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OBSERVATIONS ON THE 1971 SUMMER RED TIDE IN TAMPA BAY, FLORIDA[1]

K. A. Steidinger and R. M. Ingle

Florida Department of Natural Resources Marine Research Laboratory
St. Petersburg, Florida 33731

ABSTRACT

A 3½ month summer red tide (Florida west coast) caused by the unarmored dinoflagellate, Gymnodinium breve, is described and discussed. Observations support the following: 1) estuaries normally present a low salinity barrier to this neritic species, 2) heavy cell concentrations are aided by physical factors rather than increased cell division, 3) inshore and nearshore reef fisheries are the only ones affected and then only temporarily, and 4) commercial bivalves are safe for human consumption 1-2 months after a red tide has ended. Further it is suggested that 1) G. breve may bloom from a resident cyst population, 2) pollution does not trigger a Florida red tide, 3) G. breve probably blooms almost annually, and 4) major Florida red tides can be predicted by monitoring programs.

INTRODUCTION

The 1971 summer red tide in Tampa Bay, Florida and surrounding Gulf of Mexico waters provided an opportunity to evaluate and substantiate past concepts of red tide dynamics. It is felt that documentation and interpretation of this specific outbreak will lead to a better understanding and explanation of future Florida red tides.

The environmental optima for the much publicized 1971 outbreak were established a month prior to any released reports. A fish kill in Sarasota Bay (4-27-71) was later attributed to the presence of Gymnodinium breve, a toxic unarmored dinoflagellate. The Sarasota outbreak was of short duration and the fish kill received little notice from the public.

RESULTS AND DISCUSSION

When scattered fish kill reports along the Ft. Myers-Englewood beaches were first received (5-28-71) and the possibility of a red tide was indicated, Florida Department of Natural Resources Marine Research Laboratory biologists were sent (6-2 and 6-4) to sample inshore waters from Venice to Boca Grande. Analyses revealed heavy concentrations of the blue-green alga Oscillatoria (=Trichodesmium) erythraea and moderate concentrations of the red tide organism, Gymnodinium breve (up to 150,000 cells/liter). Subsequent samples, collected by various county health officials and FDNR law enforcement officers and examined by our laboratory staff, showed that G. breve was present as far north as St. Petersburg and that populations were steadily increasing.

Within the first two weeks of June, moderate fish mortalities occurred from Sarasota to Ft. Myers. Later, red tide blooms which originated offshore moved into two large estuaries—Charlotte Harbor and Tampa Bay.

Low Salinity Barrier

Tampa Bay, a shallow (mean depth approximately 3.4 m) drowned-river valley, is actually a complex of bays: Old Tampa Bay, Hillsborough Bay, Roberts Bay, Boca Ciega Bay, Terra Ceia Bay, and Tampa Bay proper. The complex is fairly large (approximately 587 km^2) and has recently been overdeveloped by dredging and filling of bay bottoms. Many sections have extensive fingerfills with canals and shallow bayous. Old Tampa Bay is fed by two small tributaries, Rocky and Sweetwater Creeks, while Hillsborough Bay is fed by the Hillsborough and Alafia Rivers. Tampa Bay proper is fed by Big and Little Manatee Rivers. Normally, salinity of upper reaches rarely rises high enough to support G. breve populations, but because of a severe 1970-1971 drought these salinities were between 28-30 $^{o}/oo$ instead of the normal 20 $^{o}/oo$. This enabled G. breve, once in the estuary, to survive. Calm seas, mild weather, high solar radiation, and good nutrient conditions (Tampa Bay is a highly enriched estuary) contributed substantially to the organism's proliferation. Once heavy rains drained into the bay system, decline of G. breve corresponded with decline in salinity.

In past known red tides, G. breve rarely penetrated beyond Boca Ciega Bay and lower Tampa Bay with the exception of 1963 when G. breve reached the Courtney Campbell Causeway area. Field observations showed that salinity is a limiting factor in red tide dispersal and that estuarine waters normally present a low salinity barrier. This has been suggested previously by Aldrich and Ray[2] and Morton and Burklew.[3] The concept of a low salinity barrier is also supported by earlier laboratory results[4] which revealed that G. breve has an optimal salinity range of 27-37 $^{o}/oo$ with poor survival below 24 $^{o}/oo$.

Physical Concentration vs. High Cell Division Rates

Gymnodinium breve probably divides prior to daybreak, similar to other dinoflagellates. All the population does not divide at the same time. Division rates from culture work indicate about 0.4 to 1 division/day.[5] John Finucane (National Marine Fisheries Service Biological Laboratory, St. Petersburg Beach, personal communication) was among the first to stress that high counts of G. breve (millions/liter) in a bloom were not created overnight by high rates of division. If division rates cannot account for increased population, there must be concentrating mechanisms that recruit and maintain large populations. This was also suggested by Ryther.[6] Physical parameters such as winds, tides, currents, convergences, divergences, and density gradients serve to concentrate planktonic organisms. Several of these probably influenced the Tampa Bay incident and counts as high as 21.5×10^6 cell/liter were recorded.

All samples were collected during daylight hours and no dividing cells were observed. Thus, divisions were taking place during noncollecting hours—6 PM to 9 AM—or increases in cell densities were from cyst populations. Initial sampling indicated that G. breve was entering the bay via the ship channel. Tidal exchange, particularly several high spring tides, would provide transport for the entry of G. breve and upper Tampa Bay's poor flushing rates could contribute to its retention. Once in the confinement of the bay, surface parcels of heavy G. breve populations, as well as accompanying dead fish, were continually influenced by gentle wind actions (5-10 MPH). City officials could predict the movement of dead fish by noting wind direction. Gymnodinium breve may be distributed throughout the water column but is more concentrated at the surface during daylight hours; therefore, gentle winds are capable of displacing and spreading populations. Seliger et al.[7] attributed the daily movement and accumulation of bioluminescent Pyrodinium bahamense (armored dinoflagellate) in Oyster Bay, Jamaica to 1) phototactic nature of the organism, 2) wind moving surface populations, and 3) poor flushing rates of upper bay reaches. The division rate of P. bahamense (0.3 to 1 division/day) could not account for daily increased population densities.

Dead Fishes

Not only was the wind playing a role in population dispersal but it may have been nurturing the bloom, as well. There is reason to believe that decomposing fish release suitable nutrients that stimulate G. breve growth.[8] Discoloration during the 1971 Tampa Bay bloom was heaviest in windrows of dead or badly deteriorated fish, but this localization might have been influenced also by winds acting simultaneously on all elements near the surface.

Many dead fish never surfaced but remained on the bottom. Fish floating on the surface were stopped from entering residential canals and bayous by oil booms extended across canal mouths. Cleanup crews then removed the accumulated carcasses for disposal on land. St. Petersburg city officials estimated that 2,367 tons of fish were removed during cleanup attempts costing $155,763. Normally when red tide hits, removal of dead fish is a problem only on the beaches, where they are buried in sand or removed. However, the Tampa Bay incident presented different problems because of seawall lined canals.

During fish kills, aerial surveys were useful in reporting locations of discolored seawater (a potential fish kill) and masses of dead fish. Ingle et al.[9] first brought to attention the usefulness of aerial surveys in phytoplankton blooms and red tides along the west coast of Florida.

On the evening of August 3rd hundreds of sharks (lemon, hammerhead, sand, bonnethead, and others), traveling in groups of about 20 individuals each, crowded a several square mile area in Old Tampa Bay. Charles Dugan (MRL biologist) noted these sharks gorging themselves on dead, decomposing, or dying fishes. In addition, he reported that fishermen were using old beached dead fish as bait to successfully catch sharks. Although sharks are known scavengers, this is the first report of such an incident occurring during any red tide. The day after these observations were made, only a few individual sharks were sighted. No further incidents followed, even though fish kills continued for several weeks.

The Effect of Red Tide on Fisheries

Smaller bottom fishes (catfish, eels, and other "trash" fishes) are apparently more susceptible to G. breve toxin since they are generally killed earlier and in larger numbers than are larger, faster swimming species. Species behavior and varying tolerances to G. breve toxin are obvious factors in this susceptibility. In this respect, fishermen, whether sports or commercial, have always had an understandable concern about red tides. However, data analyses for two severe red tides (1947 and 1953) showed that landings of major commercial and sport species were unaffected.[10] Contrarily, nearshore reef fish populations are affected, though temporarily. During this outbreak the Sarasota SCUBA Diving Club investigated reefs up to 10 miles offshore Venice, Florida. Their initial dives established that the reef fisheries up to 11.3 km or 13.7 m of water had been affected—no grouper, jewfish, hogfish, beau gregory, or other regular inhabitants were sighted. The invertebrate populations appeared to be relatively unaffected, with two exceptions: there was an increased stone crab population and a complete kill of the Atlantic deer cowry. Within a month, fish began to repopulate the inshore reefs, particularly jewfish and grouper (personal communication, Dr. D. E. Williamson, Sarasota SCUBA Diving Club). Another aspect of Gulf or bay fishing during red tides is that vacationers are reluctant to fish or eat fish from what they consider contaminated water. This is unfortunate because live fish showing no signs of distress are edible and present no danger.

Shellfish Toxicity

Shellfish such as oysters and clams are filter feeders and as such take in and accumulate G. breve toxin without apparent ill effects. At the first signs of a red tide, shellfish beds are monitored for toxicity by county health officials. If shellfish prove toxic or are suspect of becoming so, beds are closed to harvesting until tests indicate that the meat is safe for human consumption. Field data[3] and laboratory data[11] show that oysters detoxify at a rapid rate and that beds can probably be opened within a month or so after the end of a red tide. Toxicity data (Florida Department of Health and Rehabilitative Services, Division of Health, Jacksonville, Florida) from the 1971 summer occurrences agree, since shellfish showed no toxicity two months after the red tide had ceased in Sarasota County.

Temperature and Red Tides

The 1971 red tide was first noted in major proportions in late May and it continued in various parts of the west coast until early September, which makes it a typical red tide in duration (2-4 months). During this period, water temperatures rose as high as 33°C but were consistently high during the day, between 30 and 32°C. The occurrence of *G. breve* blooms at these temperatures is somewhat anomalous. Laboratory studies[12] showed a tolerance of 7-32°C but no growth at the extremes. Rounsefell and Nelson[5] suggested an optimal range of 16-27°C. Miss V. Stewart (Conservation Consultants, Inc., personal communication) observed *G. breve* in Tampa Bay at almost 38°C (100.3°F). Time is widely recognized as an important factor in heat stress. We feel that it might be possible for *G. breve* to tolerate high temperatures for a short time. It appears doubtful, though, in view of all other relevant evidence, that large populations of *G. breve* could continue to exist in water temperatures so much higher than their optimal range. Water temperatures in these areas have well-known fluctuations and there is a good probability that records of high temperature did not represent long term temperatures experienced for the organism.

Predicting Major Gymnodinium breve Blooms

Fish kills associated with discolored water along Florida's coast were reported as early as 1844. Periods between subsequent recorded outbreaks varied from several months to 14 years. We therefore have referred to Florida red tides as sporadic in occurrence. Localized *G. breve* blooms probably occur every year, but not all blooms turn into major outbreaks. For example, in October 1970 *G. breve* bloomed in the northeastern Gulf of Mexico and caused minor, short-lived fish kills. At almost the same time (late August-September 1970), *G. breve* was blooming along the coast of the Bay of Campeche, Mexico, but again, it was a minor outbreak. Local residents stated that such outbreaks (fish kills, associated eye and throat irritation) occurred almost annually at the end of the rainy season.[13] Because many of these outbreaks are minor and of short duration, they receive little or no publicity and are rarely described in scientific literature. These observations led us to believe that minor *G. breve* blooms of limited duration and fish kills are probably an annual event and a natural phenomenon in coastal waters of the Gulf of Mexico.

Evidence that major G. breve red tides can be predicted is accumulating. Prediction is based on two types of monitoring programs: 1) determining the iron content being discharged into estuaries by major tributaries, e. g., Charlotte Harbor,[14] and 2) biweekly collections at inshore water stations to determine the presence and abundance of G. breve. If the iron content in Peace River discharge is greater than 235,000 lb over a three month period, or if G. breve reaches concentrations greater than 5,000 cells/liter, local officials should be warned to have the necessary cleanup equipment on hand (or on call) in the event of a major outbreak. Laboratory and field data implicate chelated iron with red tides;[15, 14] however, these studies do not necessarily pinpoint iron as the triggering factor.

Environmental Changes

Pollution is a common concern among environmentalists and the general public. Therefore it is not surprising that pollution has been blamed for red tides and the resultant fish kills. However, major Florida red tides have not been increasing in frequency of occurrence (e. g., the last major red tide off the Tampa Bay-Charlotte Harbor area was in 1967 and the one before that in 1963). Certainly increased population has contributed to increased pollution but not to the initiation of major red tides. Another point to be considered is the date of the first documented fish kill and suspected G. breve red tide--1844. Florida was not populous at that time and although there may have been minor incidents of pollution, these are not comparable to present conditions. Thus it appears that nutrient enrichment from industrial and human wastes is not responsible for triggering red tides, though it may prolong them, particularly in estuaries.

Man-made physical changes to the environment should also be considered. The upper reaches of Tampa Bay have a poor flushing rate, partially due to the construction of various bridges and causeways. Even though red tides are rare in the bay because of a low salinity barrier, once G. breve enters the confines of an estuarine system the organisms can be concentrated and maintained for several days. Lastly, man is denuding the land and no doubt contributing to increased land runoff. Natural land runoff, particularly of chelated metals, has a positive correlation with the start of red tides. The actual rate of increase over the years is not known, but since major red tide outbreaks are not more common this cannot be a major factor.

Past and Present Research

The Florida Department of Natural Resources Marine Research Laboratory has, through the years, conducted or supported the major red tide research efforts in Florida. Resulting contributions to our understanding of this phenomenon include the following: 1) a positive statistical correlation between the amount of iron from river discharge and initiation of red tides,[16,14] 2) basic nutrients (e. g., phosphorus, vitamins, and others) were found not to be limiting factors, primarily because of their continuous availability,[17,15] 3) field and laboratory studies as early as 1963 showed a positive correlation between the presence (and often, abundance) of G. breve and the occurrence of toxic shellfish,[18] 4) shellfish beds can be reopened in one to two months after a red tide has ceased,[3] 5) small, confined G. breve blooms probably occur every year in the Gulf of Mexico, but massive and long-term outbreaks are sporadic, and 6) most importantly, our research has provided two potential methods of predicting major Florida red tides by a) the Ingle-Martin iron index and b) G. breve cell counts.

Many of the parameters leading to major red tides have been explored, e. g., salinity, temperature, light, water stability and movement, and nutrients; however, there are several aspects that need further clarification. For example, Finucane[19] and Wilson[20] were among the first to suggest that resident populations of G. breve exist as cysts in local sediments. With recent advances in dinoflagellate life cycle work it is becoming more apparent that encystment-excystment is a regular stage in many estuarine and neritic dinoflagellates, particularly bloom species. If a resident cyst population is involved, laboratory experiments could be designed to better understand conditions leading to encystment-excystment. Presence of such cyst populations would imply that individuals excyst in cycles but that conditions must be optimal (particularly calm seas and nutrients) to support massive cell concentrations. This would further support the theory that Gulf of Mexico waters experience isolated G. breve blooms annually but that major red tide outbreaks are sporadic.

Oscillatoria (=Trichodesmium) erythraea occurs prior to most, if not all, G. breve blooms. Do O. erythraea or associated organisms such as sulfur bacteria precondition neritic waters for G. breve growth by adding or deleting nutrients or metabolites? We are currently initiating laboratory experiments on the relationships between this blue-green alga and G. breve, as well as field studies to determine the presence and distribution of G. breve cysts in coastal sediments.

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