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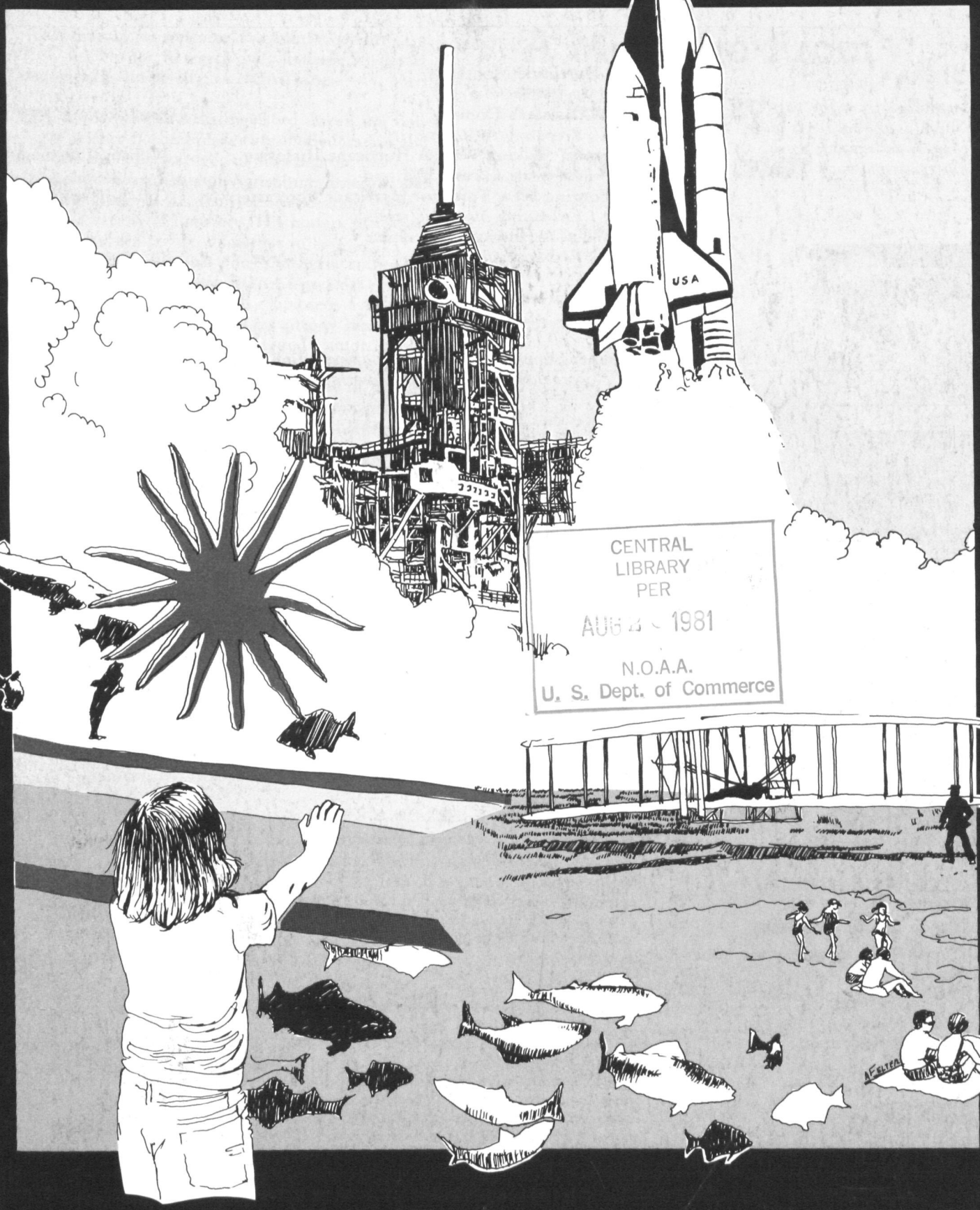

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COVER

A montage from the pages of NOAA *as the reader is led from an underwater world into space and back to earth.*

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U.S. DEPARTMENT OF COMMERCE
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A Message From The Deputy Administrator

This month, we welcome Dr. John V. Byrne, Vice-President for Research and Graduate Studies at Oregon State University, as NOAA's new Administrator.

Dr. Byrne has had a distinguished career, not only in marine science but in broader areas of education and research. He is no stranger to Washington, having served the Departments of Agriculture, Interior, and State, the National Academy of Sciences, and NOAA itself in a variety of functions. His honors as a scientist and educator are far too numerous to list.

If I may add a personal note, Dr. Byrne comes to us with the strong belief that NOAA's greatest asset is its people. His visits with NOAA employees over the past several months have added to his already substantial number of NOAA acquaintances, and reinforced his impression that the men and women of NOAA are among the most competent and dedicated in the Government. One of Dr. Byrne's early priorities is to meet as many of the NOAA family, at all levels, as soon after coming aboard as possible.

Dr. Byrne comes to NOAA with the conviction that the wise use of the oceans and atmosphere is vital to our success as a Nation, and that if we are to use these resources wisely, we must first understand the processes that control them. This understanding, he has stated, is basic to the formation of coherent national policies which will simultaneously protect our environment and strengthen our economy.

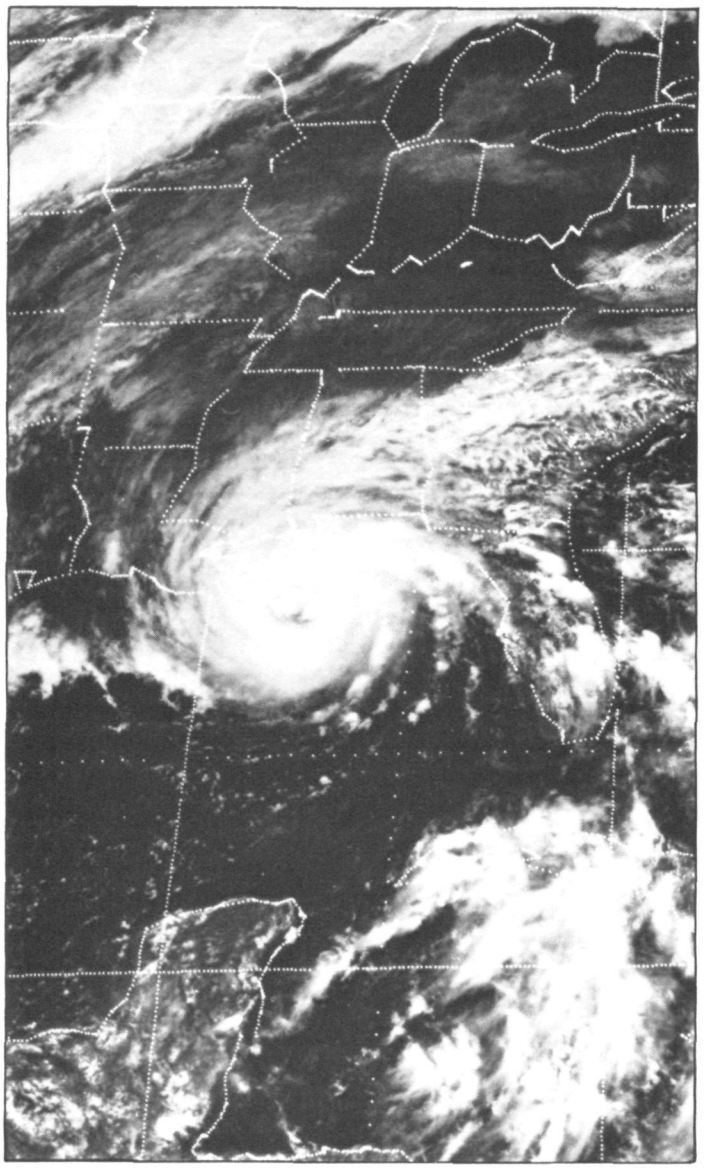
Dr. Byrne intends to fill out NOAA's management team as quickly as possible, and then to move forward vigorously with the tasks at hand. In that mission, I know he will have the support which comes from the best we call can offer, and that NOAA will continue to serve the Nation well.

Welcome aboard, Dr. Byrne.

JAMES P. WALSH
Deputy Administrator

Special Section

The Hurricane Months



Credit: NOAA

The great pinwheeling masses of clouds spinning in from the Atlantic, Caribbean, or Gulf of Mexico are now familiar features of the hemispheric weather pictures from environmental satellites. You don't need to be a satellite meteorologist to identify the hurricane with its great cloud arms circling counter-clockwise around its calm eye.

From the satellite's vantage point of perhaps 23,000 miles out in space they have a certain natural beauty—white spirals against the dark ocean moving in a stately fashion across the water.

But the beauty of the storm from 36,000 kilometers becomes nightmarish ugliness at ground level.

Black clouds blot out the sun and bring torrential rains—so heavy at times witnesses report it's hard to find air to breathe. City drainage systems cannot handle the deluge and in the countryside flash floods gouge out new stream channels. If a house is in the way, so much the worse.

The hurricane winds—roaring with deafening force hour after hour until the mind is numb with the awful sound—carry a deadly cargo of debris...tin cans, lawn *furniture, tree limbs, awnings, anything not tied down.* And if *this* wind weren't bad enough, tornadoes often dip down from the black hurricane clouds, bringing death and destruction where their whirling funnel tips touch.

And then comes the storm surge, the great mound of seawater pushed ashore by the hurricane's winds. The surge combines with the normal ocean tide to increase the mean water level 15 feet or more. Topped by pounding waves, the storm surge is the hurricane's worst killer, claiming nine of its every ten victims.

The potential death and destruction from hurricanes grows each year. Here's how NOAA experts described the threat at the beginning of the hurricane season this June.

"The nation is in the most vulnerable position in history should a major hurricane strike this year.

"Mushrooming coastal populations, public inexperience and apathy, and limited evacuation routes could combine to create a major catastrophe.

"Under today's conditions, a far smaller storm than the hurricane that killed 6,000 persons in Galveston in 1900 could bring a far more tragic disaster.

"Although it is impossible to predict that a recent downturn in the annual occurrence of hurricanes will be reversed, neither is there reason to believe the United States will be spared.

"The absence of killer hurricanes in the past several years has bred a dangerous degree of apathy, and studies have shown a marked reluctance by people in the path of a storm to leave in adequate time.

"Despite steadily-improving forecast and warning performances by the National Weather Service, and total cooperation by the media in informing the public, the 12-hour period between warning and landfall will not guarantee safety. In numerous cases it requires 18 to 24 hours to mobilize and carry out an evacuation."

The message is clear.

Americans in hurricane-susceptible areas must plan for their personal safety. They can't wait for the satellite photos. They have to prepare immediately—before the need becomes desperate.

Make no mistake, NOAA said. These are dangerous times for many Americans. These are the hurricane months. □

In Disaster's Domain

Paul Girolami

Federal Emergency Management Agency

Gulf Coast residents took great interest in preparedness during Allen's hurricane watch period in 1980. Store shelves were emptied of flashlights, batteries, portable radios, candles, water jugs, foodstuffs, and other survival items. Civil defense officials were flooded with calls asking about shelter locations, evacuation routes, and elevation of residences. By the time Allen moved inland, over 280,000 persons had evacuated high-risk coastal areas. The Gulf Coast was ready for this one.

Hurricanes, storming across the Atlantic, or in from the Gulf of Mexico or the Caribbean Sea, have killed more than 13,000 persons in the United States since 1900. More than $12 billion in damages have been caused by hurricanes and tropical storms since the turn of the century.

But Allen spent most of its fury on waterfront property from which residents had prudently moved for the storm's duration.

For the Federal Emergency Management Agency, the implementation of local evacuation plans—which FEMA had helped to develop—was most satisfying. But the Agency's job was not over when the wind and water returned to normal.

Reducing the tremendous totals in lives lost and property damaged during a hurricane is one of the objectives of FEMA. Created in 1979 by executive order, the Agency is charged with preparing for, recovering from, responding to, and mitigating the effects of domestic crises ranging from natural disasters to a potential nuclear attack to man-caused disasters. FEMA supplements the efforts and resources available to State and local governments and voluntary relief organizations by triggering and coordinating other Federal relief programs.

Under Presidential signature, the Disaster Relief Act of 1974 grants FEMA the authority and capability to provide maximum mobilization of Federal relief assistance by borrowing equipment, personnel, supplies, facilities, and other resources, with or without reimbursement, to supplement State and local disaster assistance efforts. Costs of disaster assistance as a result of a Presidentially-declared "disaster" or "emergency" are shared by Federal and non-Federal resources on a 75-25 percent basis.

In time of need a number of Federal, state and local agencies provide disaster assistance such as the airlifting of medical supplies to a hurricane stricken area. The coordination of disaster assistance recovery and mitigation efforts is a primary concern of FEMA.

Credit: National Guard Association

The methods FEMA uses to help lessen the consequences of a hurricane's devastating effects are many. One such tool is population evacuation in those high-risk areas in or near a hurricane's path. Under provisions in the Disaster Relief Act, a Federal grant of $250,000 was given to each State during the one-year period of May 1974 to April 1975 for "the development of plans, programs, and capabilities for disaster preparedness and prevention."

Evacuation plans for a variety of disaster situations were developed through this grant. FEMA continues to evaluate annually these evacuation plans with each State's emergency preparedness and disaster assistance programs.

Evacuation often plays a vital role in saving lives when a hurricane moves inland. In September 1979, 49,000 persons were evacuated from hurricane-threatened areas in four states because of Hurricane Frederic. When Hurricane Allen moved inland north of Brownsville, Tex., in August, 1980, thousands of residents in low lying cities—and many up to 20 miles inland—evacuated their homes in search of safer shelters from the storm's fury. Many evacuated on their own, but most waited for action from local emergency planners.

The public seemed quite willing to leave the area well before being encouraged to do so, due to Allen's tremendous power. Such willingness may be related to the Gulf Coast's experience with another major hurricane, Camille, ten years earlier.

Texas Governor William P. Clements, Jr. joined FEMA officials in praising the successful implementation of local evacuation efforts well before Allen hit. "The evacuations were critical in keeping the death toll as low as it was," Clements said, noting that Allen could have been worse had it not been for the excellent evacuation efforts and State and local pre-hurricane season programs.

After Allen moved inland, FEMA and all Federal agencies involved were immediately ready to help individuals, families, and businesses begin cleanup operations and return to everyday life. FEMA's response programs focus on two main areas: management and coordination of the entire Federal response, and direct or financial assistance through FEMA relief and recovery programs.

Direct disaster assistance provided by FEMA falls into two broad categories: public assistance to state and local governments and individual assistance to disaster victims and their families. Public assistance includes grants for emergency protective measures, debris clearance, and the repair and restoration of damaged public and certain private, non-profit facilities.

Individual assistance for disaster victims includes temporary housing (through privately-owned housing units available on the market; government-owned or assisted units; FEMA-owned mobile homes; or grant money for limited repairs), and individual and family grants to meet serious unmet disaster-related needs or necessary expenses.

From April 1, 1974 to September 30, 1980, Federal assistance under the Disaster Relief Act totalled $3.2 billion, including more than $849 million obligated during FY 1980 for disasters in 1980 and previous years.

In addition to its disaster response activities, FEMA has initiated several programs during the past year that provide better service to the victims of major disasters and emergencies while enhancing program efficiency and economy of operations.

One program to help reduce future hurricane-related loss of life and property destruction is being conducted by FEMA's Federal Insurance Administration (FIA). Zoning changes, stricter building codes, and enforced land-use regulations are some of the techniques employed by FIA to mitigate the impact of a hurricane's landfall. A major part of zoning changes involves "set-back" building requirements. Any new oceanfront construction, including the rebuilding of destroyed property, must be set back a prescribed distance from the shoreline. When combined with regulations preserving oceanfront sand dunes and wetlands, this policy will help mitigate the storm surge high wave effects.

FIA also urges communities to apply for coverage under the National Flood Insurance Program, thus encouraging them to enact building codes, floodplain management guidelines, prevent over-populated shorelines, and improve poorly-developed evacuation routes.

FEMA conducts interagency training and program coordination to Federal, State, and local organizations to make all parties knowledgeable of existing programs and capabilities offered by various agencies in providing disaster assistance. Federal coordination of disaster assistance recovery and mitigation efforts is a primary concern of FEMA.

Building codes, interagency coordination, and early hurricane warning and evacuation help preserve lives and reduce property damage when a hurricane strikes. But this is not enough. The Federal Emergency Management Agency and the National Oceanic and Atmospheric Administration are pooling their resources to inform the public of the dangers of tornados and hurricanes. FEMA has a multi-media Hurricane Awareness Campaign to further preparedness in hurricane-prone areas. Materials will include leaflets, radio scripts, public service announcements, news articles, and other materials to enable State and local emergency officials to conduct this campaign.

Hurricane awareness and preparedness is a team effort for everyone in high-risk communities—individuals, State and local agencies, volunteer relief organizations, and most importantly, FEMA. A greater knowledge of all phases of hurricane preparedness plus strongly restricting (and enforcing) building codes can reduce the tremendous totals in lives lost and property damage caused by hurricanes. The Federal Emergency Management Agency is working toward protection of life and property from the greatest storm on earth. □

Hurricanes unleash a double threat to coastal areas—devastating high winds and storm surge. Although these forces cannot be controlled, hurricane awareness and preparedness programs can minimize losses in life and property.
credit: Miami Herald

Gaby's puzzle

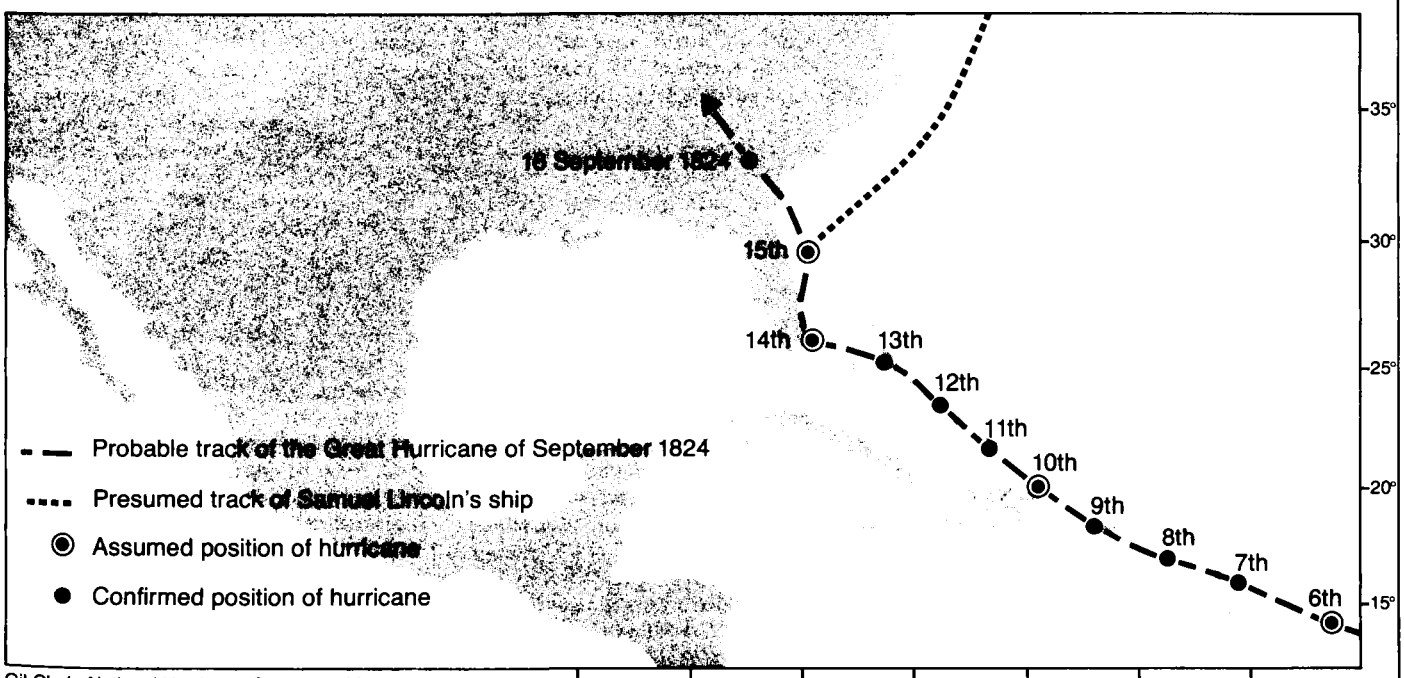
Storm Stalking With A Hurricane Historian

William J. Brennan

The known history of North Atlantic hurricanes, for all intents and purposes, began in the mid-1800's when weather statisticians first began keeping detailed enough information to pass along with considerable consistency a record of the severe tropical storms which battered the Atlantic and Gulf of Mexico coastlines of the United States.

Presumably, however, hurricanes have been assailing this part of our Nation since the North American continent was first formed. And there are, indeed, hints of hurricanes contained in journals of the country's earliest settlers.

Fortunately for Donald C. Gaby, manager of NOAA's Satellite Field Services Station in Miami, early settlers there failed to keep such detailed journals; fortunately, because one of Gaby's pleasures in life is looking backwards to see where we've been and, perhaps, to get a hint of where we're going. Gaby is a dedicated amateur historian, especially in those matters relating to weather.



Gil Clark, National Hurricane Center (10 March, 1981)

Thus, the failure of the Davis, Lewis, Hagen and Pent families—pioneer families who settled in what was then the wilderness of South Florida but is now Key Biscayne, Coconut Grove, and Miami—to keep weather records offered to Don Gaby the opportunity to unpeel the layers of years and come up with a detailed account of the earliest known "great" hurricane to hit the Miami area.

Hurricanes are no strangers to Southeast Florida. In the 80 years since 1899, no fewer than 24 hurricane-sized tropical storms have come ashore there, including one Scale 4 storm in 1926, and another in 1947. On the Saffir/Simpson Hurricane Scale, a Scale 4 storm packs winds of from 131 to 155 miles an hour, blowing down large trees, and/or has a storm surge 13 to 18 feet above normal.

Until Gaby began his intellectual snooping around, the 1926 storm—hurricanes were not legitimized with names until 1950—was considered to be the first "great" storm to attack Southeast Florida.

But no longer. Because of Gaby's interest, and because of pieces of information recorded haphazardly here and there, it generally is accepted that on September 14, 1824, the area now known as Miami was belted by a major hurricane. The storm was first reported at Guadelupe on September 7 and 8, and assed through the Lower Bahama Islands on September 11 and 12. The next day it whirled past Nassau, and struck the Miami area on September 14, then bounced up Florida's east coast, going out to sea again in the vicinity of Cape Canaveral.

Gaby's hurricane is well documented as having gone ashore for the final time September 16, drowning at least 83 persons at St. Simon Island, Ga., and causing heavy property damage and taking additional lives as far north as Savannah.

This represents Gaby's reconstruction of

the final nine days of the hurricane's life. There were, in 1824, no NOAA satellites to sight the birth of the storm, probably off the Africa coast, nor to track it hour by hour. Instead of simply looking at the familiar GOES East images to determine the path of the storm, Gaby was required to spend months poring over research books, articles from the National Archives, and unpublished letters stored at NOAA's National Climatic Center in Asheville, N.C.

Gaby's first hint about the most powerful storm to hit the Miami area for the 102-year period between 1824 and 1926 came from the pages of *Florida Wild Life*, a book by Dr. Charles Torrey Simpson published in 1932. Simpson, a pioneer Florida botanist, had retired from the Smithsonian Institution and built a home facing Miami's Biscayne Bay. On his 15-acre site were mangroves, tropical hammock, and pine woods.

"Dr. Simpson was himself quite knowledgeable about hurricanes," Gaby wrote in an article published in a Florida historic magazine, "having personally experienced many in the West Indies and Florida, and was ahead of his time in his understanding of them. The great hurricane of 18 September 1926...did immense damage to the trees and plants around his beautiful home, and his observations of this provide our first clue (to the 1824 hurricane).

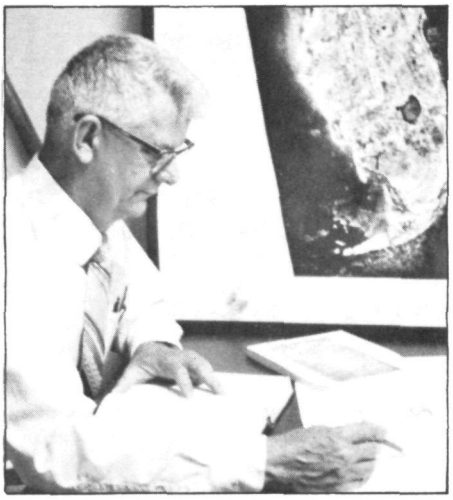
"In his hammock was living an old oak that had been blown down in an earlier storm, and from its roots had grown a young oak that in 1926 was twisted off at its base. Cutting this younger oak to clear a path through the hammock, he counted the tree rings and found about one hundred!

"Later," Gaby's article continues, "in going through the pine forest he (Simpson) found it largely devastated, and wherever the county crews had cut trees to clear the roads he counted the rings. There were many trees with about one hundred rings, and a few with more. Here was clear evidence, speaking from the past, of a great hurricane that had passed this way about a century earlier!

"What other evidence might there be? At the U.S. National Archives are the *Lighthouse Letters* from the first keeper of the Cape Florida light, and certain correspondence prior to the building of the lighthouse (in 1825)."

Among materials Gaby found at the National Archives was a letter from the tax collector at St. Augustine, Fla., to the Acting Commissioner of the Revenue, in the early 1800's the official responsible for the yet-to-be-built Cape Florida light and two others planned for the Keys. The letter, dated November 30, 1824, says in part:

"I had the honor to address you on the 28th Sept. last informing you that Mr. Samuel B. Lincoln, with whom a contract had been made for the building of three Light Houses in this Territory, had not then arrived at this place. I deem it my duty to inform you that I am still without any information from him and it seems to be the general opinion here that he and his ship with materials on board were lost in the severe gale of September last (September, 1824), on the passage from Boston to this place."



Storm stalker, NOAA's Donald Gaby is a dedicated amateur weather historian with a penchant for past hurricanes.
credit: NOAA

Reading *Lighthouse Letters* from 1823 through 1829 revealed no other reference to a storm in the vicinity of Cape Florida, according to Gaby, who comments, "Clearly a severe hurricane occurred in September 1824, about a century before September, 1926, and no other appeared to pass before or after for some time. Was this our 'great hurricane'?"

Continuing his search, Gaby found additional evidence. A French scientist, Andres Posey, published in Paris in 1862 his report *No. 346. Table Chronologique de Quatre Cents Cyclones Qui Ont Sevi dans les Indes Occidentales et dan l'Ocean Atlantique Nord, Pendant un Intervalle de 362 Annes (Depuis 1493-1855).* This listing of "cyclones" mentioned a hurricane at Guadelupe on September 7-8, 1824.

Another book, *Historia de los Temporales de Puerto Rico y Las Antilles, 1492 a 1970*, published in 1972, documents a hurricane passing across the southwest tip of Puerto Rico on September 9, 1824; and, the highly respected American weather writer, David M. Ludlum, in his *Early American Hurricanes, 1492-1870*, described a hurricane that passed through the Lower Bahama Islands on September 11-12, 1824, leaving a vessel driven high and dry at Turk's Island, and others ashore at Rum Key, Long Island, and Harbor Island. The storm later was recorded coming ashore in Georgia and eventually reaching the southern Appalachian Mountains, being known as "the Georgia Coastal Hurricane and Storm Tide of 1824," according to Ludlum.

Was the hurricane first reported in the Caribbean the same as that which smashed into Georgia? If so, could it have hit the Miami area during intervening days? These questions, Gaby knew, were crucial to his identifying the storm that decimated Dr. Simpson's home site and inland pine woods, and sank the ship carrying Samuel Lincoln from Boston to Florida.

Weather records maintained at the National Climatic Center in Asheville, one of several centers operated by NOAA's Environmental Data and Information Services, gave Gaby the final piece of evidence he felt was necessary. The record at St. Augustine, Fla., for September 14-15, 1824, showed a wind shift from northeast to south, but no special remarks about a storm, or even a strong wind, at St. Augustine itself.

The significance of this piece of information could escape one not trained in meteorology. Ordinarily, according to Gaby, a wind shift from northeast to south would indicate a storm passing over the reporting station, or just to the south or west of it. But St. Augustine's records made no mention of any notable local weather other than the wind shift. Obviously, Gaby's hurricane was not in the near vicinity of that northern Florida community.

More likely, it was well out to sea (had it not been well off the coast, St. Augustine should have experienced a strong north wind). There was a noteworthy storm somewhere within the interest area of St. Augustine, otherwise how explain the tax collector's knowledge of the "severe gale" presumed to have taken Samuel B. Lincoln to his final resting place? Imagination could lead one to speculate that mariners more fortunate than Lincoln tangled with the storm and survived it to bring word to St. Augustine. Probably after smashing through Simpson's pine woods near Miami, the storm worked its way back off the coast. And, to be well offshore passing St. Augustine, the hurricane would have had to make its eastward turn somewhere near Cape Canaveral, perhaps picking up strength again over the water and curving north, sinking Lincoln's vessel as it churned towards Georgia.

"Putting all of the evidence together," Gaby wrote in his article for *Tequesta: The Journal of the Historical Association of Southern Florida*, "the pieces made a very coherent picture of what happened long ago.

"No doubt the hurricane was born in the lower latitudes of the North Atlantic Ocean, perhaps developing from a disturbance that had its origin over Africa. On 7-8 September 1824 the hurricane passed near Guadelupe and on 9-10 September passed over southwestern Puerto Rico. For the next two days it moved inexorably west by northwest to threaten what is now Miami. The hurricane, now grown to severe intensity, bore in across Cape Florida and its eye, with its awesome stillness and calm winds, came ashore very nearly at the mouth of the Miami River.

Palm trees were ripped from the ground and scattered like straw around West Palm Beach, Fla. by hurricane winds that ravaged the city in September, 1947.
credit: American Red Cross

Then it moved northward up the coast, devastating the Simpson hammock and the inland pine woods, and out to sea again in the vicinity of Cape Canaveral. It came ashore for the last time in Georgia leaving at least 83 persons drowned at St. Simon Island and immense damage to property with additional loss of lives as far north as Savannah.

"The flooding of streams that followed as tropical downpours deluged both the coastal plain and the Piedmont brought great losses to the plantations of that region. Eventually it spent its final energy over the mountains. Somewhere along the east coast of Florida the ill-fated Mr. Lincoln with his heavily laden ship was overtaken by the great hurricane and laid to rest at the bottom of the sea.

"Not until the following year would the Cape Florida Lighthouse be built. After its completion, the remainder of the decade passed without a storm to break the peace or delay the rebirth of the tropical growth along the coast that is now Miami."

Historical researchers are like bulldogs; they just won't let go once they get a good bite on the project. And Gaby is no exception. Earlier this year while in Key West, he visited the local library on the chance that it might have old copies of the *Key West Citizen*. To his disappointment Gaby learned the first newspaper to be published in Key West came into existence in 1829; not early enough to help in his quest for the facts. But microfilm copies of *The Royal Gazette* from Nassau were available, and they contained additional information confirming Gaby's theory.

On the 18th of September 1824, *The Royal Gazette* carried a special section on "The Gale," recounting severe damage to three vessels. The following month, in it's "Meteorological Diary for September 1824," the newspaper reported statistics about "The Gale," a term commonly used in those days for hurricanes. The storm had passed north of Nassau on the evening of September 13, in keeping with Gaby's probable track of the hurricane.

Somewhere, Gaby dreams, somewhere in an attic or a barn or basement is a trunk filled with artifacts of 150 years ago. And in it is a journal, or a letter written by a traveler who just happened to be visiting one of the pioneer families in the Miami area on September 14, 1824. The journal, or letter, relates details of the horrendous storm the traveler experienced; tells of the howling winds, the terrifying storm surge, the chaotic damage that was done.

Only when he finds this fantasized documentation will Don Gaby be absolutely sure his Miami hurricane really existed. Until then, Gaby must live with the uncertainty that every historian experiences. "I know it happened but..." □

Hurricanes forecasters live on a plateau where, like Kansas City in the old song, they've gone about as far as they can go. No quantum jump in understanding or in the precision of the rather precise forecasts issued now, is on the horizon. Still, there are frontiers, and if they cannot be pushed back very far right now, they can at least be made more comfortable. It is work for toolmakers.

One of the toolmakers' new products was tried at NOAA's National Hurricane Center last summer, with the approach of Allen, the huge herald of the 1980 hurricane season in the Atlantic. The tool is a new way of estimating the rainfall from a hurricane, in virtual real time, using images from geostationary NOAA satellites. The technique, tested "quasi-operationally" at the Miami center since 1976, has evolved to the point where it is being verified under the rigors of operational use.

The arrival of this kind of new technique is important for several reasons. First, it dodges a major limitation in present satellite technology—satellites see most clearly what's on top, in this case cloud-tops, not rainfall—by letting forecasters infer point rainfall from the broad view offered by spacebound sensors. Second, the technique helps hurricane forecasters do better what meteorologists do worst—predict the atmospheric behavior of that protean, energy-bearing compound called water. Finally, the new tool illuminates more than a set of natural processes; it also demonstrates that in a large technical agency like NOAA, points of convergence among scientists can drive the evolution of an idea from hunch to operational technique.

Back in the early 1970's, when this serendipitous process began, all the satellite rainfall estimation method had to do with hurricanes was that it focused on tropical cumulus clouds, which are also the fireboxes for the larger storms. But the objective then was to develop a method of detecting changes in rainfall that could be linked to cloud-seeding in NOAA's Florida Area Cumulus Experiment. Dr. William Woodley, who now leads the experiment, and colleagues at the University of Wisconsin, began tinkering with satellite imagery, hoping to find a way of correlating what the satellites could see—the infrared temperatures of cloud-tops—with rainfall produced by the clouds. The immediate goal was to detect any effects of seeding on rainfall outside the experiment's target area in southern Florida.

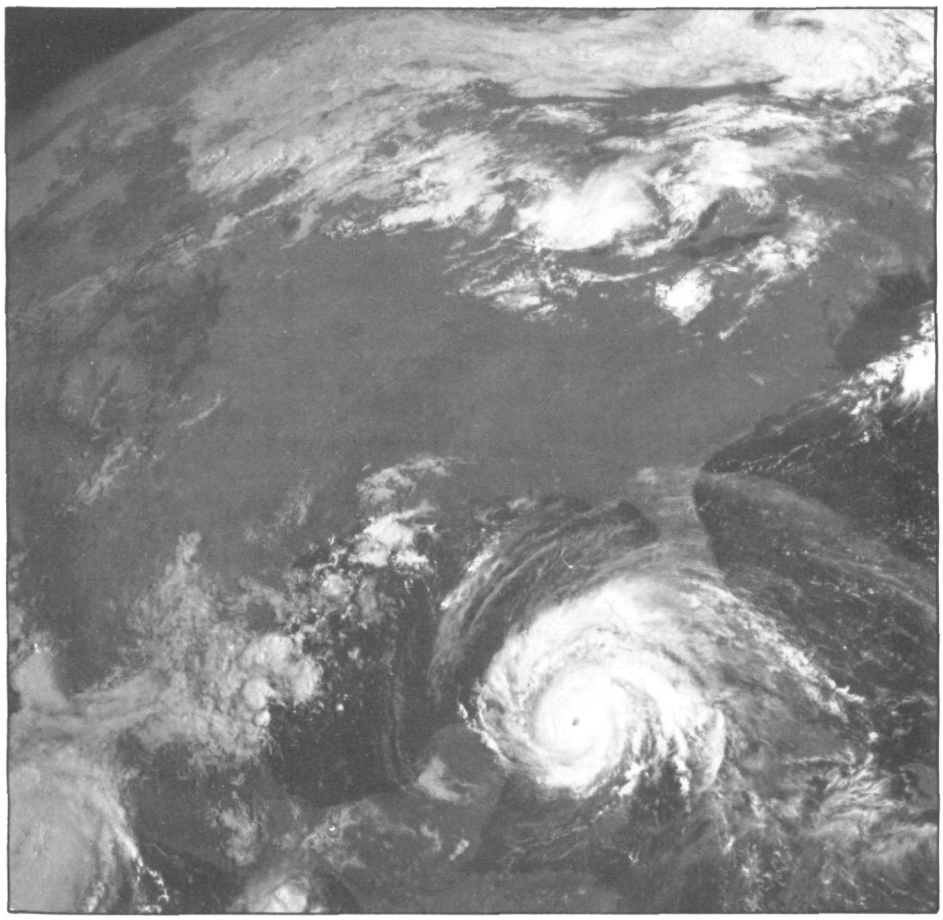
In 1972, Woodley hired a young physicist, Cecilia Griffith, to help out. "One day I walked in off the street, looking for a job, and he hired me," remembers Griffith, now a physicist in NOAA's Office of Weather Research and Modification in Boulder. This accidental meeting began the collaboration which, nearly a decade later, helped hurricane forecasters tell people ashore how much rainfall to expect, and where, from Allen.

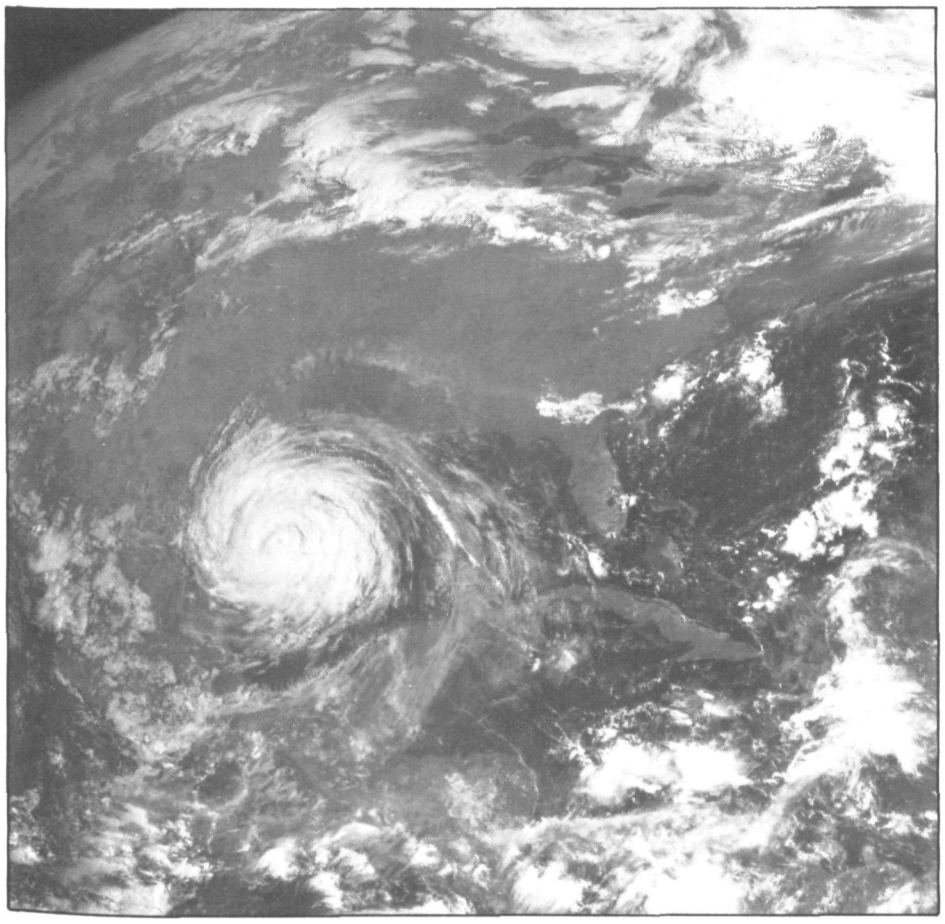
The heart of what has come to be called the Griffith-Woodley technique for estimating rainfall is in the observed relationship between the depth of clouds and the amount

Serendipity helps

Forging New Tools For Hurricane Forecasters

Carl A. Posey





NOAA physicist Cecilia Griffith (opposite) helped to develop a method for estimating rainfall in hurricanes. The method got its first real test on Allen in 1980 as the storm brushed southern Florida and came ashore on the western Gulfcoast.
Credit: NOAA

of rain they produce—the deeper the cloud, the more rainfall. Since deeper clouds extend farther into the atmosphere, their tops are colder, a difference that is detectable to the infrared sensors on NOAA's geostationary satellites.

"It wasn't completely straightforward," Griffith says now, adding, as Copernicus might have about his sun-centered system, "There were a couple of things we really had to finagle to get it to work."

It was also the kind of handwork that deflects budding scientists toward business administration. To get the cloud-top temperatures, Griffith and her coworkers had to use a device called a densitometer, with which the operator can manually scale the different shades of grey in a satellite image. Thousands of images downstream, the Griffith-Woodley technique seemed to be ready for a more difficult test—on hurricanes, for instance.

Efforts to improve hurricane forecasts had focused mainly on better predictions of storm track and intensity. Water behaves so clownishly in the atmosphere that rainfall estimates didn't seem possible, and hurricane researchers tended to neglect that side of storm prediction in favor of solving more tractable problems, even though hurricane rainfall and the floods it causes account for much of the damage from the big storms. Griffith and Woodley applied their technique, adapted slightly to accommodate the needs of hurricane forecasters, to seven storms after 1969 for which radar and raingage measurements were available.

"One of the early discoveries here," Griffith reports, "is that there was little or no relationship between either the volume or the depth of the rainfall and the intensity of the storm. This pretty much confirmed what tropical meteorologists had suspected." She adds that there were indications that hurricane intensity *was* influenced by the location of heat release, via the rainfall process, in the storm.

But average total rainfall potential, as derived from satellite imagery of the storms, agreed well with actual experience. In 1976, Griffith said, "We can say now that a hurricane is a wetter one or dryer one. The accuracy of our hurricane estimates is not really pinned down yet. But having an idea, for example, that a hurricane like Agnes is a 'wetter' storm could be extremely useful to forecasters."

It was in 1976 that Mark Waters, a satellite meteorologist with NOAA's National

Earth Satellite Service, contacted the Miami researchers, with an eye to making their technique available to the hurricane center on a quasi-operational basis. His efforts to get their technique "on the machine" at the National Meteorological Center, Griffith explains, made it possible to have the satellite data digitized in virtual real time—that is, a computer would quickly do the work previously done by Griffith and company on the densitometer. This meant meteorologists could begin testing the tool in an operational setting.

Brian Jarvinen of the Hurricane Center's research and development unit got the assignment of verifying the satellite rainfall estimation technique. "At the time," he explains, "the technique was not as automated as it is now. What they had were quantities like total area average rain and a rainfall rate—the quantities were used to define how wet a storm was compared to some standard. It gave you wetter or dryer. These are good values when you're evaluating the effects of seeding, but they weren't quite what a hurricane forecaster needed."

While Jarvinen pondered the technique, Woodley and Griffith continued to improve it. By 1979, Woodley was able to give Jarvinen what he called "core rainfall," that redistributed the rainfall through the storms. "These values looked pretty realistic," Jarvinen recalls. "We'd get sharp discontinuities in rainfall from one place to another, like you really see in Mother Nature."

And, in fact, at this point the techniques had greatly improved in sophistication. It could give three measures of gross hurricane rainfall: area average, total rainfall by storm volume, and the storm's rain potential (how much rain would fall, on the average, at a single point as the storm passed that point). But Jarvinen insisted forecasters needed some way of relating this to the kind of point data one gets from a rain gage, rather than rainfall and rainfall rates for an area. So he intented a fourth element: the rainfall profile.

"It's like taking an imaginary rain gage and walking back through the storm with it at the speed the storm is moving," Jarvinen says. "This profile gives you the distribution of rainfall, perpendicular to the direction the storm is moving. Among other things, it means you can verify your estimates."

Like walking back through the storm...

This profile, or line of imaginary rain gages, effectively simulates a straight coastline, and permits the forecaster to estimate the kind of peak rainfalls people should expect from a hurricane making landfall. Allen provided the first operational test.

"It ran beautifully in Allen," says Don Gaby, who manages NOAA's Miami Satellite Field Service Station, co-located with the Hurricane Center in Gables One Tower. "We'd use 24 hours of images, taken at 3-hour intervals, to get a composite of total rainfall profiles, really the average rainfall for the previous 24 hours. We did this every 6 hours during the hurricane. We also did what we called a final image, which was the last image before the storm made landfall. Then we continued to run the program after Allen made landfall, hoping to compare satellite estimates with actual rain gage measurements under the storm.

"I'd call it operational."

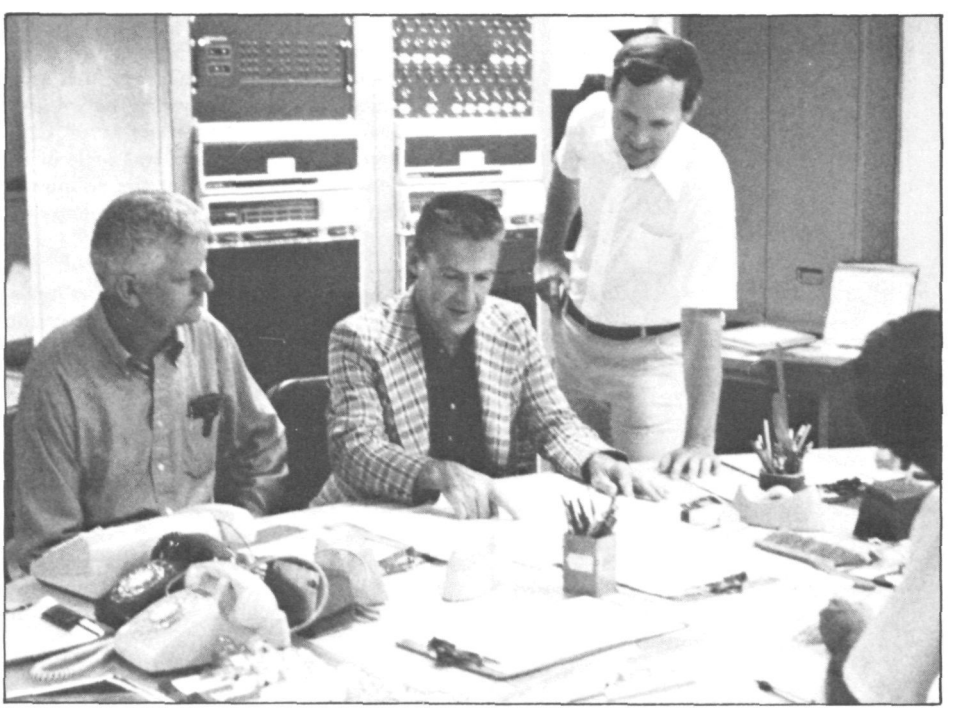
Jarvinen, however, feels the need for a dozen verifying hurricane experiences, some retrospective. He has, for example, asked Caribbean nations to send in their rain gage data for Allen, to be used in further verification of the technique.

Early efforts to confirm that the computer program worked also offered a glimpse of other uses for the rainfall-estimating technique, according to Jarvinen. "We tested it on a mid-latitude squall line, a system moving at 50 knots, and figured it just wouldn't perform with a line moving that fast. But we got peak profiles of about two inches of rainfall throughout the zone swept by that line, which agreed well with measured rainfall there. We were impressed."

The potential for broader applications is one of the compelling reasons for forging new tools in the first place. Woodley and Griffith, early on, saw their rainfall estimation method as aiding countries without strongly developed meteorological services, where satellite images could do roughly what otherwise requires an expensive network of surface instruments. And there are indications that the technique could work for those devastating rainmakers, the severe storms of the American middle west.

Not quite satisfied with what has been developed, Griffith and Woodley now want to take the next step, and develop a way of producing a real-time rainfall map. "We'd like to get the horizontal distribution of rainfall under a hurricane as well as the profile Brian developed," Griffith says, adding that a map of peak and total rainfalls would be as useful to NOAA's river forecasters as the existing tool is to forecasters of hurricanes.

But, whatever its future, a technique has evolved from one seemingly unrelated idea in one corner of NOAA, to serve the specific, operational needs of hurricane forecasters in another; and the idea has been pushed along in its evolution not only by NOAA researchers, but by skilled innovators—toolmakers—in the weather and satellite services as well. □



Analyzing a rainfall profile are, from left, Donald Gaby, manager, Miami Satellite Field Services Station, Neil Frank, National Hurricane Center director, and Jarvinen. Forecaster Miles Lawrence is in foreground.

Credit: NOAA

What To Do When A Hurricane Threatens

While major hurricanes are relatively rare events at any given location, no Atlantic or Gulf Coast area is immune. According to the National Weather Service, "Not here! We haven't had a hurricane in years," could be the most dangerous words you'll ever hear. It's best to be prepared. This could be the year.

Clip out and save this list of hurricane safety tips. Some will make things easier for you when a hurricane threatens. All are important and could help save your life and the lives of others.

In General:

When a hurricane threatens your area, you will have to make the decision whether you should evacuate or whether you can ride out the storm in safety at home.
If local authorities recommend evacuation, you should leave! Their advice is based on knowledge of the strength of the storm and its potential for death and destruction.

Stay or Leave

- If you live on the coastline or offshore islands, **plan to leave.**
- If you live in a mobile home, **plan to leave.**
- If you live near a river or in a flood plain, **plan to leave.**
- If you live on high ground, away from coastal beaches, **consider staying.**

In any case, the ultimate decision to stay or leave will be yours. Study the following list and carefully consider the factors involved—especially the items pertaining to storm surge.

At Beginning of Hurricane Season (June) Make Plans for Action

- Learn the storm surge history and elevation of your area
- Learn safe routes inland
- Learn location of official shelters
- Determine where to move your boat in an emergency
- Trim back dead wood from trees
- Check for loose rain gutters and down spouts
- If shutters do not protect windows stock boards to cover glass.

When a Hurricane Watch Is Issued for Your Area

- Check often for official bulletins on radio, TV, or NOAA Weather Radio
- Fuel car
- Check mobile home tie-downs
- Moor small craft or move to safe shelter
- Stock up on canned provisions
- Check supplies of special medicines and drugs
- Check batteries for radio and flashlights
- Secure lawn furniture and other loose material outdoors
- Tape, board, or shutter windows to prevent shattering
- Wedge sliding glass doors to prevent their lifting from their tracks

When a Hurricane Warning Is Issued for Your Area

- Stayed tuned to radio, TV, or NOAA Weather Radio for official bulletins
- Stay home if it is sturdy and on high ground
  - Board up garage and porch doors
  - Move valuables to upper floors
  - Bring in pets
  - Fill containers (bathtub) with several days' supply of drinking water
  - Turn up refrigerator to maximum cold and don't open unless necessary
  - Use phone only for emergencies
  - Stay indoors on the downwind side of house away from windows
  - Beware of the eye of the hurricane
- Leave mobile homes
- Leave areas which might be affected by storm tide or stream flooding
  - Leave early—in daylight if possible
  - Shut off water and electricity at main stations
  - Take small valuables and papers but travel light
  - Leave food and water for pets (shelters will not take them)
  - Lock up house
  - Drive carefully to nearest designated shelter using recommended evaluation routes.

After the All-Clear Is Given

- Drive carefully; watch for dangling electrical wires, undermined roads, flooded low spots
- Don't sight-see
- Report broken or damaged water, sewer, and electrical lines
- Use caution re-entering home
  - Check for gas leaks
  - Check food and water for spoilage

Blue shark were shunned by commercial fishermen until an enterprising couple turned problems into profits.

Credit: NOAA

Ryck Lydecker

Troublemaker proves profitable

The Fish That No One Wanted

"Sleep? Sure. We have about four hours twice a day when we can sleep. And eat. And overhaul gear and take care of the boat."

When Jane Christen and her husband, John, leave Terminal Island for the shark grounds, they go to fish, sleeping only because they have to. The couple snatches that rest in two shifts because it's the time their two-and-a-half mile longline stays in the water.

The other 16 hours of every day blue shark fishing off the southern California coast is spent handling the gear, processing the catch, baiting 300 hooks and resetting again. Trips during the 4-month season last year were a week long with a full day's run each way, and only time enough to unload the catch and reprovision the vessel before setting out again.

This season, the Christens have added a freezer to their boat and can now make two-week trips. And to meet the demand, they plan to fish for six months this year.

With the kind of energy it takes to keep up that pace it's not hard to understand why the *JJ* is a highliner in the San Pedro squid fleet. And it is just that kind of drive, plus a lot of innovation, that has helped Jane and John Christen make a success of blue shark fishing during the squid off-season. But last year, the Christens were all alone out there.

The blue shark of the Pacific was a fish that no one wanted. Hated by salmon trollers for the damage they do to catch and gear, the blue was shunned by commercial fishermen. Although small markets for other types of shark have always existed here and there, the blue had a reputation for spoiling quickly and fish dealers couldn't sell them. So the fishermen wouldn't catch them.

But that was before the Christens decided that the blue shark was too valuable a resource to waste. Re-rigging their 73' former shrimp trawler as a shark longliner, the two not only managed to perfect the techniques of catching and processing blues, they opened up a fishery that netted them $60,000 gross revenue in 4 months fishing last year.

"The market for shark has been increasing in the past few years," says James Squire, a fishery biologist for the NMFS Southwest Fisheries Center in La Jolla, and it's really taken off in the past three years. I suppose it has something to do with all the publicity sharks have been getting in the movies. If they're eating people, why not eat them?"

"The word 'shark' definitely has come into its own in the seafood market," reports John Casey, shark expert at the NMFS Narragansett, R.I., Laboratory. "It used to be that they were disguised with names like 'steakfish' but now people really want sharks because they're sharks."

Casey says there is also a growing sport fishery for shark, particularly around Long Island, N.Y. where charter boats specialize in shark trips.

According to Squire, thresher and mako shark have been the target of a small but successful commercial fishery off southern California in recent years. The thresher is particularly in demand because of its similarity to swordfish, now a premium-priced dish. But the blue shark has real potential, he says.

"The blue is probably the dominant species of oceanic shark in the northeastern Pacific," says Squire, chairman of a subcommittee charged with developing a fishery management plan for Pacific billfish (swordfish and marlin) and oceanic shark. "If you know what you're doing, you can make excellent catches of blue shark. But the problem in the past has been that the meat takes on an off-flavor unless processed properly right away."

And it's the attention to processing, not just to catching, that has made the blue shark fishery a success for the Christens. The key, they found, is in cleaning the fish right away and draining the blood immediately. If that is not done, the high urea content of the blood is taken on by the meat, giving it an ammonia-like taste.

The Christens have processing down to a science. After each four-hour "soak" the mainline is drawn in by winch through a stern ramp, bringing the fish up on a cutting table. In a deft operation that takes but 90 seconds per fish, Jane grabs the snout and John cuts off the tail to start the bleeding. The belly section, viscera and head come off

next, the carcass is then carefully washed and stowed in the boat's brinetank.

The Christens don't keep any sharks under four feet and Jane says the blues they catch may be up to nine feet long. It takes about six hours to pull in the catch, she says, which averages 120 fish from the 300 hooks. Dressed, the carcasses average 20 pounds and bring about half the price of the more popular mako shark.

Although last season was a commercial success, the Christens weren't so lucky when they got into blue shark longlining the year before. Although they grossed $25,000, expenses and high gear losses wiped out any profit.

"We lost money that year," says Jane. "In fact, we both wound up working on the beach to pay off our losses."

Under a NOAA grant to the West Coast Fisheries Development Foundation, the Christens drew upon their previous experience to redesign some critical parts of the longline gear. Working with NMFS staff, the California Sea Grant program and the State's Fish and Game Dept., the couple outfitted the *JJ* for another try in the summer of 1980.

Of the $86,000 NOAA grant, about $15,000 went into gear development and new fishing equipment. The rest of the grant was set aside as an operating subsidy to insure against further losses. But it was never used.

"That was all they needed to put them over the edge of risk," says Howard Ness, chief of fisheries development at the NMFS southwest regional headquarters at Terminal Island. "Because they were successful, we understand there are at least four other boats here gearing up for blue shark this season."

The West Coast Fisheries Development Foundation began a shark promotion at the retail level last year and director William Jensen reports that blue shark is now sold in supermarkets in San Francisco, Seattle, Portland and as far away as Denver. Jensen says the project has successfully established the market and it is now up to the fishermen to get into it.

Before casting off for their third shark season, the Christens gave presentations at four seminars on alternative fisheries to west coast fishermen. As a result, the growing San Pedro fleet is reportedly being joined this season by boats from San Francisco, Astoria, Oreg., and Westport, Wash.

Because so little is known about blue shark stocks on the west coast, part of the Christens' project involves meticulous recording of information on each day's catch, such as size, weight, sex ratio, water temperature, and the like. This information goes into a computer file that is used by fisheries managers, biologists, and even other fishermen.

The careful attention to recording the information by Jane Christen has made the data particularly valuable, according to Ness. When does she find time to do all that? During her "sleep" break, of course. □

Weather Support For An Historic Spaceflight

Blue skies for space shuttle

Don Witten

On December 17, 1903, Orville Wright climbed into a small air machine and flew it 120 feet. The 12-second event on that cold and windy day at Kill Devil Hill, near Kitty Hawk, N.C. was the first sustained flight ever for a powered aircraft.

On April 12, 1981, over 77 years later, NASA astronauts John Young and Robert Crippen buckled themselves into the Space Shuttle Orbiter at the Kennedy Space Center in Florida, and were rocketed into space. After circling the Earth 36 times in their unique aerospace vehicle, the two astronauts returned to earth for a glider-landing in California. Their 54-hour, 933,000-mile flight was the first ever for a craft designed to leave the earth as a rocket and return like an airplane.

As far apart in time and complexity as these two historic flights were, one factor did not change: the potential impact of the weather. Not only was poor weather capable of delaying either of these missions, but it could always pose a threat to the lives of the fliers.

Weather did, in fact, impact the timing of the Wright Brothers' first flights. A combination of poor weather intermixed with mechanical problems delayed the flights from September to December.

In his diary, Orville Wright described the weather observations and conditions at Kill Devil on December 17:

"When we got up, a wind of between 20 and 25 miles was blowing from the north... After running the engine and propellers a few minutes to get them in working order, I got on the machine at 10:36 for the first trial.

"The wind according to our anemometer was blowing a little over 20 miles (corrected) 27 miles according to the Government anemometer at Kitty Hawk. On slipping the rope, the machine started off increasing in speed to probably 7 or 8 miles."

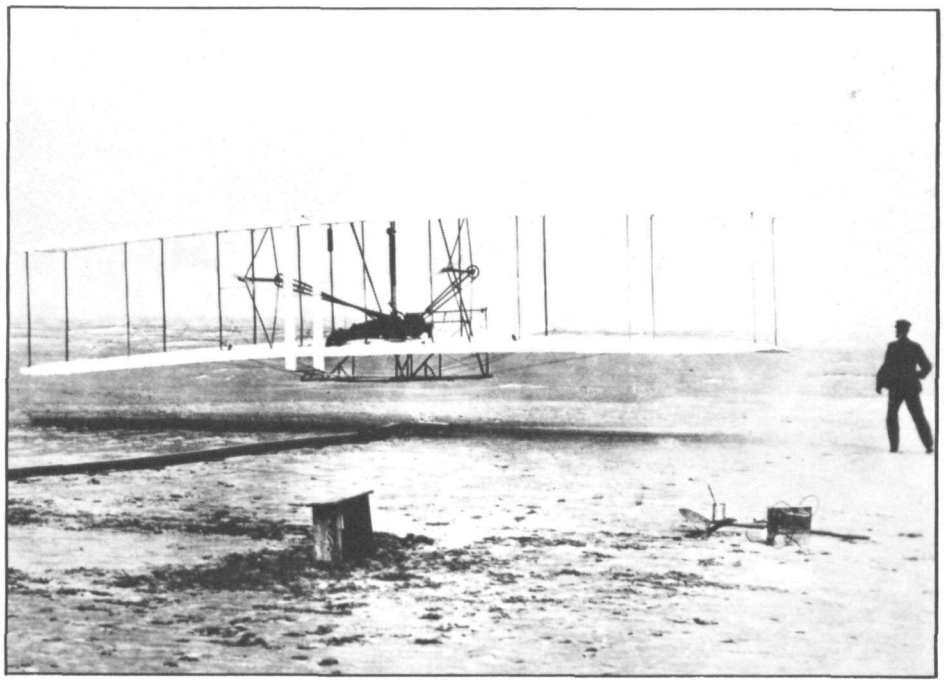
Although the Shuttle launch was delayed 48 hours due to a computer problem, the weather cooperated throughout the mission; it was excellent from start to finish. The ease with which the mission proceeded after launch was captured by a NASA Shuttle flight controller who noted in his log: "My God, nothing is happening."

While the Wright brothers had to con-

"With all the knowledge and skill acquired in thousands of flights in the last ten years, I would hardly think today of making my first flight on a strange machine in 27 mile an hour winds, even if I knew that the machine had already been flown and was safe. After these years of experience, I look with amazement upon our audacity in attempting flights with a new and untried machine under such circumstances..."

ORVILLE WRIGHT

Credit: Library of Congress



Credit: NASA

USA

tend with the weather only at Kill Devil Hill for a period of several hours, the NASA flight controllers and astronauts needed a global perspective for the 2-day Shuttle mission. They required accurate forecasts for launch day in Florida, and for 48 hours beyond for both the California landing site and the backup site in New Mexico. Other forecasts had to be available for three overseas landing sites in Spain, Hawaii, and Okinawa, if an emergency forced a landing outside the United States.

If the weather for the Shuttle mission had been similar to that for the Wright brothers, NASA flight controllers might have been reluctant to issue "Go" for launch. Maximum allowable head winds for the Shuttle landing were limited to 28-miles per hour, close to the existing winds for the Wright Brothers' first flight.

Other weather conditions required for a safe Shuttle landing included maximum cross winds of 11-miles per hour, only scattered clouds, no rain, and no lightning within 10 miles of the landing site or below 60,000 feet anywhere along the Shuttle's descent path.

The focal point for weather analysis and briefings for the Shuttle mission controllers and astronauts is a three-man group of meteorologists from NOAA's National Weather Service. Headed by Richard K. Siler, the group makes up the Spaceflight Meteorology Branch which NWS maintains at NASA's Johnson Space Center in Houston, Tex., to support all manned missions.

Members of this group include Roger K. Carter and Searl E. Richards. They were assisted by Jim Nicholson of the Satellite and Space Support Division, headed by Burton H. Kirschner.

During the 2-day mission of the Shuttle Orbiter, weather observations and site forecasts were provided by field units of the National Weather Service, the Air Weather Service, and other weather elements of the Department of Defense.

According to Siler, the landing phase of the Shuttle mission was the most critical time from the standpoint of the weather.

... a threat to the lives of the flyers.

To explain the critical need for good landing weather, the NWS meteorologist compared a typical landing of a commercial airliner with that of the Space Shuttle. A transcontinental airliner cruising at 40,000 feet (seven and one-half miles) altitude normally takes about half an hour to descend and land. In bad weather, the pilot can circle the airport many times and land in limited visibility with the aid of navigation instruments. If landing at one site is determined to be impossible at the last minute, the aircraft can be diverted to another airport.

"The landing site for the Shuttle, however, must be selected before the craft leaves earth orbit," Siler explained.

"Once the Shuttle begins its hour-long descent, two-thirds of the way around the globe, it is powerless to change the designated landing site because the craft is essentially a glider," Siler said.

"The weather is a critical factor," he added. "It has to be excellent both along the vehicle's descent route and at the predetermined landing site."

As the Shuttle was leaving orbit, sounding rockets were launched from Pt. Mugu, Calif., to check upper atmosphere wind velocities along the craft's descent path.

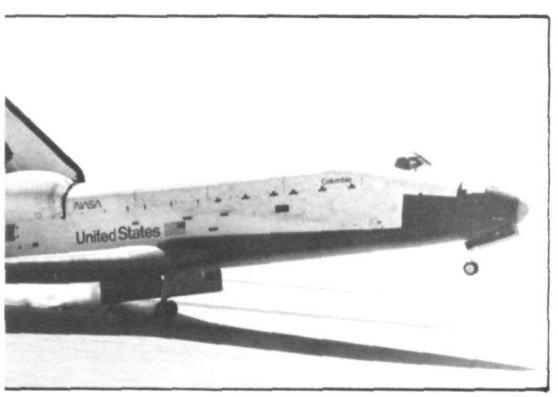
Other atmospheric data were collected with additional sounding rockets, balloon-borne radio-sondes, and the NOAA-6 satellite as the Shuttle returned to earth. This information is now being used by NASA engineers in post-flight analysis of the Shuttle's design to withstand extremely high temperatures created by atmospheric friction during re-entry.

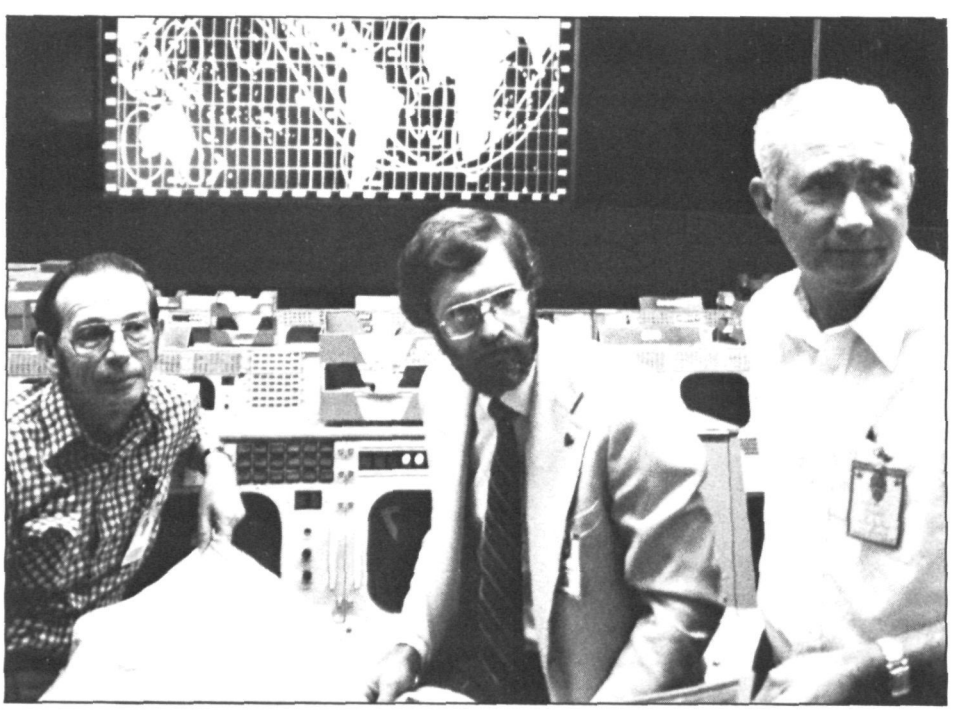
"Essentially, we developed atmospheric profiles from the surface to 400,000 feet using atmospheric temperatures, pressure density, humidity, and the wind data," said Melvyn E. Gelman of the Climate Analysis Center at the NWS National Meteorological Center, Camp Springs, Md.

If marginal weather had developed unexpectedly at Rogers Dry Lake where the Shuttle was scheduled to land, mission controllers were prepared to make ever more atmospheric observations. They would have ordered a T-38 jet aircraft to test fly landings at the lake with a backup Shuttle astronaut at the controls.

As it turned out, there was not a need to test landing conditions at the lake; the sky was clear and the wind calm—perfect weather for landing.

The only sign of the weather's impact on the mission was a pair of slight ruts left in the lake bed as the 98-ton Shuttle touched down. It had rained in that part of California two weeks earlier—an unusual occurrence—and the ground had not yet dried completely.



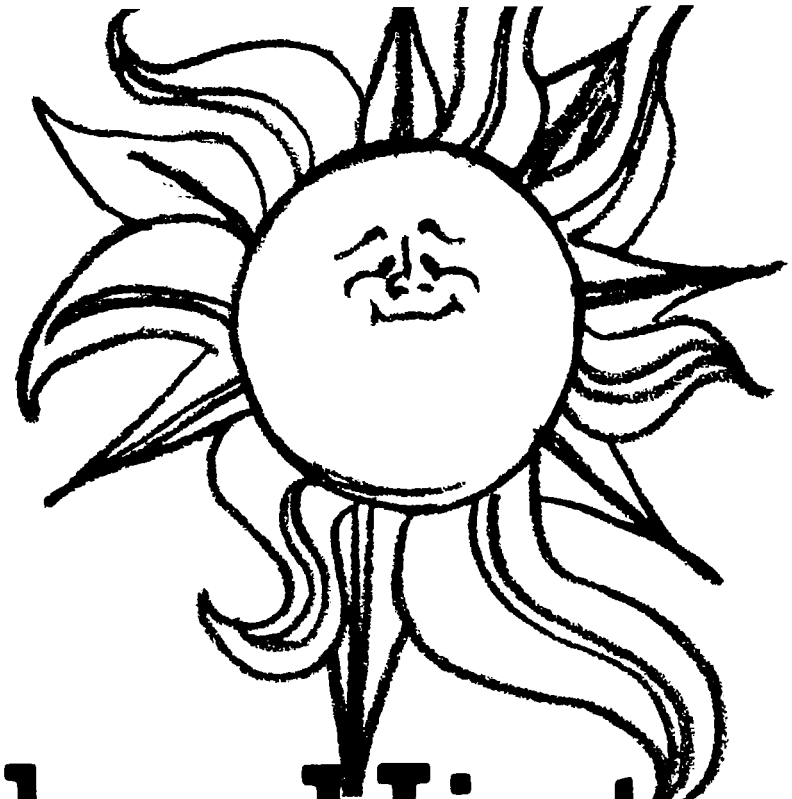


NOAA's Searl Richards (left) and Dick Siler flank NASA's Neil Hutchinson, Shuttle flight director. Above, the Shuttle descends for a near-perfect landing.

Credit: NASA

"Mad dogs and Englishmen go out in the midday sun," Noel Coward reported of colonial administrators reckless of their health and sanity in southern climes. His wry warning is actually rather sound advice considering what we know today of heat stress.

Here's what NOAA's experts say:



Easy does it

Hot Weather Hints

Slow down and take it easy. Stay out of the sun. Eat a little less food, drink a lot more water. Find a cool place whenever you can.

Follow that advice and you'll withstand summer's heat a lot better. Even in times of long and extreme heat waves, you'll have a better chance to stay reasonably comfortable—or to avoid getting seriously ill—by making sure you know heat wave safety rules, and following them carefully.

Excessive heat killed nearly 20,000 people in the United States in the years from 1936 to 1975. The effects of heat waves can build up in people who don't take proper precautions, and cause heat stress, ranging from small symptoms such as easy fatigue and high pulse rate to heat stroke with delirium and collapse.

Important causes of heat stress are high temperature, high humidity, little air movement, too much physical activity, and radiant heat from the sun, bright lights, a stove, or other sources. Other contributing factors are physiological characteristics that differ from person to person, atmospheric pressure, and clothing.

If you see someone suffering from heat stroke, call a doctor or get the patient to a hospital immediately. Delay can be fatal.

To avoid suffering from summer heat, follow these safety tips:

- Slow down. Your body can't do its best in high temperatures, and might do its worst.
- Heed your body's early warnings that the heat is getting to you. Reduce your level of activity immediately and get to a cooler place.
- Dress for summer. Lightweight, light-colored clothing reflects heat and sunlight and helps your body's regulatory system maintain normal body temperature.
- Put less fuel on your inner fires—in other words, eat less. Foods such as proteins that increase metabolic heat production also increase water loss.
- Don't dry out. Heat wave weather can wring you out before you know it, so drink plenty of water while the hot spell lasts.
- Stay salty. Unless you're on a salt-restricted diet, take an occasional salt tablet or some salt solution when you've worked up a sweat.
- Avoid thermal shock—that is, try to accustom yourself gradually to the heat. Treat yourself extra gently those first few beastly hot days.
- Get out of the heat whenever you can. Physical stress increases with exposure time, so keep it down. If your home isn't air conditioned, drop into a cool store, restaurant, or theater every so often—anything to keep your exposure time down.
- Don't get too much sun. Sunburn makes the job of heat dissipation more difficult. □

The Seattle Aquarium opened its doors to the public for the first time on May 20, 1977. Located in Seattle's Waterfront Park, the facility offers a unique experience to the visiting public. It also provides a unique opportunity for an exchange, with NOAA, of people, knowledge, and ideas.

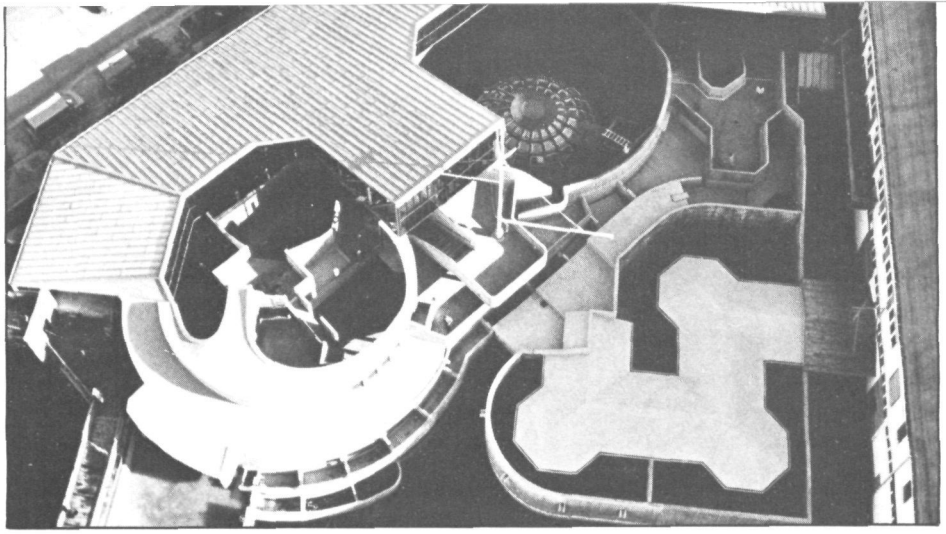
Efforts involving the National Marine Fisheries Service and personnel from the aquarium demonstrate this sense of working together.

Formal cooperative programs began with the Northern fur seals which are held at the aquarium as part of a cooperative research and display program. The goal is to rear young fur seals from less than a year old to the point where they reproduce at age 5 to 6. Seals raised in other captive situations have not grown in the same manner as their wild, adult counterparts. However, with the large pool and the special feeding regime specified by the research plan these seals appear to be growing much more normally.

Other biologists at the aquarium have worked with NOAA scientists to develop techniques for the hatching and rearing of marine fish eggs. Some of those techniques have been used by the aquarium to hatch and rear species which had not been previously reared. Those efforts won for the aquarium the American Association of Zoological Parks and Aquariums Edward H. Bean Award (for outstanding achievement in

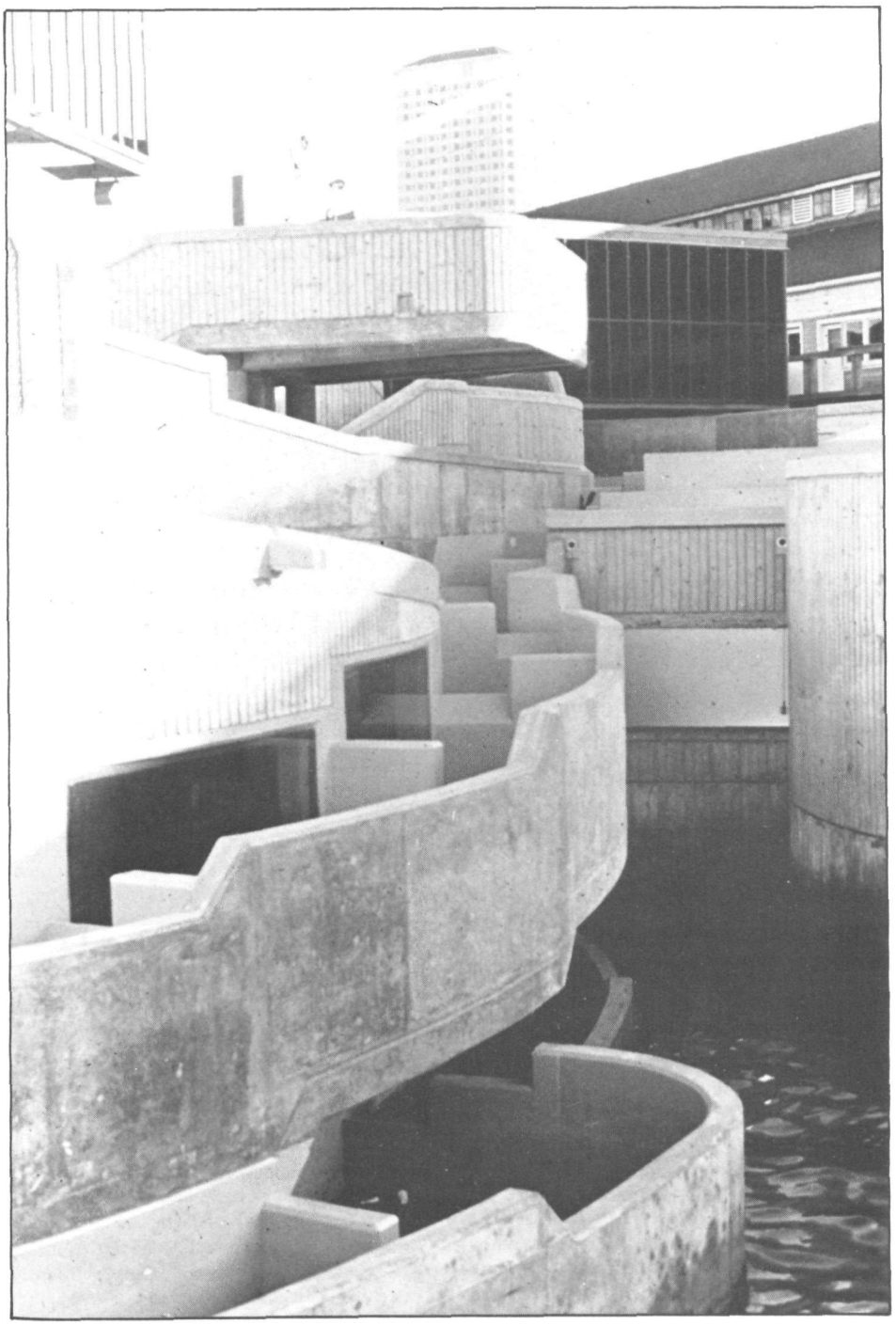
The Northwest's Fanciest Fishing Hole

H. Doug Kemper
Director, Seattle Aquarium



The wonder and mystery of the sea...a child watches a Sea Star inch its way up a window at the Seattle Aquarium (facing page, above) in the Dome room (facing page, below), where visitors are surrounded by marine life in its natural state. The facility (left) cost $5.4 million, and includes a fish ladder (below, left) where salmon are hatched, reared, and released to the sea; in time they return up this ladder to spawn.

Credit: All Photos Seattle Aquarium



propagation) for the Pacific spiny lumpsucker.

Cooperation has not been limited solely to scientific matters. Many NOAA scientists regularly serve as speakers for the aquarium's evening lecture series. Not only do scientists assist the aquarium, NOAA vessels do also. The NOAA Fisheries Research Vessel *John Cobb* was a part of the aquarium's Year of the Coast Festival during the fall of 1980. Hundreds of aquarium visitors toured the vessel and learned more of the NOAA mission. Not all cooperation takes place at the aquarium. Seals and traveling exhibits from the aquarium were prime attractions at the last two NOAA Northwest and Alaska Fisheries Center open houses.

A major element in the success of the aquarium is a unique exhibit "storyline." Rather than a random collection of displays, each exhibit at the Seattle Aquarium is placed in a specific sequence which tells a step-by-step "story" concerning the natural history and biology of aquatic animals as well as the concepts of habitats and ecosystems. Eight major exhibit themes move the visitor from entry to exit.

Starting with "Life Began in the Sea," a large multi-media construction, the visitor moves on to "Adaptations" which consists of living displays of fishes which show examples of how life adapts through natural selection. "Diversity" follows and points out the large variety of ocean life forms and that not all life in the sea is fish-like. Since the entire aquarium was designed to emphasize the Northwest and, specifically, Puget Sound, all animals in "Diversity" are inhabitants of the Sound and the Northwest region. From here the visitor moves to "Ecosystems," a graphic display accompanied by living exhibits which explain primary production and other elements of how matter and energy move through an environment. "Ecosystems" serves to introduce "Living Places in the Sea" which is a brief overview of the major life zones of the sea; the Open Sea, the Deep Sea and the Continental Shelf. Several living exhibits, a representative coral reef, mangrove swamp, and open sea aquarium accompany or are planned for this exhibit theme which continues with "Living Places in Puget Sound." At this point the major exhibits of the aquarium begin. Three large,

A group of children observe marine life through one of the portals of the unique Dome room, giving them an intimate eye-level view of the creatures of the sea.

walk-through habitats (Sandy Beach, Salt Marsh, and Rocky Coast) containing representative intertidal habitats with representative flora and fauna are the first elements of this exhibit theme. Each exhibit displays birds, fishes, invertebrates, and plants typical of Puget Sound shores. Along the public pathway small specially designed aquariums allow visitors to clearly view small, burrowing or otherwise secretive inhabitants of these environments. An introductory exhibit of the many families and representative of species of fishes that live in Puget Sound follows the intertidal displays and introduces the visitor to sub-tidal Puget Sound–the Underwater Dome.

Entering from a darkened corridor, the Dome visitors are suddenly surrounded by water and marine life. Instead of standing outside a tank, the viewers are now participants in the exhibit itself, experiencing what it is like to be surrounded by a world of water and its inhabitants. The diversity of underwater life in Puget Sound, presented in separate exhibits throughout the aquarium, can be seen here as a complex, interacting community.

Although this room seems to be below the water, it is actually above sea level. It consists of a 30 foot diameter hemisphere of window panes and concrete mullions surrounded by a 400,000 gallon aquarium which is filled from Puget Sound. The hundred and five viewing windows are sealed in place by caulking and water pressure.

The exhibit was divided into two areas by placing the observation hemisphere off center in the tank. The smaller side depicts a subtidal piling environment; the larger portion of the tank represents the open water. The walls and floor are painted so that the visual effect is to make them disappear. Although visitors are looking through only 25 feet of water, animals appear to be moving in the open sea; silently cruising by, changing color and scale as they disappear in shadows toward the far wall of the tank and suddenly reappear.

Specimens in the Dome are those native to Puget Sound. Different species are constantly coming into view as others disappear from sight. Schools of herring, mackerel or salmon pass by. Other familiar species are perch, bass, lingcod and rockfish. Some of the octopuses making their way across the window panes were captured under the aquarium piers. The only sharks presently cruising Dome waters are the dogfish common to Puget Sound; however, other local species are planned for display in the future.

Dome fishes are fed three times a day by divers. Their diet consists of herring, squid, crab, rockfish fillets and prepared food pellets. Each evening the water entering the Dome from Puget Sound bypasses the filtering system. This allows nutrients—minute plants and animals—to enter the tank and supplement the food supply.

The Dome exhibit, as a whole, can be enjoyed from the central viewing floor; but to appreciate its complexity, visitors should plan to sit on a low bench near the glass and let the marine life encircle them. Bottom fish come alive, seastars use their tube feet to climb the windows, and an anemone ray may unfurl its tentacles. Ordinarily, these sights are only for divers.

Following the Dome exhibit, both underwater and above water views of marine mammals; sea otters, Northern fur seals and harbor seals are available. The final major exhibit theme of the aquarium is called "People and the Sea." It is an all-important display that attempts to relate all the previous information and exhibit exposure to the individual visitor as a member of a technological society which has impact and influence, both good and bad, on the ocean environment. Several displays of food from the sea, underwater exploration, aquaculture and other regional, historical and contemporary subjects are now completed or are planned for the future.

Winding its way through the aquarium storyline is a fish ladder cascading from a salmon hatching exhibit to Puget Sound. Salmon are hatched and reared continuously at the aquarium and the fingerlings are released to the open sea to grow, mature and return to spawn. The Seattle Aquarium was designed and developed to be an exciting, dynamic and educational natural history institution. It certainly has achieved that objective. □

Six feet below the barge, the diver maneuvered the cumbersome airlift into a new section of the wreck. Carefully sifting the mud before allowing it to be sucked up the hose, he inadvertently missed the small round copper penny which quickly clattered up the pipe. It was not missed however, as it landed up on the sieve barge. For there, a dozen pair of eyes were minutely scanning the barge's screen for the smallest artifact discharged from the tube, and when the penny was spotted, excitement quickly ran the length of the working platform, for here was the first truly dateable artifact. This find would finally tell the archaeological team that this was the wreck for which they were searching—a wreck from the War of 1812 and lost in the final year of that war—1814.

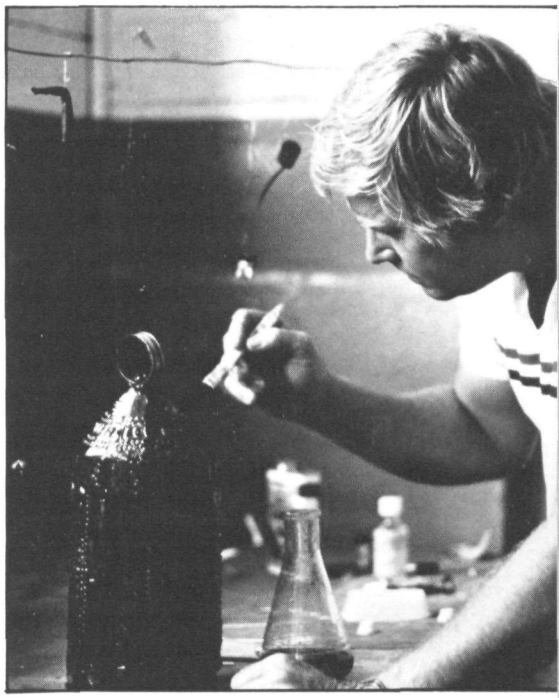
The wreck site was on the upper reaches of the Patuxent River, less than a dozen miles from Washington, D.C., and forty miles from the mouth of the river where it joined the Chesapeake Bay. It was, the dive team believed, the final resting spot of the Chesapeake Flotilla, lost on August 22, 1814, when the small American naval force of seventeen vessels under command of Commodore Joshua Barney, finally ran out of water and luck and was put to the torch before capture by the British troops on their way to burn Washington. The coin, the only one that would be found that year, gave a date of 1803, showing that the ship must have sunk sometime after that date. Additional artifacts found in the ship and measurements taken of the ship itself would allow the underwater archaeologists to conjecture that they had located one of Barney's missing vessels and, because of its size, very likely had located the flagship—the *Scorpion*.

This naval engagement was just one of many incidents to take place in the Maryland and Virginia tidewater, for ever since the first settlers from Jamestown set out to explore the Chesapeake, it has been the trade route for commerce and exploration. Warships, fishing boats, steam boats, sailing craft and ferries all plied these waters over the past 374 years, providing settlers with transportation long before roads and highways of today were constructed out of the Indian paths of yesterday.

And, as with most watercraft, their existence is finite. Fire, collision, rot, warfare and piracy certainly accounted for a large number of ship losses in the Chesapeake. The amount of cultural resources lying on the bottom of the Chesapeake and its tributaries is phenomenal. One local historian, currently inventorying the Bay's wrecks, estimates over 3,000 ships were lost between 1608 and 1900 within the confines of the Bay itself. Willard Bascom, a noted oceanographer, several years ago wrote: "Statistics for the 18th and 19th centuries indicate that approximately 40 percent of all wooden sailing ships ended their careers by running onto reefs, rocks, or beaches made of rock, sand or coral. This is a fantastic number of ships, perhaps as many as three hundred thousand per century for the world's oceans." Since there are few trained underwater archaeologists in the world today (although their numbers are growing), this leaves a great number of wrecks which are located and salvaged by scuba divers before an underwater archaeologist can survey them and determine their value to the history and knowledge of humankind. Underwater sites in the western Mediterranean, for example, where clear waters beckon to divers, most sites shallower than 150 feet were quickly located and looted during the 1950's and 1960's. However, in the Chesapeake, we are certainly more fortunate, for its murky waters have tended to limit diver activity and as a consequence within its waters lies a treasure trove of information.

Tidal waters such as those in the Chesapeake, provide good protection for wrecks, for in addition to poor visibility, low salinities tend to limit such marine boring creatures as *Limnoria*, teredos, and marine fungi which, in marine waters, can fairly quickly reduce ship timbers level with the bottom. Sedimentation, also can protect shipwrecks as was found in Maryland's Patuxent River. For here, land development and poor farming practices accounted for an estimated sedimentation rate of over 285 tons per square mile per year being deposited in the upper

A coin dated 1803.
A conservator cleans and preserves artifacts.



Ten feet down, a lost flotilla

Archaeology Beneath The Chesapeake

K.R. Hollingshead*

**The author is with the National Marine Fisheries Service, in the Marine Mammal and Endangered Species Division in Washington, D.C. He is also a member of the Nautical Archaeological Associates of Upper Marlboro, Md.*

Credit: All Photos NOAA

river. This rate was significant enough to have brought to an end the navigation of the upper river and to bury many shipwrecks under its protective layer.

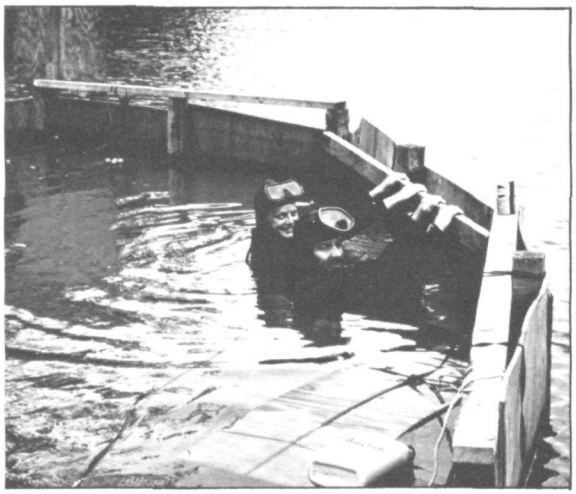
The single greatest obstacle encountered by underwater archaeologists and divers alike working in coastal environments is visibility, or rather, the lack of it. Mostly caused by particular matter in the water, both organic and inorganic, it is impossible to describe to non-divers the sensation of not seeing anything but a dark swirling nothingness in front of the faceplate. Of course, if an underwater archaeologist intends to work in such an environment, that person must quickly learn to rely on the other senses to compensate for the loss of sight. One quickly learns to "see" with the hands, and after some training, one is able to move around on a wreck fairly well. Of course, a knowledge of ship architecture also aids in gaining a familiarity with the surroundings.

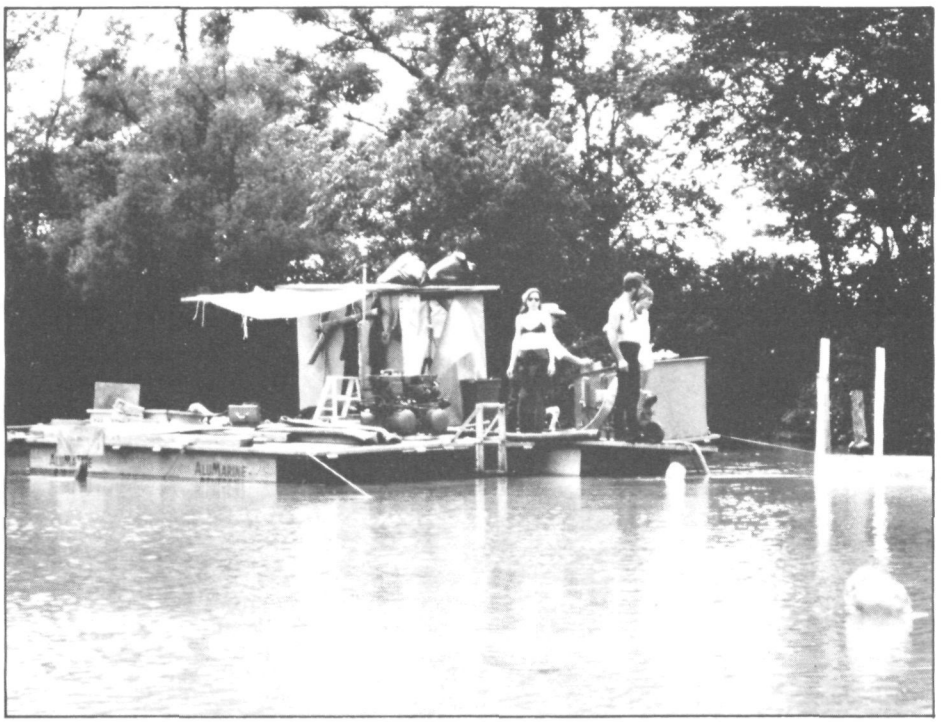
It was fortunate that the States of Maryland and Virginia both recognize the value of their drowned cutural resources, and as a consequence, both have active programs underway to preserve this cultural heritage. Since 1976, the Virginia Research Center for Archaeology under the auspices of the Virginia Historic Landmarks Commission, has funded an underwater archaeological survey and excavation of several of the numerous vessels scuttled by Lord Cornwallis in 1781, prior to his surrender at Yorktown. This project is currently proposing to build a cofferdam around one or more of these wrecks wherein visitors can watch archaeology in action.

In Maryland, the site for that State's first underwater archaeological site excavation was the quiet community of Wayson's Corner, approximately 20 miles from the Nation's Capitol. This small crossroads of trailer parks, homes and restaurants, became the gathering spot in 1980 for the underwater archaeologists, divers and support staff of the Patuxent River Submerged Cultural Resources Survey. This survey, conducted under a grant from the Heritage Conservation and Recreation Service and administered by the Maryland Historic Trust, began in 1979, when the Nautical Archaeological Associates of Upper Marlboro, Maryland, and the Calvert Marine Museum of Solomons, Maryland, made transects of the Patuxent River with a marine proton magnetometer. Areas of the river had been specially selected because oral history or research indicated the greatest liklihood of making significant finds. After the magnetometer indicated an anomaly, a "hit", divers would enter the water to verify the location. It is amazing how many bed springs, coils of cable, and other large iron objects are on the river bottoms. During the two week survey in 1979, the survey team located the remains of a gunboat of the Chesapeake Flotilla lost in St. Leonard's Creek, and several 18th and 19th century schooners and fishing craft, including the remains of one small boat which dated around 1680. But the most significant find would come at the conclusion of the expedition almost as if planned.

By the conclusion of the survey season, the small team had reached the area of Spyglass Island where they all knew, should lie the remains of Commodore Joshua Barney's ill-fated flotilla of seventeen vessels and several merchantmen. Yet, it was unclear to them why such locally well known wrecks had not been discovered by divers previously. As they moved up the narrow river, the magnetometer continued to show numerous small "hits", and marker buoys were tossed overboard each time. Completing the run, the surveyors noted that all markers were approximately equidistant from one another and stretched along the river for a distance of some 1,650 feet, very close to the length of the lost fleet if they had been tied up bow to stern as reported. Divers were sent over the side at the sites, but upon returning, reported only a sand bottom in water depths of 5 feet and no parts of any ships protruding above the bottom. A water jet was put into operation, and after many hours of work, the outline of one of the wrecks became apparent. However, it was located under 5 feet of sediment and the question of why it had not been found previously had been answered. During the probing the single find, was a turtle shell, absent from its owner and thereby the wreck site received its name—the Turtle Shell Wreck. Excavation would await the 1980 field season.

The story of the Chesapeake Flotilla is a fascinating one, although little known outside the Chesapeake. Commodore Joshua Barney, Revolutionary War hero, had a fleet hastily constructed in Baltimore to meet the threat of the British on the Chesapeake. By the spring of 1814, his fleet was ready and they sailed and rowed out of Baltimore to meet the British who had established an outpost at Tangier Island. Since his fleet of eighteen vessels was no match for the large British fleet, he could only annoy or disrupt the British incursions. By June 9, Barney had been trapped in St. Leonard's Creek, a tributary of the Patuxent River and the British launched what they believed to be a final attack. It was repulsed. Again they attacked and again he repulsed them. Then on June 26, Barney launched his own attack which sent the Royal Navy frigates retreating





Above and right, Cofferdam and the excavation barge are shown. On opposite page plan and profile schematics of the excavation areas.

down the river freeing Barney from the confines of the creek. The British were stunned by the defeat and decided to await reinforcments before again tackling the feisty Commodore. By August 18, 1814, the British amassed the largest wartime naval force ever to enter the Bay. There were over twenty vessels of war, including four ships-of-the-line, a large train of transports and supplies, and a landing force of four thousand men. At noon, they moved into the Patuxent; Barney wisely moved further upriver. Although the British must first destroy Barney, their goal was to attack the Nation's Capitol. At Benedict, Maryland, the British troops landed to march along the west bank of the Patuxent, supported by a number of light vessels.

Recognizing the inevitable, Barney abandoned his boats above Pig Point, leaving each with a small crew, and took his remaining 400 men to join the American forces preparing to defend the Capitol. Admiral Sir George Cockburn wrote of the flotilla's destruction on the 22 of August:

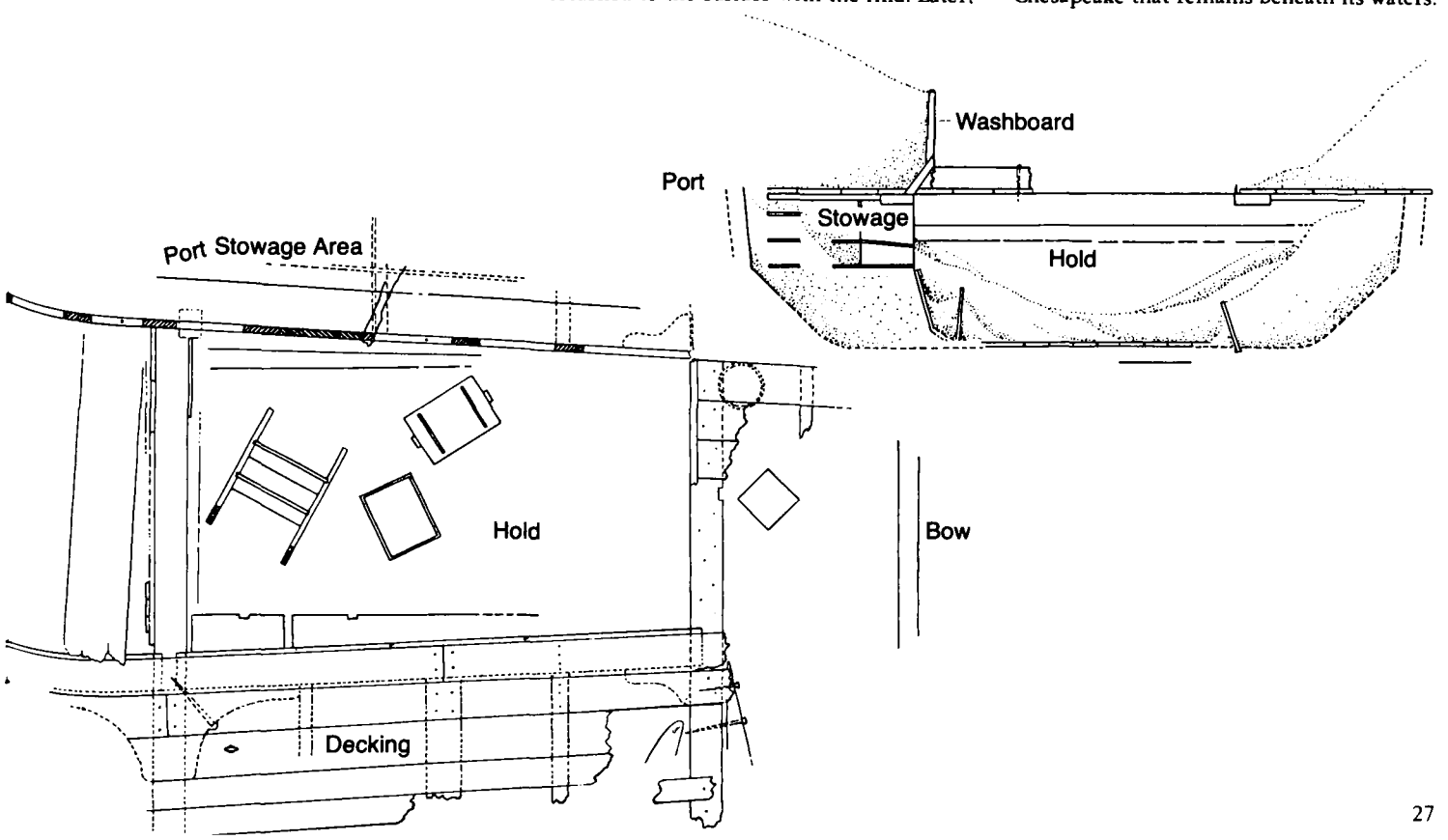
"As we opened the reach above Pig Point I plainly discovered Commodore Barney's broad Pendant in the headmost Vessel, a large Sloop, and the remainder of the Flotilla extending in a long line astern of her. Our boats now advanced towards them as rapidly as possible, but on nearing them we observed the Sloop bearing the Broad Pendant to be on fire, and she very soon afterwards blew up. I now saw clearly that they were all abandoned and on fire with trains to their magazines, and out of the seventeen vessels which composed this formidable and so much vaunted flotilla sixteen were in quick succession blown to atoms, and the seventeenth, in which the fire had not taken, were captured...I found here lying above the Flotilla under its protection thirteen merchant schooners, some of which not being worth bringing away I caused to be burnt..."

Now, in June, 1980, Nautical Archaeological Associates and the Calvert Maine Museum returned to Pig Point ready to conduct an indepth excavation under a new grant from the Trust. Four 25-foot long barges were moored over the site and a temporary plywood cofferdam constructed around the extremities of the wreck. Then, using an airlift, the divers carefully removed the blanket of sand, mud, and debris covering the wreck which was reached at a depth of approximately 5 feet. The purpose of the airlift was to remove the overburden from the site-but not to remove the artifacts. Spoil from the site was pumped through a 3 inch hose and onto a specially constructed sieve box up on the barges where it was carefully searched for anything that might be missed by the diver below. By June 11, the divers had cleared the area down to the deck of the ship and had discovered the open hatch entranceway. Carefully, working their way downward layer by layer, and working almost entirely by touch, in the poor visibility each artifact recovered was carefully plotted in both horizontal and vertical dimensions and removed for preservation. Early finds included a complete military field surgeon's instruments, carpentry tools, bottles and ceramics. Since each item had its own story to tell, the careful analysis of each item in relation to another was made. One of the divers, while carefully excavating a storage section, came upon a mass of grey clay. Not fully aware of what he possessed, he returned to the surface with the find. Later, tender loving care would allow an entire ship's lantern to be reconstructed from the metal fragments within the clay.

Reluctantly, on June 27, with funds running low, the Project Director, Donald Shomette, gave the word to rebury the wreck to protect it until some time in the future when funds would again become available to complete the excavation.

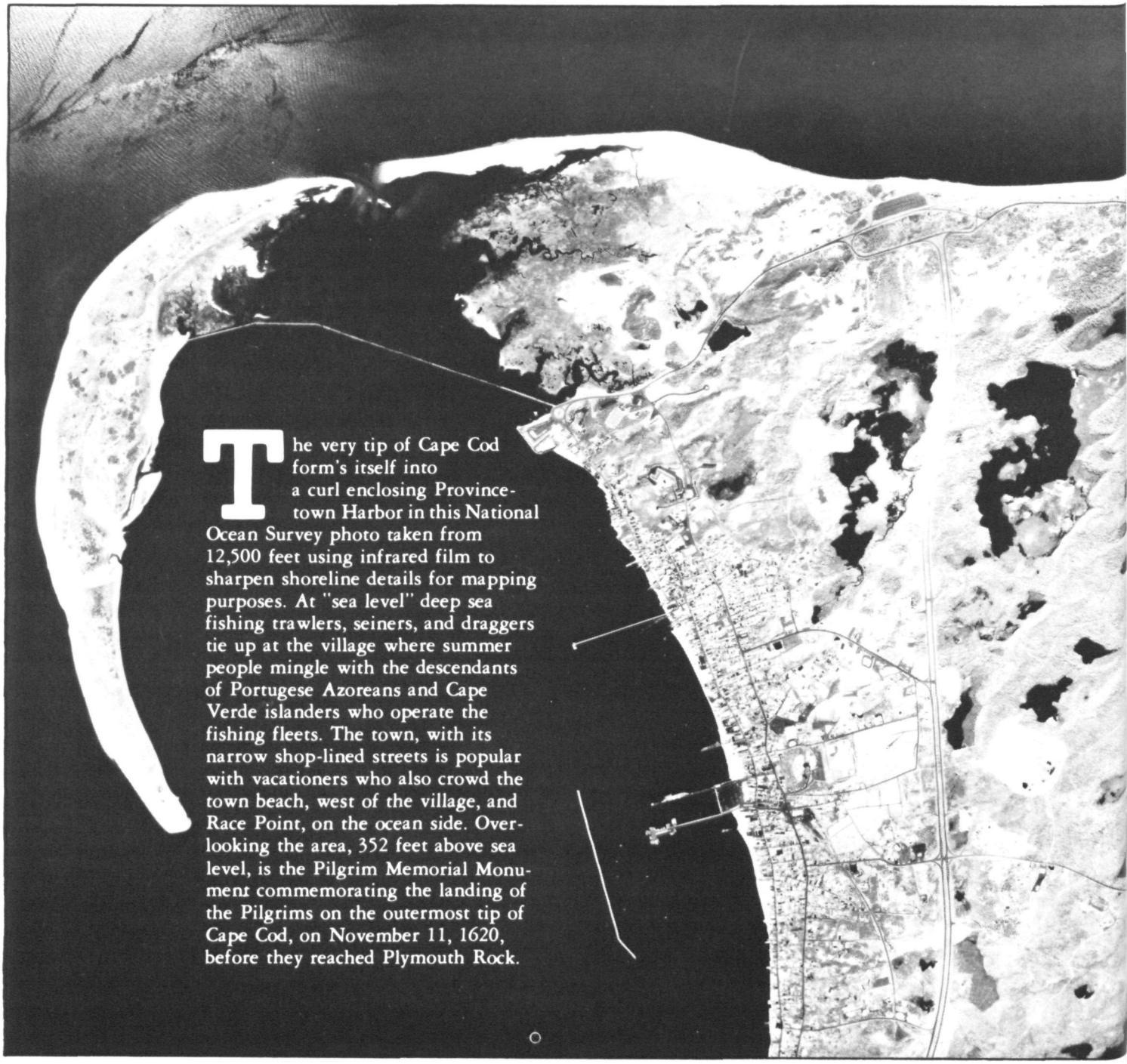
During the project, artifacts recovered and returned to the surface were given a field catalog number, photographed, sketched and then placed in a plastic bag to prevent drying and deterioration. In preparation for the recovery of artifacts, the State had funded for a conservation laboratory to be constructed at Solomon's Island, Maryland. There, in the historic Lore Oyster House, a 19th century building currently being renovated as a working oyster house and museum display by the Calvert Marine Museum, the conservation laboratory was constructed during April, 1980. Under contract, a trained conservator was hired to clean, stabilize, and preserve the recovered material. By the end of September, close to 150 artifacts were available for study and display.

Now with the expedition completed,, the artifacts preserved, and the technical reports written and presented, these archaeologists and divers could pause to reflect on what they had accomplished. They could gain some satisfaction that they had contributed in some small way to the store of information on American history although they realize that much still remains to be learned even on this seemingly minor event in history. But it remains to be seen whether others will view this work in the same light and whether funds will be available in the future to continue probing into the history of the Chesapeake that remains beneath its waters.

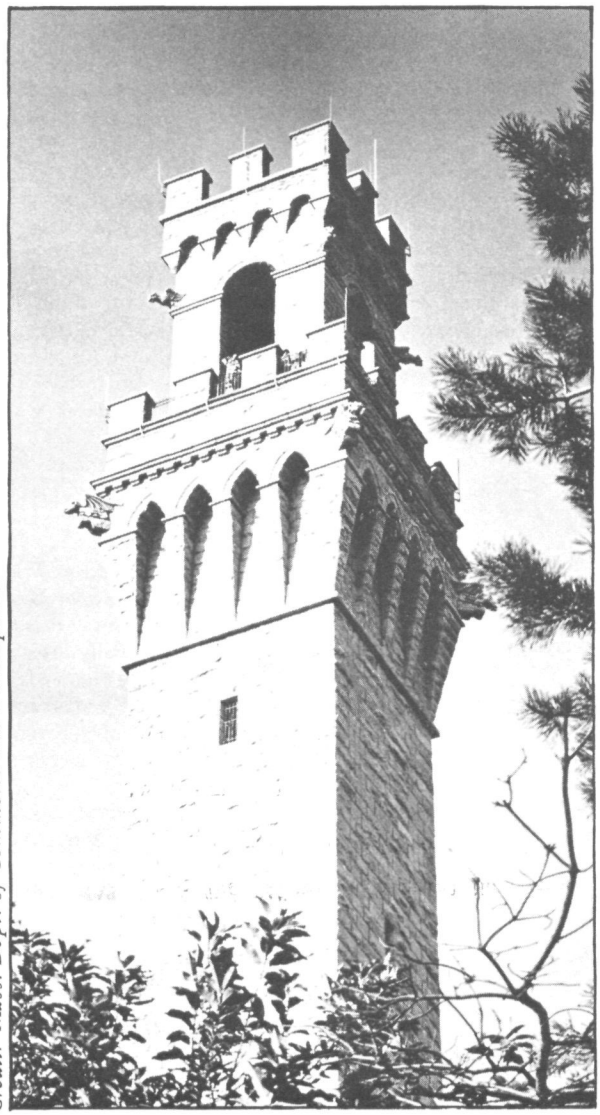


CITY-SCAPE

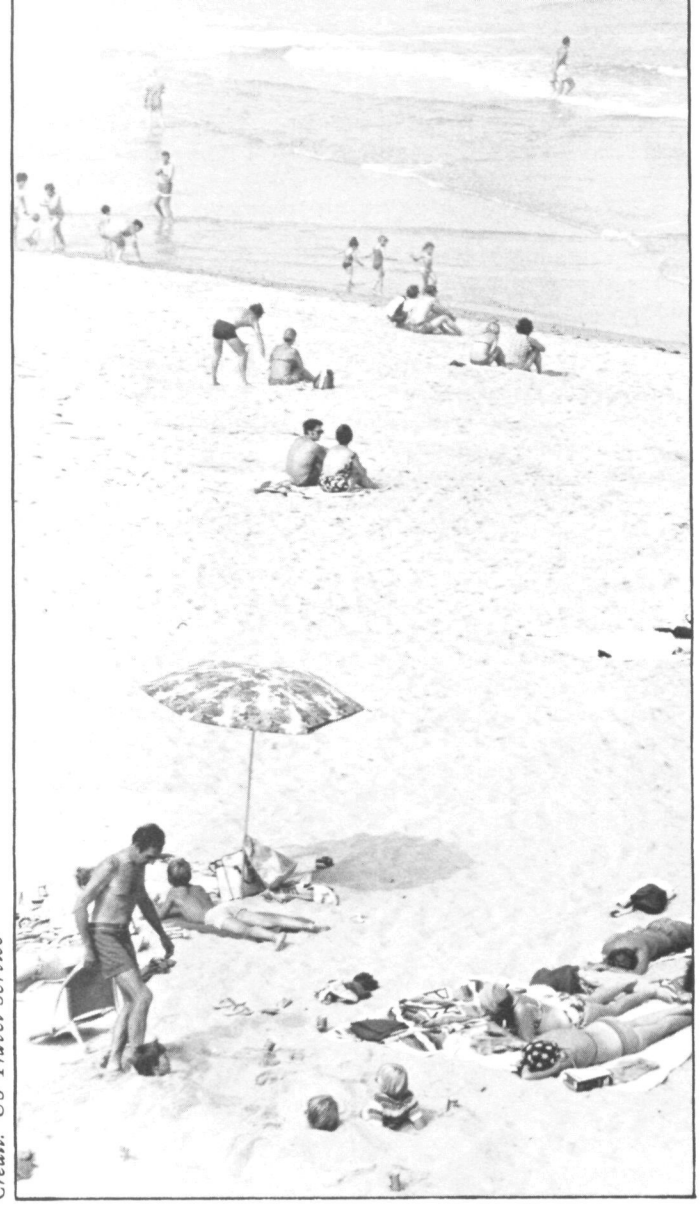
Land of the Pilgrims' Pride



The very tip of Cape Cod form's itself into a curl enclosing Provincetown Harbor in this National Ocean Survey photo taken from 12,500 feet using infrared film to sharpen shoreline details for mapping purposes. At "sea level" deep sea fishing trawlers, seiners, and draggers tie up at the village where summer people mingle with the descendants of Portugese Azoreans and Cape Verde islanders who operate the fishing fleets. The town, with its narrow shop-lined streets is popular with vacationers who also crowd the town beach, west of the village, and Race Point, on the ocean side. Overlooking the area, 352 feet above sea level, is the Pilgrim Memorial Monument commemorating the landing of the Pilgrims on the outermost tip of Cape Cod, on November 11, 1620, before they reached Plymouth Rock.



Credit: Mass. Dept. of Commerce and Development



Credit: US Travel Service

Credit: National Park Service

Credit: Mass. Dept. of Commerce and Development

Keeping The Wind Watch In Boulder

Louise Purrett-Carroll

When the atmospheric blocks of high and low pressure areas take up certain positions in the western United States, the wind roars down the eastern slope of the Rockies, and Front Range communities, at the foot of this aeloian waterfall, batten down the hatches.

It happens, on the average, several times a year, usually in the fall to early spring. In some areas, the winds gust to well over 100 miles an hour. They perform a kind of cleansing. Whatever's loose—shingles, litter, mobile home skirting, an old tree limb—can be blown away. Auto windshields and westward-facing windows become pitted from the occasional sandblasting. Human inhabitants may be exhilarated, frightened, or depressed by the howling wind; there's something disconcerting about watching your picture window bulge inward under some enormous invisible weight. At night, when audio dominates visual, the winds play a constant distant roar accented by the thud of a gust against the outer walls. Somehow gritty dust seeps through double-paned windows to settle in a thick coat on window sills.

Often the winds begin suddenly, the first powerful gust sweeping through town, raising a cloud of dust and debris as it goes. They rise rapidly, gusts of 40 miles (64 kilometers) an hour giving way to gusts of 70 or 80—well over the hurricane threshold. It isn't long before Al Bedard's telephone begins to ring.

Alfred J. Bedard, a scientist at NOAA's Wave Propagation Laboratory in Boulder, oversees a network of automated wind-sensing stations around town, the Boulder Wind Network.

In addition to measuring wind speed and direction, instruments in the network, installed and maintained by Carl Ramzy of NOAA, measure temperature, pressure, and solar radiation. Their readings are transmitted instantly to a computer across the hall from Bedard's office at the NOAA laboratory.

On wind storm days, Bedard is a resident expert on how hard the wind is blowing where. A school principal may need to decide whether to close early and send the children home or to keep them there until it's safe. A construction line supervisor may want to know if the winds are rising, so he can tie down loose materials. A radio station may want to broadcast cautions to its listeners. Many callers are individuals who are simply curious.

After a windstorm—most last only a few hours—when all the readings are filed in the computer, Bedard invokes a special program he devised and has the computer draw a map of the Boulder area with the peak gusts and times they were recorded for each of the five sites in the network. The maps are distributed to local newspapers and radio stations.

Hurricane force winds in the Rockies.

The network, which Bedard and a National Center for Atmospheric Research (NCAR) scientist, Tony Rockwood, set up, has been in operation for nearly 3 years. In that time, it has provided data unprecedented for its density and continuity, data that NOAA and other scientists are filtering to learn more about winds and how terrain affects them—from the chinook and bora winds that roar down from the high mountains to the gentlest zephyrs.

A year and a half ago, the Boulder Wind Network was a valuable player in a pilot study of the high-speed downslope winds and the upslope circulations that bring snow from the plains. The study, which Bedard coordinated, involved NOAA, NCAR, the University of Colorado, and Colorado State University. The 2-month experiment, call AEOLUS, was to study a variety of Front Range atmospheric ciruclation conditions and associated cloud processes that occur in Boulder Valley in the winter. In addition to the wind network, the scientists used the instrumented tower at the Boulder Atmospheric Observatory near Erie, instrumented aircraft, balloons, NCAR's portable automated instrument network, and NOAA's array of remote sensors, including a huge VHF radar in a mountain valley west of Boulder.

One case the experimenters captured in their records showed how upper level air flow can wear away an inversion. Early in 1980, cold air from Canada settled in Boulder Valley, the combination of snow on the ground and clouds above maintaining a strong inversion. Then a low pressure area approaching to the northwest caused an increased flow aloft. On March 5, at 10 p.m., a number of instruments that had been recording total calm showed an abrupt increase in wind. At the same time, the temperature increased more than 22 degrees F (12 degrees C).

The remote sensors showed a layer of wind shear and turbulence, probably where the upper level winds blew across the top of the inversion, that gradually descended until the winds reached ground level. The researchers believe with proper monitoring of the atmosphere, such shear events may be predicted, to aid aircraft operations along the foothills.

This pattern, says Bedard, is not unusual for Boulder Valley. "One thing that happens here is that cold air sitting over Boulder protects us, for a while, from high winds flowing over the top. But eventually it erodes away, and the wind works its way down. That's one reason it seems to hit so suddenly sometimes."

By itself, the wind network has recorded a great variety of wind conditions. Rummaging through a drawer of charts, Bedard remarks, "I never had such a pile of data in my life, and such good data." Many of the wind events the network has recorded

Boulder and other communities on the eastern side of the mountain are battered by high winds several times each year.

Credit: NOAA

scientists were familiar with in a general way. What the wealth of new measurements does, says Bedard, is document some of these events for the first time, and reveal the details of what happens.

The computer where the network's readings are stored can regurgitate them in a variety of forms, so these relatively simple measurements can be manipulated to derive many inferences.

One printout, a diagram that looks like a segmented clock, shows how much of the area's wind comes from each of 36 directions during a given month. A scattering of arrows shows the direction and velocity of winds recorded at a particular station. The data can be average to derive the mean wind speed for a certain hour, day, or month. One graph shows that, for August, 1979, four miles (seven kilometers) an hour was the most frequent velocity reading at a particular site. If someone wants to know how much wind it took to remove his roof, the computer can provide the maximum gusts during the critical time period at the nearest station. Simultaneous measurements from different stations can be compared to infer broader patterns.

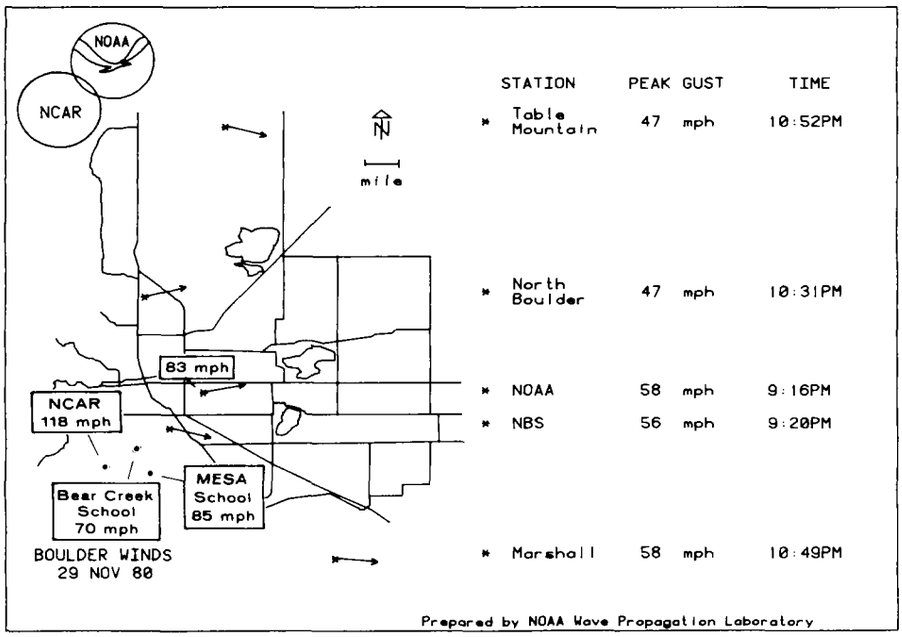
The same data can be displayed in different ways. The distribution of wind directions can be presented either in a bar graph, or as flocks of dots, each representing the relationship of wind speed to direction.

Bedard can extract the greatest variety of data with his terminal at the lab. But researchers with computer terminals can tap into the NOAA network by phone line. The National Weather Service forecast office in Denver has a terminal that forecasters use to call up winds, temperature, or pressure in Boulder. Though the two cities are only 30 miles (48 kilometers) apart, Front Range weather is highly variable and there may be significant differences. Windstorms from the west, for example, tend to die out by the time they reach Denver.

Though such dense, constant measurements can add immeasurably to scientists' understanding of wind and weather, the wind network has many uses beyond forecasting and research, some of them highly immediate and pragmatic. As public awareness of the network spreads, Bedard receives more and more calls. Last October, he began keeping a log of requests for wind information.

"Consulting engineers use wind statistics for siting buildings," he says. "Builders use wind data for filing their environmental impact statements—what gets blown around if a wind comes up when they're doing something. The Public Health Service has called for wind statistics. A company testing a wind screen to contain fly ash particles at a local powerplant wanted to know when would be a good time to test the screen.

"Teachers call. One wanted to know where to locate an experimental wind-driven turbine, as a demonstration for students. I get a lot of requests from individuals and engineering firms interested in wind power. And, the news media call a lot."



Sometimes the wind connection is not so obvious. One caller wanted the mean wind direction for a certain place and time to help track down a lost dog. A dog on the loose, explains Bedard, "tends to travel up-scent—upwind. So they thought they might be able to tell which direction he went." (A limitation to Bedard's role as wind oracle is that he gets little feedback of what callers do with the information he gives them; he doesn't know if the dog was found.)

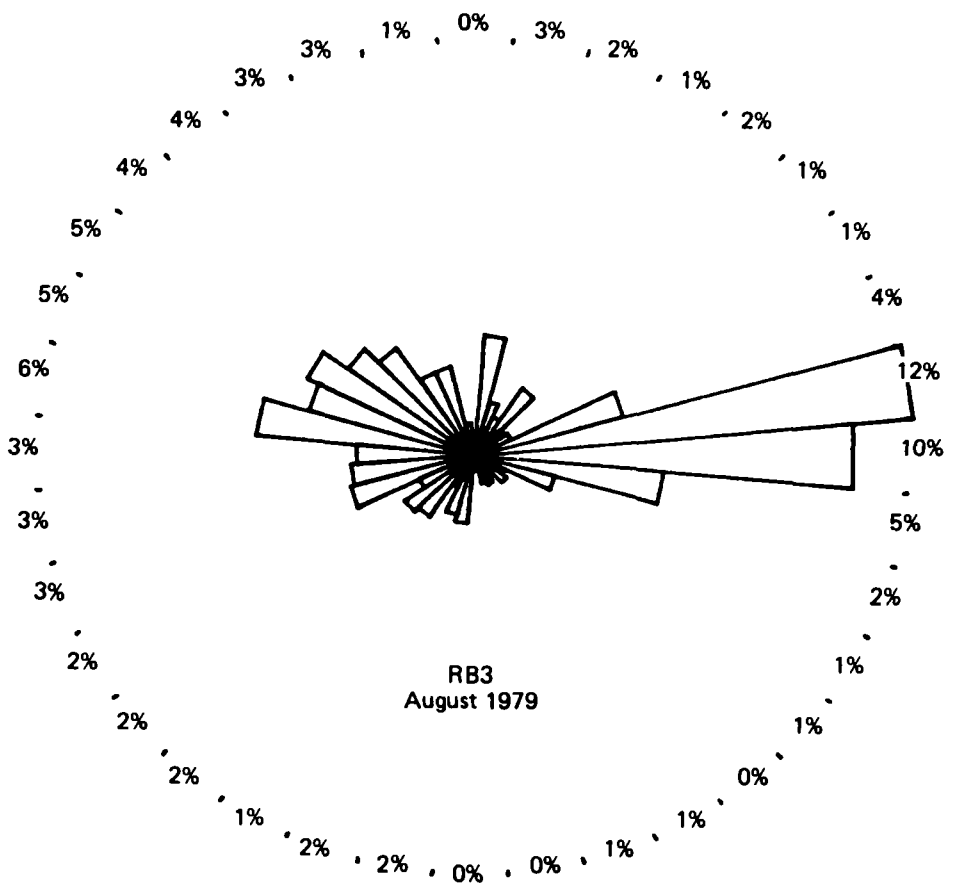
The present wind network is a streamlined successor to one NOAA established in 1972, a loosely knit association of recording anemometers. The instruments were located at NOAA and NCAR facilities, schools, the Boulder *Daily Camera* office, local industries, and private backyards, and were maintained by volunteers. Most instruments were of the type that traces a squiggle of wind velocities on a strip of paper. Some simply marked peak gusts. The number of stations varied, with a maximum of about 25. After a windstorm, a NOAA employee would telephone each site, and someone there would read off the peak gust and the time it was recorded. These were printed on a map of the city, which was then reproduced and distributed. The strip charts were collected and archived at the NOAA labs.

These records confirmed patterns in the wind velocities that layman's wisdom had suspected—for example, that the worst winds usually blow in the southwestern part of Boulder. Though it contributed much, that earlier network had its limitations. Data might be lost due to the absence or illness of a volunteer observer, and it sometimes took half a day to collect readings for a map. The new network has no such problems; the data come in automatically and instantly.

The present network applies the most advanced technology available, but it is by no means finished. "We're constantly improving the software," says Bedard. Recently, the Solar Energy Research Institute in Golden provided pyranometers to be added to each site to keep track of solar radiation. Soon, Bedard and Ramzy hope to add heated rain gauges. These would keep a record of rainfall with a tiny bucket that tips over whenever it gets a certain amount of moisture. The number of "tips" is recorded and relayed, with the rest of the weather data, to the main computer. A heated rain gauge can measure the amount of moisture from snowfall by melting it.

The network might also provide a valuable service to aviation in Denver, says Bedard, helping air traffic controllers with a recurring problem. Airplanes usually land into the wind. The arrival of a new warm or cold front, Bedard explains, brings a radical shift in wind direction, and the airport must reroute traffic to an entirely different set of runways. The problem at Denver's Stapleton airport (and probably at many others) is that "if a cold front comes down from the north, it doesn't show well enough on standard weather maps to say when it will reach the airport. So when it hits, they have to hold up traffic while they reroute it. This usually means delays of half an hour or so, and burning a lot of extra fuel. If the control tower knows within a short increment of time—5 minutes or so—when the front will hit, they can start planning ahead and avoid delays.

The stations in the wind network would detect the arrival of the front by the abrupt change in temperature. The lapse in time between when the front reaches successive



A computer records a wind storm's peak gusts and even draws the NOAA gull on the map opposite. More computer graphics (left) shows the prevailing winds of August are from the west.

stations can tell how fast it is travelling, and, therefore, when it would reach Stapleton. An additional station, probably to the east of Boulder, would provide wide coverage across the leading edge of the front. Such wind-shift warnings probably would be issued not by the wind network itself, but through a prototype weather service the NOAA labs are developing. The prototype weather service's computer would query the wind network computer for data to formulate a warning.

The Boulder Wind Network will probably never be finished. Its dual nature as both a research tool for studying winds—and *ways* to study winds—and as a service to a community with changing needs, ensures that.

Such a network would be instructive and useful almost anywhere. Along the Front Range of the Rockies, where the hills and mountains force the air into a dance with endless variations, and where the violent rush of the wind can disrupt the routines of a city, it is doubly so. □

Chinooks And Boras—The Mountain Winds

Boulder's scenic location at the foot of the Rockies brings high winds as well as tourists, for the winds, both the warm chinooks and cold boras, are born in the mountains.

The winds are not unique to Colorado's Front Range. The conditions that create them here create them elsewhere.

The name chinook, now applied to the warm dry wind on the eastern slope of the Rockies, was first used at Astoria, Oregon, where a warm wind blowing off the Pacific seemed to come from the direction of a Chinook Indian camp.

Chinook wind begins with the ascent of moist air up the windward slopes of mountains. As the air climbs, it expands and cools rapidly until its moisture condenses as rain or snow, which releases heat. By the time the air reaches the top of the mountains, it is very dry. As it slides down the leeward side, it is compressed, and warms rapidly.

This warm air, coming as it usually does in the winter, and often replacing cold continental air, sometimes causes dramatice increases in temperature—as much as 20 to 40 degrees F (11 to 22 degrees C) in 15 minutes. In one case in Montana, there was a rise of 31 degrees F (17 degrees C) in 3 minutes. Sometimes the boundary between chinook and continental air masses wavers back and forth. One morning in Rapid City, South Dakota, the temperature shifted back and forth several times between 10 to 15 degrees F (-12 to -9 degrees C) and 55 degrees F (13 degrees C). The most rapid rise was 44 degrees F (24 degrees C) in 15 minutes.

The chinook is also called the snow eater because it causes rapid melting and evaporation of snow on the ground. A foot of snow may disappear in a few hours.

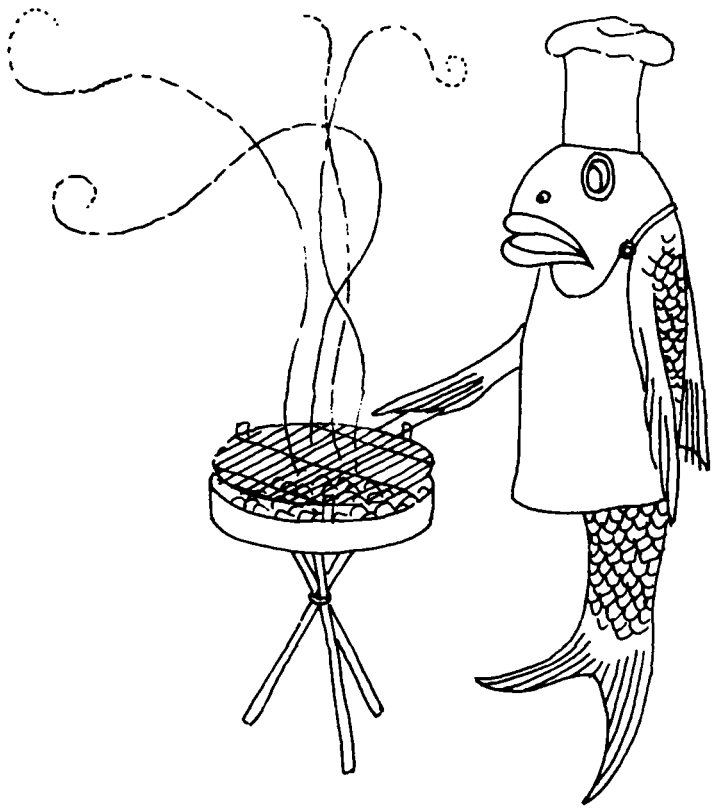
Such warm, dry winds descend the leeward slopes of nearly all mountains and mountain ranges. Along the Alps, they are known as foehn. In upper Bavaria the foehn creates an optical quirk that makes the Alps visible from places where normally they would be out of sight, and is blamed for depression among the inhabitants.

Southern California suffers a similar type of wind, called a Santa Ana, that occurs when air rushes down from the high inland plateaus. It is named for a canyon through which it often blows.

The Crimean area along the Black Sea, Libya (where it is called a ghibli), and the Andes of Argentina (where it is called a zonda) are among the other settings for chinook-type winds.

Sometimes the wind blowing down from the mountains is cold, not warm. These winds, the boras, are so cold when they start their descent, or descend so rapidly, that the compressional heating does not warm them even to the normal level for the region. The term bora was originally applied to the cold northeast wind that chills the Dalmatian coast of Yugoslavia when cold winter air from Russia crosses the mountains and sinks to the relatively warm Adriatic coast. Like Colorado's chinooks, Yugoslavian boras can exceed 100 mph. Bora winds are well known in Bulgaria, the northern shore of the Black Sea, and Novaya Zemlya, islands of the Russian Arctic.

Okay, you backyard barbecuers. It's summertime. Break out the grill and try something new and different. These tempting dishes are designed for out-of-doors cooking. So slice up the slaw, fill the wash tub with iced tea, and get ready to fend off hungry neighbors. These summer seafood treats are surefire taste treats.



The Grill Gourmet

LOUISIANA SHRIMP BOIL

5 pounds shrimp, fresh or frozen
1 gallon water
1 lemon, sliced
1 small onion, sliced
½ cup salt
½ cup seafood seasoning
1 clove garlic, sliced
Seafood cocktail sauce

Thaw frozen shrimp. Pour water into a large kettle. Add seasoning. Cover and bring to the boiling point over hot coals. Add shrimp. Cover and simmer for 5 minutes. Drain. Serve with seafood cocktail sauce. Serves 6.

WHITEFISH IN FOIL

2 pounds whitefish fillets or other fish fillets, fresh or frozen
2 green peppers, sliced
2 onions, sliced
¼ cup butter or margarine, melted
2 tablespoons lemon juice
2 teaspoons salt
1 teaspoon paprika
Dash pepper

Thaw frozen fillets. Cut into serving-size portions. Cut 6 pieces of heavy-duty aluminum foil, 12 x 12 inches each. Grease lightly. Place a portion of fish, skin side down, on foil. Top with green pepper and onion. Combine remaining ingredients. Pour sauce over fish. Bring the foil up over the food and close all edges with tight double folds. Make 6 packages. Place packages on a grill about 5 inches from moderately hot coals. Cook for 45 to 60 minutes or until fish flakes easily when tested with a fork. Serves 6.

FISHERMAN'S DELIGHT

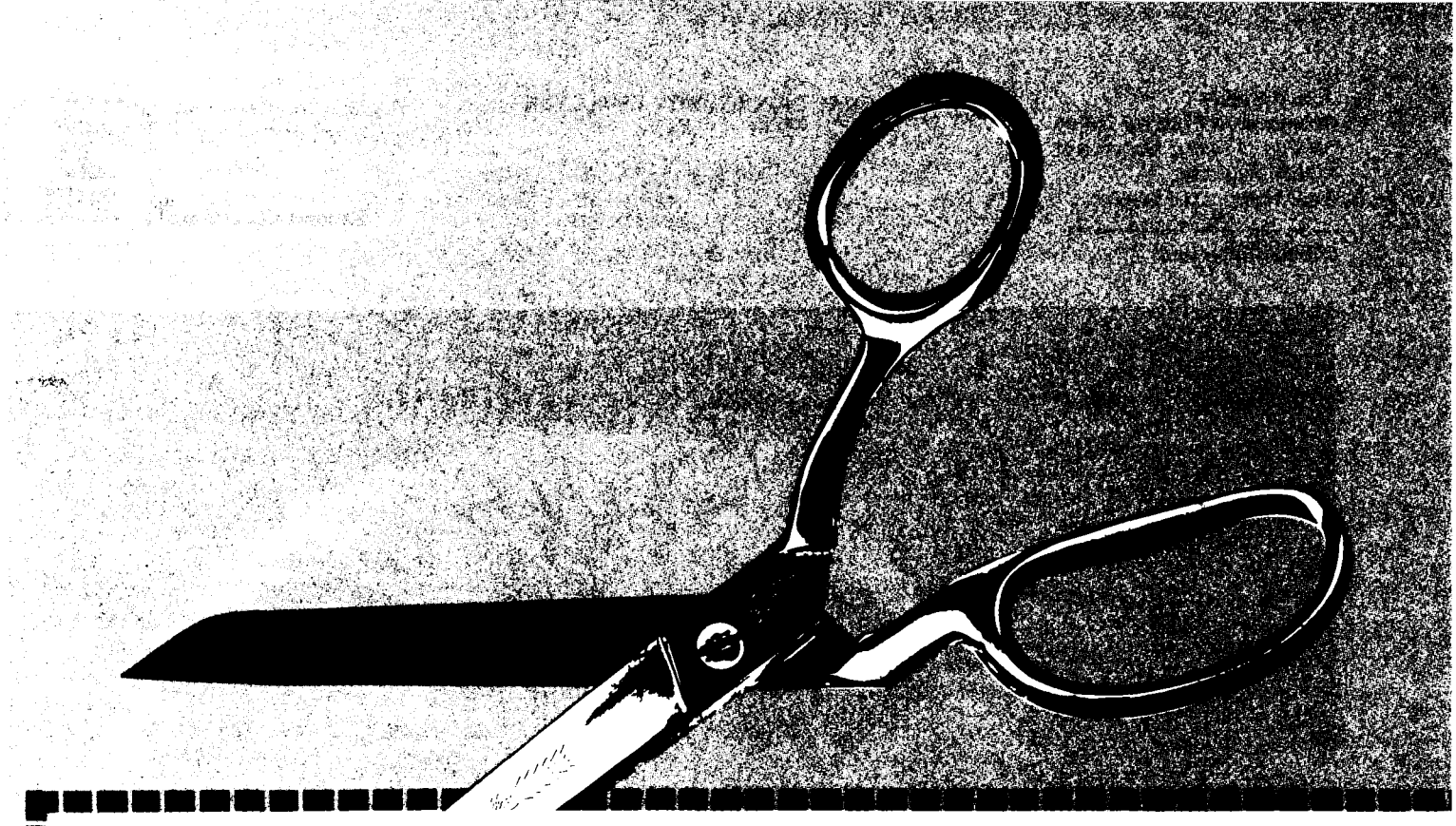
2 pounds pan-dressed yellow perch or other small fish, fresh or frozen
2 tablespoons lemon juice
2 teaspoons salt
¼ teaspoon pepper
2 pound sliced bacon

Thaw frozen fish. Clean, wash, and dry fish. Brush inside of fish with lemon juice and sprinkle with salt and pepper. Wrap each fish with a slice of bacon. Place fish in well-greased, hinged wire grills. Cook about 5 inches from moderately hot coals for 10 minutes. Turn and cook for 10 to 15 minutes longer or until bacon is crisp and fish flakes easily when tested with a fork. Serves 6.

CHESAPEAKE BAY CLAMBAKE

6 dozen soft-shell clams
12 small onions
6 medium baking potatoes
6 ears of corn in the husks
12 live, hard-shell crabs
Lemon wedges
Melted butter or margarine

Wash clam shells thoroughly. Peel onions and wash potatoes. Parboil onions and potatoes for 15 minutes; drain. Remove corn silk from corn and replace husks. Cut 12 pieces of cheesecloth and 12 pieces of heavy-duty aluminum foil, 18 x 26 inches each. Place 2 pieces of cheesecloth on top of 2 pieces of foil. Place 2 onions, a potato, an ear of corn, 1 dozen clams, and 2 crabs on cheesecloth. Tie opposite corners of the cheesecloth together. Pour 1 cup of water over the package. Bring foil up over the food and close all edges with tight double folds. Make 6 packages. Cover with hood or aluminum foil. Cook for 45 to 60 minutes or until onions and potatoes are cooked. Serve with lemon wedges and butter. Serves 6. □



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Sea otters relax at the Seattle Aquarium. *See the story on page 22*