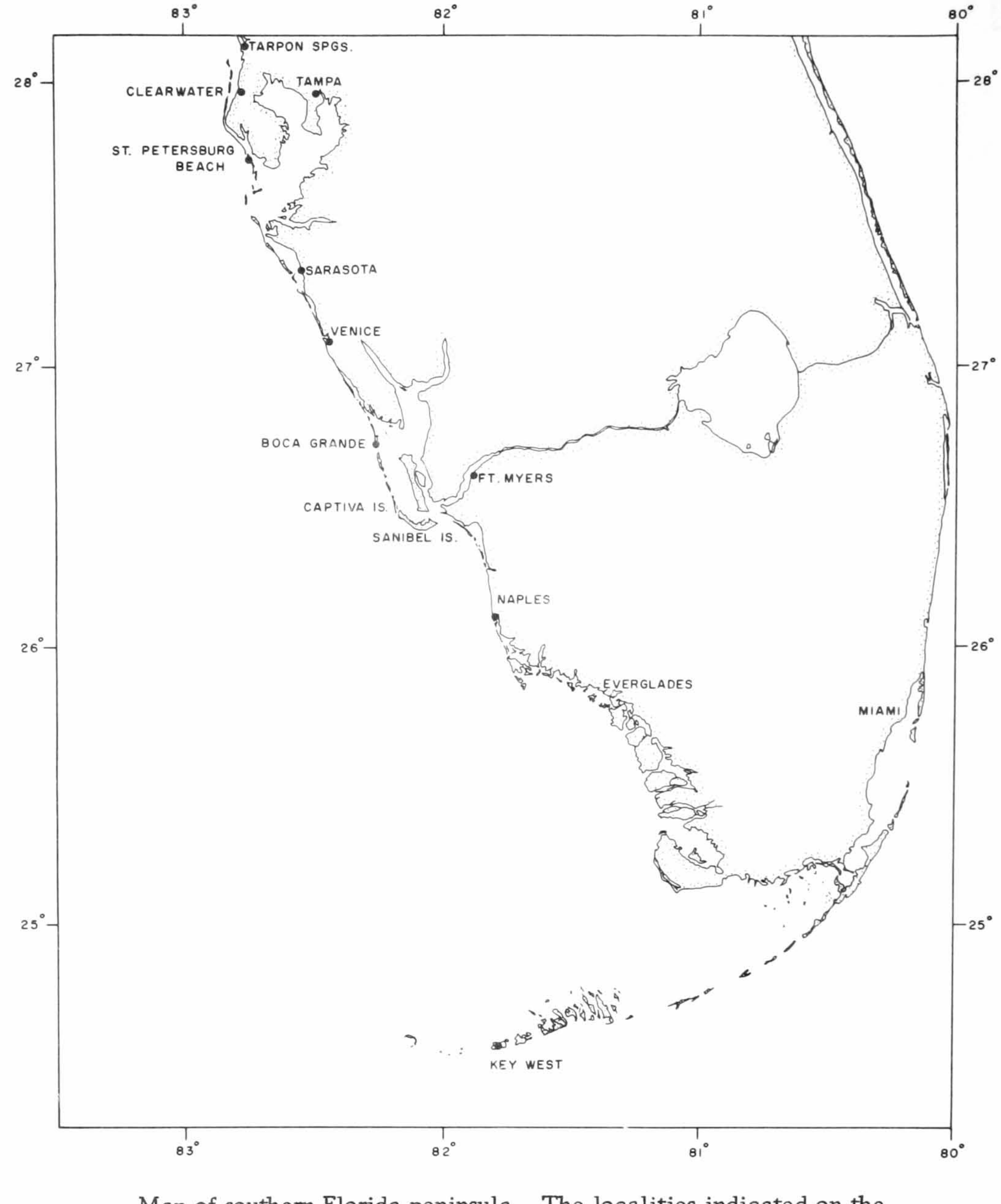


Map of southern Florida peninsula. The localities indicated on the west coast have felt the effects of periodic Red-Tide outbreaks.

COVER--Masses of floating fish killed by the Florida Red Tide.

THE FLORIDA RED TIDE

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 "Red Tide" had returned to the Florida Gulf coast after an absence of 30 years.

This fish-killing natural phenomenon, 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 local 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", however, is somewhat of a misnomer. Actually, there is no particular tide involved, and the red color is not always as characteristic as are several shades of green interlaced with yellows and browns.

In the wake of this "tide", millions of decaying dead fish were deposited on the beaches. 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. This water became thick and slimy to the touch when dipped up and allowed to stand for 5 or 10 minutes. According to eyewitnesses, 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, affected Boca Grande, including the inshore waters around Sanibel and Captiva Islands. All the beaches in the Fort Myers area were littered with 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 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".

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 true crabs apparently were 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. Furthermore, 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 spasmodic coughing, a burning sensation in the nose and throat, and irritation of the eyes. These effects were particularly noticeable when waves were breaking and the wind was blowing from the water.

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 Red Tide remained at least 3 miles from shore. A northeast wind kept the dead fish from being washed ashore.

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 lowvelocity south-southwest winds. During the fall and winter of 1953-54, fish kills continued sporadically, with only small numbers being killed.

On June 29, 1954, an extensive Red Tide fish kill occurred; 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.

The only authenticated occurrence of a Florida-type Red Tide outside Florida waters took place in September 1955. Reports indicated that this outbreak had affected at least 150 miles of the Texas and Mexican Gulf coast.

Smaller and more scattered outbreaks occurred sporadically between Tarpon Springs, Florida, and the Everglades during the period September-December 1957.

The most recent signs of Red Tide were observed in September-November 1959 between St. Petersburg Beach and the Everglades. The period 1955 to the latter part of 1957 and the year 1958 were not marked by outbreaks.

Although the 1946-47 outbreak of Red Tide on the Florida Gulf coast may have been the longest and most severe ever recorded, visitations of discolored water, associated with dense concentrations of various micro-organisms, and mortalities of fish, have occurred in many other parts of the world.

In 1832, during the voyage of the 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, from the seacoast of the State of Washington and British Columbia, and from the Narragansett Bay of Rhode Island.

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.

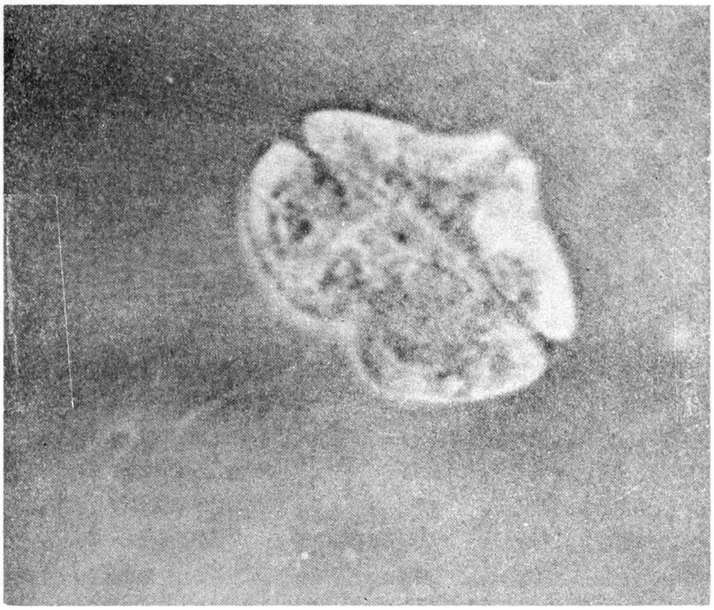
As federal and state fishery scientists began to delve into the problem of the Red Tide, they first encountered the theory--widely held in Florida--that the extensive fish mortality was caused by chemicals from war munitions allegedly dumped in coastal waters. Lewisite gas, which contains arsenic, was believed responsible. However, 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.

In December 1947 the Fish and Wildlife Service issued a release summarizing the cooperative investigations made during the preceding summer. The organism associated with the plague was identified as a minute single-celled marine flagellate, 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 of two extremely small flagella or whips projecting from the tiny soft cell. It is classed among the dinoflagellates (that is, "whirling organism with a whiplike appendage") of the large group of organisms called Protozoa, and belongs to the particular genus called *Gymnodinium*. The name *Gymnodinium brevis* first proposed for it was later corrected to *Gymnodinium breve*, to satisfy the rules of scientific nomenclature.

A small laboratory was established in Sarasota in 1948 by the U. S. Fish and Wildlife Service after Congress had provided special funds to study the problem. The laboratory remained in operation through June 1952, when for economy it was transferred to the Service's Galveston, Texas, Laboratory.

Early in 1953, a field station was set up at Fort Myers. Under the direction of the Galveston Laboratory, the staff of the Fort Myers station began 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.

When the Fort Myers' facilities became unavailable in 1955, the Florida station was moved to Naples, in which area the work continued until 1957. A move to St. Petersburg Beach in 1957,



Gymnodinium breve, magnified to 1450 times natural size. Note the trailing flagellum (difficult to see at lower left) lies in the clearly visible transverse groove of the organism. The pale areas are bright green chloroplasts.

where the station is operating at present, provided more adequate facilities, and also made it possible to begin a more concentrated study of Tampa Bay and the adjoining area of the Gulf. This type of careful regular examination of a more localized Red Tide area is providing more definite information on the sequences of physical, chemical, and biological events which are associated with the appearance and disappearance of "blooms" (development of massive algal concentrations) of G. breve. A marked relationship was noted between rainfall (and resultant land drainage) and occurrences of dense G. breve populations; outbreaks occurred only during years in which rainfall was well above normal.

The Fish and Wildlife Service has tried in several experimental efforts to determine the effectiveness of localized applications of copper sulfate in preventing or counteracting blooms of G. breve. (This chemical has been successfully used in the treatment of algal blooms in relatively small bodies of fresh water.) During the 1952-54 period three small-scale trials took place, and a much larger effort was carried out during the 1959 outbreak. In the latter case, 105 tons of copper sulfate were distributed on the coastal area between St. Petersburg Beach and Tarpon Springs. Both boats and airplanes have been used to distribute the chemical. The results of these tests indicate that copper sulfate can reduce or eliminate G. breve from treated waters for a short period of 1 to 2 weeks after treatment. However, the combination of excessive cost, short duration of control, and possibility of harm to other marine life render application of copper sulfate inadvisable.

During the 1952 outbreak, the Service was able to collect several samples of water containing G. breve which were shipped to its Beaufort, North Carolina, and Galveston Laboratories, 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. Eventually, however, the organisms either died or entered a dormant stage which could not be stimulated to return to the active growth phase. The Haskins and Beaufort Laboratories were also unsuccessful in their culture attempts. Failure to keep this organism growing artificially was one of the most serious barriers to productive research.

In 1953, Red Tide organisms at the Galveston Laboratory were first cultivated artificially. The ability to grow the organism under controlled conditions gave the scientists a tremendously important research tool. Continuous study became possible.

The culture of 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 are testing various chemical compounds in an attempt to discover an effective control agent. Since the organism can be grown at will, control research can be continued in the laboratory when the Red Tide disappears as it did after the 1947 outbreak. About 5,000 compounds have been tested so far. Several of these seem to be even more toxic per unit weight to G. breve than copper sulfate.

Research carried out at the Galveston Laboratory definitely established G. breve as the primary toxic agent in Florida Red Tides. Pure cultures (free of any other form of life) proved fatal to fish in short periods of time.

Another advance came with the development of a completely synthetic medium (every ingredient known and carefully measured) which would support the growth of G. breve in the laboratory. The ability to grow pure cultures in this type of medium has made it possible to add and subtract constituents to the medium in known amounts and observe their effects on growth of the organism. This type of procedure is presently providing information concerning the nutritional requirements of this dinoflagellate. Several vitamins and trace metals have been found important to growth in culture. Such experiments have also suggested an organic nitrogen requirement.

The development of pure cultures and a defined medium has also greatly facilitated the laboratory study of the effects of various environmental factors on G. breve. The influence of salinity, pH, temperature, and light are being investigated. Results thus far indicate the organism to be a tropical marine flagellate, adversely affected by brackish or fresh water as well as sudden drops in temperature. Furthermore, in culture the organism is dependent on light for its energy, evidence of a plant-like method of nutrition. Analysis of the cells has corroborated this indication, revealing the presence of chlorophyll and other characteristically plant pigments.

At present the evidence seems to indicate that Red Tides occur on the west coast of Florida only when certain peculiar conditions prevail--a shift from offshore to onshore winds following a period of abnormally heavy rainfall and land drainage. These circumstances may lead to the accumulation of an unusually nutrient-rich mass of marine water which is kept from dispersing seaward by the winds blowing toward shore. In this water mass, G. breve rapidly reproduces into a bloom, and becomes poisonous to fish life. As the fish die, their decaying bodies may release nutrients which nourish the bloom and intensify it.

Further laboratory and field work will provide the basis for any meaningful answer to the presently unanswerable question, "Can the Florida Red Tide be stopped?" Furthermore, we must realize that the information produced by such work can have broad application to other problems too. In 1958, at the conclusion of a critical review of the U. S. Fish and Wildlife Service's Red Tide research program, a member of the advisory board emphasized this point: ". . . I want to stress what other people have stressed. You haven't had just one research program. Research you are doing is going to bear on a great many fields. . . . Through the years this [sic] data will be useful to a great many industries."

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