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FLORIDA'S RED TIDE PROBLEM

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Destructiveness of the 1946-47 outbreak

In November 1946, when fishermen near Naples, Florida, reported tremendous numbers of dead fish floating with the wind and tide in reddish-colored patches of sea water extending 10 to 14 miles offshore, Federal and State fishery scientists suspected that an outbreak of "poison water" had returned to the Florida Gulf coast after an absence of 30 years.

This fish-killing plague, always associated with discolored water, was no newcomer to Florida coastal shores. Its first recorded appearance was in 1844. It occurred again in 1854, 1878, 1880, 1882, 1883, 1908, and 1916. "Poison water," "black water," "yellow water," and "rotten water" were some of the terms applied to earlier occurrences.

The new outbreak, characterized by a reddish-amber discoloration of the water, was soon popularly tagged as "red tide" in the reams of newspaper and magazine publicity that recorded its progress. The term "red tide" is somewhat of a misnomer. Actually, there is no particular <u>tide</u> involved, and the <u>red</u> color is not always as characteristic as are several shades of green interlaced with yellows and browns.

In the wake of this "tide," as it crept slowly northward up the west coast of Florida, millions of decaying dead fish were deposited on the beaches. The air coming off the water was polluted with a pungent and irritating "gas" which caused coughing and choking. Municipal authorities wrestled with the problem of disposing of tons of dead fish that littered the bays and beaches. Charter-vessel sport fishing practically came to a standstill. Commercial fishing had to be curtailed.

Observers reported that patches of the deeply colored water sometimes took on an oily appearance. When dipped up and allowed to stand for 5 or 10 minutes, this water became thick and sirupy and slimy to the touch. According to eye witnesses, the fish died quite suddenly after entering patches of the red water.

Early in January 1947 this outbreak, accompanied by a mass of dead and dying fish, reached Boca Grande, invading the inshore waters around Sanibel and Captiva Islands as it passed. All the beaches in the Fort Myers area were littered with the bodies of dead fish, which were reported to be accumulating at the rate of more than a hundred pounds to the linear foot of shoreline. In February, dead fish were washed ashore on Englewood Beach, a few miles south of Venice, marking the northernmost boundary of mortality. By March the discoloration of the water had disappeared, and the sea returned to normal. No more dead or dying fish were found. The situation cleared itself before a great deal could be learned about it.

After a brief respite during the spring months, the red tide showed up again in the same general areas in July and August, with fish mortality rivaling or exceeding that of the previous winter. Airplane reconnaissance over the Gulf in July reported "acres of dead fish."

An Associated Press dispatch out of Clearwater on August 5, 1947, read:

> The extended mass of tons of dead fish killed by the so-called "Red Tide" floated northward along Florida's Gulf coast slowly today, with the head of the huge jumble of fish about 15 miles north of here.
>
> As it passed by the beaches here the mass was about six miles offshore. Fringes of the rotting collection of fish have touched shore at spots along Pinellas County shorelines.
>
> An estimated 400 pounds of fish were washed ashore here today and were promptly picked up and destroyed by the city sanitary department.
>
> Fishermen said the group of dead fish with its accompanying red discolored water was moving northward at the rate of about two miles an hour.

Dr. Franklin E. Campbell, Pinellas County health director, said observers had told him the long, strung-out floating mass of fish was about 60 miles long and about 30 miles wide.

A mid-September hurricane finally dispersed this outbreak.

Estimates placed the destruction of valuable food and game fishes during the 1946-47 red-tide invasion at several hundred million pounds. Attendant economic losses, including interruption of sport and commercial fishing and damage done to resort centers through loss of winter visitors and consequent lowering of real-estate values, reached a large but unknown figure.

Practically all species of fish, including such large forms as tarpon and jewfish, were included in the victims of the red water. Most oysters in affected areas died. Horseshoe crabs died by the thousands, but the true crab apparently was unharmed. Sponges showed no ill effects (the principal sponge beds near Tarpon Springs were outside the red-tide area).

To the tons of dead fish deposited on the beaches must be added an enormous quantity that never reached the coast but floated and disintegrated in the offshore waters. Certain species, like mackerel, do not float when dead.

In addition to the annoyance of having decaying fish deposited on the beaches of shore communities, spoiling their use for bathing and sunning, beach residents and visitors to the Gulf coast during the 1946-47 red-tide siege complained of an odorless but highly irritating gas that emanated from the water. It caused spasmic coughing, a burning sensation in the nose and throat, and irritation of the eyes. These effects were particularly noticeable when waves were breaking or when the wind was blowing from the water.

For several days, when the onshore winds persisted, life on Captiva and other islands of the affected areas was very uncomfortable. Virtually the whole population was sneezing and coughing and suffering from other symptoms resembling those of a heavy cold or hay fever. People subject to such discomforts found it wisest to stay away from the water areas during times of highest irritation. For those who had to work on the beach, some relief could be obtained by breathing through an ordinary dust mask of gauze and cotton. (So far as is known, there were never any serious or permanent effects from these irritations.)

Red tide in other places

Although the 1946-47 outbreak of red tide on the Florida Gulf coast was believed to be the most severe ever recorded and of the longest duration, similar visitations of red water, with accompanying mortalities of fish, have occurred in many parts of the world.

In 1832, during the voyage of H.M.S. Beagle, Charles Darwin, the English naturalist, reported red water off the coast of Chile. At Port Jackson, Australia, serious destruction of oysters and mussels was recorded in 1891. Between 1899 and 1934, 24 outbreaks of red water were recorded in Japan, 16 of which killed fish and shellfish. In California, deep discoloration of coastal water from Santa Barbara to San Diego was noted in 1902, and red water was observed near La Jolla in 1906, 1907, 1917, 1924, 1933, and 1935. Similar accounts of red water, frequently accompanied by heavy mortality of fish, have been reported from the Malabar Coast of India, the seacoast of the State of Washington and British Columbia, and from Narragansett Bay of Rhode Island.

The earlier outbreaks usually were brief, for storms, active ocean currents, and changing temperatures readily destroyed the organisms responsible, thus permitting conditions to return to normal promptly. The Florida outbreak of 1946-47 was unusual in duration and probably was brought about initially by a long period of calm and warm weather.

An emergency survey begins

Despite the fact that red tides have occurred in many parts of the world during the past century, scientific studies of such marine phenomena have been largely descriptive. A comprehensive study of the basic problem of why red tides occur and whether man can predict and control them had never been made.

When the U. S. Fish and Wildlife Service in Washington, D. C., learned in January 1947 of the seriousness of the outbreak, no Federal funds or personnel were available to make the necessary investigation, but the Service was able to respond to local and Congressional requests for aid by making arrangements for several specialists to study the situation. Drs. F. G. Walton Smith and Gordon Gunter, of the Marine Laboratory of the University of Miami, visited the west coast of Florida about the middle of January to collect samples of water and make observations which might pin down the cause of this high mortality of fish. The Woods Hole (Massachusetts) Oceanographic Institution agreed to make chemical analyses of water from the affected area. In March, Dr. Paul S. Galtsoff, chief shellfish biologist of the Fish and Wildlife Service, visited the area. Local chambers of Commerce and civic groups offered assistance.

Later in 1947, when the first reports came in of the recurrence of the red tide about July 15, W. W. Anderson, a biologist of the Fish and Wildlife Service stationed at New Orleans, was sent to Florida to make an immediate investigation. From July 20 to 30 he centered his activities at Venice and Sarasota.

Dr. Smith, of the University of Miami, was appointed by the Fish and Wildlife Service as a collaborator. He arrived in Venice on July 21 to assist Mr. Anderson. A similar appointment was given

Alfred H. Woodcock, of the Woods Hole Oceanographic Institution, an expert in the field of gas analysis and aerosols.

After completing the necessary field surveys, Mr. Anderson returned to New Orleans at the end of July, only to be recalled to Florida for further red-tide work during the second week of August. At that time he visited Tarpon Springs, Clearwater, and Sarasota.

Fish kill not caused by dumping of munitions

As Federal and State fishery scientists began to delve into the problem of the red tide, they first encountered the theory--widely held in Florida--that the extensive fish mortality was caused by chemicals from war munitions allegedly dumped in coastal waters. Lewisite gas, which contains arsenic, was believed responsible. Several facts, however, showed that this theory was illogical. The only record of any deposit of lewisite gas was that of the disposal of some leaking containers off Mobile, some 300 miles distant, in the autumn of 1947, almost a year after the 1946-47 red tide began.

Additional discounting of this theory came when researchers checked a lengthy report of the outbreak of 1916, written by Dr. Harden F. Taylor. The 1916 outbreak was identical in every detail with the one in 1946-47, even including the presence and effects of the "pungent gas" which had caused so much respiratory discomfort. It was evident that if both outbreaks were the same in every respect, munitions dumping could not have been responsible for both, since the armed forces certainly did not make such disposals in 1916 when preparations had hardly begun for World War I.

Another important objection to the theory of mustard-gas poisoning from the dumping of munitions was the fact that the minute, drifting marine life upon which many fish feed, collectively known as "plankton"--the members of which are delicate and extremely susceptible to chemicals--was normally abundant in the red-tide areas in 1946-47. Had there been chemical pollution, the waters would have been largely barren of plankton. If deprived of plankton, the sea water would have appeared crystal clear and highly transparent, whereas the red-tide water was very turbid and loaded with plankton.

The red-tide "bug" is identified

In December 1947 the Fish and Wildlife Service issued a release summarizing the cooperative investigations made during the preceding summer, at the peak of the red-tide outbreak. Cause of the fish-killing plague was identified as a minute single-celled marine organism, less than a thousandth of an inch across. This tiny organism is something like a plant and something like an animal. It can propel itself through the water--in an irregular spiral sort of movement--by the threshing or flipping about of an extremely small flagella or whip projecting from the tiny soft cell. It is classed among the dinoflagellates (that is, having a "whirling-whiplike" appendage) of the large group of organisms called Protozoa, and belongs to the particular genus called Gymnodinium. The specific name Gymnodinium brevis was proposed for it by Charles C. Davis of the University of Miami, during the course of the survey.

Under certain conditions these cells split in two, and divide again, at such a rate that they soon dominate the waters they occupy. Concentration of billions of these organisms gives the sea water a reddish or amber color because of the orange-colored granules contained within each cell. At times the concentration of G. brevis has exceeded 60 million cells per quart of water in streaks of red tide.

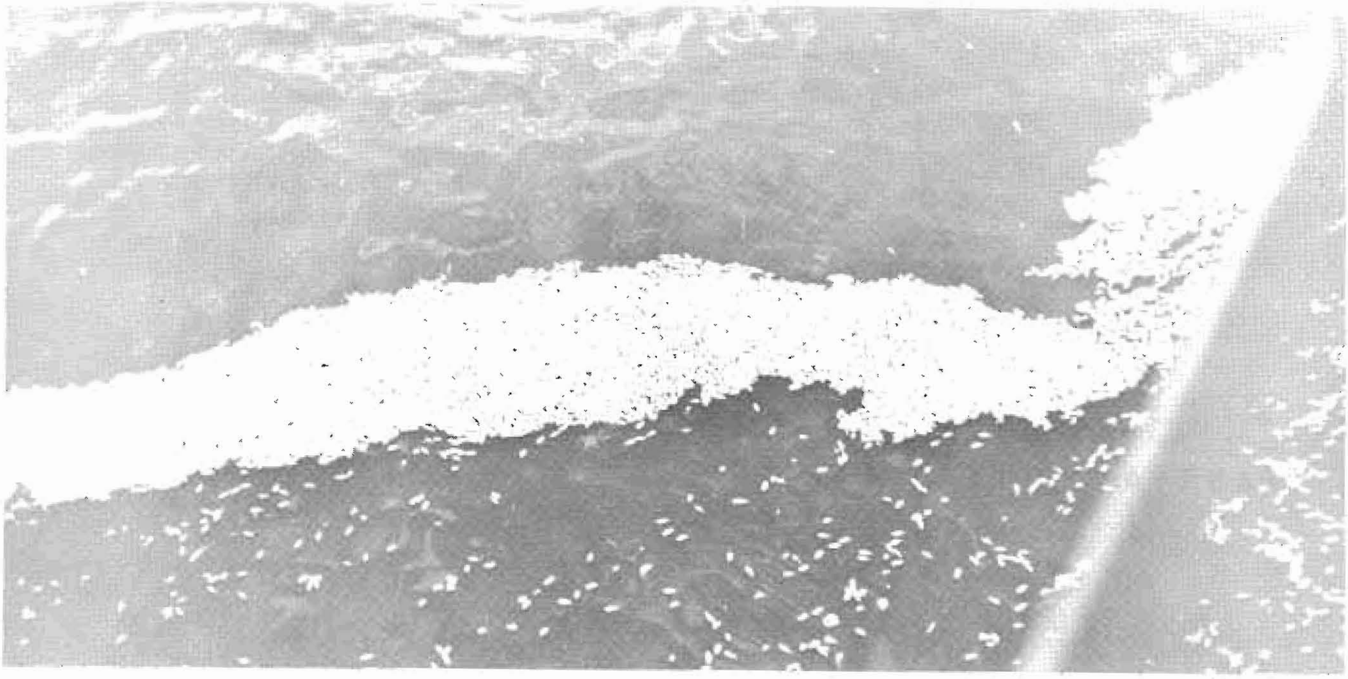
G. brevis liberates into the water a deadly toxin which is responsible for the great destruction of fish and other aquatic animals which accompanies red tides. The poison produces the symptoms of a neurotoxin, but its chemical composition is still unknown. In all probability this toxin enters the blood stream of the fishes and subsequently causes death. It has been determined that the organism does not cling to or clog the gills, and the fish do not die of suffocation.

Many persons had assumed that the masses of decomposed fish were responsible for the obnoxious gas that was causing so much respiratory discomfort during the height of the red-tide outbreak. This idea was discarded after tests showed that the substance producing the "gas" came from the discolored sea water. These poisons given off by the red-tide organism were carried in tiny droplets of windborne spray, liberated by wave action from red-water areas. When air-borne, the substance is then an aerosol and not a gas, and in its air-borne form is filterable.

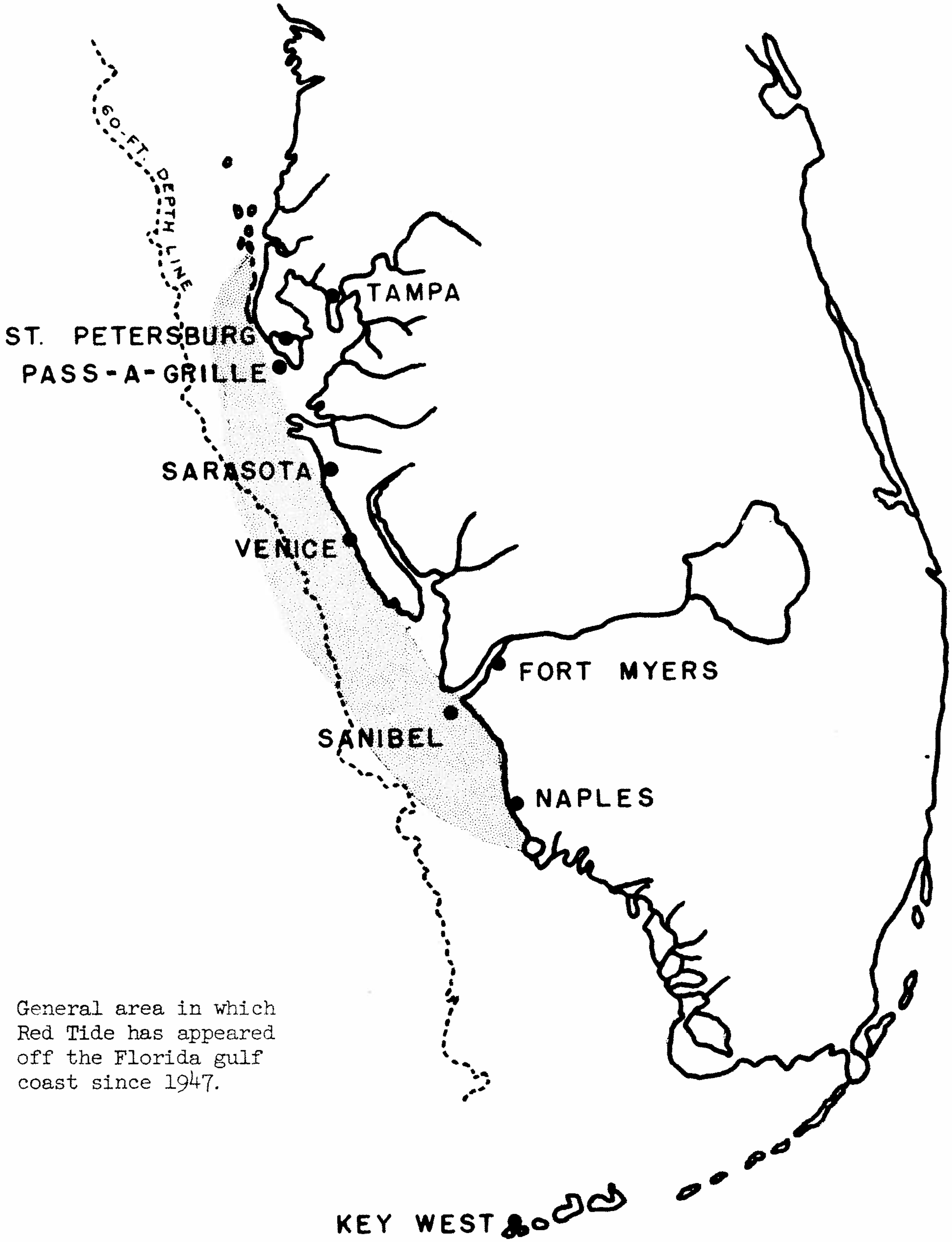
Conditions that produce red tides

Red tides occur on the west coast of Florida only when certain peculiar conditions prevail: after a period of abnormally heavy rainfall followed by a shift from offshore to onshore winds. These circumstances lead to the accumulation of a mass of water of abnormally low salinity, which is kept from dispersing seaward by the winds blowing toward shore. In this water mass, the organism G. brevis explodes into what biologists call a bloom (an extraordinary increase in numbers), and becomes poisonous to fish life. As the fish die, their decaying bodies release nutrients which nourish the bloom and intensify it.

Florida red tides usually occur in an area from 30 to 40 miles below Fort Myers on the south to Clearwater on the north. This is a coastal stretch of about 150 miles. The coastline is irregular and there are many islands (keys), bays, and estuaries. The Gulf is shallow (not more than 60 feet) out to an average of 20 miles from the coast. Since fish kills seldom occur elsewhere within the Gulf, apparently something peculiar to the coastal environment of the west coast of Florida make it a favorable habitat for G. brevis.



RED TIDE ON THE FLORIDA GULF COAST IN THE SUMMER OF 1947
Above: Mass of dead fish floating in the gulf southwest of St. Petersburg Beach (from an altitude of about 150 feet).
Below: Fish and turtles strewn along Madeira Beach near St. Petersburg. (Staff photos, St. Petersburg Evening Independent)



General area in which Red Tide has appeared off the Florida gulf coast since 1947.

The theory is now held that the red-tide organisms are able to multiply rapidly because nutrients are received through drainage from the land. The extensive marsh drainage of southwest Florida is being investigated in relation to its ability to stimulate the growth of *G. brevis*. The relation is complicated by the timing of rain, wind, and tide, and the warmth of the sun.

A Federal laboratory is set up in Sarasota

Because the 1946-47 red-tide invasion caused such heavy financial losses to the Florida west-coast area, Congress provided special funds to permit the Fish and Wildlife Service to study the problem. As a result, a small laboratory was established in Sarasota in 1948, and Federal fishery scientists, in collaboration with University of Miami scientists, began to seek the basic causes of this baffling phenomenon, for the purpose of developing predictive and preventive methods. Two lines of research were followed: (1) Laboratory culture experiments were carried on to determine under controlled conditions what elements were conducive to the growth of the red-tide organisms; and (2) hydrographic work was conducted at sea to ascertain under what conditions the organisms flourish in nature.

The laboratory remained in operation through June 1952, when for economy it was transferred to Galveston, Tex., and combined with the Service's Gulf of Mexico fishery investigations. During the whole time the laboratory was maintained at Sarasota, there were no red tides and not a single specimen of *G. brevis* was discovered in Florida waters.

The red tide returns in 1952

In November 1952 the red tide staged a repeat performance, with its range extending approximately 15 miles north and south of Fort Myers. For the most part the tide did not come closer than 3 miles from shore. A northeast wind kept the dead fish from being washed ashore.

As soon as Albert Collier, head of the Service's Gulf of Mexico fishery laboratory in Galveston, heard of the outbreak on November 12, he sent microbiologist John Howell to Fort Myers by the first plane. Upon arrival, Mr. Howell arranged with the Coast Guard for flights over the affected area in order to determine its location and dimensions. Then, on board a Coast Guard vessel, he went to the area thus located to obtain samples of the organism for identification. By then the patch of red tide had pretty well run its course, but he was able to get several samples which he shipped to the Service's laboratories at Galveston and at Beaufort, N. C., and also to the Haskins Laboratory, a noted private microbiological laboratory in New York City.

At the Galveston laboratory the cultures lived for several days when inoculated with sea water from the red-tide area. All at once, however, all the Gymnodinium in them either died or went into a spore phase which resisted all efforts to stimulate it into bloom. The Haskins Laboratory reported a similar experience with its culture. Failure to keep this organism growing artificially was one of the most serious barriers to productive research.

The Service's research vessel, the Alaska, based at Galveston, reached the red-tide area on November 16, and the scientific crew made detailed hydrographic studies over the entire area, observing the behavior of the bloom and collecting samples of water for chemical analysis ashore. All meteorological and river-flow records for the preceding several weeks were gathered to see whether they might show the environmental conditions leading to this invasion of the red tide.

On November 22 a new outbreak developed across the mouth of San Carlos Bay. This was reported immediately by a Coast Guard plane and the Alaska was able to get there at once to collect all the hydrographic data that the instruments of the vessel could measure. In addition, the Alaska attempted to break up this patch of red tide by cruising back and forth over the affected area and discharging a concentrated solution of copper sulfate into the water from its ballast tanks. This experiment apparently was successful, for the copper sulfate killed the organisms in the wake of the vessel and the patch of red tide dissipated shortly afterward.

After the November 1952 recurrence, scientists found the organisms in certain isolated marshlands and bays adjacent to the coast. With this discovery the solution to the red-tide problem came much closer.

New outbreaks in 1953-54

Early in September 1953, another red tide commenced, with all the familiar symptoms. Great quantities of fish were killed in an area 5 to 20 miles from shore, extending in patches along 60 miles of the coast from Venice to Clearwater. By September 9 the dead fish were reported moving inshore under the influence of low-velocity south-southwest winds.

During this outbreak, copper-sulfate crystals were placed in sacks and towed behind small boats, off Anna Marie Key, at the mouth of Tampa Bay. Again this experiment was successful in killing the organisms. The water also returned to a color nearer normal. This second control experiment was refined on the basis of experience gained from the first, and was carried out with facilities and services of private citizens of St. Petersburg and the U. S. Coast Guard.

During the fall and winter of 1953-54, fish kills continued sporadically, with only small numbers being killed. The apparent intermittent nature of these outbreaks was attributed to new waves of fishes moving into the infested area rather than to the decline of the immense blooms. During the last half of April 1954, a larger kill was reported below Fort Myers.

Beginning on June 29, 1954, an extensive red-tide fish kill occurred: on that date, Fish and Wildlife Service biologists observed dead fish from Longboat Key off Sarasota to Sanibel Island below Fort Myers, an area roughly 50 miles long. The seaward extent was 15 miles on the northern part and 8 miles on the southern.

Discolored water was present throughout the area. G. brevis, the red-tide "bug," had been found in coastal and estuarine waters all winter and spring. Concentrations varied but usually the numbers were small (a few hundred to the quart). They were found consistently at Sarasota, Venice, and Sanibel Island, and at times at St. Petersburg. The continued presence of G. brevis fitted the Service's theory of the conditions that cause the blooms and the resultant fish kills, that is, rainfall and greater-than-normal land drainage and mild and mostly onshore winds.

The Federal Government's present research program

From 1948 the Federal Government spent approximately $50,000 each year on red-tide research, until 1953 when the appropriation was reduced to $35,000. In the fiscal year 1955, $70,000 has been earmarked for the Fish and Wildlife Service's use. In January 1954, the Service reestablished a field station in Florida, this time at Fort Myers, in order to follow the development of a red tide through all of its phases. A team of 12 biologists, chemists, and technicians is now at work on this project; 5 technical employees are at Fort Myers and the remainder are at the Galveston laboratory, headquarters of the Gulf Fishery Investigations.

At Fort Myers, ocean currents, river discharge, tidal fluctuations, and temperature sequences are being studied. A continuous search is maintained for the red-tide organism so that its normal, nonblooming, habitat and habits can be learned.

Other work assigned to the Fort Myers station includes the systematic and routine daily collection and charting of weather and tide records, taking and examining water samples inshore and offshore between the Ten Thousand Islands and the St. Petersburg beach area at frequent intervals, and periodic flights over the whole area by arrangement with the U. S. Coast Guard. An interesting observation over the past year has been that G. brevis has been present over this whole range, but in small scattered patches most of the time.

In May, a new 43-foot vessel, since named the Kingfish, was delivered at Fort Myers for use in studying the ocean conditions that cause red tides. This diesel-powered vessel has excellent electronic gear aboard, including a recording instrument for temperature and salinity readings, loran for position-finding, and radar for tracking.

Since September 1953, for the first time in history, red-tide organisms have been cultivated artificially at the Galveston laboratory.

The ability to grow the organism artificially has given the scientists a tremendously important research tool. Continuous study is now possible. Already, laboratory studies have shown that G. brevis needs both sulphur and vitamin B_{12} to thrive.

Growing the red-tide organism in the Service's laboratory at Galveston, where there are excellent facilities and personnel, is providing some of the answers to Florida's red-tide problems, and will continue to do so. For example, the scientists at Galveston can now test many different chemical compounds to determine which are most effective control agents, what levels of concentration are best, and what sets of conditions are essential in order for G. brevis to flourish. Since the organism can now be grown at will, control research can be continued in the laboratory if the red tide disappears as it did after the 1947 outbreak.

Red-tide water has also been shipped to the Service's laboratory at Woods Hole, Mass., where it has been found that this water is as poisonous to fish in laboratory experiments as it is in the ocean. In working with the red-tide water in the laboratory, the same "gas" has been noticed.

Service scientists believe that the only hope for effective control of the red tide is to learn to predict the combination of meteorological and hydrographic factors that establish the "setting" for the bloom, and then to isolate and poison the small beginning blooms before they expand. It is likely that once a bloom starts it is fed at a tremendous rate by the fish that are killed.

Advantage may be taken of the fact that the greatest concentrations of G. brevis appear in patches which are, probably, the centers of their more rapid propagation. It is possible that the destruction of the initial populations may stop their further spread. Copper sulfate, in minute dilution, will kill the organism. The search continues for more effective and less expensive control chemicals.

Control measures are not feasible after the red tide has spread over large distances. The coastal areas extend about 150 miles from Clearwater to Naples. Concentrations of the organisms have been seen as far as 25 miles at sea. It is obviously impossible to poison the whole ocean.

Coordinating red-tide studies

Because the interest in the red tide has been so widespread in the Gulf of Mexico, the Gulf States Marine Fisheries Commission, established by a compact among the five Gulf States, has appointed a special red-tide committee, of which Dr. F. G. Walton Smith, Director of the University of Miami Marine Laboratory, is chairman. On the committee are representatives of the University of Florida at Gainesville and of the Fish and Wildlife Service, by law the primary research agency of the Gulf States

Marine Fisheries Commission. The work of the three agencies is thus coordinated. This red-tide committee is undertaking various projects which together will constitute a complete red-tide research program.

Control measures, involving help from local citizens through the stockpiling of chemicals such as copper sulfate, are being organized by the Gulf Coast Coordinating Committee, a "voluntary group of citizens dedicated to the control and elimination of the red tide." St. Petersburg, Sarasota, and Fort Myers have been selected as stockpiling locations.

The Fish and Wildlife Service is working closely with this coordinating committee. As emergency situations develop, the Service will plan, direct, and supervise the experimental use of copper sulfate on a wide scale, and will interpret and evaluate the results. Local units of the Gulf Coast Coordinating Committee will be called upon to assist in the execution of the control experiments. The copper sulfate may be sprayed from boats or dusted from planes.

With the complete cooperation of many agencies and individuals, it may be possible through collections and analyses of weather data, of run-off, and of artificial water releases from the big rivers to predict red-tide occurrences. By well-timed patrol and early detection it may be possible to destroy red tides as they develop. This is the ultimate goal of the coordinated red-tide research.

Summary

Progress on Florida's red-tide problem since the 1946-47 outbreak can be summarized as follows:

1. "Red tides," noted for their discolored water, are caused by a tiny marine organism so small that it cannot be seen by the naked eye. Gymnodinium brevis is the scientific name of this fish-killing plague which also produces a "gas" irritating to nostrils and throats of people.

2. Rainfall, marsh drainage, salinity, wind, and temperature--in certain combinations--provide the physical conditions in which the red-tide organisms can get started. These organisms multiply rapidly and derive nutrients from the fish that are killed, as well as from land drainage.

3. Red-tide organisms are now being grown artificially in the laboratory, thus permitting the testing of different chemical compounds as control agents. Copper sulfate is the most promising to date.

4. Federal and State research is coordinated and citizens' groups are organized to report the detection of new outbreaks and to assist in control measures in an emergency.

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