will be much smaller, only 2 x 2 x 4 feet inside. The Weather Service has never had anything quite like it before.

"Also on order is a low-speed wind tunnel, able to reproduce winds up to hurricane speeds—75 knots. We don't need a high-speed tunnel because we're not in the airplane business. Our primary interest is air flow into and around objects, like anemometers and rain gages. If we do have need for a high-speed tunnel, we can visit another agency.

"Besides these items, we have diligently searched the surplus lists and picked up two shock-and-vibration testers and a dust chamber.

"The dust chamber we got from the Navy. It originally cost the Government something like $30,000; you couldn't duplicate it today for $50,000. We got it for the price of transportation from Mechanicsburg, Pa.—about $1,500—on a flatbed truck. Had to rip out the back of a warehouse to install it.

"So gradually we are acquiring some of the tools we need to do a good job of test and evaluation."

I asked if there was anything else high on the shopping list.

"Lots of things. We badly need data-logging and computing facilities. One of our basic jobs is to test observational instruments. You get a new instrument and put it beside one that has been operating many years. The problem then is logging the data you get. You can either hire people to run out every five minutes or so and log the data around the clock, or you can buy electronic equipment that will sample the data on demand; put it on tape. We bought one data logger last year that has 16 inputs—that is, it will sample 16 items once a second. We plan to use it on every test program coming along. Lately, it has been used in evaluation of an Israeli instrument shelter. We need more such data loggers."

What were some of the items tested recently at Sterling?

"We tested the weather radar remoting system. Some of the TV weathermen are now showing pictures taken from these. The images are reproduced on a cathode-ray tube or by facsimile, on paper. You can tell a radar-remote image because it doesn't have a sweep like a true radar. It takes 90 seconds to produce a picture.

"Then we tested a mortarboard psychrometer that fruit growers in California wanted to compare with standard instruments to see if they could use it to foretell frost. It checked out fine. These psychrometers are now in use, telling the growers when to light smudge pots, start their wind machines, or whatever.

"We ran an experiment with a cathode-ray-tube typewriter at the Washington Forecast Office, and this is now part of a larger program. The keyboard looks like a standard typewriter. When you type, it generates words on what looks like a TV screen. The idea is, when the forecaster assimilates all the data from maps, charts, and instruments, for him to sit down at this device and type the forecast, correct it on the screen in front of him, punch a button, and have it go out over the line. This eliminates the need for a special communicator. The way it's done now is for the forecaster to type the message on an ordinary typewriter, give the message to a communicator, who sits down at a teletypewriter, and punches out a perforated tape, which he then takes to another machine, inserts and sends out over the wire.

"Correction on this CRT machine is very clever. You can backspace, you can erase. If you forget a word, you can separate a message and insert a word.

"And you can use so-called 'canned' messages. These are messages in the computer's memory, such as 'Good morning, the National Weather Service brings you the latest forecast for Washing-

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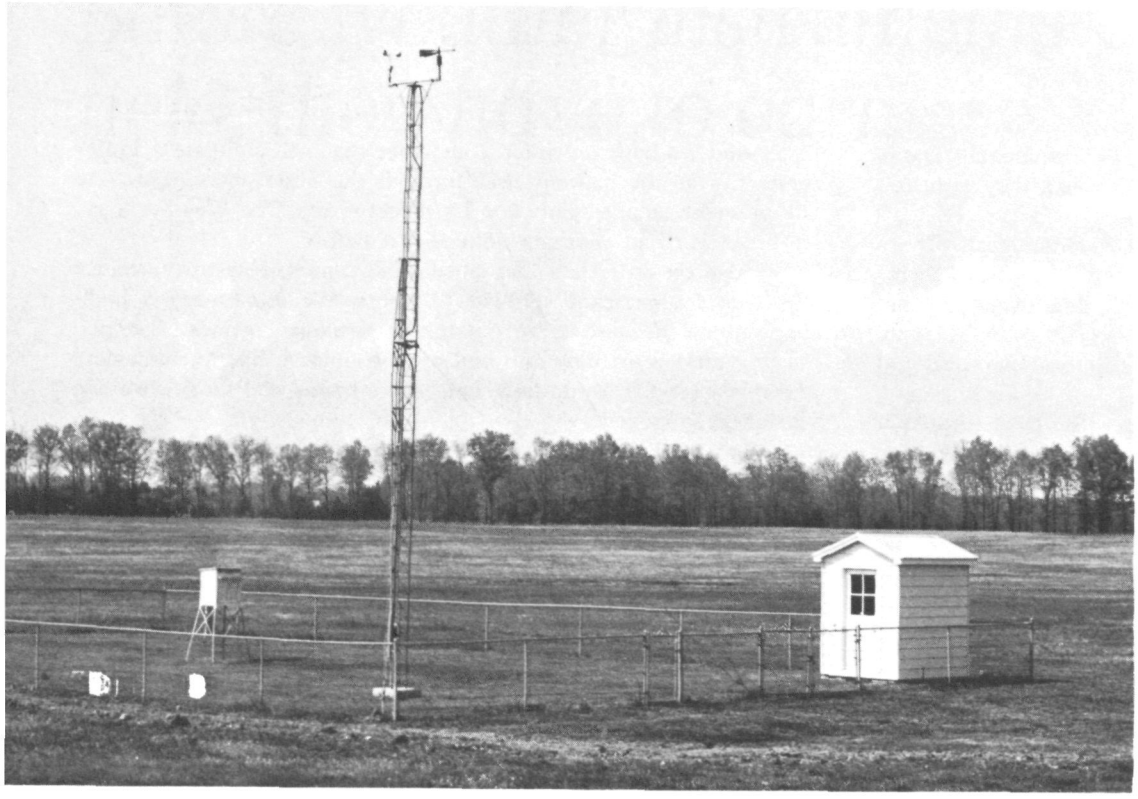
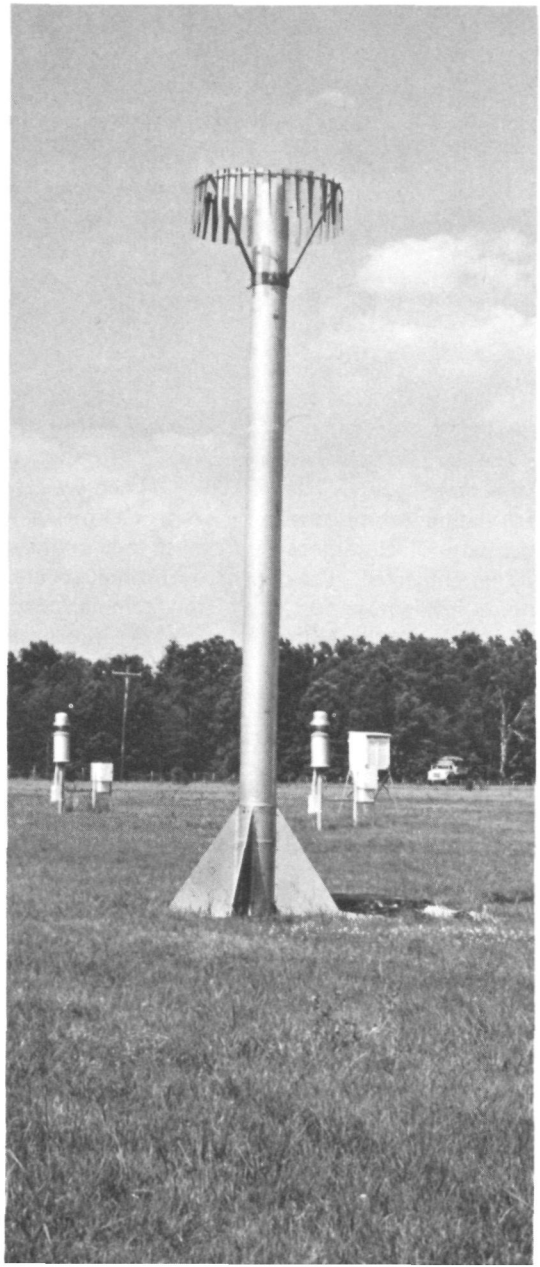




(Top left) Do not disturb for 200 years. The Environmental Data Service's Reference Climatological Station is to be an oasis for measurements of climate change. (Top right) William E. Eggert is Director of the Test and Evaluation Laboratory. (Lower left) Transmissometers measure visibility at airports to determine whether conditions call for instrument or visual flight rules. (Right) Precipitation gages and instrument shelters gather data for evaluation. Rocket-shaped tube with the hula-skirt top is a precipitation gage for regions where deep snows accumulate. (Far right) Israeli instrument shelter in the foreground is undergoing comparison with a standard United States shelter.

ton, D.C., and vicinity. The weather today will be (blank.)' The forecaster would push a button, ordering, say, canned message number 14, fill in the blank, push another button, and send it on its way.

"We evaluated for the Office of Hydrology a flash-flood-warning device that is essentially a float which signals when the water in a stream reaches a certain height, then sounds an alarm. Typically, it would be placed on a post or a bridge support at a height where obvious flood danger existed. The signal would go by telephone line to an office manned 24 hours a day, such as a police station, where a siren could be activated."

Any big surprises, I inquired, during test programs?

"One of our most dramatic tests was of three balloon-tracking radars that were to go aboard ship for the BOMEX experiment. To evaluate these, we had built on contract a ship-motion simulator—three telegraph poles with a platform suspended between them and actuated by winches, two on one axis and one on another. Cables go from the winches through pulleys on top of the poles down to the 'deck.' By varying the speed of the winches we produce pitch, roll, and yaw.

"During the evaluation we discovered a fourth motion which occurred during a power failure. KERPLUNK!

"Fortunately, the equipment wasn't damaged. It fell about six feet."

What things have been under evaluation this year?

"We've been testing a new instrument shelter for Israel. The shelter was financed and built under Public Law 480, aimed at helping emerging nations. An Israeli scientist developed this equipment thinking it would be useful in such applications. Also, we're interested in it because it's durable, being of light, glass-fiber material, and more modern-looking than ours. We want to know if we could get the same readings from this box as from our standard airways shelters.

"Then there are tests of new evaporation pans for the Office of Hydrology. The goal is to overcome misleading measurements. What's wanted is evaporation that simulates very closely that from a lake or river. You can't measure evaporation from the body of water itself because you can't control the amount that goes in, compared to the amount that goes out. A variety of pans are under test. One, patterned after a Russian model, looks like a small swimming pool, 20 feet across by six feet deep. The Russians say you need something this big to come closer to simulating lake evaporation than you can with our smaller pan, four feet across.

"Evaporation pans are primarily for long-range studies—ecology, drought, irrigation requirements.

"Then there are pyranometers being tested. These are for measuring incoming solar and sky radiation. Some of these could be used for turbidity measurements, to tell if atmospheric pollution is increasing.

"For the World Meteorological Organization, we have been evaluating a pit-type rain gage. The idea is a rain gage that can be used by many countries so we can compare measurements. Right now there is no standard gage. The pit type is different in that it's sunk into the ground; most rain gages are about 5 feet above the ground. The elevated types have wind problems, blowing around, over and past the top of the gage. The thinking is that the pit gage would provide a truer reading. We'll see.

"And, of course there is a continuing program with the AMOS III-70.

AMOS stands for Automatic Meteorological Observing System; III stands for the stage of development, 70 for the year of purchase. This is an automatic weather station that gives temperature, dewpoint, wind direction and speed, cumulative precipitation—that sort of thing. We tested it, and now 16 of them are being procured for installation.

"At present we're evaluating add-on modules for the AMOS III-70—more sensors. One is to measure peak wind; another is an index of visibility. Under development is a sensor to detect the beginning and end of precipitation and a sensor to detect clouds over the station. We'll test those later."

What comes after AMOS?

"RAMOS. That's a Remote AMOS. It will be capable of operating on a battery, with no power lines required, and will report data by radio. A network of RAMOS's in hard-to-get-to places could report back to a basic receiving station, which would collect the data and put it on a teletypewriter circuit. RAMOS will be a lot smaller than the AMOS III-70, as a result of electronic advances such as integrated circuits."

Where will you put these remote units?

"There are many candidate sites—data-sparse regions, hostile environments such as mountaintops, deserts, polar regions. Not long ago, Dr. Cressman, Director of the National Weather Service, pointed out that offshore oil rigs in the Gulf of Mexico are great sources of information, except during hurricanes when all the people are pulled off. Think how useful data would be from a RAMOS unit as a hurricane approached."

The name of the game is automation, isn't it?

"Yes, and miniaturization. For example, we soon will be testing and evaluating radiosondes for NEXAIR (Next Generation Upper Air Equipment), a development program begun about two years ago that will completely replace present upper-air observing equipment, using balloon-born radiosondes of a much-different type. It's an entirely new wind-finding system which does not require large, radarlike antennas on the ground, but uses electronic equipment small enough to fit into a box the size of a household refrigerator."

Any other significant work going on?

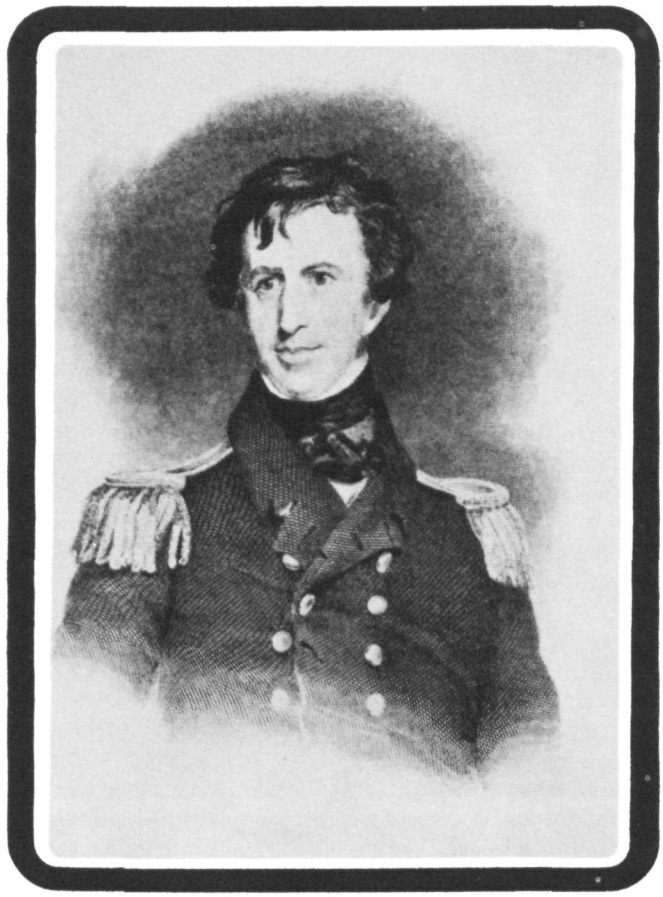
"More than we can cover here. For example, we have a branch that is not concerned actually with test and evaluation but with development of new observational techniques. This unit is looking into ways of automating measurements of sky condition—that is, the cloud height, cloud cover, and visibility portions of the hourly sequence report. This is the toughest part of the weather observation to do automatically. Much of it is by eyeball now—observers scan the sky and estimate the cloud cover. Cloud height is measured by instruments. It's the kind of information used in the standard hourly weather observations made at close to 1,000 places across the country—vital for both aviation and public weather forecasting."

What, I inquired, do you regard as your biggest accomplishment so far?

"I think it would be the creation of a facility capable of doing real testing and evaluating of equipment and techniques, starting from almost zero capability."

And your greatest need?

"A new building." □



CHARLES WILKES, 1798-1877

A set of masterful copperplate engravings at the National Ocean Survey memorializes

THE WILKES EXPEDITION

BY ALBERT STANLEY

A three-year, 87,000-mile global voyage of the mid-1800's, stormy in more ways than one, produced a significant contribution to the National Ocean Survey's rich heritage of copperplate engravings.

The privately financed expedition, headed by Naval Admiral (then Commander) Charles Wilkes, from 1838 to 1842, accomplished many things including confirmation of the existence of the Antarctic Continent. At the conclusion of the voyage, Wilkes was assigned to the Coast Survey (forerunner of the NOS) while 27 engraved marine charts of the Pacific Northwest were made. They constitute a tangible reminder of perhaps the most romantic period of American cartography.

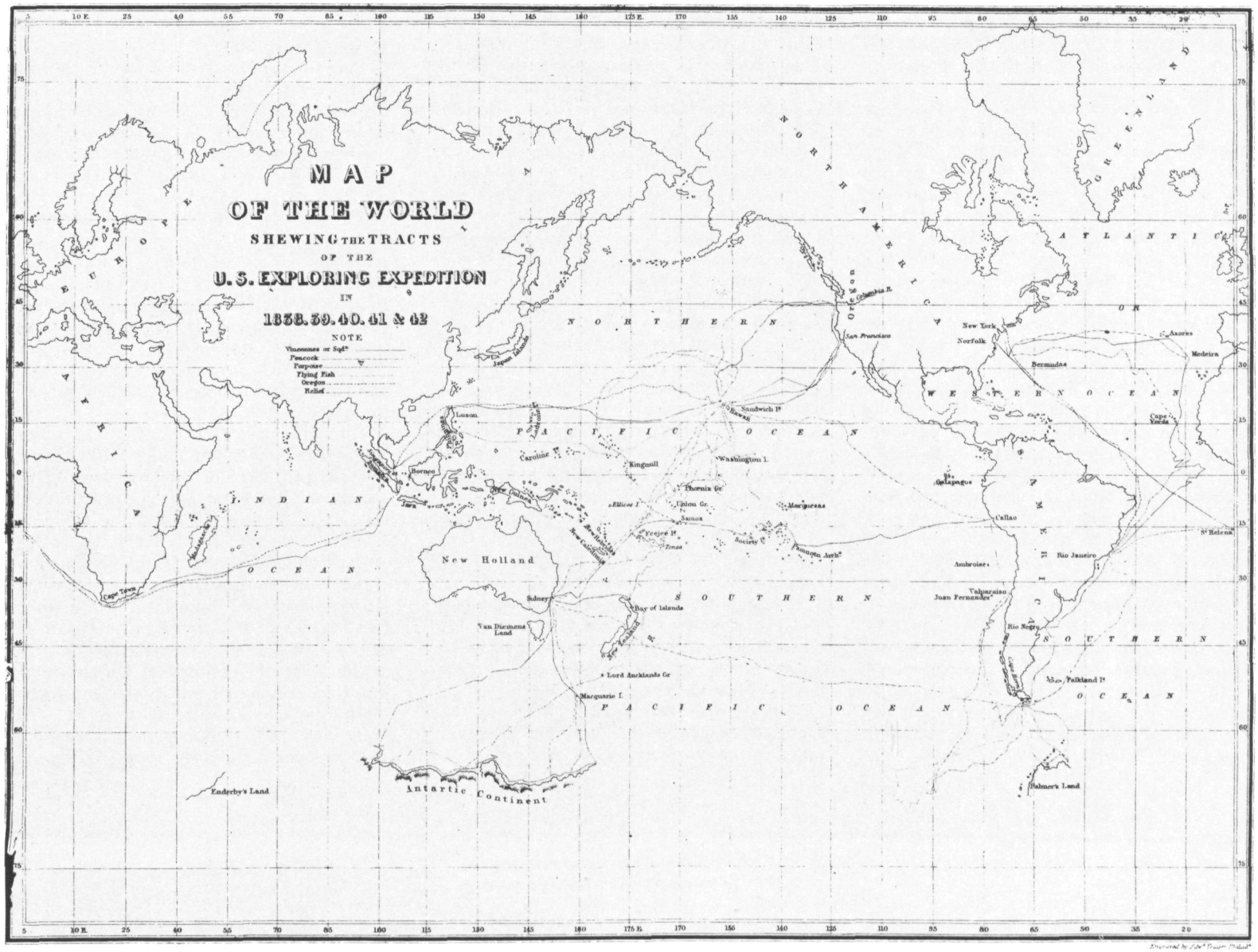
The expedition that made them possible was a saga of high adventure, one for which the sailor-scientist was superbly fitted.

Wilkes was born in New York City on April 3, 1798, and entered the Merchant Marine Service at the age of 17. He was appointed a midshipman in the U.S. Navy in 1818 and by 1826 had attained the rank of lieutenant. During the next five years, he saw extensive sea duty including participation in two exploring expeditions. He was assigned shore duty in Washington as head of the Depot of Charts and Instruments, a job that required checking the accuracy of various instruments used in navigation. This work developed considerable personal interest in science including Wilkes' realization of the need for a national observatory. At his own expense, a small observatory was constructed in which he installed a transit instrument that had originally been procured for the U.S. Coast Survey.

During periods when he was awaiting orders or on leave of absence, Wilkes studied under Professor Ferdinand R. Hassler, founder of the United States Coast and Geodetic Survey. Wilkes was engaged in hydrographic surveys in Narragansett Bay during 1832-33 when work of the survey of the coast was reassigned to Superintendent Ferdinand Hassler. In 1837-38, he commanded the PORPOISE engaged in surveys of Georges Bank and the Savannah River.

The expedition which made his name famous started in 1838, when he was given command of a long-planned exploring expedition into the south polar region, in the Pacific Ocean, around Cape of Good Hope, and thence across the Atlantic to home port, thereby encircling the globe. The expedition consisted of the sloops VINCENNES and PEACOCK, the brig PORPOISE, the supply ship RELIEF, and the tenders SEA GULL and FLYING FISH. The only ships to make the entire voyage were the VINCENNES and PORPOISE. The SEA GULL was lost off Cape Horn in the spring of 1839; several months later, the RELIEF was ordered home from Callao due to its being slow and impeding progress; the PEACOCK, wrecked off a bar at the mouth of the Columbia River, was replaced by a merchant ship bought at Astoria and renamed the OREGON: and the FLYING FISH was sold at Singapore on the return voyage as being unseaworthy.

Difficulties were encountered from the very beginning of the great national en-



The Wilkes expedition started in 1838 and explored the south polar region, the Pacific, around the Cape of Good Hope, and thence across the Atlantic.

deavor. Many hardships were endured and internal dissension occurred during the long cruise. When the young lieutenant got underway with his small flotilla, he had no illusions as to the conditions of the ships assigned him. They were ill-equipped for making a sustained cruise of the proportions envisioned, and the crews were difficult to handle. Wilkes decided to set sail as early as possible, and after assembling at the rendezvous point at Hampton Roads, Virginia, the squadron departed on August 18, 1838. The long voyage of discovery ended upon arrival at New York three years and ten months later, having sailed a distance of 87,780 miles.

An orderly schedule was maintained throughout the world cruise. On arrival at a preselected port-of-call, an astronomical station was usually set up, a survey was executed in as much detail as circumstances permitted, and the expedition scientists made onshore investigation of regional geology, botany, and other ecological factors. The official record included details of history, political structure, native habits and

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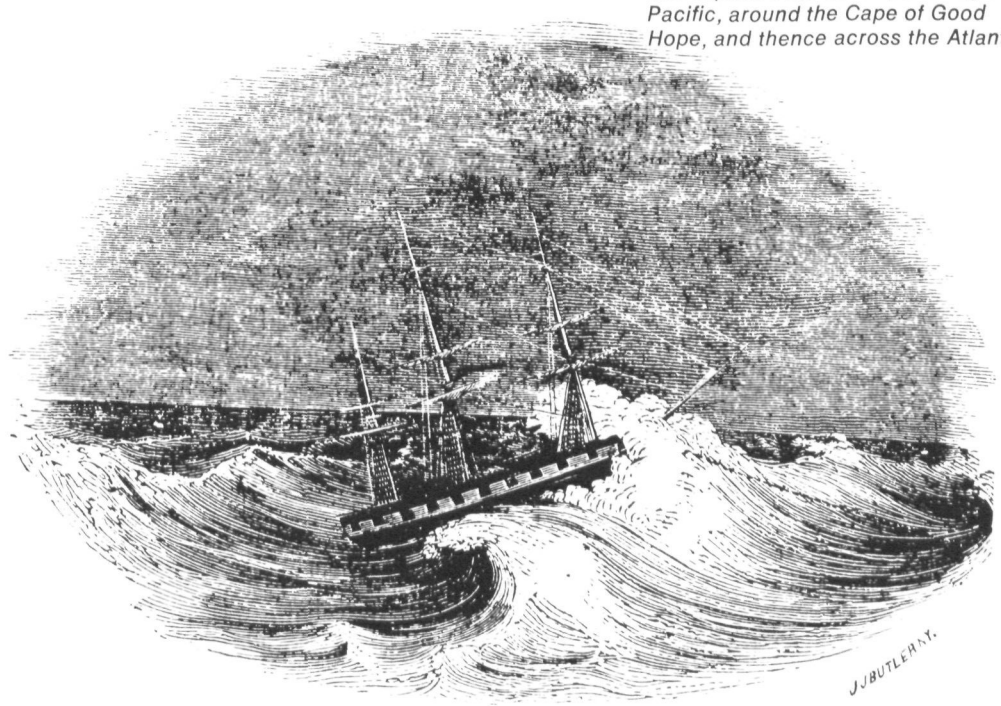

The VINCENNES encountered rough seas at the entrance to San Francisco Bay.

customs, and commercial opportunity. A highlight of political significance was the treaty Wilkes signed with the Sultan of Sooloo.

The first leg was eastward to the Cape Verde Islands. The flotilla then recrossed the Atlantic to Rio de Janeiro, sailed down the east coast of South America, around Cape Horn, and up the west coast, arriving in Callao, Peru, in the summer of 1839. At Callao, as well as at Valparaiso, Chile, magnetic and astronomical observatories were set up and scientific investigations pursued.

Perhaps the most notable accomplishment of the voyage was the discovery of the existence of Antarctic Continent. During the winter of 1838-39, Wilkes based the squadron at Tierra del Fuego and made an excursion southward into the Antarctic regions with the 96-ton FLYING FISH, reaching latitude 74° 14′ south. Although one or two short stretches of the continent had been sighted shortly before, this sortie and subsequent exploration encompassed over 1,500 miles of Antarctic coastline. These treks demonstrated beyond a doubt a continuous coastline and not a range of detached islands. "Wilkes Land," part of the vast Antarctic land mass, gives due credit to Charles Wilkes by perpetuating the name of the explorer.

In the years that followed, either the entire squadron or individual ships visited and explored the South Pacific Islands, Australia and New Zealand (1839-1840), the Hawaiian Islands (1840), and the northwest coast of America and California (1841). The return trip was made via the South Pacific (1841), the Philippines, Singapore, Cape of Good Hope, and St. Helena (1842). The expedition arrived at Staten Island on June 10, 1842, to end one of America's great sea epics.

The plan for the expedition was far-reaching and had many facets relating to the scientific stature of the United States. All disciplines were involved but physical inventories were the most pertinent. The chief fields of exploration were the coast of the Antarctic continent, islands of the Pacific Ocean, and the American northwest coast. Hydrographic surveys were made of about 280 islands in addition to the territorial waters of the United States from San Francisco Bay to the Strait of Juan de Fuca and including the Oregon Territory. By establishing the existence of the Antarctic Continent and sailing along its perimeter, substantial contributions were made to world knowledge of geography. More than 180 charts were constructed by Wilkes as a result of the expedition.

Investigation was made of the Samoan and Fiji Islands to select a safe harbor for whalers and other U.S. vessels and to make arrangements ensuring adequate supply bases. Wilkes then returned to the Hawaiian Islands to meet a supply ship from the United States. From this point, the squadron sailed to the Northwest coast of America to make surveys of the coast of Oregon Territory and California.

The VINCENNES left Honolulu on April 4, 1841, and reached the mouth of the Columbia River 22 days later. Wilkes proceeded immediately to the Strait of Juan de Fuca where surveying was started of those waters. The ship was almost wrecked off Destruction Island but arrived at the working grounds in May and anchored in Port Discovery. All ship personnel were assigned to surveying tasks and for the next six months the various parts of the Strait of Juan de Fuca and Puget Sound were surveyed and mapped. The collection of data included vital information obtained from the settlers and missionaries in that region and from various posts of the Hudson Bay Company.

Three extensive exploring expeditions were made inland. One under Wilkes landed near Tacoma and struck southward to Ft. Vancouver just north of the present site of Portland. The trek followed the Columbia River and the Willamette Valley to the falls of the Columbia River. A second expedition crossed the Cascade Range north of Mt. Rainier, continued onward to the Columbia, crossing it, and later penetrating to Ft. Colville almost at the northeastern corner of the State of Washington. On the return trip, they penetrated into Idaho and turned south following the Snake River to Ft. Walla Walla and then to their point of beginning. This expedition devoted some study to the

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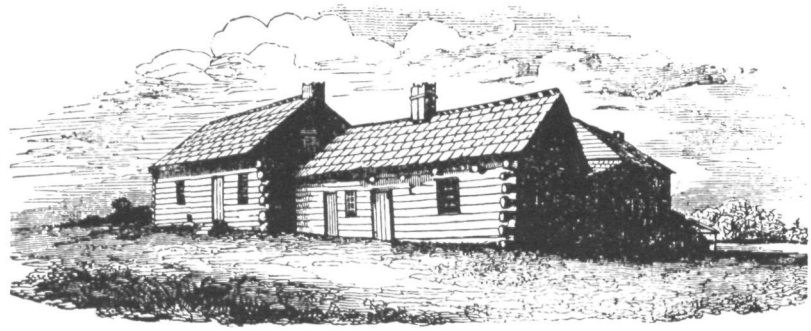
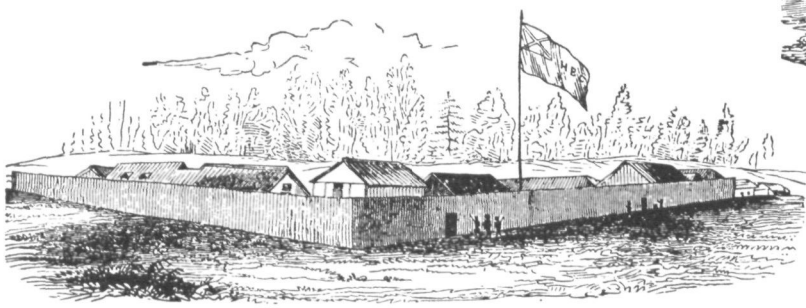
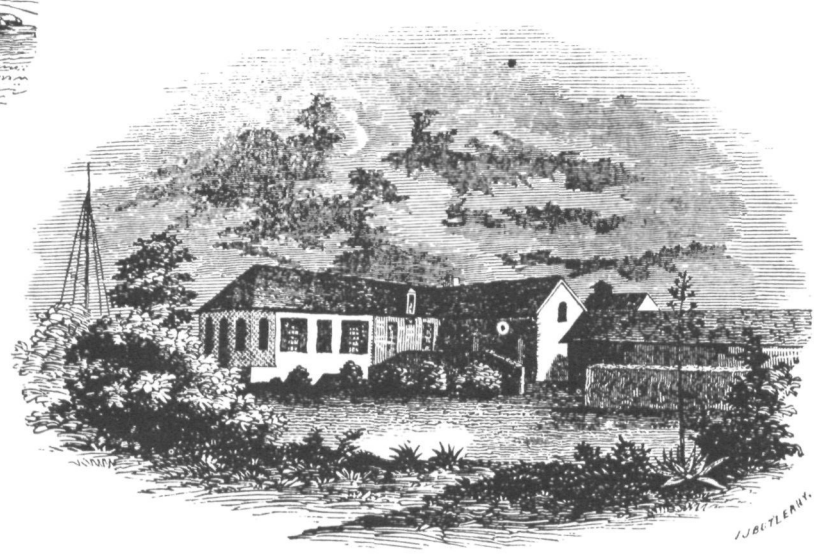
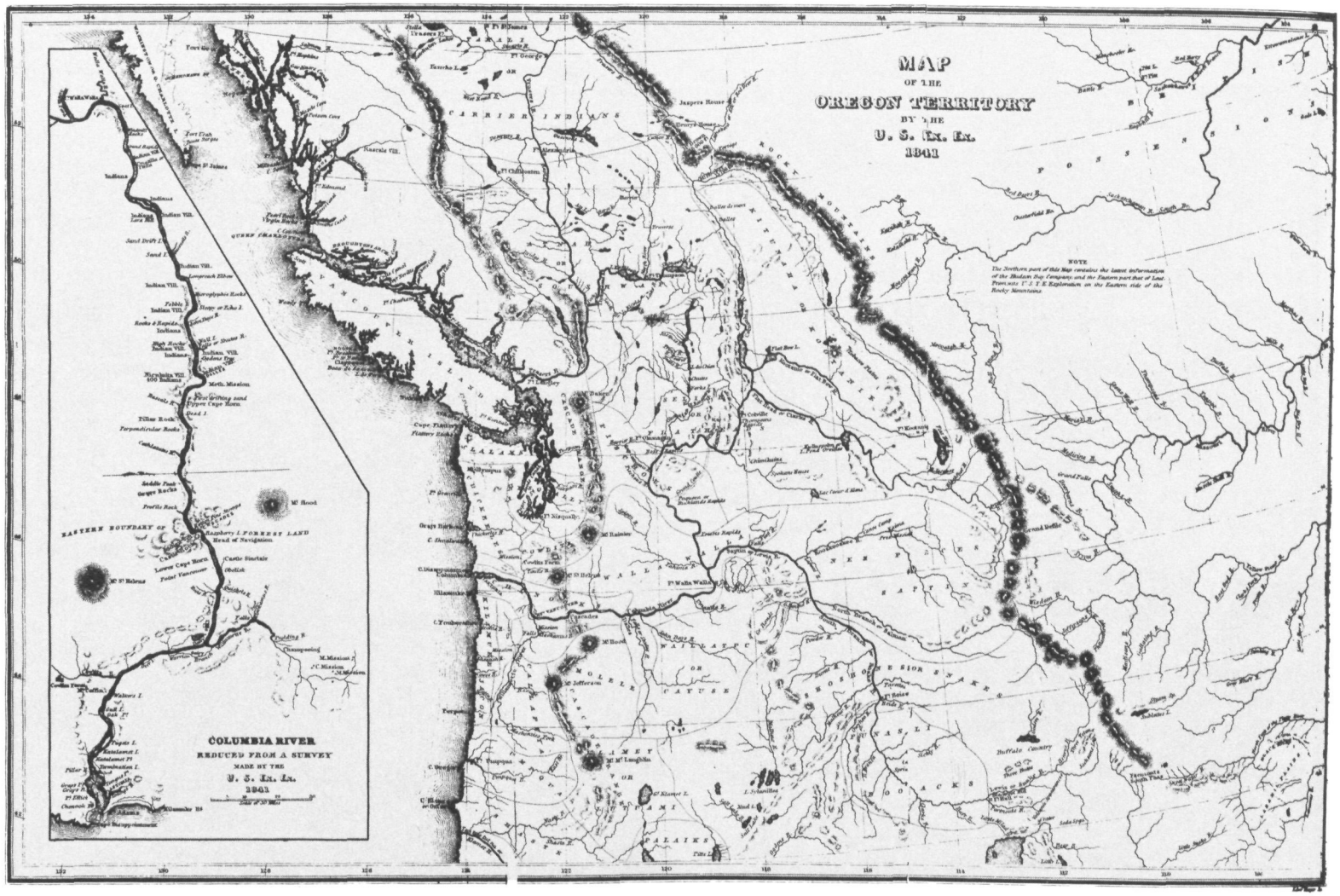






(Right) Old mission house in Oregon.
(Above) Fort Vancouver, just north of the present site of Portland, Oregon.
(Right, below) Longwood, St. Helena, where Napoleon was exiled.



Oregon Territory, from engraved map number 135 of the Wilkes series of 1841.

APPENDIX.

XIII.

[L. S.]

I, Mohamed, Sultan of Sooloo, for the purpose of encouraging trade with the people of the United States of America, do promise hereby and bind myself that I will afford full protection to all vessels of the United States, and their commanders and crews, visiting any of the islands of my dominions, and they shall be allowed to trade on the terms of the most favoured nation, and receive such provisions and necessaries as they may be in want of.

2dly. In case of shipwreck or accident to any vessel, I will afford them all the assistance in my power, and protect the persons and property of those wrecked, and afford them all the assistance in my power for its preservation and safe-keeping, and for the return of the officers and crews of said vessels to the Spanish settlements, or wherever they may wish to proceed.

3dly. That any one of my subjects who shall do any injury or harm to the commanders or crews belonging to American vessels, shall receive such punishment as his crime merits.

In witness whereof I have hereunto set my hand and seal, in presence of the datus and chiefs at Soung, island of Sooloo.

February 5th, 1842.

[L. S.]

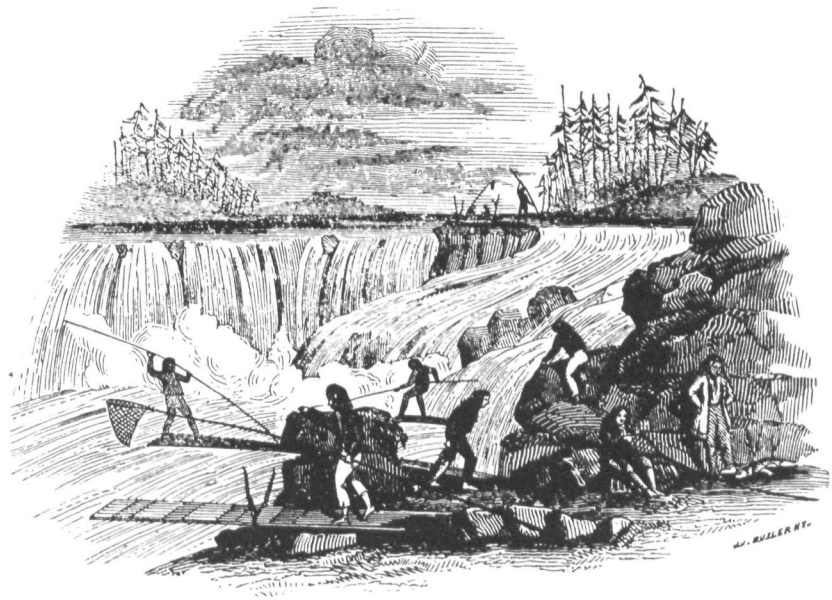
[L. S.]

Witnesses.

CHARLES WILKES,
Commanding Exploring Expedition.

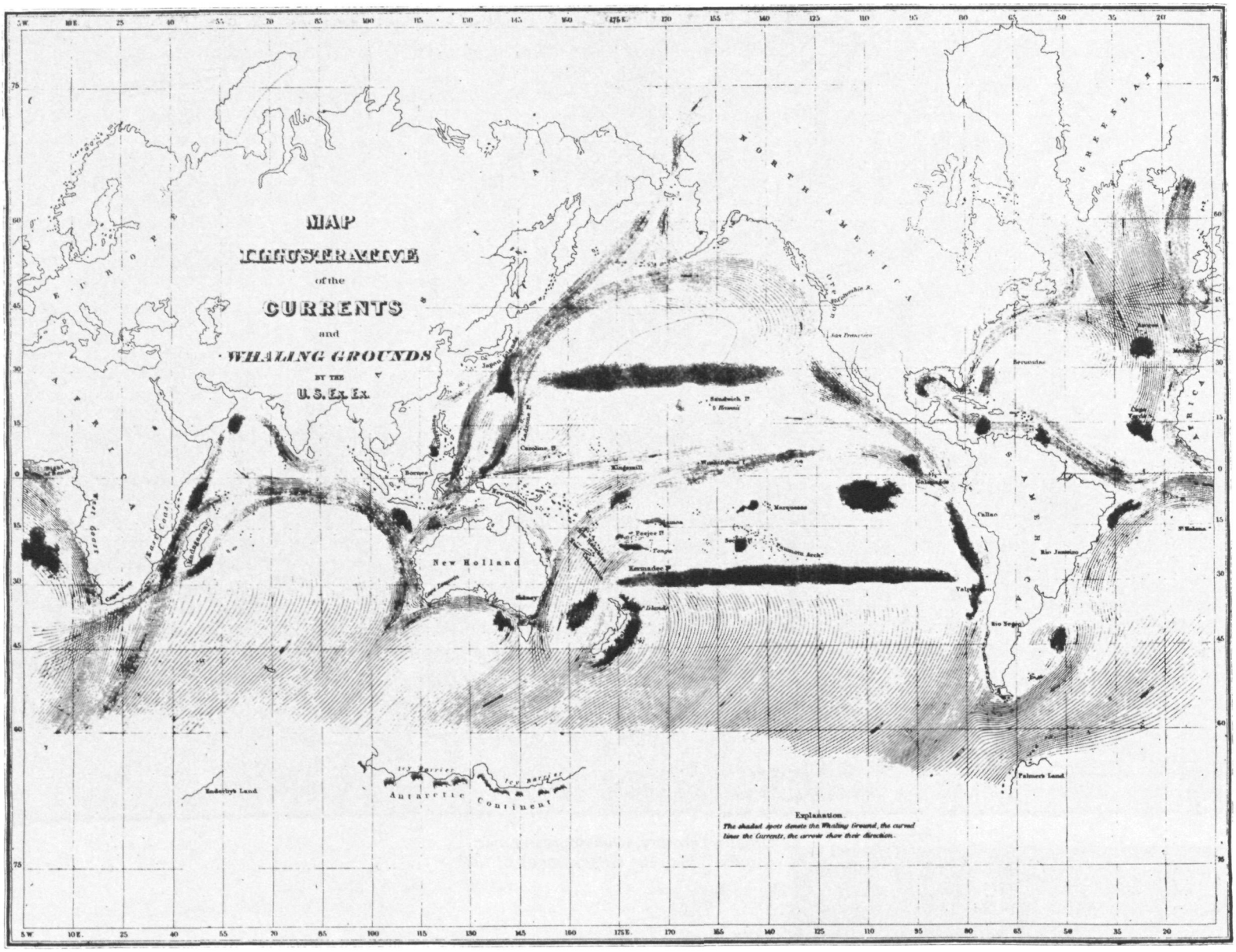
WILLIAM L. HUDSON,
Late commanding U. S. Ship Peacock.

R. R. WALDRON,
Purser, U. S. Exploring Expedition.



Willamette Falls in the Oregon Territory.

One of the highlights of the expedition was the treaty with the Sultan of Sooloo, which Wilkes signed on behalf of the United States.



Wilkes' concept of Pacific Ocean currents in 1841.

Grand Coulee which it passed enroute. A third expedition followed the Columbia River up to its junction with Walla Walla River.

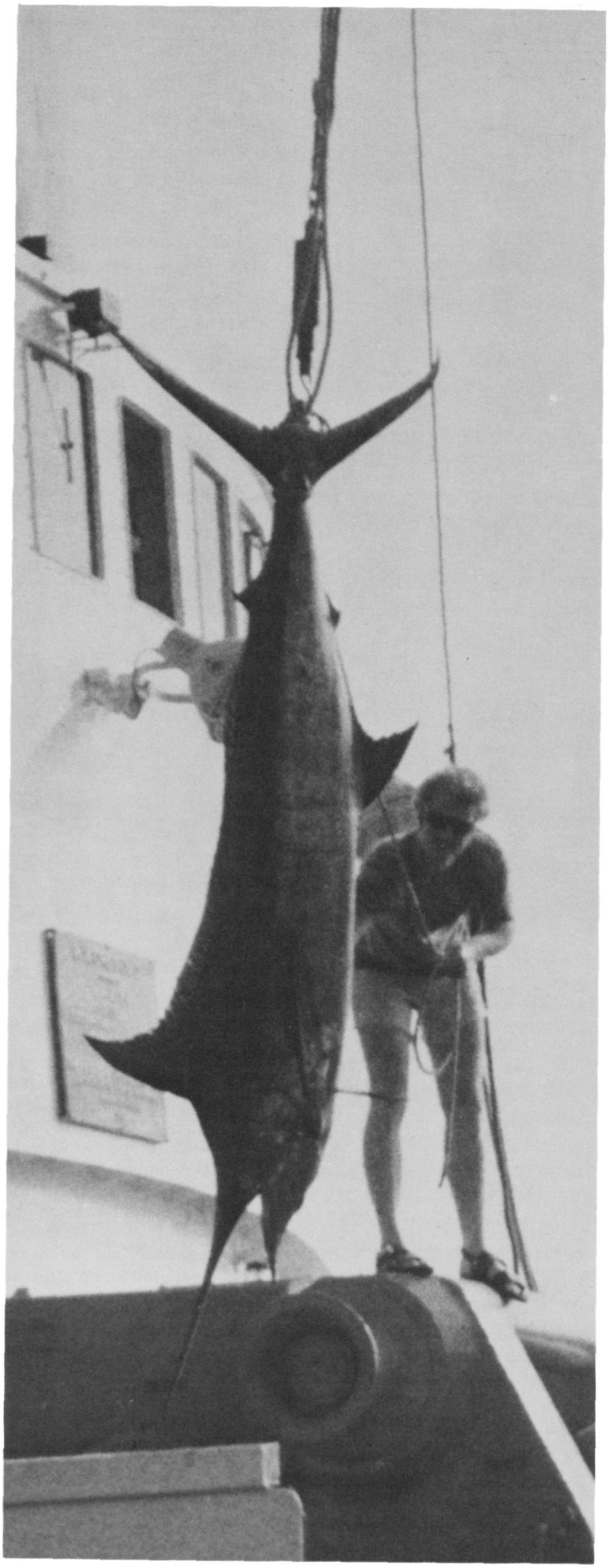
The work of surveying Puget Sound continued at a rapid pace and, on June 16, the ships moved out into the Strait of Juan de Fuca and continued work there. During the latter part of June, Wilkes received the news that the PEACOCK had been wrecked off Cape Disappointment, but that all hands had been saved. Surveying was discontinued and the ships departed the working grounds on August 2, 1841, arriving off Astoria on August 6. Wilkes then shifted his command to the PORPOISE, dispatched the VINCENNES to San Francisco, and proceeded to make a detailed survey of the Columbia River. The PORPOISE proceeded up the Columbia River to Ft. Vancouver and, while there, was joined by the party which had been surveying Grays Harbor. The survey of the Columbia River to the head of navigation was continued.

Meanwhile, an expedition was ordered to explore overland from Vancouver to San Francisco joining the VINCENNES there. The surveys of the Columbia and the Willamette Rivers were completed on August 6 and the VINCENNES proceeded to San Francisco. A surveying expedition was also dispatched up the Sacramento River and reported reaching the residence of Captain Sutter of "Sutter's Mill" fame during the California Gold Rush. He held an appointment as Governor of the district. Much valuable information was obtained from him and the investigation was continued up the Sacramento River to the present site of Sacramento City. Surveys were also made of the northern section of San Francisco Bay and San Pablo Bay with a small party visiting the mission at Santa Clara.

Meanwhile, the overland party which had departed Ft. Vancouver made its way slowly to San Francisco. They encountered illness and hostile Indians as they made their way past Mt. Shasta to the valley of the Sacramento, but survived without casualties. The party finally reached Captain Sutter's headquarters at New Helvetia and journeyed down the river to join the VINCENNES after almost two months' absence.

These surveys are reflected in the copper engravings now in the possession of National Ocean Survey. The collection comprises an interesting map of the Oregon Territory, seven charts of the Columbia River, most of Puget Sound, charts of the Sacramento River, and San Francisco and San Pablo Bays. Other areas covered are Grays Harbor, Strait of Juan de Fuca, Admiralty Inlet, Port Discovery, and detailed charts of selected ports, harbors, and inlets.

The engravings show evidence of great skill in their execution. In later decades, copperplate engraving such as practiced during the time of James McNeill Whistler reached new heights. However, the Wilkes engravings played an important role in the development of copper engraving, since the record indicates that they were executed prior to all but the earliest of the engraved charts of the National Ocean Survey. It may be assumed that experience gained in producing them contributed materially to the art of copperplate engraving. □



NMFS scientists and sport fishermen team up to track the Loop Current.

Gold Mine of GAMEFISH

BY ANN WEEKS

The arrival of spring in the subtropics is scarcely noticeable to outlanders from cooler climes. But to those on intimate terms with the explosion of life that accompanies the coming of subtropical spring weather—particularly in oceanic areas and more particularly in big-game fishing centers, such as the Gulf States—May and June herald the beginning of the big action.

Subtropical seas go through decided changes as the waters warm. Currents and flows often intensify, mixing of cold and warm water alters the chemistry of seawater, and swarms of newborn plant and animal life transform broad oceanic stretches into a rich brew of nutrients consumed by larger forms. The big, savage fighting fish are not far behind.

Gulf of Mexico fishermen have long been wise in the ways of nature in nearby waters, as have marine scientists in national, state, and private institutions in gulf regions. The two groups, which have a long history of cooperation, joined forces this June to investigate big-game fishing in the northeastern Gulf of Mexico as it related to the "Loop Current," an oceanic phenomenon discovered some years ago, but not closely analyzed until fairly recently.

The current, thought to be present for most of the year, strengthens in the early months of the year. It surges up from the Caribbean in the spring, sweeps past the Yucatan Peninsula into the gulf in a broad northwest-to-northeast arch, then loops southeast and east around the Florida penin-

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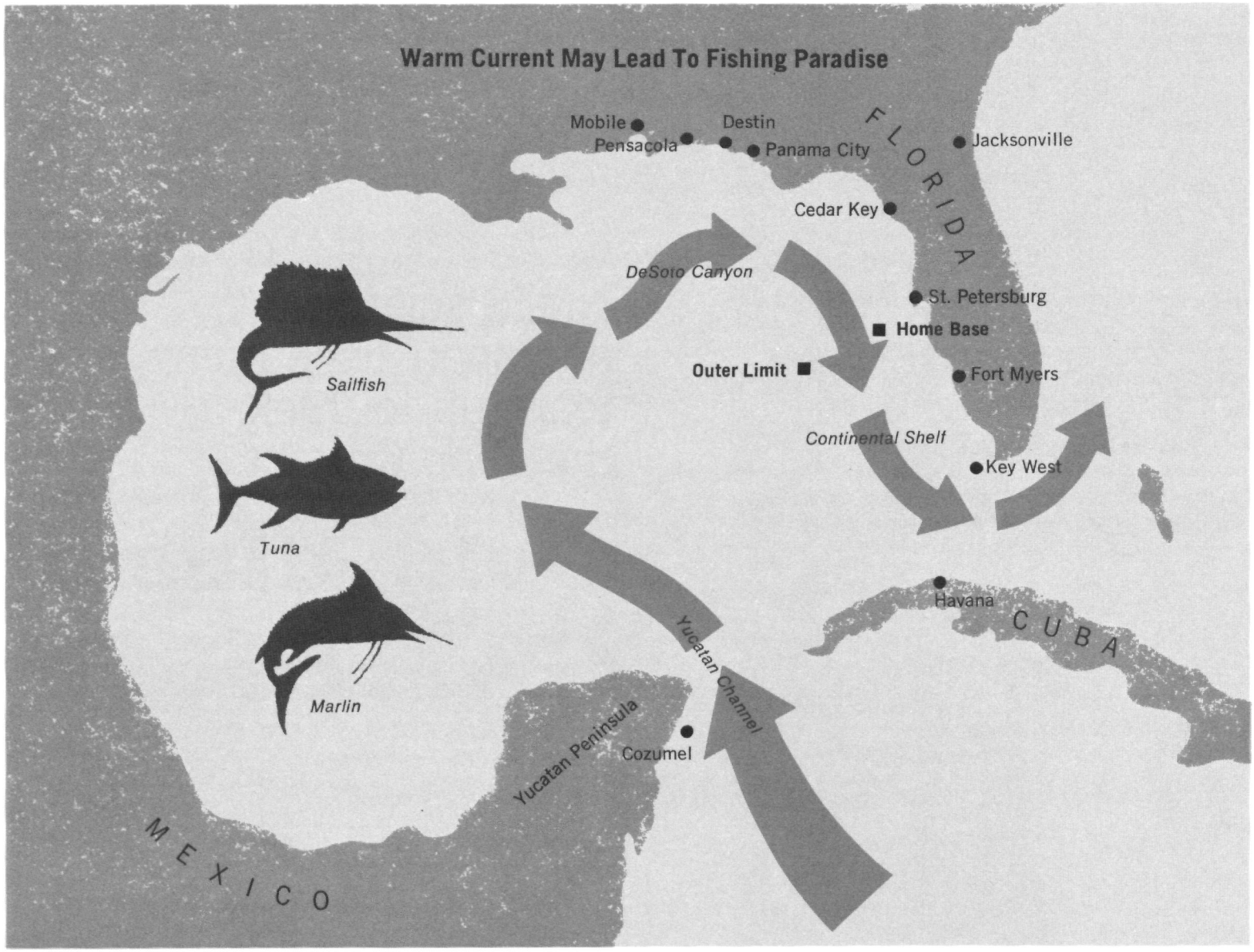


Each spring, a warm fish-laden current comes up from the Caribbean and streams into the Gulf of Mexico at more than 40-million cubic meters per second, a feeder line that is opening up the Gulf to the possibilities of one of the great game-fishing grounds of the world.

sula, and swings into the Straits of Florida. This 100-mile-wide marine conveyor belt, traveling up to 80 miles a day, carries with it such valued sportfish as marlins, sailfish, wahoo, broadbill swordfish, tuna, and dolphin. Snapper and grouper feed in its lower reaches.

The existence of the Loop Current was suspected in the late 1940's and early 1950's, and confirmed in the 1960's, largely on the basis of investigations by the National Marine Fisheries Service, including repeated voyages by the research vessel OREGON. Much of the data that eventually resulted in the definition of this important marine feature was gathered and studied by NMFS scientists stationed at the Panama City, Fla., Eastern Gulf Sport Fisheries Marine Laboratory. (Until 1970, this laboratory was under the direction of the Bureau of Sport Fisheries and Wildlife.) A considerable body of evidence also was contributed by sportfishermen operating out of Louisiana ports.

Additional light was cast upon the phenomenon as a result of the EGMEX (Eastern Gulf of Mexico) research cruises of 1970, which included participants from several NOAA elements; the U.S. Coast Guard; the Florida Department of Natural Resources; the Universities of Miami, South Florida, Florida, and West Florida; Florida State University; Nova University; Florida Institute of Techonology; and Texas A&M University. Private industry and a number of foundations contributed vessels, equipment, and personnel to the EGMEX studies. Data collected were wide-ranging, from oceanographic, biological, and chemical samplings to satellite and aircraft observations.

By 1969-70, gamefish enthusiasts in the Tampa Bay region of the Florida west coast became actively interested in finding out whether the exciting catches enjoyed in the northern gulf—where billfish catches alone have been running about 1,500 fish per season in recent years—might be possible in the eastern gulf. They wondered if it might be profitable to fish in the vicinity of the Loop Current as it flowed southward off the Florida coastline.

Early in 1971, plans were laid for an investigation called "Operation Loop" to take place June 13 to 16. Twelve sportfishing boats were involved in the exploratory fishing expedition, including three party boats, one a 90-footer, two 65 feet long. Accompanying the small fleet was the 170-foot NMFS research vessel OREGON II, which traveled from her home base at Pascagoula, Miss., to lend scientific assistance. The point of rendezvous was at the 27th parallel and slightly to the west of longitude 84 degrees, about 80 to 100 miles offshore, in 49 fathoms.

The scientists from Florida installations

who accompanied the fishermen were: Robert Smith, State University System of Florida Institute of Oceanography; Harold Allen, Deputy Regional Director at NMFS, St. Petersburg; Eugene Nakamura, Director of the NMFS Eastern Gulf Sport Fisheries Marine Laboratory, Panama City; and Grant Beardsley, NMFS Tropical Atlantic Biological Laboratory, Miami.

"Operation Loop" (the name coined by Red Marston, sportswriter for the St. Petersburg *Times* and a participant in the sportfish/scientific investigation) was called "an unqualified success" by the fishermen involved. The scientists described the venture as "promising." Grant Beardsley commented: "I saw a great many indications of a sport fishery, including the sighting of marlin, good sargassum weedlines that were productive, plus a great deal of bird activity, something we don't see much of in south Florida waters. There is a definite potential out there." Beardsley can be presumed to know whereof he speaks—he held a blue on the line for about two hours, then lost the fish, estimated at 300 pounds.

All agreed that catches and sightings of gamefish were spectacular. Numbers of blue marlin were sighted, several struck baits, and one 220-pounder was caught for the first time in the memory of sportsfishermen in waters off St. Petersburg; a broadbill swordfish and five giant oceanic sunfish (Mola-Mola) were seen; sailfish, wahoo, dolphin, tuna, barracuda, grouper, snapper, and shark were caught or sighted.

The OREGON II fished on two longline sets (about 150 hooks in each) took numerous oceanographic readings, and collected seawater samples and biological specimens. The captured blue marlin was taken aboard the research vessel for weighing and measuring and kept for biological study. Temperature and depth recordings, compared with catches and sightings, disclosed that fishing was best at 80.8 degrees Fahrenheit, in 60 to 80 fathoms; in deeper waters toward the middle of the loop of the current, fishing was poor and concentrations of plankton in the water were reduced.

Marine data gathered in Operation Loop will be added to scientific material collected for two or more decades off the Louisiana coast in sportfish regions now believed to be associated with the current on its initial northwest rush through the gulf. Experienced observers consider that only now are they beginning to understand the ramifications of the flow of the enormous current, even though its existence has been known for some time.

Scientific hypotheses hold that the loop current begins to move in January or February near western Cuba, and is pushed along by the northeast trade winds. Those winds blow across the warm equatorial water and help move the current in a north equatorial drift pattern. By March, the front edge of the current reaches the Yucatan Channel and begins a northward course which takes it to the Mississippi Delta area; as it passes by the Delta country, the current gains in strength until it reaches a high flow per day by late April. It also takes on additional nutrition from the rich outflow of Delta waters. At that time, sportsmen from Louisiana—most of them fishing out of South Pass—take first crack at the large gamefish feeding at the edges of the current, gathering up impressive catches of marlin, sailfish, yellowfin and bluefin tunas, dolphin, and wahoo.

From the beginning, these gulf coast fishermen have shown a remarkable willingness and ability to collect scientific data needed to define the relatively new fishery. Their fish-tagging program—established cooperatively with the Louisiana Fish Commision and the NMFS Eastern Gulf Sport Fisheries Laboratory — provides yearly details on identification of species, notation of weight, standard length, total length, girth and sex, and examination of the stomach contents of large gamefish. Environmental conditions such as salinity, chemistry of the water, wind speeds and direction, weather, and comparisons of total fishing days with catch and effort are also studied.

When the loop current reaches its summit, flowing on an eastward course toward Florida, the Panhandlers from Pensacola, Destin, and Panama City get a chance to wet their lines. Opportunities for fishermen from Cedar Key, St. Petersburg, and Fort Myers come somewhat later as the current continues on its looping course toward the west coast of Florida, then southward. Scientists working in gulf areas now hope for collections of marine data from the northeastern and eastern regions of the gulf, as the sportfishing fraternity continues its pursuit of fish along the route followed by the loop current.

The enthusiasm of Florida fishermen is not dampened by warnings that the presence of the big gamefish cannot be predicted with certainty in ensuing years, or that larger sportfish boats may be needed to handle extra fuel for longer trips and longer stays on the fishing grounds, or that substantial cash outlays may be required for heavier tackle, or even that some anglers may have to go back to school to learn how to catch the heavier gamefish. Long before the 1971 season ended, plans were well under way for the Marlin Tournament of 1972. □

Loop Current

Dr. Robert Smith, State University System Institute of Oceanography, 830 First St., South, St. Petersburg, Fla. 33701, is engaged in summarizing and making copies of information collected on Operation Loop, including:

1. **Depth recordings (bottom traces), longitudes and latitudes of good fishing locations.**
2. **Information about fish seen at the surface, how many struck bait, and how many were caught.**
3. **Type bait used for caught surface fish.**
4. **Fuel—total carried, total used.**
5. **Reports of water temperatures taken.**
6. **Approximate cruise route and areas trolled.**
7. **LORAN coordinates and approximate time of day when fishing was best.**
8. **Totals of bottomfish caught; average weights of red snapper and grouper.**

Interested readers should send queries to Dr. Smith, with self-addressed, stamped envelope.

MAN ON THE *MOVE*

Arriving at St. Paul Island, left to right: Philip Roedel, NMFS Director; Howard Pollock, NOAA Deputy Administrator; Harry Rietz, NMFS Alaska Regional Director; Secretary Stans; Stuart Bigler, NWS Alaska Regional Director; and Secretarial assistant Tom McSpadden.

Secretary of Commerce Maurice H. Stans made a flying trip to Alaska and the Pribilof Islands in July to inspect NOAA programs in the North. He was accompanied by NOAA Deputy Administrator Howard W. Pollock, former Congressman from Alaska, and Philip M. Roedel, NMFS Director. During his whirlwind trip, the Secretary viewed the fur seal harvest and concluded: "Any implications . . . to the effect that baby seals are harvested, that harvesting is depleting the herd, that harvesting methods are inefficient or inhumane, or indiscriminate, are totally unfounded." About a month later, a panel of six eminent veterinarians making an independent review of NMFS practices on the Pribilofs came to the same conclusion. Highlights from the Alaska visit are pictured here.

On St. Paul Island, left to right: (kneeling) Dr. Mark Keyes, NMFS Seattle; and Mr. Pollock; (standing) Frank McMahon, Humane Society of the United States; John Walsh, International Society for the Protection of Animals; Secretary Stans; Mr. Roedel; Mr. Rietz; and Richard Denney, American Humane Association.

From left, Juan Leon Guerrero, weather service meteorological technician on St. Paul Island, with Secretary Stans and Mr. Bigler.

(Above) Aleut workers in the sealskin processing plant explain the inspection system to Mr. Pollock. (Right above) Seal skins are packed in barrels. From left, Mr. Pollock, Secretary Stans, Mr. Bigler, and Pribilof Program Director William Peck. (Right) Mr. Peck describes blubbering operation to Secretary Stans and Mr. McSpadden.

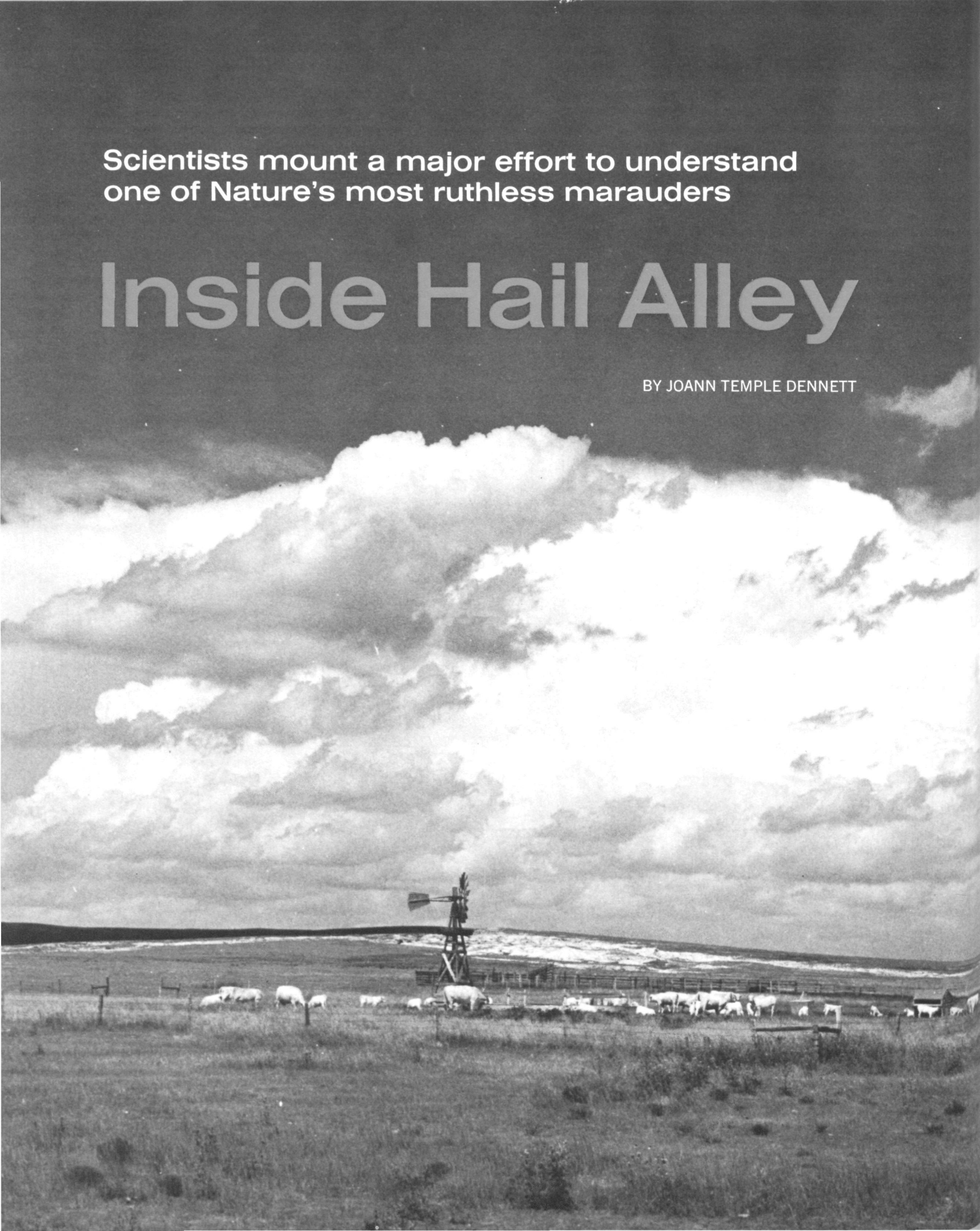
Six eminent veterinarians of the American Veterinary Medical Association studied methods employed in fur seal harvesting. With Dr. Keyes and Secretary Stans (fourth and fifth from left) are veterinarians Dr. Bernard S. Jortne, Dr. William V. Lumb, Dr. Alvin F. Moreland, Dr. Wallace M. Wass, Dr. Leslie E. McDonald, and Dr. C. Roger Smith.

Roy Hurd of NMFS Pribilof Program with Secretary Stans on St Paul Island.

Scientists mount a major effort to understand one of Nature's most ruthless marauders

Inside Hail Alley

BY JOANN TEMPLE DENNETT



"Grover One, Grover One, Mark! I'm over the gas station right now and proceeding up to Interstate 80."

The men clustered in a dimly lit trailer watch the plane's path on their various radars. Some are noting his position over the gasoline station on a map while others are marking the plane's position on various radars. The station will then be used to calibrate the radars to each other. There aren't very many landmarks in the vast, arid plains of Hail Alley in northeastern Colorado and a gasoline station located at an intersection visible from 5,000 feet is as good a "mark point" as anything else in this hot, wind-blown country.

Scientists working on the National Hail Research Experiment (NHRE) almost doubled the population of Grover, Colorado, when they moved in this summer to start pilot studies on a five-year-long intensive effort to study hailstorms and possible ways to suppress the growth of severe hail.

Grover is ideally situated for this project: where Colorado joins Wyoming and Nebraska, less than 15 miles to the north, is the approximate center of Hail Alley, USA. Here, cumulus clouds boil up from the hot earth to produce the highest frequency of hailstorms anywhere in the Nation.

Hail is not only frequent here but also frequently impressive. Potter, Nebraska, held the nation's record for the largest hailstone (1½ pounds) from 1920 to 1970. In September 1970, Potter lost this dubious honor to Coffeyville, Kansas where a 1.67-pound hailstone fell. This year, hail two to three inches in diameter fell in the NHRE project area on two successive days, July 14 and July 15.

Hail is a widespread problem, not only here but throughout the Nation. Hailstorms do two hundred to three hundred million dollars' damage to crops and property each year in the United States. Tremendous savings may be possible if the fury of the hailstorm can be reduced—perhaps by making it convert its ammunition to rain or small hailstones through seeding from aircraft.

Hail research has been going on for a number of years in most of the nations of the world where hail does severe damage. Canada, France, Italy, Kenya, and the Soviet Union are among the countries that have been trying to learn to suppress hail.

The United States' effort, focused in NHRE, settled quite appropriately in Hail Alley. NHRE, supported by the National Science Foundation, is a cooperative effort involving a number of universities, federal agencies, and other organizations including the Atmospheric Physics and Chemistry Laboratory (APCL) of NOAA/ERL, Colorado State University (CSU), and the University of Wyoming. The experiment is being managed by the National Center for Atmospheric Research (NCAR) in Boulder.

Everyone in Grover knows where "the site" is—"go two blocks to the end of town, cross the railroad tracks and just keep going till you get there. You can't miss it."

"You can't miss it" is right. As you're rolling along a dirt road kicking up a cloud of dust into the unrelenting sunshine pouring down on a mile-high, 100° Colorado plains' summer day, you pass a few cattle, some sheep, even an occasional antelope. Then, suddenly, just past some huge white rock outcroppings, an installation reminiscent of *"The Andromeda Strain"* appears. Eight glistening white double trailers, four radars, blinking red lights, and a moving green flag signalling a "go" day—"go" for expected hailstorm activities.

Five aircraft flew nearly full-time with the NHRE project and another six planes participated for part of this year's pilot study. Five trucks stand by to dash out and collect hail specimens where they fall. Four hundred and thirty five stationary sites gather information on precipitation and weather conditions. In addition to the radars at the Grover site, two units 30 miles away in Greeley, Colorado, are active in the projects.

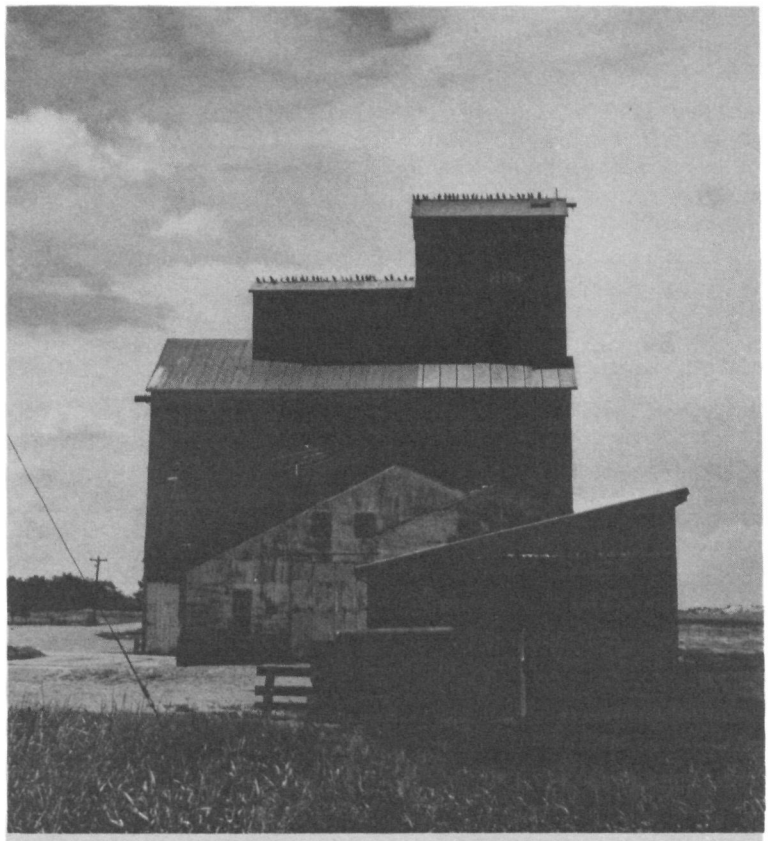
This summer, the researchers concentrated on testing new research systems for full-scale use in NHRE over the next four years. According to William C. Swinbank, NHRE director at NCAR, the five-year project is designed to gain fundamental knowledge about the physics and dynamics of severe storms that may produce damaging hail and to test the effectiveness of seeding techniques for reducing the destructive force of hailstorms. He says:

"It appears that the right amount of a seeding agent such as silver iodide, introduced into a potentially severe hailstorm at just the right time and place, can make the storm convert its moisture into rain or small hail, rather than large, destructive hailstones. Although this technique promises to work, a detailed understanding of just what happens inside seeded and unseeded hailstorms is needed before it will be possible to decide whether or not cloud seeding can be used consistently and effectively to reduce hail damage."

In addition to setting up and testing research systems, the NHRE scientists used the 1971 season to observe unseeded hailstorms with radar, research aircraft, automatic sampling devices, and other research tools. Good ground and aircraft data were obtained from June and July storms and this NHRE information is well supplemented by upper air rawinsonde information collected by meteorological teams from the U.S. Army and Air Force, stationed at Grover, Fort Morgon, Sterling, and Kimball.

NOAA/APCL's major effort this year was directed toward the ground network—a vital data tool in understanding natural storms and an imperative aid in accurately assessing the effects of any seeding attempts.

continued



Pigeons perch on the tallest building in Grover, Colo., the town that served as headuarters for the hail experiment.

Colorado cattle graze peacefully as a thunderhead builds behind them.

Hail collection sites were spread around the experimental area, with the cooperation of private land owners.

Byron B. Phillips, deputy director of APCL, and Joint Operations director of NHRE, with Gary Gazer of NCAR explained:

"We outlined an area 50 miles by 50 miles. Inside this rectangle, we had 420 specially designed stations to record weather and precipitation in a fine grid detail."

One hundred twenty of these were precipitation stations, in part fashioned from galvanized garbage cans, and a model of NOAA/APCL economy. Each unit contained a rain gage, hail impactor and hail pad to make a record of the time each individual hailstone fell, and its size, and the number of stones that fell in a given area and their momentum. The pad is Styrofoam covered with aluminum foil on which each hailstone leaves a permanent imprinted record of its arrival. Half of these stations included a collection box refrigerated with dry ice. Hail samples were collected following each storm. An additional 100 stations had a rain gage and the hail pad and the remaining 200 stations were hail pad stations only.

The cross-section of one hailstone can look vastly different from that of another. Wet and dry growth regimes show clearly in the cross-section but this is not simply linked to distinct physical properties of the hail cloud. Only one hailstone shape seems clearly identified as related to a typical microphysical cloud structure. This is a conical-type stone which appears to grow only in the more laminar flow updrafts which contain supercooled water in the form of small cloud droplets.

Thus, hailstones collected and stored at subfreezing temperatures after their fall can reveal a number of properties useful for interpreting their life history and perhaps show the combined effects of a number of properties such as liquid water content of the parent cloud, temperature effects, and relative motion of the cloud and hailstone.

The stone hardness can vary along the circumference depending on the stone's orientation during its fall. Peeling off various growth layers identifies various homogeneous growth regimes. The temperature difference across a cross-section may be indicative of the level of formation if the growth proceeded in the so-called dry state wherein the stone surface is not covered by a film of liquid water.

Since hailstones can yield some information about the storm they fell from, it is important that NHRE scientists collected stones from the same storms which are being studied by radar and aircraft. Mobile vans with freezers gather these stones and bring them back to Boulder for study and final correlation with the storm characteristics measured in the air.

The aircraft, used this year in initial studies, will play a large role in NHRE's coming years. Although cloud seeding was not a prime objective for the 71 pilot NHRE study, one aircraft was available during the final part of the project effort to perform some seeding tests if nature cooperated by sending the right kind of storm through the hail research area in northeastern Colorado.

The aircraft, from the South Dakota School of Mines and Technology, was fitted out with seeding equipment, and prepared to perform seeding experiments on potential hailstorms that moved into the experimental area. The NHRE researchers made three seeding flights this summer primarily to test seeding techniques and operational procedures.

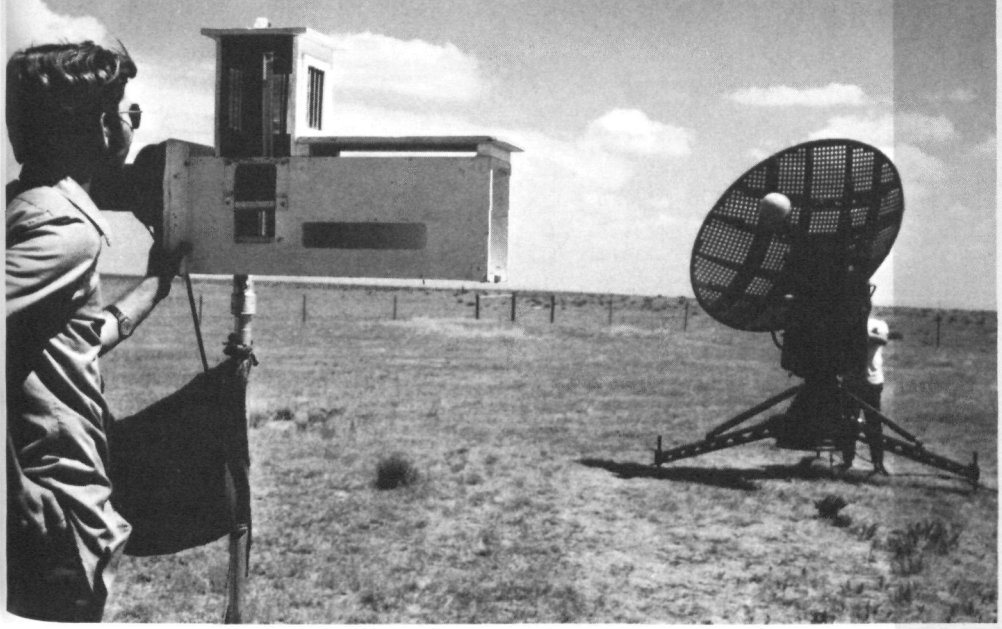
A specially instrumented DC-6 aircraft, operated by NOAA's Research Flight Facility (RFF), Miami, Florida, was on duty with the Colorado project for four weeks. Regarded as a complete mesometeorological observation system, this aircraft flew around hailstorms to analyze air movements through the storm, determine the number of individual hail cells within the storm (meso-structure), and study atmospheric conditions in proximity to the storm.

The DC-6 equipped with a digital data recording system is capable of recording meteorological observations every second during flight. Circumnavigation of the actual storm cell provided much detail on the air flow through the storm. Later computer analysis of the recorded flight data will yield a map of the aircraft's flight track with the winds at flight level superimposed. With this information, scientists are able to evaluate the amount of air flowing in and through the storm in relation to the cell structure of the storm as recorded by the aircraft and ground radars.

The RFF plane has three radars—a 30-cm unit which provides cross-sectional views of the storm at right angles to the aircraft, a 5-cm unit mounted in the nose, and a 10-cm unit mounted in the belly. These radars are equipped with contour mapping devices which show centers of high storm intensity.

A Doppler navigation unit on the aircraft provided data on aircraft position, aircraft heading; true airspeed; drift from true heading due to wind, wind direction, and wind speed at flight level; distance traveled; radar altitude; pressure altitude; difference between radar-measured altitude and altimeter reading; pressure at flight level; air temperature; and liquid water content.

On days when hailstorm research appeared possible, the NOAA/RFF aircraft was called at Buckley Field in Denver in the early afternoon to conduct weather reconnaissance at its operational, cloud-base altitude of about 10,000-feet. This aircraft carried 17



At Grover, technicians launched and tracked radiosondes to obtain upper-air information.

persons, each with his own observing or recording job. The Grover site alerted the mobile hail laboratories and the radar stations when the DC-6 took off.

This continuous survey provided data necessary to determine the dynamics of each storm. The detailed cell structures were then obtained from radar information which provided horizontal and vertical cross-sections of the storm.

The record of the wind field at flight level could then be superimposed on the radar display to show the major inflow and outflow areas with respect to the radar display. Vapor flux into the storm was obtained from flight humidity and wind records.

Other aircraft involved in similar ways this summer included: a Buffalo and a Sabreliner from NCAR, a Beech Baron from South Dakota School of Mines, an Explorer Glider from NOAA/Environmental Research Laboratories (ERL), a C-45 from the University of Wyoming and an F-101 and a T-6 from Colorado State University. Two NASA aircraft were involved for short periods of the project. Flying at different altitudes through and around a storm cloud, these aircraft provided much detailed information of the life history of each storm studied. The high-altitude Convair 990 jet from the National Aeronautics and Space Administration's (NASA) Ames Research Center in California participated in the NHRE project. Flying at 41,000 to 43,500 foot altitudes aboard this high observing "platform," NOAA/APCL scientist Dr. Peter M. Kuhn was seeking to measure the amount of water pumped into the stratosphere by towering cumulonimbus or thunderheads. This work was done by NASA and NOAA in a pilot project of the Department of Transportation.

Final analysis of aircraft observations of the storm will be combined with the analyses of the storm's characteristic from ground-based radar and NHRE facilities to provide a better understanding of the storm's dynamics.

Measurements were also made to illuminate storm processes on a microphysical scale. Equipment aboard the DC-6 aircraft counted the concentration of freezing and condensation nuclei near the cloud base. In order for rain drops or hailstones to form inside a cloud, these condensation or freezing nuclei must be present for water vapor to collect or freeze on.

Natural nuclei come from a variety of sources such as dust, smoke, sea salt, meteoritic dust, and air pollution. Accurate measurements of the number of natural condensation and freezing nuclei present in a cloud are important in determining the future rain and hail development of that cloud.

Next year, with the 1971 pilot experience under their belts, the NHRE researchers will be trying to understand and modify severe hailstorms. □

The buttes which characterize the flatlands of northeastern Colorado are visible in the distance beyond one of the hail collection stations.

A mother remembered the safety rules and rescued her child from a rip current

Mrs. David Bell and daughter Lisa.

ONE LESS VICTIM

Lisa Bell, whose father David Bell is an accountant with the National Ocean Survey triangulation party G-18, was swept to sea in a rip current not long ago. Instantly, her mother, Evelyn Bell, recalled an article she'd read in the July 1967 *ESSA* Magazine. In it, Dr. Harris B. Stewart, Jr., now Director of NOAA's Atlantic Oceanographic and Meteorological Laboratories, had described rip currents and how to escape them. Following the remembered advice, Mrs. Bell quickly saved her daughter. She recounted the rescue in a letter to a friend at NOAA headquarters.

We have a niece in Tampa her hubby is in the Air Force. We went down a couple of wk ends ago. She sure had a wonderful time + loved it down there, except for one thing. Lisa nearly drowne in the ocean near St. Pete. I had to go in after her Clothes + all. A wave caught her + swept her out over her head about as quick as you can bat an eye.

I always stay at the waters edge when at the ocean. I was about ankle deep, picking up shells. She didn't holler or anything. She wasn't too far out. My niece Judy went out to play + I saw her reach out + miss her + the old adrenalin zoomed. I think I walked water. We were out over my head + the under tow got her. We went under a couple of times but I talked to her + she didn't panic, thank goodness.

Thanks to ESSA's book of several years ago, I knew what + how to get out of a rip tide. In fact I still have that book + make everyone read it that I know of going to the beach. I even made a copy of it several yrs. ago of the article + sent it to the families at home (N.C.) I think we were in N. Dak. at the time. The article made such

an impression on my mind that I never forgot what to do, it all came automatic. It sure benifited us. I ask Lisa why didn't she holler, she said I thought you knew I was over my head. I ask her was she scared + she said; yes, til I saw you coming + then I knew I'd be alright. what faith.

Lisa said, Now I know why you always tell me to stay in one place, + you have to go with me all the time when at the beach. If she hadn't been able to swim as well as she did, I'm afraid she would have been gone before I could have gotten to her. Well enough of this Somebody up there still likes me.

Anyway, would you thank the guys of "NOAA" while were "ESSA" at the time the article was written, because I deeply feel, their article saved my life + Lisa's.

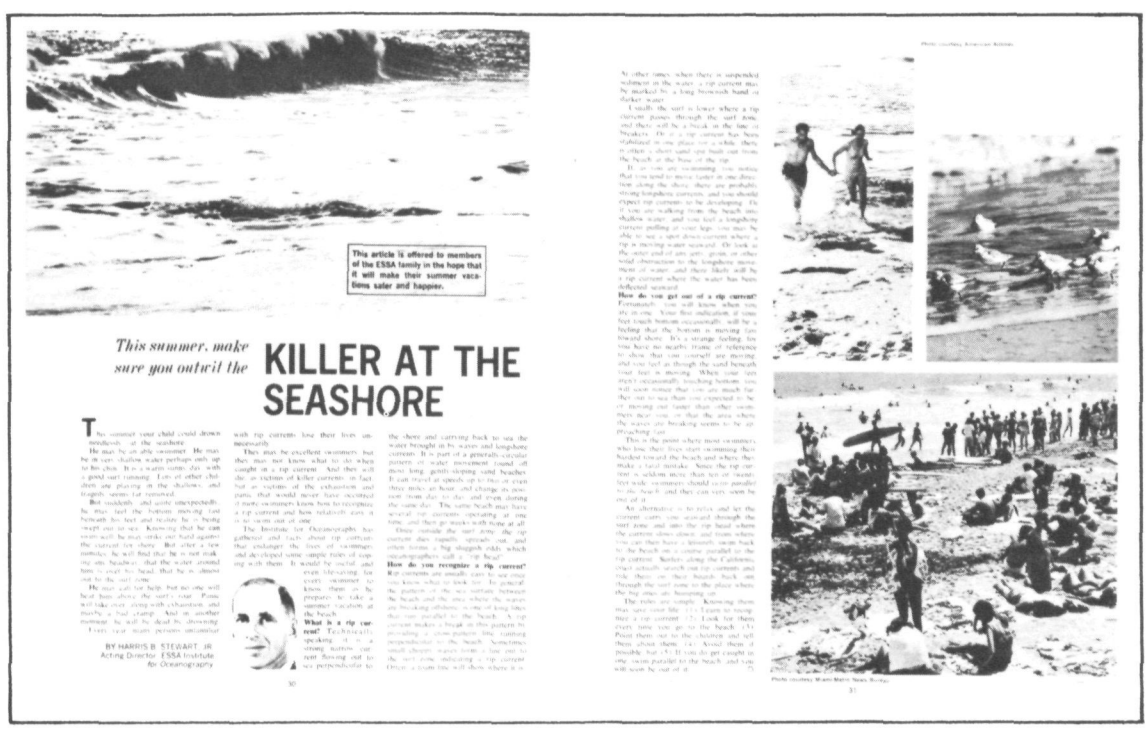
The rip current can occur at any ocean beach. It is a strong, narrow current flowing out to sea perpendicular to the shore, carrying back to sea the water brought in by waves and longshore currents.

Rip currents are usually easy to see. In general, the pattern of the sea surface between the beach and the area where waves are breaking offshore is one of long lines that run parallel to the beach. But a rip current breaks this pattern by creating a cross-pattern line running perpendicular to the beach. Sometimes, small choppy waves form a line out to the surf zone, indicating a rip current. Often, a foam line will show where it is. At other times, when there is suspended sediment in the water, a rip current may be marked by a long brownish band of water. Usually the surf is lower where a rip current passes through it, and there is a breach in the line of breakers.

Caught in this insidious, powerful ocean action, the swimmer finds himself swept rapidly to sea. At this point, many make the fatal mistake of striking directly for shore—against the current. But because the rip current is seldom more than ten or twenty feet wide, the quickest route to safety is parallel to the beach.

Remember these rules:

1. **Learn to recognize a rip current.**
2. **Look for them every time you go to the beach.**
3. **Point them out and explain them to the children.**
4. **Avoid them if possible, but**
5. **If you do get caught in one, swim parallel to the beach, and you will soon be safe again.**



This article is offered to members of the ESSA family in the hope that it will make their summer vacations safer and happier.

This summer, make sure you outwit the **KILLER AT THE SEASHORE**

BY HARRIS B. STEWART JR.
Acting Director, ESSA Institute for Oceanography

Dr. Harris B. Stewart, Jr., now Director of NOAA's Atlantic Oceanographic and Meteorological Laboratories, described the dangers of rip currents in this article in the July 1967 ESSA Magazine.

To escape humdrum work, Marie Fellechner became a meteorologist and now heads a weather radar station

A FEMININE FIRST

NOAA Profile

BY HELEN SILVER

Bored with the same old job? Become a radar meteorologist and your horizons will widen considerably.

That's what Marie Fellechner did, and she went on to become the first woman meteorologist in charge of a weather radar station in the United States.

Sitting in front of the $100,000 screen of the National Weather Service's WSR-57 radar facility formally dedicated on February 9, 1971, at the Naval Air Station at Patuxent River, Maryland, Miss Fellechner recalls it all happened rather spontaneously.

"I was a little tired of the clerical bit at my job with the State of Pennsylvania Public Assistance Department in Philadelphia where I'd lived since early childhood. My job as a junior clerk seemed a little dull with everyone patriotically rushing to enlist in the army or obtaining federal employment during World War II," she says.

"I saw an announcement in the Philadelphia paper that Henry P. Adams, the Meteorologist in Charge of the Philadelphia Weather Bureau Office at the old airport, was interviewing women for positions as observer-briefers. This seemed interesting, but I didn't get to the interview because Mr. Adams had already been swamped with applications," Miss Fellechner remembers.

However, Mr. Adams only hired two women at that time, and another opportunity came for Miss Fellechner in 1943 when he again advertised in the newspapers with a "war service announcement." She passed the exam which was actually an aptitude test and was selected to serve as a surface observation specialist at the Philadelphia office, becoming one of the first women to be employed by the Weather Bureau as a meteorologist.

She advanced to assignment as aviation-weather and public service briefer during her 17 years at the Philadelphia station. "By then," she says, "I again wanted to do something different."

A vacancy announcement for a radar meteorologist paved the way for a change. She decided she'd like a try at it, got the job, and soon was scanning the famous New York skyline from equipment atop the RCA Building at Rockefeller Plaza.

Although Miss Fellechner found living in New York quite expensive, she managed to save enough money to return to school for additional training in mathematics, physics, and other subjects related to meteorology. "I loved school," she says emphatically. "If I were rich, I'd have become a career student."

Earlier she had attended J. W. Hallahan Catholic Girls High School and completed two years' work at Immaculata College from 1935-37 in Philadelphia. She enjoyed every moment of her return to college at Drexel Institute of Technology, also in Philadelphia.

In 1964, she rejoined the Weather Bureau as a radar specialist at the Washington National Airport station, where she worked until it was decided to relocate the radar operations to Patuxent River, Md.

With her appointment as Meteorologist in Charge of the new station, Marie Fellechner became the second women in the National Weather Service's Eastern Region to be named as Meteorologist in Charge of a major installation. At the present time, she and Mrs. Hazel Tatro, at the National Weather Service Office in Greensboro, North Carolina, are the only women M.I.C.'s in the United States.

The Patuxent site was chosen because it is ideally located as a network site and because of the Navy's excellent cooperation. It provides a clear radar view of the Washington metropolitan area and its major air terminals. The new radar is used to detect precipitation within a range of 250 miles, and to identify and track squall lines, tornadoes, hurricanes, and other destructive storms in the area.

The Patuxent River radar was first commissioned by the Navy more than ten years ago to scout hazardous weather approaching Washington from the northwest. When inclement weather moved into range, the Navy unit temporarily became an active part of the National Weather Service's radar reporting network.

Now newly modified and activated with the assistance of the Navy, the Patuxent River radar facility becomes part of the National Weather Service's basic observation network. It fills the need of a strategic coastal surveillance unit without sacrifice of protection to the nation's capital. It replaces the radar at Washington National Airport which was blocked from monitoring storms approaching from the northwest by interference from tall buildings. "You never knew what kind of weather was lurking in the blacked out northeast quadrant," says Miss Fellechner.

Serving with Miss Fellechner at the Patuxent River facility, are two very essential electronic technicians and four operational meteorologists, including two trainees. During the short time she has been in charge of the new station, Miss Fellechner reports she has found a big improvement in radar reception, with no obstructions at all.

Being a Meteorologist in Charge is a new responsibility for her and she has been kept quite busy handling the financial details of running a station, requisitioning of supplies, and helping the station personnel get details of their relocation worked out. In addition, she has been working a detail herself a good part of the time to divide the responsibility, although she doesn't work a night shift. The station operates round-the-clock with the regular operators working shifts. Other people at Patuxent, both Navy and civilian personnel, have been extremely helpful in this transition period, Miss Fellechner said.

Since the station opened, there hasn't been a real siege of bad weather. Miss Fellechner remarked that "having a severe weather box or squall line pass through might be a good experience for the trainees."

This gives the impression that the Meteorologist in Charge is also waiting a bit restlessly for a real test of the capability of the Patuxent radar installation.

Miss Fellechner describes her own adjustment to her new locale as easy. She and her mother live in a new home in a pretty wooded area in nearby Hollywood, Md., and have two pet kittens. Her favorite subjects, besides meteorology, are art and photography, which are her hobbies.

Now a veteran of 28 years with the National Weather Service, Marie Fellechner is one of the increasing number of women finding challenging and rewarding careers in the scientific and technical programs of NOAA. □

Lake Survey Center research is helping to solve a winter navigation problem

ICE: the traffic stopper

BY WILLIAM P. WARD

Lake Survey scientists on wintry Lake Superior look like Arctic explorers.

Ice means cubes for chilling beverages.

True, but there is much more to the story of ice.

Geologists, for instance, tell us that ice occurs in nearly as many different forms as do rocks. Fresh water freezes faster and to a greater extent than salt water, and, on the fresh-water Great Lakes, ice presents a problem which has plagued man since the beginning of water travel.

During the navigation season, the Lakes are alive with freighters, ocean-going ships, and pleasure craft, making full use of this vast avenue of waterborne transport. Interstate and international shipping depends on the Lakes for reaching the center of the continent. Millions of tons of cargo come and go on the Lakes every year, the port of Chicago alone handling some 50 million tons a season. Since the opening of the St. Lawrence Seaway, Chicago, Detroit, and Toledo have become international ports. Hydroelectric power plants on the St. Marys, Niagara, and St. Lawrence Rivers produce low-cost electricity for industry and private use.

With the arrival of winter, lake shipping grinds to a virtual halt. From January to the end of March, most of the Lakes are a vast, silent wasteland of ice, although some portions usually remain relatively ice-free. Lake Superior in February looks for all the world like the North Pole. U.S. Coast Guard ice breakers stationed around the Lakes aid late-running ships trapped by the ice and maintain certain limited areas of the Lakes in navigable condition. Winter shipping on the Lakes is reduced to colliers running between Toledo, Ohio, and Detroit, Michigan, with light traffic in a few other areas such as lower Lake Michigan. The rest of the lake fleet is in winter anchorage at various ports around the Lakes.

The effects of winter ice are not limited to shipping interests. Constantly shifting ice can tear docks and pilings from their foundations and gouge the beaches. In spring, massive ice jams block rivers and the channels connecting the Lakes. Such jams can actually stop the flow of water in a river, causing extensive flooding in low lying areas.

Why and how does ice form in a body of water the size of one of the Great Lakes? Where does the ice travel during the course of the winter? What causes ice to cover more extensive areas and be thicker in some years than in others? How and why does ice decay?

The answers to these questions are being sought by the scientists and engineers of Lake Survey Center's Lake Hydrology Branch, which now includes the former Ice and Snow Branch. Through programs of observation and laboratory research the answers are slowly becoming clear.

For the past several years, the phenomena of ice formation, growth, and decay have been studied in detail by the Lake Hydrology Branch. The scientists have found that ice begins to form when the air temperature is well below freezing and the water temperature is close to freezing, and that the best conditions for ice formation are a clear, cold night with little or no wind.

Ice forms first in sheltered areas along the shore of the lake, and is called "shore ice." Winds and waves break it up, forming ice floes. Those floes drift around the lake, driven by wind and currents, and as they drift, they grow in size. Wave spray freezes on the floes and some may freeze together, forming larger floes. Eventually the lake is covered with large and small masses of drifting ice. Small floes bump into larger floes and freeze to the larger floes, eventually producing an ice sheet. The sheet drifts until it becomes stranded in shallow water close to shore. By this process, vast areas of the lakes become covered by drifting and solid ice. What appears on the surface to be a dull, featureless ice sheet is really a highly intricate thing.

For several years, Lake Hydrology Branch personnel have been studying the ice sheet of Whitefish Bay in Lake Superior. The field crew travels on the ice using snowmobiles, skis, and snow shoes, and camps out on the ice in polar tents. Shelters containing meteorological instruments are set up around the shores of the bay to measure temperature, winds, humidity, snowfall, and sunshine during the field season.

At work on the ice, the field team measures ice thickness and water temperature. Team members use chain saws to cut samples from the ice sheet—samples that may be two feet square on top, more than three feet thick, and weigh 70 to 80 pounds. After locations have been recorded and top ends of the samples carefully labeled, the blocks are packed in burlap bags. In the past, scientists also collected water samples from below the ice to monitor the water quality of the bay during the winter.

The ice samples are destined for the laboratory in Detroit, where they will undergo crystalographic analysis. In the laboratory, the samples are stored in a walk-in freezer, constantly kept at 30 degrees below zero (F.). Connected to the freezer is the "cold room," where the temperature is maintained between 15 and 20 degrees above zero.

Working in the cold room, scientists measure and photograph the ice samples. First, a large block is cut into small, workable pieces on an ordinary band saw. Thin sections of the ice are made, in much the same way as are geological or biological thin sections. A small piece of ice is mounted on a glass slide and shaved to a few thousandths of an inch thickness with a microtone.

To study the orientation of the ice crystals, the thin sections are examined under polarized light. The crystals have an astonishing range in size. The smallest may be less than a tenth of an inch in diameter, while a large crystal may be over three feet long! By studying the crystal orientation, scientists can determine how the ice grew. They also examine bubbles and dust trapped in the ice.

With ice crystal structure data and records from the meteorological instruments, certain patterns and relationships between weather and ice formation can be identified.

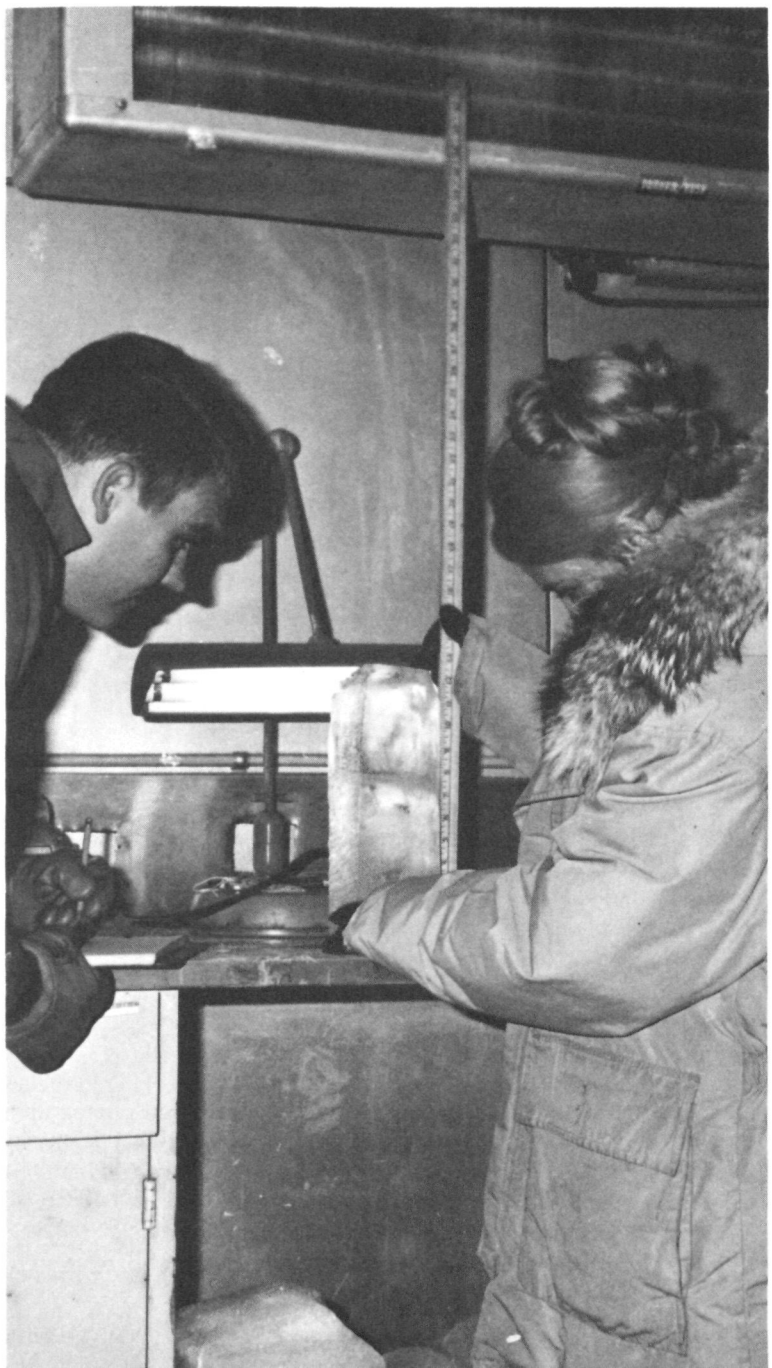
Studying the distribution of ice in the Great Lakes often requires a view from above. Lake Survey scientists have several ways of achieving this view. Pictures from NOAA weather satellites are used to identify large areas of ice cover. High-altitude aerial photographs provided by the U.S. Air Force are made into mosaic maps of certain areas in the Lakes and the connecting channels.

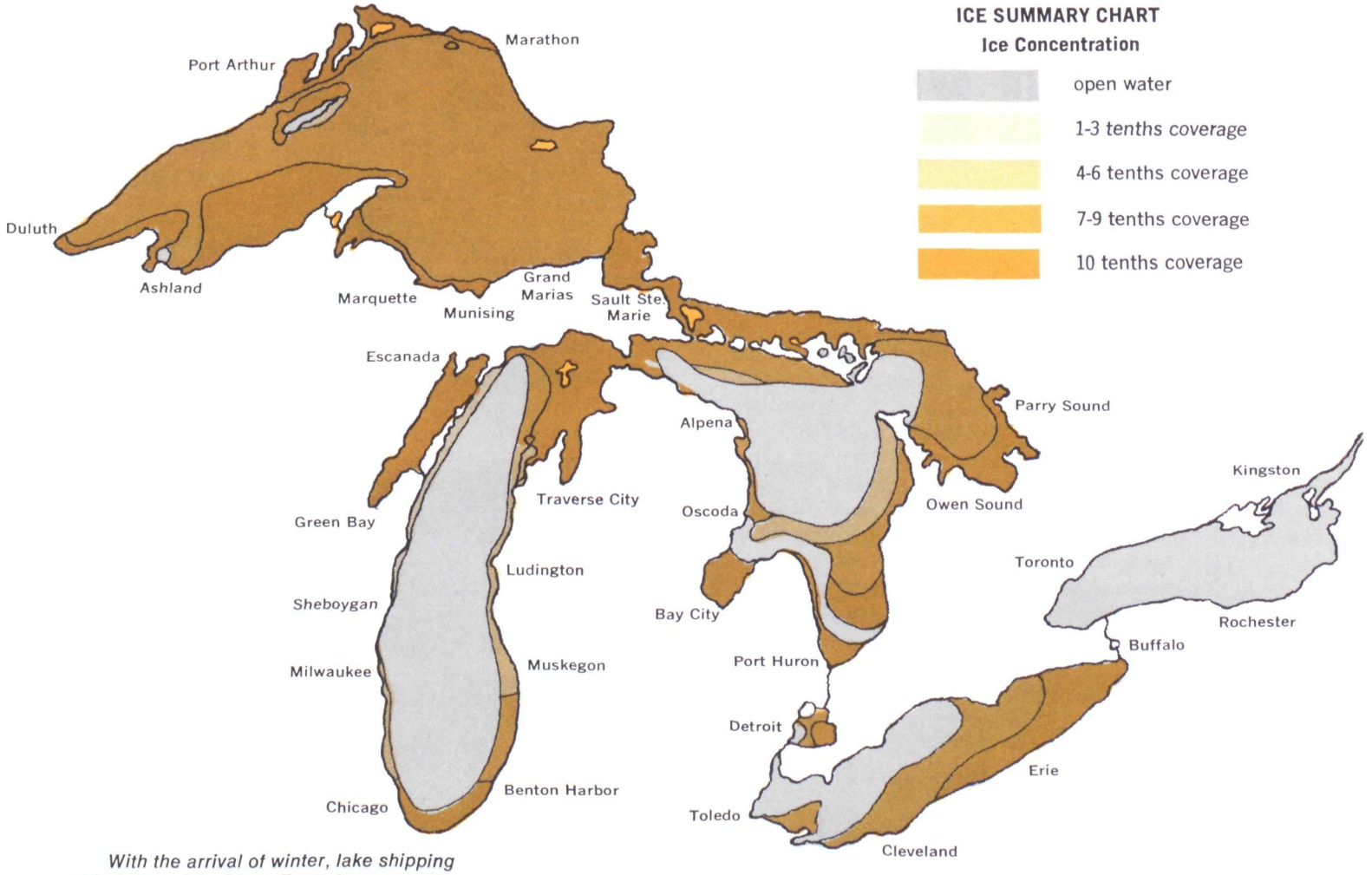
After the initial ice cover has formed, usually by the end of January, Lake Survey

continued

William P. Ward, a geologist, worked for four years in what is now the Lake Survey Center's Limnology Division, before entering private industry in August 1971.

(Above) Coast Guard icebreaker at right assists ore carrier CASON J. CALLAWAY through Lake Superior ice field. (Below, left) Lake Survey technicians set up base camp on an ice sheet. (Right) Technicians make preliminary analysis of ice sample in the cold room. Later, thin sections will be cut for microscopic examination.





With the arrival of winter, lake shipping grinds to a virtual halt. From January to the end of March, most of the lakes are a vast, silent wasteland of ice.

technicians take to the air armed with field glasses, cameras, tape recorders, special lake charts, and "long johns," in their own program of aerial ice reconnaissance. With the aid of the U.S. Coast Guard, Lake Hydrology personnel fly over and around the Lakes. During these flights, they map the ice cover using a special set of descriptive symbols. Features of the cover are described on tape, and any unusual aspects are photographed for future reference. The information obtained from the flights is then compiled into ice charts.

Ice charts are distributed during the winter months to shippers and the Coast Guard for navigational use. Hydroelectric power plants also use the charts in adjusting their ice booms, to prevent ice being taken into the turbines. At the end of the ice season, information from the ice flights, ground observers, the Coast Guard, and the Canadian Department of Transport is compiled into a report of the ice characteristics for that winter. These summary reports are used to detect patterns in the formation and breakup of the Great Lakes ice cover. Other researchers use the reports in investigating circulation patterns and lake energy balance.

The possibility of winter navigation on the Great Lakes is attracting considerable attention these days. The problem is principally one of maintaining the channels and rivers connecting the lakes in an ice-free condition. Away from shore, ice cover is usually rather open and generally can be navigated. At harbor and channel entrances, as well as in rivers, ice poses a problem to navigation. In the past, ice breakers have been used exclusively to keep critical areas ice free. Research in Whitefish Bay, however, has uncovered some evidence to indicate that breaking the ice cover may only serve to thicken it. Although more research on the subject is needed, preliminary results seem to show that very thick pressure ridges may form along the tracks of the ice breakers. Broken pieces of ice pushed onto the solid cover also serve to thicken it.

Bubbler systems and dusting techniques have been studied as alternate ways of keeping lake areas ice-free. Both methods have been used with varying success in other countries. Simply described, a bubbler system is a long plastic pipe with small holes along the top, placed on the bottom at the harbor entrance. Air is blown into the pipe and bubbles through the holes. As the bubbles rise to the surface, they create an upwelling of water from the bottom, which is warmer than the surface water. Thus, the surface water of the harbor is warmed, and ice formation is prevented.

Dusting is most often useful in the spring, to hasten breakup of the ice cover. A thin layer of some heat-absorbing material is spread over the ice surface; the material absorbs heat from the sun and warms the ice to the melting point. In some countries finely ground coal is used for dusting. Chemicals such as rock salt or ammonium sulfate are not used because of possible harm to the water quality. Several possible materials for use in dusting are being investigated. The ideal material must have high heat-absorbing capacity, but still be non-polluting.

Lake Survey's basic research into ice phenomena produces data that is essential to others involved in problems of ice and ice control. The U.S. Army Corps of Engineers, long a leader in Federal navigation improvements, is the agency charged with engineering feasibility studies, and the U.S. Coast Guard, with its fleet of ice-breakers, has for years been vital to early and late navigation on the Lakes. These governmental units, and certain private interests including some universities and colleges, are working together to solve this age-old problem.

The economic benefits of large-scale winter navigation would be tremendous and, if the goal can be reached, would provide a marked stimulus to waterborne commerce. But Mother Nature will be a determined and stubborn adversary and much work remains to be done. □

The LAND KILLER: DROUGHT

BY PATRICK HUGHES

"We ain't lost everything... we get to keep the mortgage."

On "Black Sunday," April 14, 1935, a dust storm engulfed Stratford, Texas, and despite their dust masks many people suffocated.

"These storms were like rolling black smoke. We had to keep the lights on all day. We went to school with the headlights on and with dust masks on. I saw a woman who thought the world was coming to an end. She dropped down on her knees in the middle of Main Street in Amarillo and prayed out loud: 'Dear Lord! Please give them another chance.' "

This was the eyewitness account of a Texas schoolboy during the dust bowl drought of the 1930's, when for four years great clouds of blowing topsoil often obscured the sun over much of New Mexico, Colorado, Oklahoma, Kansas, and the Texas Plains.

As bad as the dust was, it was only a symptom. The disease was drought, a cancer on the land that returns again and again to haunt the farmer and cattleman, and to remind the city dweller of his ultimate dependence on nature.

There have been relatively few dedicated students of this devastating weather aberration. One man who has studied the character and behavior of American droughts and charted their seemingly capricious course is Wayne Palmer of NOAA's Environmental Data Service. Author of the nationally-used Palmer Drought Index, he is one of the country's leading authorities on drought.

The drought of the 1930's, which unfortunately coincided with the economic disaster of the Depression, has indelibly imprinted on the American mind the image of dust-streaked Texas and Oklahoma farm families abandoning their parched, cracked land for the green promise of California. Much of this notoriety is a direct result of the terrible dust storms of 1935-37, when unusually strong winds joined with the drought to produce a natural disaster. Other droughts have been as bad, but usually less spectacular. Farming methods then in use were such that if the weather was dry and windy, the soil would just blow away. And it did.

For some parts of the country, the drought of the 1950's was worse. In Texas, it was the worst on record. Most of Texas' quarter of a million square miles did not have what old timers call "a public rain" for 5 or 6 years.

The drought seems to have begun along the Rio Grande River in 1950; by the fall of 1956, western farmers were praying for rain. Relentlessly, one of the worst droughts in our recorded weather history spread across America's heartland. Acre after acre, mile after mile of parched, barren land stretched from horizon to horizon.

Dr. Edmund Schulman of the University of Arizona's Laboratory of Tree Ring Research, studying the concentric rings of thousands of trees (where wet years are recorded as wide rings and dry years are narrow rings), concluded that it was the worst drought to afflict the American Southwest in 700 years.

Major rivers could be jumped on foot and the bottom of giant reservoirs lay naked and cracked. Irrigation canals—the life blood of farms in our arid western states—ran dry. In a few places, dust storms actually created small, mobile deserts, with sand dunes moving forward in wave-like ripples with every breeze.

In five years the drought took $2,700,000,000 from the pockets of Texas farmers and ranchers alone. Stockmen in Arizona, New Mexico, Oklahoma, Kansas, Colorado, and Nevada had to sell or butcher even their breeding stock, while dairy farmers of Kansas and Missouri, unable to find feed or water, were forced to liquidate herds they had spent their lives building.

In Kansas, two-thirds of the state's 115,000 farmers had to find off-farm jobs, while in Oklahoma, farm families were moving off the land at the rate of 4,000 per day by 1957. In Texas, ex-ranchers were pumping gas or working at the general store or roadside hamburger joint. Many of these men were working off their own land for the first time in their lives. The young men, in particular, moved to the cities.

Despite the scope and duration of this drought, the total misery of the dust bowl days was missing. With the national economy booming, jobs were available in nearby towns and factories, and most farmers and ranchers could ride out the hard times. And advances in farming practices such as irrigaiton, deep plowing, and the use of cover crops made it possible in many areas to save the soil from the wind. Even the dust storms were relatively few and far between, while the government's soil-bank payments, liberalized credit, subsidization of stock-feeds, and other measures helped the drought-stricken farmer and rancher get by.

The situation even generated a kind of grim humor, such as the Texas story: "Well, the wind blew the ranch plumb into Old Mexico, but we ain't lost everything. We get to keep the mortgage."

The Northeast's worst drought in 160 years began in the early 1960's. It brought unemployment to loggers, government disaster aid to dairy farmers, irrigation to tobacco fields, a private rainmaker to Fitchburg, Massachusetts, and severe or critical water shortages to scores of cities and towns in the most thickly populated section of the United States.

New Yorkers or visitors could get a glass of water in a restaurant or hotel only if they asked for it. It was forbidden to water lawns or wash cars, and steel harnesses were installed on fire hydrants to prevent street bathing, a longtime summer sport for city children.

Real concern over this prolonged period (1961-1967) of predominantly dry weather arose in October 1963, about the warmest and dryest October of record over most of the United States east of the Continental Divide. Forest fires were numerous, and continuing drought in the Great Lakes region caused an alarming drop in lake levels. A few wells and springs in the Northeast failed in 1963, but many went dry in 1964. Early in 1965, the reservoirs for the City of New York were down to 25 per cent of capacity.

After mid-1965, the heart of the drought area shifted southward to the Potomac River Basin. By the summer of 1966, residents of the Nation's Capital were facing the grim possibility of water rationing.

The unusual thing about the Northeast drought was its duration. Past weather records suggest that a drought lasting five years or more in this area would occur on the average of only once in several centuries.

Drought returned to the Southwest in the fall of 1969 and visited southern Florida the following year. Abnormally dry weather set in over southern California and parts of Arizona late 1969, spread across New Mexico and west-central Texas by mid-1970, and over central and south Texas in the fall of 1970.

In February 1971, high winds coated northern Texas and parts of Oklahoma with a thick layer of dust. In March, dust generated by winds gusting up to 43 miles per hour obliterated the sun over parts of Texas for nine hours. Three days later another dust storm, lasting for 17 hours, blanketed West Texas in a choking, blinding shroud of dust. By April, many parts of Texas had had no appreci-

continued

able rain for many months, over 2,000,000 acres had been damaged by wind erosion, and huge tumbleweeds were drifting across baked, barren land.

In Texas, Oklahoma, New Mexico, and Arizona cracked soil and dry lake beds characterized the countryside. By June, cattle and sheep were weak and thin. Many starved to death. Ranchers sold out and went to look for jobs in the city. Some farmers went bankrupt and others borrowed to the hilt. Most of the 200,000 bats that live in the Carlsbad Caverns of New Mexico fled their caves, where there was no food or water. They could be seen in thick flocks in the town of Carlsbad and along the Pecos River hunting water insects. Even gravediggers complained, because the dry ground was so hard to dig.

Meanwhile, south Florida from Orlando to Key Largo was suffering its worst water shortage in more than 200 years. Abnormally dry weather began in mid-1970. By the spring of 1971, the drought, augmented by the ever-increasing water demands of a growing population, reached disaster proportions. Haze and smoke from thousands of Everglades grass fires were shrouding the sky. The fires, coupled with the lack of water, drove thousands of animals and fish from their natural homes.

The Everglades swamplands, normally covered with shallow water, were so dry that in some places the soil itself—peat formed from centuries of decaying vegetation—was burning. Such fires are almost impossible to stop until they burn down to rock or sand. If enough of the soil burns, the Everglades could become a desert.

Drought has been a scourge of man since he first appeared on this planet. Unlike a hurricane or flood, drought creeps up on you. Initially, everyone welcomes the long spell of fine weather, but appreciation gardually turns to apprehension as water supplies decrease, and eventually to despair as crops wither, streams are reduced to a trickle, and little islands begin to appear in the reservoirs. No one knows why drought came, if or where it spread, nor how long it will stay.

In the simplest terms, a drought is a prolonged and abnormal water deficiency. Severe or extreme drought conditions can result in near zero crop yields, serious livestock feed shortages, lack of water for cities and industries, greatly increased fire hazards, and a general disruption of the local or regional economy. If a large-scale drought is severe enough and lasts long enough, it can seriously damage the Nation's whole economic structure.

In the United States, drought severity is measured by the Palmer Drought Index, developed by Palmer in the early 1960's. The Index provides an objective tool to determine the extent and severity of drought conditions at various times and in various parts of the country, and to compare one drought with another. It was first published in 1961 in the national *Weekly Weather and Crop Bulletin,* a joint periodical of the Departments of Agriculture and Commerce.

Palmer's father struggled through the dust bowl days of the 1930's, while Wayne himself fought the drought of the 1950's. A native of Nebraska, he joined the Weather Bureau as an observer in 1937 while still attending Wesleyan University in Lincoln. Following his graduation in 1939, he went to work for the Bureau full time. Fourteen years later he hung up his meteorologist's hat to return to his father's wheat and cattle farm in southwestern Nebraska.

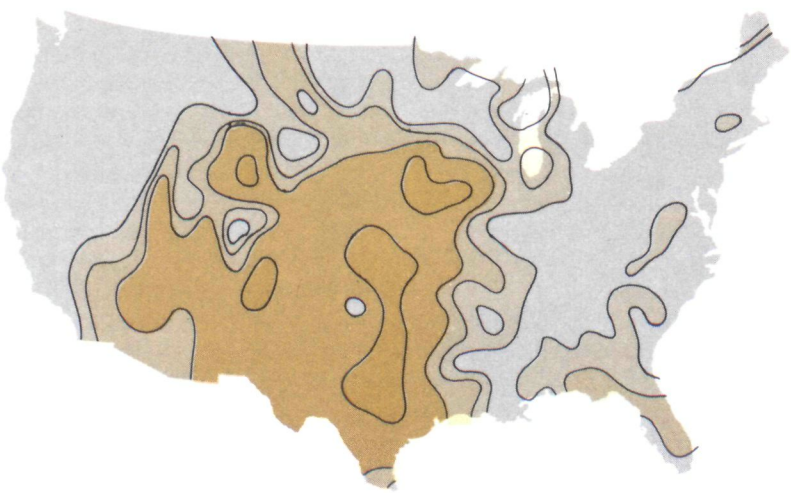
". . . my father reached the point where he couldn't handle the farm by himself. I had some theories on weather and agriculture I wanted to try on a practical basis, so I went back to Farnam to grow wheat." Those weren't very good wheat-growing years. When Wayne returned to meteorology in 1956, he was determined to do something about drought.

"I had and have no illusions about predicting the occurrence of drought. I am interested in defining, measuring, evaluating, and classifying meteorological drought, and in determining climatological probabilities of drought severity and duration."

After exploring numerous blind alleys, he finally devised a technique which provides drought severity index values that are locally significant as well as comparable in space and time. Briefly, the Palmer Drought Index determines the amount of precipitation needed in a given area during a particular time period for near-

MAXIMUM DROUGHT SEVERITY
(Palmer Index)
May 1 to October 31, 1934

MAXIMUM DROUGHT SEVERITY
(Palmer Index)
May 1 to October 31, 1956



Drought Severity	Palmer Index
Moderate	—1 to —3
Severe	—3 to —4
Extreme	—4 to —6
Very Extreme	—6

In the United States, drought severity is measured by the Palmer Drought Index. It provides an objective tool to determine the extent and severity of drought conditions and to compare one drought with another. (Above) Drought severity maps for 1934 and 1956.

The recent Southwest drought brought dust storms that recalled the dust bowl days of the 1930's.

normal operation of the established economy. This is calculated by considering the normal climate of the area, as well as current and recent weather conditions. The temperature, soil evaporation, plant transpiration, precipitation, and the area's average weather conditions are used to compute a drought index value.

Palmer's Drought Index calculations are based in part on the pioneering studies of the late C. W. Thornthwaite, one of the fathers of applied climatology—the application of past weather knowledge to the solution of environmental problems in the real world. His work has been the foundation for most modern attempts to assess the water balance, and provides a simple, usable approximation of the climatic need for water.

Weekly maps of drought severity are prepared from calculations of the Palmer Drought Index made on the electronic computers of the Environmental Data Service's National Climatic Center in Asheville, N.C. The computations are based on weekly temperature and rainfall observations over all 344 climatological divisions in the 48 contiguous states. The temperature observations are used to estimate the rate at which moisture has evaporated, while the rainfall measurements indicate replenishment of the moisture supply.

On the basis of these supply and demand figures, the amount of rainfall that would have been necessary over each division each week to sustain the evaporation, runoff, and moisture storage considered normal for the climate and weather of each area is computed. When compared with the actual weekly rainfall, this value described the "wet" or "dry" status of each division each week.

When abnormally dry weather persists in a given area week after week with only minor interruptions, this series of weekly rainfall deficiency values is used to compute drought index numbers. If the dry weather persists for a long time, the drought becomes progressively worse, and drought index values go from "mild" through "moderate" and "severe," and finally to "extreme."

From time to time droughts of similar severity occur in two or more areas with vastly different climates—New Jersey, for example, as compared to eastern Oregon. Each area is affected in its own way. Extreme drought in New Jersey usually means low water tables, deficient stream-flow, depleted reservoirs and, now and then, serious shortages in soil moisture. In eastern Oregon, on the other hand, extreme drought produces dry ranges, critical fire hazards, and a shortage of water for irrigation and livestock use. The many and varied effects of a prolonged drought depend on the peculiar climatic conditions and established economies of the areas affected.

The terrible experiences in the Great Plains in the 1930's when, at one time or another, serious drought afflicted the entire midsection of the country from Canada to Mexico, and from the Great Lakes to the Sierras, brought home to farmers the climatic truth that the semi-arid lands of the West could not be farmed by the same methods used on the farmlands in the more humid eastern portions of the country. Since then, a number of techniques have been developed to promote maximum absorption of the moisture and minimum loss of top soil due to dryness and high winds. These include new farm machinery that covers the soil surface with wind-

continued

resistant clods, terrace farming, and "trashy" or stubble mulch farming, which leaves the remains of previous crops exposed to stabilize the soil and promote better absorption of rainwater. Improved farm technology, however, is no substitute for a good rain.

From 1948 to 1962 drought accounted for 39% of all indemnities paid to farmers by the Federal Crop Insurance Corporation. The next largest weather category—floods—accounted for only 14% of the total losses. With each succeeding year a drought takes an increasing toll of capital and resources and leaves more and more farmers and ranches—and those with whom they do business—with nothing except debts.

During the drought of the 1950's President Eisenhower—remembering the drought that helped plunge his own father into debt—summed up the personal impact of drought on hundreds of thousands of rural Americans in these words: "Of the many natural forces that wage war on farmers and ranchers, the most demoralizing is a prolonged drought. In its grip the individual farmer is well-nigh helpless."

Palmer's index was designed to evaluate the scope, severity, and frequency of prolonged periods of abnormally dry weather by considering all aspects of an area's water needs, including streamflow and water storage. However, since a modest shower will often help crops but do little toward refilling a reservoir, he developed a second standard, the Crop Moisture Index, which is strictly a measure of the status of agricultural drought. This index responds rapidly to the occurrence or non-occurrence of rain, and considers only the weekly moisture used by crops as compared to the amount required for normal crop growth. Successive weekly values of crop moisture anomaly are combined to provide a measure of the cumulative severity of agricultural drought.

The Environmental Data Service began publishing Crop Moisture Index in the national *Weekly Weather and Crop Bulletin* in the April 15, 1968 issue. The maps portray recent crop moisture conditions—delineating areas in which crops have been hindered by abnormal dryness or wetness, and areas where moisture conditions have been favorable for plant growth. The maps do not show detailed local variations in crop response. Rather they describe crop moisture conditions on a fairly broad, regional basis—parts of states, for example, rather than parts of counties.

The Crop Moisture Index is used primarily by State and Federal agencies and by corporations with wide regional or national interests. The former use the index as an early warning system for such problems as wind erosion and to gage agricultural water supplies. The commodity analysis division of a large national corporation has called the index "one of our bibles."

Droughts are prolonged weather anomalies, and conditions have always returned to normal sooner or later, thus the outlook is always favorable for the end of a drought. Often the problem is surviving until nature is ready to resume more moderate ways.

The dynamics of drought are not very well understood, certainly not to the degree where we can predict its occurrence, duration, or intensity. Meteorologists usually explain a specific drought in terms of abnormal atmospheric circulation cutting off precipitation in the affected area. This explanation, however, says nothing about the fundamental forces which produce the unusual circulation pattern. Solar cycles, the relative temperature difference between ocean and continent, volcanic eruptions (which eject large amounts of dust into the air and thus may alter the earth's radiation balance), and changes in the gaseous composition of the atmosphere have all been blamed. The actual cause of drought may include any or all of these, and possibly other factors as well.

Meteorologists generally discount the idea that manmade effects are responsible for droughts. While urbanization and pollution can definitely influence climate, most weathermen think that these artificial factors are too weak to affect the great upper-air circulatory wind patterns that flow around the globe.

According to past performance, a major drought seems to occur in the Great Plains and American Southwest about every 20 years. There was drought there in the 1890's, the teens, the 1930's, the 1950's and now again, in the 1970's. (The drought in the East in the early 1930's and again in the 60's were separate phenomena, and not part of this pattern).

These quasi-periodical occurrences of drought are not regular enough to predict, but rather show up in after-the-fact analyses. This apparent relative regularity may be misleading; the 100 years or so of weather records available is too brief a period to definitively establish long term climatic trends. Drought predictions based on past history currently present about the same problems as predicting the behavior of the stock market from past performance. Both are highly speculative ventures.

From April 1 to May 31, 1971, NOAA's Experimental Meteorology Laboratory conducted a special cumulus seeding experiment in an attempt to alleviate the worst drought in Florida's history. The attempt was made in response to a request by Florida's Governor Reubin Askew.

The question of whether dynamic seeding could break a drought was never considered. "That is meteorologically impossible," Dr. Joanne Simpson, EML Director, emphasized. "Dynamic seeding is not optimally or perhaps even usefully employed as a tool to combat a drought, but should rather be used with a water management program, to seed when conditions are most favorable."

Cloud seeding requires clouds, and not just any kind of clouds. For effective seeding efforts, the clouds must grow to high enough levels where significant conversion of water to ice begins to occur naturally. Drought conditions severely limit the occurrence of those kinds of clouds.

Nevertheless, sixteen seeding missions were flown by NOAA's Research Flight Facility aircraft during the experiment. Impressive growth and merger with significant rainfall was observed on several of the days.

Mother Nature, of course, is the best rainmaker of all, and until she changes her current ways, water will remain short in Florida and the Southwest.

Because of the severity of the drought in the southern and southwestern United States this spring and summer, Palmer was in frequent consultation with officials of the Office of Emergency Preparedness, who were briefing President Nixon each week on the status of the drought. In early May the Environmental Data Service and the National Weather Service (one of EDS' sister agencies in NOAA) joined forces to increase the availability of Palmer's national drought severity analyses. The drought index maps are now transmitted weekly by the Weather Service's National Meteorological Center to all subscribers to their facsimile service and to Weather Service offices around the country, which in turn distribute them to local news media. Beginning in May, NBC's "Today" Show began displaying the map on the weather report segment of the program, and various individual stations have been using the map on their local TV weather shows.

Meteorologists today acknowledge that they know relatively little concerning the causes of drought and, thus, cannot predict their occurrence, severity, or duration with any reasonable degree of reliability. What they do know is that more research is needed. And one key to the success of that research effort could well be the work of Wayne Palmer, whose Drought Index and Corp Moisture Index make it possible to define what we mean by drought, and to correlate droughts occurring at different times in different places. □

mermaids, barnacle geese, moonstruck mullet, giant squid

AND OTHER FISH STORIES

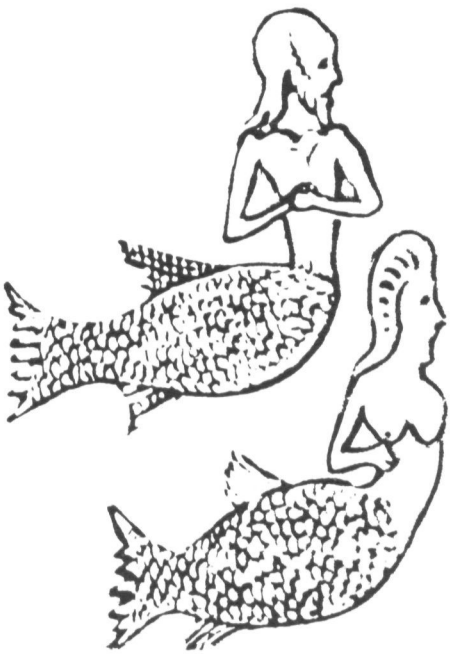
BY MARY RYDER

Long before Jonah met the whale, myths and legends were sprouting and growing wherever men gathered to talk about the sea.

Under the critical eye of science, myths tend to fade rapidly into unromantic reality. But the ocean is a mysterious realm where grotesqueries keep close company with the commonplace, and where truth often wears the guise of fantasy. Given the casual manner in which folklore mixes fact and fiction, and the seafaring man's love of elaboration, the durability of saltwater myth is scarcely surprising.

The legend of the mermaid, a creature half human and half fish, is generally attributed to the sighting of dugongs and manatees (or sea cows) by sailors or fishermen. The theory is that the longer he had been away from home, the more likely the sailor was to mistake these homely creatures for beauteous mermaids. Christopher Columbus himself reported the sighting of three "mermaids" off the coast of Hispaniola, or Haiti, early in January of 1493. However, he recorded regretfully, ". . . they were not as beautiful as they had been painted. . . ."

Gods that were half man and half fish were fairly common among early cultures. The ancient Chaldeans worshipped a fish-god, which later evolved into a sungod with a fish-tailed sun goddess as wife. The motif also showed up among the Babylonians, with a related moon goddess. In the Mediterranean, the Greeks seized upon the theme and invented a whole host of sirens, mermaids, and tritons. Both the Mexicans and Peruvians had fish gods, and the North American Indians believed they had been conducted from Asia to the New World by a fish god.



The legend of the mermaid, a creature half human and half fish, is generally attributed to the sighting of dugongs and manatees by sailors and fishermen.

The association between fish and religion tended to be relatively straightforward in pagan cultures, but such was not the case with Christian theology. Seafood became a matter of theological concern because of a Catholic restriction—no longer in effect—against eating "flesh meat" on Fridays and other days of abstinence. Fish was not considered to be flesh, and so provided an acceptable substitute, along with eggs, milk, and cheese. The definition of fish was extended also to include marine mammals. Porpoises, although known to be mammals at least since the time of Aristotle, were eaten as fish by Europeans for many years.

And then there was the strange case of the goose that became a fish.

The resemblance of the goose-necked barnacle to an immature, shell-clad bird, complete even to "wings" and "tail-feathers," was sufficiently convincing that early ecclesiastical authorities permitted the eating of geese on fast days, classing them as fish, rather than fowl.

Alexander Neckham (1157-1217), author

continued

of the first English encyclopedia, soberly reported the existence of "a bird called bernekle, which grows from pine wood when it has been steeped in the seas for a long time." At the beginning of the 13th century, Pope Innocent forbade the practice of eating the barnacle goose. In 1435, Pope Pius III, visiting King James I of Scotland, attempted to track down the goose, but whenever he arrived at a place where the bird was reported to exist, it mysteriously disappeared, causing him to observe plaintively that "miracles flee further and further."

Izaak Walton, blessed among anglers, was a product of England's lively Elizabethan age, but flourished before science had done its work against a naive preference for the wondrous. A man who maintained that eels are produced from dew or the soil would have no difficulty in believing that geese come from barnacles, and it is not surprising that the Compleat Angler refers to ". . . barnacles and young goslings bred by the sun's heat and the rotten planks of an old ship. . . ."

In 1660, the author, J. Childrey, stated firmly in "The Natural Rarities of England, Scotland and Wales," that "Barnacle or Soland Geese . . . come of an egg and are hatched as any other Geese are."

Fortunately for the longevity of the myth, "The Natural Rarities" lacked the benefits of instant communication. This made it possible for the Danish medical writer, Bartholinus, to proceed with an open mind when he subjected the controversial barnacle to microscopic scrutiny in 1661. The skeptical Dane arrived at the melancholy conclusion that the inside of the shell could not possibly be confused with feathers of birds—it was obviously made of insects or worms.

And in the same year, Sir Robert Moray, first president of the learned Royal Society, described barnacle shells with perfectly shaped little birds growing inside, with "nothing wanting as to internal parts for making up a perfect Seafowl."

Stouthearted disdain for letting facts spoil a good story, or a good meal, was more than usually successful in the case of the Barnacle Goose. As late as 1884, it was reported that the Church of Brittany continued to exempt geese from the rule forbidding the eating of flesh or fowl on Fridays.

Even with the benefit of television, book reviews, and enlightened skepticism, some of our less convenient seafood myths have endured well into the 20th century.

There is no way of knowing how many "big ones" got away because young sportfishermen were discouraged from fishing on Sunday, in the belief that anyone who broke the Sabbath to go fishing would catch nothing at all, or, even worse, would find the Devil on his hook.

And even today, everyone over 30 has heard that it is inadvisable to eat oysters during months spelled without an R. Although this rule has been faithfully observed by countless generations of Americans, it actually pertains only to European oysters.

The European oyster is unique in that it retains its young until tiny shells are developed, and eating one during non-R months is, consequently, like eating an oyster stuffed with sand. Other oysters, however, courteously refrain from developing shells until the free-swimming larvae "set."

On the east coast of the United States, oysters are actually at their best in May and June, when they begin to store glycogen, an animal starch, in preparation for spawning. During the summer and early fall, oysters become thinner and more watery, with a decline in flavor. The fattening cycle usually resumes in October or November.

In spite of efforts by the oyster industry and by the National Marine Fisheries Service, the myth persists among oyster-lovers, unintentionally reinforced by the practice, in some states, of prohibiting harvesting from public oyster grounds during the spring and summer—a prohibition designed to protect the oyster supply.

Lack of refrigeration in years gone by may also have contributed to the longevity of the oyster myth, since unrefrigerated oysters would be likely to spoil in hot weather.

In the Bayou Country of the Gulf Coast, tradition has long held that mullet seined during the full moon are "moonstruck" and will never make it to the frying pan.

The scientific basis for this bit of folklore is that feeding mullet taken from warm waters during hot weather, and kept without refrigeration, will deteriorate in a matter of hours. Yet folklore maintains a firm hold on the minds of those who deal with the sea—a fact that was demonstrated again when a processor called the Pascagoula, Miss., Technological Laboratory of the National Marine Fisheries Service for advice regarding a lighting installation in his new freezer.

The processor was thinking in terms of banks of fluorescent lights, which he knew produced an artificial "natural" light. His question—can fluorescent lighting produce "moonstruck" frozen mullet fillets?

The giant squid provides us with a sea-myth-in-reverse, a reality regarded by the general public as a mere literary device that has been exploited by every writer of adult fantasy from Jules Verne to Ian Fleming.

It comes as something of a shock, even to those able to keep an open mind regarding the Loch Ness Monster, to learn that marine scientists speak factually of the "smaller" giant squids from 8 to 12 feet long and weighing up to 350 pounds.

The large economy size—a different species—runs up to 60 feet long, and weighs about half a ton.

The existence of these giants was hotly debated among the scientific community over a span of some centuries, and the controversy was not satisfactorily settled until around the last quarter of the last century, when some two dozen of the creatures were captured off Newfoundland.

The giant squid was first written about extensively by Olaus Magnus, last archbishop of the Swedish Roman Catholic Church, in a history of the northern nations published in 1555. Magnus used the old Norwegian name of "kraken," and described the squid as resembling a great tree pulled out by the roots, and capable of inflicting great damage.

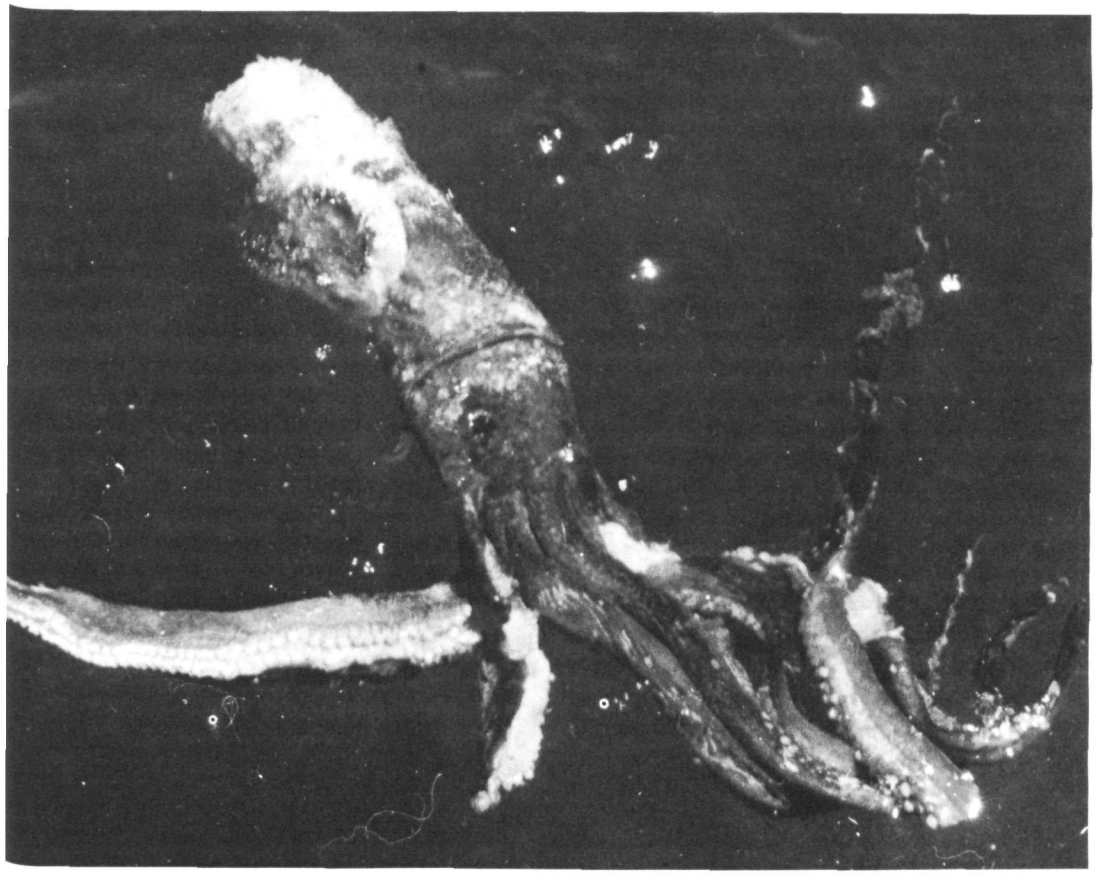
When the Swedish naturalist, Carolus Linnaeus (1707-1778) undertook to systematize the naming of things, he listed the kraken under the imposing name of *Sepia microcosmos*. However, some of the more flagrantly embellished reports of the beast must have shaken his faith in its existence, since *Sepia microcosmos* was deleted from the authoritative 10th edition of his *Systema Naturae*.

Even more than the snub by Linnaeus, a weird "History of the Mollusks," published by a French systematist around the beginning of the 19th century, did much to undermine belief in giant squids. The author, Denys de Montfort, recorded not only that the kraken attacked sailing ships, but that a school of them had sunk ten men-of-war in a single night.

Around the middle of the same century, encounters between vessels and squids, during which the squids lost pieces of arms to sailors with scientific proclivities (or a strong instinct for survival), provided tangible evidence that the giants did, indeed, exist. It remained for Dr. Addison E. Verril of Yale, marine biologist and specialist in mollusks, to convince the scientific community by publication of a series of detailed scientific observations, culminating in the monograph, "The Gigantic Squids (Architeuthis) and their Allies," in 1879.

In 1958 a giant squid which had been attacked by sharks was picked up by a vessel from the Pascagoula, Miss., Exploratory Fishing and Gear Research Base of the National Marine Fisheries Service. Harvey R. Bullis, Jr., base director, who was aboard when the squid was encountered, described it as "a relatively small one, about 45 feet long."

Apparently, these squids are almost never found at the surface unless suffering from an illness, harmed by sharks, or disgorged by sperm whales, which feed almost exclusively on squid. There are not many specimens preserved in museums, and few of those are in really good condition. For in



The giant squid is a sea myth in reverse, a real monster that may be as much as 60 feet long and weigh up to half a ton.

spite of its impressive size, *Architeuthis* is a soft, flabby creature, with arms and tentacles easily pulled apart.

Science has not yet settled with complete certainty whether giant squids exist capable of dragging sailing vessels down to a watery doom, as has been reported in interesting, but unauthenticated stories. If such do exist, they are a far cry from the flabby slow-moving *Architeuthis*, and probably bear a closer resemblance to the smaller squids mentioned earlier. These latter are described as having strong bodies with powerful jet funnels for propulsion, strong massive arms and tentacles, and wicked beaks capable of biting oars and boat hooks in two. Whales have been taken in the South Pacific bearing sucker scars the size of dinner plates—scars which could have been made by a large octopus, but which, if made by squid, indicate the existence of animals well over 100 feet long.

Few creatures of land or sea have inspired such a wealth of myth, symbolism, folklore, and outright superstition as the dolphin.

Mythologies as diverse as the Greek and Maori contain stories of heroes saved from drowning by dolphins. Greek gods sometimes took the form of these animals, or were accompanied by them; even the desert-dwelling, landlocked Nabateans carved stone goddesses with dolphin tiaras and regarded the dolphin as a talisman of life and a token of good luck. The Byzantines had no religious regard for these creatures, but believed that dolphin fat, eaten with wine, would cure hydrocephalus; that its teeth could ease the teething of children, and that dreaming of dolphins signified good, although dreaming of any other creature of the water was an evil omen.

The dolphin found its way into the Christian tradition. "Take up your nets and come follow me, and I will make you fishers of men," Christ invited Simon, Peter and Andrew. From this text, fish came to symbolize souls gained through baptism or conversion. The dolphin was thought to be a fish, and the motif was found on baptismal basins, on gravestones in the catacombs, and, with an anchor, on the lids of Christian coffins. Stories of saints often featured rescue from drowning by friendly dolphins, and fishermen believed that they had only to call dolphins by the name of Simon and the amiable beasts would help by driving fish into the net.

Whether the name of Simon exerts any influence or not, reports of dolphins serving as able assistants to fishermen have come from widely separated parts of the world—Greece, Africa, India, the South Pacific, the Amazon jungle, Soviet Russia. In such areas, dolphins are respected as business partners, cherished as pets, or regarded with superstitious veneration.

This last is particularly true of fishermen of the Amazon who profit by the services of a freshwater dolphin, the bouto. It is believed that burning the oil of this strange mammal to light a hut can cause blindness, but that the eye of a bouto, prepared by a witch doctor, gives its possessor astonishing powers, including the ability to hex his neighbors. On the practical side, the bouto not only helps the fisherman by "herding" fish into the shallows where they can be speared, but the dreaded flesh-eating piranha, regarded as a tasty snack by the bouto, carefully avoids areas where the dolphin is present.

The fisherman's reverence and admiration for dolphins, though widespread, is by no means universal; some insist that the helpful sea-going bird-dog image is pure myth; that the dolphin is a gluttonous devourer of fish and a vicious destroyer of nets.

In 1966, the Soviet Fisheries Minister appealed to fishermen of all nations to refrain from catching or killing dolphins because they were "marine brothers of men" by virtue of their intelligence. A spokesman for the Israeli Fishermen's Union retorted bitterly that, far from being brothers, Israeli fishermen considered dolphins "our worst enemies," and that his union had set up a special "war committee" to devise methods of fighting them.

A particularly cherished myth concerns the benevolence of dolphins toward humans in escorting lost swimmers to shore, or pushing drowning persons to land. The pro-myth faction points out that, as air-breathing mammals, dolphins can drown, and sick or injured animals have been observed being pushed to the surface and supported there by their companions in an effort to keep them from drowning. The argument is that man is recognized as a fellow air-breather and given the same sympathetic assistance that would be rendered another dolphin.

The other side, while conceding the validity of reports of dolphin rescues, argues that the motivation is not interspecies altruism, but simply playfulness. To the dolphin, the human is merely a floating object to be investigated and pushed along the surface, and the skeptic explains further that the human is taken toward shore or into shallow water simply because the action of the sea automatically carries floating objects toward land.

Whatever the motivation behind the dolphin's practice of pushing people shoreward, his political acumen leaves much to be desired. This was demonstrated during World War II when some downed American airmen had to beat off dolphins who tried to push their raft to the nearest land—a Japanese-held island. □

An NOS program in Florida seeks to discover

WHERE THE SEA REALLY BEGINS

BY CAPTAIN JACK E. GUTH

A seaward boundary, to most people, is a simple thing: the line where the land meets the sea.

Unfortunately, this simple line does not meet the specifications that international, Federal, and state law demand. A determination of seaward boundaries is a highly complicated matter which has strained relations between nations, between coastal states and the Federal government, and between them and private property owners.

Captain Guth is Chief of the Coastal Mapping Division, Office of Marine Surveys and Maps, National Ocean Survey

As we become ever more aware of the strategic importance of the sea and the riches which lie within its depths and the land it washes, the more urgent becomes the task of amicably establishing jurisdictional boundaries. The United Nations has been laboring for years to solve these and similar problems. An International Law of the Sea Conference is tentatively scheduled for 1973 in an attempt to iron out some differences.

People have different ideas about who owns what part of the ocean. Nations disagree over how far out to sea they have legal jurisdiction, the range differing from three to two hundred miles.

Those that agree on distances may disagree on jurisdiction. Who owns the fish? Who has the mineral rights of the land under the sea? Who controls the surface use and the air space above it? Is it legal for one nation to pollute water that drifts into another's jurisdiction?

The determination and mapping of this simple meeting line of land and sea is a first requirement, because it represents a base from which all seaward boundary lines and legal jurisdictional authority can be governed.

Not only is international vs. national jurisdiction at stake, but Federal government vs. State government ownership also is in question. States benefit from large financial revenues through the sale and lease of water submerged lands. Oil leases on our submerged continental shelf are a major economical resource, and their ownerships are some of the most hotly disputed Federal-state cases in our courts. The value of petroleum produced from offshore areas is approaching one billion dollars a year.

State vs. private ownership is also becoming an increasing problem. States are feeling the public pressure to protect the coastlines from building booms and pollution. They must safeguard the breeding grounds for water fowl and marine life and the beautiful shores for recreational uses. But the individual's ownership rights must also be protected. Consider the land value of a few feet of shoreline on Manhattan Island or Miami Beach. People everywhere are recognizing the need to bring ecology and human needs into better balance, and the first logical step in this process is to map the lines that have received general legal jurisdictional acceptance.

Florida was the first state to recognize the importance of mapping these lines on a statewide basis, and to do something about it. It sought assistance from the U. S. Coast and Geodetic Survey (predecessor to NOS) for its historical coastal mapping capability.

In April 1969, a cooperative agreement was negotiated between NOS and the State of Florida, on a 50-50 cost-sharing basis for mapping their seaward boundaries. Many dual benefits are to be gained from this agreement. The end-product maps will be a benefit to the state for land management, conservation, and exploitation of its offshore resources. NOS will benefit by improving its programs of tidal observations, analyses, and predictions; by enhancing its geodetic control net; and upgrading its marine charting programs.

This program is by no means a small task. It is a technically difficult job and although progress is on schedule, it will take another five years to complete. In November 1970, Secretary of Commerce Maurice H. Stans said: "This was a pilot project to develop the most efficient and effective methods whereby the Federal government in cooperation with a State government could provide the basic data required to help resolve not only questions involving federal/state areas of jurisdiction but also similar disputes involving the state/local governments and between local governments and private ownership."

This project exemplifies the outstanding Federal-state cooperation that can be developed to accomplish a common goal.

In order to understand what is being done in Florida, it is necessary to explain some of the scientific problems involved.

The world is a complex body of earth and water; tremendous forces from inside the earth and outer space push and pull at the surface and cause the line between land and sea to change constantly.

Earthquakes devour great land masses; landslides fill in large sections of coastline; ocean waves erode and build up the shores; and wind and rain and time constantly change the line where the sea and land meet. The world oceans have been rising very slightly over recent decades—one theory being that the polar icecaps are melting. And, man himself is continually altering the coastline—witness the major seaport developments and the Venice-like housing developments that have sprung up all along our coast.

Even if we considered our shoreline stable, the sea rises and falls continually, shifting the location of the line. The sea not only goes up and down, but it goes in and out. A rise of a few inches will flood a mile inland in some areas.

Daily tides rise and fall at all ocean coastlines. The tidal range (difference between low and high tides) varies from less than one foot in some areas, such as parts of the Gulf of Mexico, to 35 feet at Anchorage, Alaska, and 47 feet in the Bay of Fundy, Nova Scotia. These daily and semi-daily tides are related to the gravitational pull of the moon, and to a lesser degree by the sun.

Not only does the tide range fluctuate daily, but there is a long-range cycle which occurs about every 19 years. However, the lines of tide level, at any location, can be accurately determined by observing the actual tides (with a recording tide gage), over a 13-month period, averaging their readings, and refining the results by referencing them to standard gages, which are permanently installed at select points over our entire coast, and have been in operation for many years. In the State of Florida, permanent stations have been operating at Miami and Daytona Beach for over 19 years.

The first phase of the NOS-Florida project was to install about 50 temporary tide gages at frequent intervals over a couple hundred miles on the east coast, from north of Cape Kennedy to south of Miami. During this phase, NOS personnel trained state personnel in the installation of gages so that they could carry on this portion of the project in the future. The state also provided the necessary coordination relating to plans, schedules, and cooperation with local authorities. The gages in this first area have been in operation for over 13 months, supplying the necessary data to establish accurate tidal datum (tide high-and low-water lines).

Once the sea level is accurately determined, several tide lines can be used to determine different seaward boundaries.

The mean low-water tide line is the reference (baseline) for measuring international-national seaward boundaries. It is also the reference for establishing the seaward boundary between Federal and state jurisdiction, which is generally accepted at three miles offshore.

The mean high-water tide line is generally accepted as the seaward boundary between state and private ownership.

These lines must be accurately drawn on a map to be useful for seaward boundary determination. Precise geodetic horizontal and vertical land surveys are required to reference the lines to a common mapping grid. All lines must be tied to the national geodetic net—horizontal and vertical monumented position—if they are to be accepted as legal in our courts. The second phase of this project was to tie the tide lines to the national geodetic net.

At every tide gage in Florida, at least three permanent monumented bench marks (tidal bench marks) were installed by state personnel. These bench marks are the permanent reference for tide lines, and they provide the local and state surveyors' starting points from which they can survey and mark seaward boundaries. NOS and state personnel made vertical surveys (leveling) between these bench marks and the geodetic bench marks inland (generally along major highways) to tie them to the national geodetic net.

The third phase of this project—after tide lines were established and were tied to the national geodetic net—was to draw the tide lines on a map. To accomplish this, a specialized aerial photogrammetric mapping technique is used, which is accurate and economical.

NOS, using its own aircraft, took color and infrared aerial

continued

photography at mean high water and mean low water. Utilizing sophisticated photogrammetric techniques, an NOS cartographer can depict the two lines and accurately produce them to a map.

To be certain the cartographer interpreted the photographs properly, his work is inspected by an NOS field unit. A two-man unit, usually working from a small boat, actually field-identifies points on the ground related to those on the photo.

The final Florida maps are photomosaics at 1:10,000 scale. The photos of the land are in black and white, the water areas in blue, and a dotted offshore red line displays the low-water line, a thick solid red line is the high-water line, and a thin inshore line displays the limit of vegetation where the high-water line cannot be photoidentified.

The importance of this cooperative program for producing these maps, as recognized by ocean and ecology scientists and engineers, can be described by quoting the October 1970 statements of Claude R. Kirk, then Governor of Florida, to the Secretary of Commerce:

"At the time when our cooperative program was initiated, there was not established procedure or similar service performed elsewhere in the nation on a state wide basis I understand that our program was recognized as a pilot model or prototype for development and adoption in other coastal areas of the nation as appropriate. For many reasons, not the least of which is for determination of the offshore boundary delineating state and federal jurisdiction, this program is of great importance to both the state and the nation.

"I believe that the product to be obtained under this program will be of inestimable and pertinent value not only to this state and the nation, but similar products will be eagerly sought by other coastal states of the nation on completion of the prototype. This program has the respect of the engineers, surveyors, geologists, and hydrologists of this state. Need for its early completion is of great importance to other work of the state and the nation pertaining to oceanography, estuarine surveys, and specific environmental studies now underway along coastal areas. I suggest that your Department may soon be recognized in the performance of this program for a landmark achievement in the ecological and environmental consideration of the estuarine, coastal, and marine resources of the nation."

One serious unsolved problem remains in mapping seaward boundaries. Until recently, the vast areas of our nation's wetlands (swamps, marshes, tide flats) were considered wastelands. Now, much of it is becoming valuable property, and the mapping of its boundaries is a technical challenge. The wetlands lie between the low tide and high tide lines. They exist mostly in the inland back bay areas, protected from the continuous ocean wave action that prevails on the open coast. These areas are covered with a variety of vegetation, from short grass to tall mangrove trees. The problem with mapping these areas is that present aerial photogrammetric techniques cannot penetrate the vegetation to delineate the high- and low-water lines. Determining these lines with field survey crews is impractical because it is slow, physically difficult, and dirty work.

In the past few years, progress has been made in developing new mapping techniques for wetlands. Color aerial photography in some localities indicates certain types of vegetation that can be identified and related to a line at a certain stage of tide. Sophisticated airborne sensors are being evaluated for their adaptability to mapping techniques. Thermal sensors could possibly be used to distinguish the difference between water and land due to their sensitivity to difference in temperature. Chemical sensors can possibly distinguish between the two by their difference in chemical characteristics. And density sensors might distinguish their difference from their unit weight. If any of these or other remote sensing possibilities prove reliable, techniques will be developed to relate them to a line on a map.

Unfortunately, the development of these systems may be many years in coming. However, the seaward boundary mapping requirements, in those areas of our coast that are critical now, can be satisfied. Aerial photographs and remote sensing imagery can be taken over the areas, and the data complemented with known ground truth. At frequent intervals, tide gages can be installed and the tide lines determined. At those points, a field party can identify the lines on the imagery for transfer to the map. These data would then become historical documentation for legal jurisdiction as future claims and disputes arise. Although the precise location of these tide line points would not answer the total mapping requirement, enough basic information would be available to settle most disputes. The important thing is that it would furnish accurate historical data from which reasonable judgments could be made. A moderate investment now would save countless legal fees and long drawn out court trials.

In years past, NOS accomplished seaward boundary surveys to different degrees for different interests. It determined precise mean low-water lines in Louisiana and California to satisfy boundary disputes. In 1970, it established the base line from which the international seaward boundary between Mexico and the U.S. in the Gulf of Mexico was determined. It has the ongoing mapping program with the State of Florida, and is assisting or advising three other coastal states in their coastal mapping needs.

As new mapping requirements become important to the nation and advance techniques develop, NOS will be ready. □

(Top) Working in Florida, National Ocean Survey personnel establish a tide gage. (Bottom) A tidal marsh has been transformed into a Venice-like development.

Admiral Powell Heads NOAA Fleet Operations; Holmes to AMC; Taylor Renamed to PMC

Rear Admiral Allen L. Powell has been named Associate Director of NOS's Office of Fleet Operations to manage NOAA's fleet of 46 ships. Rear Admiral Powell has served as Director of NOS's Atlantic Marine Center in Norfolk, Va., since December 1968. Prior to his Norfolk assignment, he headed the National Ocean Survey's Ship Construction Group at Rockville, Md., headquarters. He received the Commerce Department's Gold Medal for exceptional performance. Prior to this he served aboard various ships of the agency and with field parties in the United States. Rear Admiral Powell joined the Coast and Geodetic Survey in 1942 and served during World War II as a regimental survey officer. He received an engineering degree from the University of Texas in 1938.

Named to succeed Rear Admiral Powell as Director of the Atlantic Marine Center is Captain Alfred C. Holmes, who will hold the rank of Rear Admiral in the NOAA commissioned corps. Holmes, who has 29 years of Federal service, has served most recently as the Technical Assistant to the Associate Director of the Office of Aeronautical Charting and Cartography and Chief of its Research Group. He has been with the Commerce Department since 1949, when he joined the Commissioned Corps following graduation from Oregon State University. As Director of the Center, he will have jurisdiction over the eastern seaboard, including ship bases at Norfolk and Miami and field offices in Norfolk and New York.

Rear Admiral Norman E. Taylor has been reappointed Director of the Pacific Marine Center of the National Ocean Survey by Secretary Stans. Rear Adm. Taylor's reappointment will extend to May 31, 1973. He is the first Director of an NOS marine center to be reappointed. Prior to his assignment as Pacific Marine Center Director, Rear Adm. Taylor served 13 years aboard 12 ships of the Coast Survey fleet which took him into nearly all U.S. coastal waters and included command of the USC&GS Ships HILGARD, WAINWRIGHT, LESTER JONES, and SURVEYOR. He served with geodetic field parties in the continental U.S. and with a tides party in Hawaii. Rear Adm. Taylor joined the Coast and Geodetic Survey, predecessor of the National Ocean Survey, in 1943.

NOAA-HUD Study Probes Storm Surge Effects

A new study will be undertaken by NOAA and the Department of Housing and Urban Development to determine the extent of inland inundation from storm surges, one of the sea's greatest dangers in coastal areas.

Storm surges result from hurricanes and other marine storms which cause the sea level to rise above normal tidal heights.

The study is part of a larger survey being conducted by various government agencies for HUD's Federal Insurance Administration to determine the damaging effects of hurricanes and other severe ocean storms on coastal areas. The information is being used as the basis for establishment of Federal insurance rates for private structures in shore areas.

Principal investigators in the storm-surge study are Dr. Chester Jelesnianski of the National Weather Service's Techniques Development Laboratory and Dr. Albion Taylor of the Air Resources Laboratory. The study is being coordinated by Everett Ramey of the National Ocean Survey's Coastal Mapping Division.

Funds totaling $63,000 for the 1972 fiscal year that began July 1, are being provided by HUD.

Ship Base Dedicated; AOML Facility Progresses

NOAA dedicated its new $1,000,000 Ship and Ocean Engineering Facility in Miami, Fla., September 2.

The facility will serve as a ship base and ocean engineering laboratory for NOAA's National Ocean Survey. Based at the facility, located at the New Port of Miami, are the NOAA Ships DISCOVERER and RESEARCHER and one or two vessels of the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences. The facility consists of four one-story buildings, leased from Dade County, including one office building, one laboratory building and two warehouses.

Principal speaker at the ceremony was Dr. Robert M. White, NOAA Administrator. Others included Rear Adm. Don A. Jones, NOS Director; Dr. Harris B. Stewart, Jr., Director of NOAA's Atlantic Oceanographic and Meteorological Laboratories; and Captain Hubert Keith, Jr., Ship Base Commander. Included among the 100 invited guests present for the ceremony were Dr. Henry King Stanford, President of the University of Miami; Admiral I. J. Stephens, director of the New Port of Miami; Admiral O. Smeder, Commandant, 7th Coast Guard District Headquarters; Congressman Dante Fascell of Florida; Lester Freeman, executive director of the Greater Miami Chamber of Commerce; and Otho Bruce, senior vice president of the First National Bank of Miami.

Meanwhile, the new facility for the Atlantic Oceanographic and Meteorological Laboratories of ERL on Virginia Key at Miami is nearly 50 percent completed. The building will be some 74,000 square feet and will include facilities for the Physical Oceanography Laboratory, National Hurricane Research Laboratory, Marine Geology and Geophysics Laboratory, Sea-Air Interaction Laboratory, and the Office of the Director. In addition, there will be offices for the EDS National Oceanographic Data Center's southeast office, an engineering laboratory, conference area, computer facility, refrigerated core storage room, diving locker, marine sediment and chemical laboratories, two senior scientist wings, rooftop meteorological installation, photo laboratory, data center, administrative offices, and a library.

The new laboratory is adjacent to the National Marine Fisheries Service's Tropical Atlantic Biological Laboratory and directly across the street from the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences. These three groups form the nucleus of the 165-acre Marine Science Park established in 1969 by both the City of Miami and Dade County as a center for marine and atmospheric research.

Johnson Appointed As General Counsel

From left: Mr. Johnson, Chief of NOAA Personnel Division Guy H. Dorsey, and Dr. White.

Raud Earl Johnson has been sworn in as General Counsel of NOAA by Dr. Robert M. White, NOAA Administrator. Since 1962 Mr. Johnson has been associated with the New York City law firm of White & Case, specializing in general corporate law.

In his new post he heads NOAA's Office of the General Counsel, which provides legal services for all components of the agency.

Born in Milwaukee, Wisconsin, in 1936, Mr. Johnson is a 1958 graduate of Princeton University, where he studied government and economics at the University's Woodrow Wilson School of Public and International Affairs. Under a Fulbright scholarship, he then attended the University of Cologne in Germany. Returning to the United States, he entered Harvard Law School and received his doctor of laws degree in 1962.

North America Going Counterclockwise; Sinking, Rising, Tilting, NOS Finds

It is a well-known fact that violent natural forces, such as earthquakes, storms, and volcanoes are continually altering the face of the earth. Now scientists say that the continents are slowly sinking, rising, tilting, and rotating. Continuing investigations by Charles Whitten, chief geodesist of the National Ocean Survey, and other geodesists have resulted in better insight into the problems that arise as the land undergoes subtle but marked changes.

Recent studies by geologists and geophysicists indicate that the North American continent is rotating counterclockwise at the rate of five degrees every 10 million years. Any point on the west coast —Seattle, Washington, for example—will in the next 10 million years, rotate some 100 miles southward. While the west coast is rotating southward, the east coast is moving in a northerly direction. Thus, Washington, D.C., some 10 million years ago was about 100 miles further south, somewhere near the present location of Richmond, Va. (Europe and Asia are apparently moving clockwise, in an opposite direction to that of North America, and somewhat more slowly, about four degrees every 10 million years).

More important, however, to the future is the disclosure that North America is sinking, rising, and tilting as it rotates. Evidence of this can be seen in the slowly, but inexorably rising waters which imperil homes and industries along the Atlantic and gulf coasts and some of the Great Lakes, and the spray which increasingly whips across the Chicago lakefront as the waters of Lake Michigan continue to rise. New studies during the past three or four years by geodetic field parties of NOS indicate that the Atlantic coast from Portland, Maine, to New York has either sunk as much as 10 inches in this century or the ocean has risen by the same amount, probably a combination of both. The computations are based on a comparison with surveys of elevations made 40 to 80 years ago. The surveys show that the New England coast is subsiding at a rate of about one-fourth of an inch per year, or about 2½ feet per century. Northern Illinois appears to have risen approximately 18 inches during the past seven decades at a rate of more than two feet a century. Northern Michigan and Northern Wisconsin are being uplifted at a rate of approximately ½-inch per year, or 5 feet every 100 years. The continent from Wisconsin-Michigan to the Atlantic coast is therefore tilting almost 7½ feet per century. To the south, along the gulf coast of Louisiana, the land is subsiding approximately 1½ feet per century.

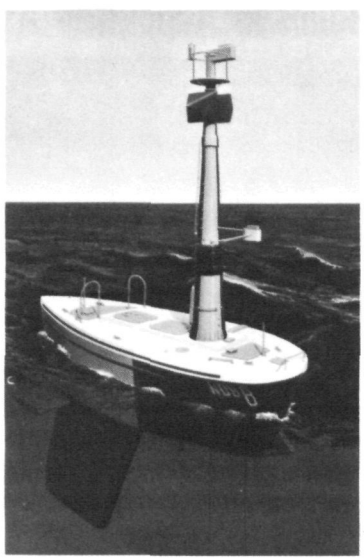
NOAA is engaged in a program for releveling a basic surveying framework within the 48 conterminous states. Several loops of this resurvey, which vary from approximately 200 to 300 miles on a side, have been completed. Chillicothe, in south-central Ohio, an area which has been found to be relatively stable, is being used as the base from which conclusions are being drawn on the movement of the continent. Mr. Whitten added that one probable cause for the earth's subsidence is the tremendous rise in industrial activity with the ever-widening demands for increased supplies of water, especially on the east coast.

Lt. Bryson Develops New Wire Drag System

Lt. (j.g.) A. Y. Bryson, an officer aboard the NOAA ships RUDE and HECK, has developed a system for determining depths over wrecks and shoals in areas where extreme currents and low visibility prevent the use of a conventional leadline. Lt. Cdr. Merritt N. Walter, the ships' commanding officer, reported that the substitute system employs an air pressure gauge on the surface, supplied with compressed air from a scuba bottle connected to a hose placed at the depth to be measured. Air pressure necessary to equalize the water pressure at the end of the hose is measured by a sensitive gauge which can be converted to depth in feet (if the gauge error is known), water density, temperature, barometric pressure and other variables. Using this system, depths have been measured accurately to within approximately three-tenths of a foot. The new system has been named the Bryson Gauge.

Data Buoy Contracts Announced

The Lockheed Missiles and Space Company, Sunnyvale, Calif., has been selected to develop and test a unique ocean platform design for NOAA's Data Buoy Project Office. An important step in the agency's development and testing of new hull and mooring concepts, the contract is expected to total about $1.4 million. The buoy designed by Lockheed is a 28-foot, boat-shaped hull with a large stabilizing keel. It can be transported by truck or barge, and readily towed to its station at sea. An antenna is integrated into its mast structure, and the mooring line is attached to the hull directly below the mast foundation, so as to ensure that the buoy streams with the current. Sensors on the buoy platform are expected to be limited to those required to check the performance of the hull and mooring, and their effects on environmental measurements. The hull will be fabricated and basic equipment installed at the Lockheed Shipbuilding Company, Seattle, Washington. Final equipment, integration, and pre-deployment testing of the platform system will be performed at the Buoy Project's facilities at the Mississippi Test Facility, Bay St. Louis, Miss. This buoy system, as well as several larger, fully instrumented buoy platforms, will be deployed for test and evaluation in



the Gulf of Mexico during the spring and summer of 1972. The U.S. Coast Guard Cutter ACUSHNET, berthed at Gulfport, Miss., will deploy and service the ocean platforms during the two-year test period.

NOAA has also announced the award of competitive design contracts for two types of limited capability buoy systems for gathering ocean and weather data. One system is to be moored in a fixed position, while the other will drift freely.

Under a $425,000 contract, the Re-Entry and Environmental Systems Division of General Electric, Philadelphia, Pa., will design both a drifting and a moored buoy system.

Lockheed Missiles and Space Company was awarded a $270,000 contract for design of a moored buoy system.

The Magnavox Company, Government and Industrial Division, ASW Operation, Fort Wayne, Ind., has a $260,000 contract for designing a drifting buoy system.

These limited capability systems are intended to supplement larger and more sophisticated buoys now being built for NOAA's National Data Buoy Center. Although their unattended operational lifetime will be less than that of the more complex systems, they will be easier to deploy at sea. In addition to their role in future operational systems, the limited capability buoys are expected to be useful in special experiments, air-sea interaction investigations, pollution studies, and possibly for data-gathering in the paths of severe storms. They should also be suitable for the 1974 Atlantic Tropical Experiment of the Global Atmospheric Research Program, which may require as many as 90 drifting and 10 moored buoys.

The contractors' designs are to be completed by February 1, 1972. Thereafter, one contractor will be selected to build a maximum of 10 moored buoy systems and one to build as many as 20 drifting buoy systems.

Both the drifting and the moored buoys will gather and transmit oceanographic and meteorological data. In the Gulf of Mexico test, data will be transmitted to the Coast Guard's Radio Station at Miami, Fla., but both systems are to be capable of conversion to allow satellites to collect and store the data for readout by a NOAA Command and Data Acquisition station.

Atmospheric measurements to be gathered by the moored system are air temperature, air pressure, and wind speed and direction. In the ocean, water temperatures will be measured near the surface and at depths of 10, 20, 50, 100, and 200 meters. At 200 meters, the system will also measure water pressure. It is to be capable of operating unattended for six months in operational programs.

The drifting buoy is intended to be dropped from an aircraft to the sea surface, where it will drift freely measuring air temperature, air pressure, wind speed and direction, and near-surface ocean temperature. It should be capable of operating unattended for three months.

The National Data Buoy Center has become part of an Office of Marine Technology in NOAA's National Ocean Survey.

Weather Offices in 43 Cities Have Pollution Forecast Role

The National Weather Service has designated 43 of its weather stations in large cities Air Stagnation Advisory Offices (ASAO's) to ensure national coverage in forecasting weather conditions which could lead to a dangerous buildup of pollutants unless emissions are curtailed.

The ASAO's were created, with the cooperation of the Environmental Protection Agency, to help state and local pollution control agencies meet and maintain the air quality standards issued by EPA for the entire nation.

Each ASAO will provide pollution control agencies within the area of its responsibility (an individual state or state-size area, depending on topography and population distribution) with an early advisory that meteorological conditions conducive to a pollution episode may be imminent. It will then predict the duration and termination of such conditions.

Ideally, the combination of timely information from the NWS, coupled with effective abatement actions by control agencies, should prevent any city from ever reaching an "emergency" stage during an air pollution episode.

ASAO's will incorporate the Environmental Meteorological Support Units (EMSU's) presently functioning in 14 of the designated cities and 12 EMSU's that are planned.

To guide the ASAO's, weather analysts of the National Meteorological Center use computerized techniques to determine where stagnant conditions may develop over large areas of the country. This type of prediction service has been available since 1960.

In the following cities, weather stations have been designated ASAO's: Albany, N.Y.; Albuquerque, N. Mex.; Anchorage, Alaska; Atlanta, Ga.; Birmingham, Ala.; Boise, Idaho; Boston, Mass.; Buffalo, N.Y.; Charleston, W. Va.; Chicago, Ill.; Cleveland, Ohio; Columbia, S.C.; Denver, Colo.; Des Moines, Iowa; Detroit, Mich.; Ft. Worth, Tex.; Great Falls, Mont.; Honolulu, Hawaii; Houston, Tex.; Indianapolis, Ind.; Jackson, Miss.; Kansas City, Mo.; Little Rock, Ark.; Los Angeles, Calif.; Louisville, Ky.; Memphis, Tenn.; Miami, Fla.; Minneapolis, Minn.; New Orleans, La.; New York, N.Y.; Oklahoma City, Okla.; Philadelphia, Pa.; Phoenix, Ariz.; Pittsburgh, Pa.; Portland, Maine; Portland, Ore.; Raleigh, N.C.; St. Louis, Mo.; Salt Lake City, Utah; San Francisco, Calif.; San Juan, P.R.; Seattle, Wash.; and Washington, D.C.

NMFS Acts To Save Ten More Marine Species

The National Marine Fisheries Service has acted to prohibit foreign fishing vessels from taking ten more species of marine animals after determining them to be creatures of the Continental Shelf.

Creatures of the Continental Shelf are defined in the 1958 Geneva Convention on the Continental Shelf, to which the United States is a party, as those which at the harvestable stage "are immobile or are unable to move except in constant physical contact with the seabed or subsoil of the Continental Shelf." This Convention is implemented by a 1964 U.S. law commonly known as the "Bartlett Act" under which the United States has the right to reserve to its own nationals the right to harvest certain marine resources determined to be creatures of its Continental Shelf, except as otherwise provided by international agreement.

The animals added include: Precious red corals and black coral; surf clams and ocean quahog; and the following crustacea: Dungeness crab, deep sea red crab, northern stone crab, golden king crab, and two species of California king crab (*Paralithodes rathbune* and *Paralithodes californiensis*).

Species previously listed by the U.S. as creatures of the Continental Shelf included: tanner, king, and stone crabs; red and pink abalone; Japanese abalone; queen conch; and four kinds of sponges.

Chesapeake Bay Study Underway

The National Ocean Survey is conducting a seven-month, 934-mile geodetic survey along the shores of the Chesapeake Bay, in response to a request from the Baltimore District, U.S. Army Corps of Engineers. It is required to establish firm control of the elevations of the network of tidal gaging stations to be used in the design and verification of a working hydraulic model of Chesapeake Bay. This hydraulic model will be the world's largest estuarine model and a most significant environmental tool for the accomplishment of the Chesapeake Bay Study. The study will lead to a bay-wide plan for the maintenance and enhancement of the environment of Chesapeake Bay.

MIT's Lehman Named To Ecology Office

Dr. Richard L. Lehman of the Massachusetts Institute of Technology has been appointed to the staff of NOAA's Office of Ecology and Environmental Conservation. Since 1968 he has been a member of the research staff of MIT's Laboratory for Nuclear Science, supervising a radiation protection program.

The Office of Ecology and Environmental Conservation is responsible for ensuring full consideration of environmental protection matters. It works closely with conservation and ecological groups and represents NOAA on governmental and other organizations involved in conservation and ecology.

Dr. Lehman was a physicist with the University of California's Lawrence Radiation Laboratory from 1957 to 1964, when he became assistant professor of biophysics and nuclear medicine at UCLA's Laboratory of Nuclear Medicine and Radiation Biology.

Dr. Lehman received his bachelor's degree in 1951 and his master's degree in 1953 from the University of Oregon, and his doctorate in biophysics from the University of California in 1963.

Sea Bottom Map Aids Fishermen

The issuance of a sea bottom map designed specificially as an aid to commercial fishing has been announced.

The map covers an area off the coast of Oregon extending north from the California border approximately 120 miles and out to sea to 1500-foot depths.

The map, the first of its kind, was drafted by the National Ocean Survey and is based largely on data gathered by Commerce Department ships since 1889, with additional data furnished by Oregon State University. The publication resulted from a joint National Ocean Survey and Oregon State University Sea Grant program.

Termed a surficial sediment map, the publication portrays through different patterns the various sediments found on the sea bottom, including mud, sand, rock, and muddy sand. Dr. Hyman Orlin, Special Assistant to the Director for earth science activities, said: "The map was prepared as a service to the fishing industry. Not only do some species of fish tend to congregate at certain depths, but they also prefer particular bottom cover. A knowledge of the characteristics of a region will reduce the fisherman's reliance on chance and increase his catch."

In addition to sediment, the map portrays the topography of the sea bottom and contains Loran lines which enable fishermen to determine their position at sea. Orlin explained that fishermen previously had to consult two publications —a bathymetric map and a nautical chart—to determine the sea bottom's topography and their position.

Florida Governor Reubin Askew presents outstanding service award to Jack Brawner (right), NMFS Regional Coordinator for District Two, for distinguished performance in seafood marketing.

all in the family

PERSONNEL NOTES

Elroy C. Balke has been named Regional Hydrologist in the NWS Central Region headquarters, Kansas City. He replaces Verne Alexander, who has retired.

Capt. Eugene A. Taylor has been appointed Deputy Associate Director of the NOS' new Office of Fleet Operations. For the past year he has been Chief of the Operations and Requirements Division, Office of Marine Surveys and Maps. He holds the Department of Commerce Gold Medal for his work in satellite triangulation.

J. Virginia Lincoln, Director of the EDS' Aeronomy and Space Data Center, Boulder, Colo., has been elected vice-chairman of the Association of Federal Professional and Administrative Women, Denver Region.

Dr. Hoyt A. Wheeland will head the NMFS Service Statistics and Market News Division.

Dr. Ray E. Jensen, Chief of the Data Acquisition Branch at NWS Southern Region headquarters, has been awarded the 1971 Stark Award of the American Society for Horticultural Science for contributions to the improvement of fruit trees.

Dr. Neil Frank, hurricane specialist at the National Hurricane Center, has won the Miami Federal Executive Board's Man of the Year Award, in the Professional-Scientific category.

Alan H. Shapley, Director of the ERL's Office of Geophysical Monitoring, has become Acting Associate Director for Geophysics and Acting Director, Aeronomy and Space Data Center, EDS.

Capt. Robert E. Williams, Director of the NOS' Lake Survey Center, Detroit, has been named to the Great Lakes Basin Commission by Secretary Stans.

Cdr. Kelly Taggart, NOAA Commissioned Corps, has become Executive Officer of the NOAA Ship FAIRWEATHER. His last assignment was program planning and coordination officer, Office of Hydrography and Oceanography.

Lt. Cdr. Philip C. Johnson, NOAA Commissioned Corps, is coordinating an NOS study at Cornell University of urban surveying activities.

L. Gilbert Burdine, NOS, will coordinate efforts by local, state, and Federal agencies to reestablish horizontal and vertical control networks in Los Angeles County damaged by the February earthquake.

Tillman Gladney has become Chief, Surface Systems Branch, in NWS' Data Acquisition Division. He previously served in NOAA's Office of Plans and Programs, Atmospheric Division.

Ernest S. Ethridge has been selected to head the NWS Shreveport, La., office.

Herbert T. Hirata has been appointed Chief, Observations Section in the NWS' Pacific Region.

Arlin E. Snider has been appointed State Climatologist for Illinois after service with the NOAA Office of Plans and Programs.

Wesley Irvin has been named NWS Manpower Management Officer. He has worked more than 15 years in the NWS' Headquarters Data Acquisition Division.

Dr. James J. Rahn has been appointed Pennsylvania State Climatologist. He transfers from the Agricultural Climatology Service Office, EDS.

Lt. John T. Atwell, NOAA Commissioned Corps, has been assigned to Ft. Pierce, Fla., for two years' duty with the Smithsonian Institution's submersible program, to help determine how submersibles may be applied to NOAA missions.

Luther E. Bivins has been chosen Chief of the Evaluation Branch of the NOIC's Testing Division, after nine years with the Naval Oceanographic Office.

Albert O. Bangert, former principal assistant at the Omaha, Neb., NWS office, has succeeded Edward F. Stapowich as meteorologist in charge.

Jack Townsend, chief of the College, Alaska, Observatory, has been elected Lieutenant-governor of the Alaska-Yukon Division, Kiwanis International.

Dr. Hugh J. McLellan, former Associate Scientific and Technical Director, U.S. Naval Oceanographic Office, has joined the Office of Sea Grant as Associate Program Director for Institutional Support.

Jacob W. Morgan, of the Chicago NWS Forecast Office, has been named meteorologist-in-chief at the Springfield, Ill., office.

Dr. Warren B. Johnson, Chairman of the American Meteorological Society's Committee on Atmospheric Turbulence and Diffusion, has been appointed NOAA's Chief of the Model Development Branch, Division of Meteorology, Triangle Park, North Carolina.

Hugo V. Goodyear has been named Chief of the NOS' Office of Hydrology's Special Studies Branch.

Donald A. Kluckman is now Official-in-Charge at the Pueblo, Colo. NWS Office, replacing Loren J. Allison, retired.

Ervin A. Wesley has been assigned as Official-in-Charge of the NWS Office in South Bend, Ind., where he has served for many years.

Charles F. Knudson has been named Acting Chief of the NOS' Seismological Field Survey in San Francisco, succeeding William Cloud, retired.

Richard L. McNeely, Chief of the NMFS' harvesting efficiency program at the Seattle Exploratory Fishing and Gear Research Base, has been chosen Outstanding Federal Employee of the Year in the area.

Jack L. Hummel, of the Syracuse, N.Y. NWS Office, has been named to head the Burlington, Vt., office.

Kenneth W. Hagy has become Meteorologist - in - Charge of the Wilmington, Del., NWS Office, succeeding Guy Anderson, retired.

David H. Owens is head of the Austin, Tex., NWS Office. He replaces David P. Barnes Jr., who becomes assistant head of the Atlanta, Ga., Forecast Office.

Billy F. Greer, NMFS Chief of Financial Assistance, Gulf and South Atlantic Region, has been honored by the naming of a shrimp trawler for him, in recognition of outstanding service to the industry.

James F. Lander, Chief of NOAA's National Earthquake Information Center, has been cited by the Office of Emergency Preparedness for outstanding contributions to its programs.

Capt. Gerard E. Haraden, NOAA Commissioned Corps, has been assigned as Chief of Operations at the NOS Pacific Marine Center, Seattle. He previously directed NOS' Anchorage, Alaska office.

Dr. F. E. Elliott, of Washington Technical Institute, has joined NOIC as Assistant to the Director.

Arnold R. Hull, former Commander of the Air Weather Service's Sixth Weather Wing, has been appointed Acting Associate Director for Climatology, EDS.

Lloyd L. Clay, Chief of NOS's Coast Pilot Branch, has been awarded the Colbert Medal of the Society of American Military Engineers for efforts leading to the development of a new application for computer-assisted type composition.

Earthquake Research Project Undertaken By NOAA and HUD

A research project to reduce earthquake hazards through improved land use and building codes and to provide information for improving insurance programs will be undertaken by NOAA and the Department of Housing and Urban Development.

To start the project, HUD will provide $155,000 to NOAA for the 18-month study. NOAA conducts a broad program of studies related to earthquake hazard reduction and has developed strong working ties with the Earthquake Engineering Research Institute. EERI, a non-profit corporation established in the public interest, consists of experts in all aspects of earthquake engineering. A significant aspect of the agreement is that NOAA will be able to call upon the capability in earthquake engineering of the EERI. Also participating will be the National Bureau of Standards and the U.S. Geological Survey.

The project is described as an opportunity to learn from the unique testing experience of the Los Angeles earthquake of last February and to develop and bring together knowledge on earthquake hazard reduction techniques. The study will provide information and recommendations to improve seismic risk mapping and single-family structure site planning, engineering, design and construction so as to reduce the hazards, damage and losses from future quakes. Existing techniques for the estimation of earthquake losses to structures will be validated, refined and extended.

A report on the state-of-the-art of seismic risk zoning, earthquake resistant design of housing, public facilities and utilities and building codes will also point out opportunities in the governmental and private sectors for the reduction of the earthquake hazard. By working closely with related studies conducted by the Los Angeles City and County Governments and the State of California, much of the new knowledge generated will be readily available for immediate use by these governmental units.

Named as Project Manager for NOAA is Dr. S. T. Algermissen, Chief, Geophysics Group; Project Manager for HUD is Dr. Arthur Zeizel, Environmental Factors and Public Utilities Division.

A CORRECTION

Authorship of the article "High and Low," in the July issue of NOAA, was mistakenly credited to John Hanna. The article was written by Grace Wegner. The editors of NOAA regret the error.

Schoning Appointed Deputy Director of Fisheries Service

Robert W. Schoning, who has been Oregon State Fisheries Director since 1960, has been named Deputy Director of the National Marine Fisheries Service. He will work with NMFS Director Philip M. Roedel on all aspects of fisheries research and development on both national and international levels.

Well known as a fishery scientist, administrator, and author on fishery matters of the Pacific Northwest, Mr. Schoning was Director of Research for the Oregon Fish Commission and spent two years as Assistant State Director before becoming the Director.

Mr. Schoning received his bachelor of science degree in fisheries from the University of Washington, and has done graduate work in fisheries and mathematics.

He is a member of the U.S. Department of State Fishing Industry Advisory Committee, the Oregon Committee on Natural Resources, and several professional and conservation organizations.

Weather Service—NBS Inaugurate Storm Information Service

The Commerce Department's National Weather Service and National Bureau of Standards have established a storm information service for deep-water sailors in the Atlantic and the Pacific.

The service consists of hourly broadcasts of up to 42 seconds each giving information about major storms that might produce trouble for ships at sea. The weather broadcasts are superimposed on Bureau of Standards time signals carried by stations WWV and WWVH.

The broadcasts are made around the clock. Station WWV carries information about storms in the western North Atlantic, 16 minutes after every hour, on radio frequencies 2.5, 5, 10, 15, 20 and 25 Mega-Hertz. WWVH lists storms in the eastern and central part of the North Pacific, 49 minutes after every hour, on 2.5, 5, 10, 15 and 20 MHz. The ocean areas involved are those for which the U.S. has warning responsibility under international agreements.

If there are no storm warnings in the designated areas, the broadcasts so indicate. The brief messages are designed to tell mariners if there are storm threats in their areas—not to provide complete information. Mariners are expected to check with one of the regular marine broadcasts for details.

Four Universities Named by Secretary Stans As The Nation's First Sea Grant Colleges

Secretary of Commerce Maurice H. Stans has announced the first four United States institutions to receive the designation of Sea Grant Colleges.

They are the University of Washington, the University of Rhode Island, Oregon State University, and Texas A&M University. Formal ceremonies marking the occasion were held in the Secretary's office on September 17.

"This is an historic moment in the marine affairs of the Nation and one in which the Commerce Department, as the national civil focus for oceanic matters, is proud to participate," Secretary Stans said. "In the 19th century, the Land Grant College concept began to widen our national horizons in agricultural and mechanical arts. The Sea Grant College concept working through existing institutions, will help America toward more effective development and conservation of our final unexplored frontier, the oceans.

"I know of few other programs which offer as much long-term promise for the Nation."

The National Sea Grant Program, now conducted by the Commerce Department's National Oceanic and Atmospheric Administration, was created in 1966 under Public Law 89-688. With matching funds from states and other organizations, it makes possible grants to universities and other institutions, public and private, for research and development, education and training, and marine advisory services. Sea Grant programs roughly parallel those of the Land Grant Program.

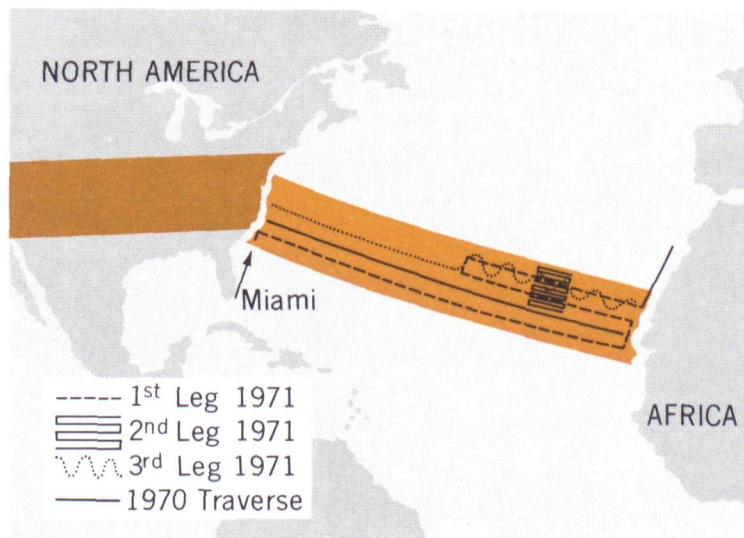
In its first few years of operation, the Sea Grant Program has invested more than $40 million in projects in 27 states, the Virgin Islands, and the District of Columbia. Currently, there are approximately 90 active individual projects, and 13 institutional grants covering a total of 457 projects, in the areas of fisheries and aquaculture, ocean engineering, coastal zone resources management, marine pharmacology and pharmaceuticals, pollution, ecological studies, mineral resources, marine and coastal zone law and economics, biological oceanography, seafood science and technology, management and preservation of the environment, man in the sea, and physical and chemical oceanography.

Among the National Sea Grant Program's major accomplishments are identification of Great Lakes mineral deposits valued at more than $300 million, the first commercial harvest of cultured shrimp, new methodology for coastal zone management decisions, innovative fishery technology, acoustic counting of fish populations, and a system to use deep, cold ocean water as an aquacultural nutrient source.

Designation as a Sea Grant College, the Secretary said, is a high honor, symbolizing a mutual recognition of continuing responsibility by the Department of Commerce and the institution to maintain and develop the excellence and relevance of the institution's Sea Grant Program.

"The four universities accorded this designation have set exceptionally high standards of effort, performance, and innovation in their marine programs," he said. "Their designation stands as an inspiration for the many other institutions involved in this vital area. Their selection was by no means an easy one, for so many institutions receiving Sea Grants have made outstanding progress."

TAG Findings Being Analyzed By NOAA



Drawing shows the Trans-Atlantic Geotraverse (TAG) corridor and the various cruises made by scientists of the Atlantic Oceanographic and Meteorological Laboratories, aboard the NOAA Ship DISCOVERER. The TAG project, part of the International Decade of Ocean Exploration, will be completed in 1974. The adjoining corridor across the United States represents a crustal section established in 1968 by the Transcontinental Geophysical Survey.

Information from the first complete geophysical investigation of the sea floor across an entire ocean is being analyzed.

According to the project's chief scientist, Dr. Peter A. Rona, analyses now underway are expected to turn up information toward a more thorough and valuable understanding of past and present movements of the continents and rifting of the sea floor; an assessment of oil and mineral deposits in the deep ocean; the employment of the theories of sea floor spreading and plate tectonics in determining where and how oil and mineral deposits are laid down in the earth; and a better understanding of earthquake mechanisms.

Known as TAG, for Trans-Atlantic Geotraverse, the project was originally recommended in 1968 by the National Academy of Sciences and the U.S. Upper Mantle Committee as an activity for the Environmental Science Services Administration. Under the direction of two NOAA organizations, the Atlantic Oceanographic and Meteorological Laboratories, Miami, and the National Ocean Survey, TAG is part of the U.S. contribution to the International Decade of Ocean Exploration. It began in 1970 and is expected to be completed by 1974. The investigation was carried out aboard the NOAA Ship DISCOVERER.

Another part of the TAG project is systematic exploration and mapping in the corridor—a 200-mile wide, 3,500-mile-long rift in the ocean floor—to supplement existing data and produce maps including bathymetry (water depth), gravity measurements, magnetics, and sediment thickness. Known as SEAMAP, this activity is conducted by NOS. Other collaborators in the TAG investigations include Yale University, Florida State University, Texas A&M University, University of Connecticut, and Rensselaer Polytechnic Institute. Scientists of Australia, France, the Federal Republic of Germany, Portugal, and the United Kingdom are also engaged in collaborative work in the project.

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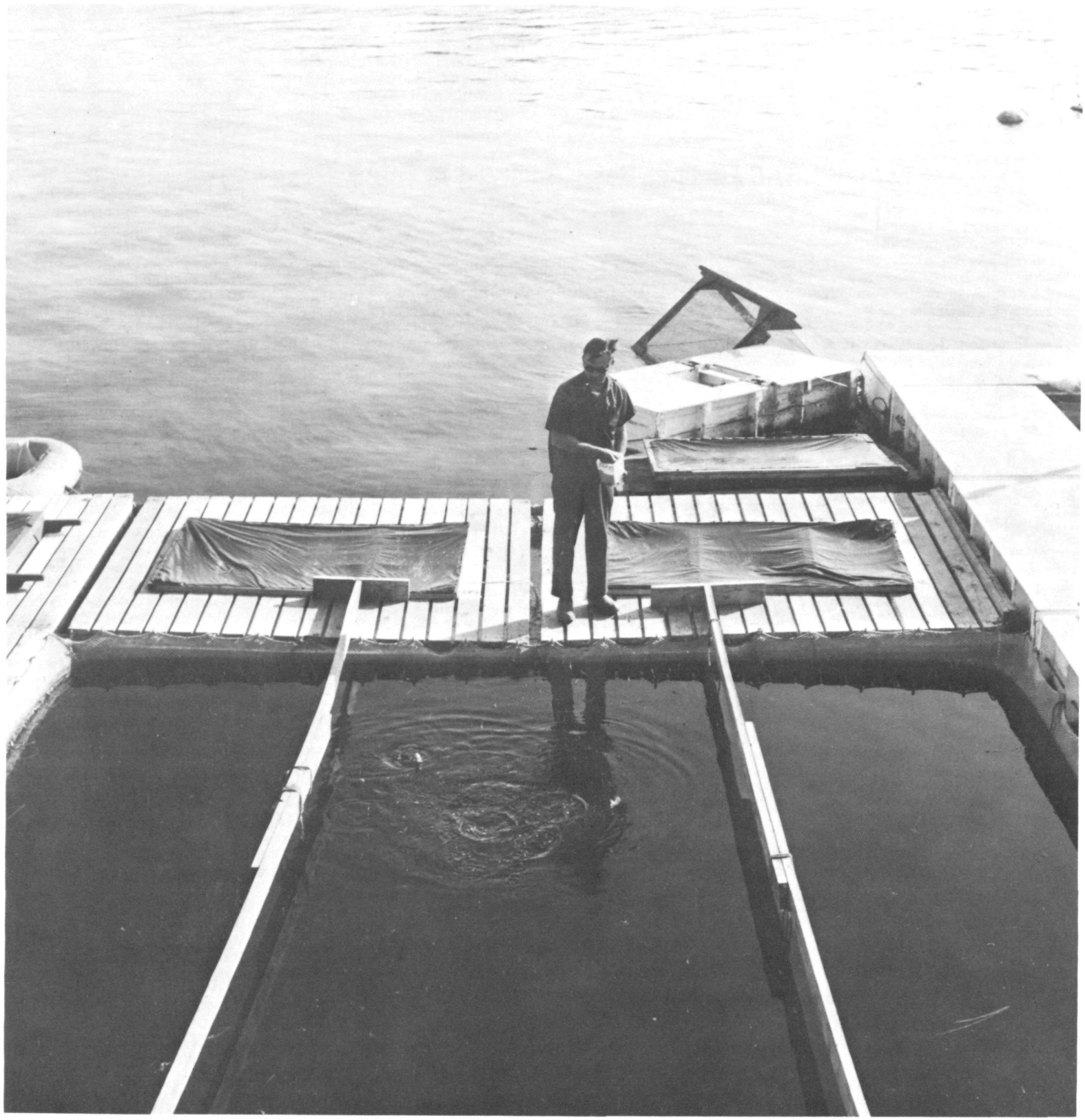

Feeding time for young salmon reared in captivity.