FLORIDA DEPARTMENT OF NATURAL RESOURCES RED TIDE RESEARCH PROGRAM[1]

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Reprinted from Proceedings of The First International Conference on Toxic Dinoflagellate Blooms, November 1974, Boston, Massachusetts. [Editor] V. R. LoCicero, Massachusetts Science and Technology Foundation, Wakefield, Massachusetts. Published 1975.

(1) Contribution No. 247, Florida Department of Natural Resources Marine Research Laboratory

ABSTRACT

The first reported fish kill accompanied by discolored water off Florida's west coast occurred in 1844. Since then, about 30 red tides have been reported, but research to define causative parameters was only activated in the early 1950's. Over the last 20 years, the Florida Department of Natural Resources (FDNR) has studied the following: 1) zone of outbreak of initiation, 2) nutrition of the causative organism, *Gymnodinium breve*, 3) hydrologic and meteorologic conditions and their importance in maintaining and transporting motile populations, 4) effects on offshore patch reef biota, 5) *G. breve* ecology in relation to shellfish toxicity, 6) taxonomy and ecology of associated phytoplankton, and 7) predictive methods.

Current FDNR research is concentrated on: 1) *G. breve* life cycle studies, 2) examining the possibility of seed beds 16 to 64 km (10 to 40 miles) offshore, 3) longevity of GB toxin in seawater and sediments, 4) susceptibility of various marine animals to GB toxin(s) in seawater or through the food-chain, 5) causes of death in affected marine animals, 6) fisheries repopulation studies, 7) further evaluation of land discharges in supporting red tides, and 8) developing methods to remove and utilize floating dead fish. This research is designed to aid in evaluating various predictive methods and to lessen economic impact. It has also become apparent that an information program is needed to educate the public on this natural phenomenon.

INTRODUCTION

Records of fish kills associated with discolored water along Florida's west coast exist from 1844. Since then, about 30 red tides have been documented (1); however, it was not until the 1946-47 red tide that scientists determined the cause (2). Florida red tides are caused by blooms of an unarmored, photosynthetic dinoflagellate, *Gymnodirium breve*. This microscopic organism produces a toxin which can kill fish and other marine animals. The toxin can also accumulate in exposed filter-feeding shellfish which then become toxic for human consumption. In the United States, *G. breve* red tides occur most frequently from the Anclote Keys to the Florida Keys, but they have occurred infrequently in the Gulf off Texas (3) and north Florida (4) as well as one incidence off the southeast coast of Florida (5). During the 1946-47 outbreak off southwest Florida, the U. S. Fish and Wildlife Service, University of Miami, and Woods Hole Oceanographic Institution initiated scientific studies to determine causal factors. Shortly thereafter, the Florida Board of Conservation (now the Florida Department of Natural Resources) became involved and since that time has actively been researching *G. breve* blooms.

PAST RESEARCH

The Florida Department of Natural Resources (FDNR) has performed or supported research in the following areas: *G. breve* morphology, nutrition of *G. breve*, biological, chemical, and physical factors involved in red tides, and prediction. The original approach, under the direction of Robert M. Ingle, past Chief of FDNR's Bureau of Marine Science and Technology, was to study coastal areas before, during, and after red tides. This was the same approach used by the U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries (now the National Marine Fisheries Service).

G. breve Morphology

Since the description of *G. breve* by Davis (2), FDNR has supported further studies of its morphology for easy, accurate identification. Wilson (6) described morphological features of motile and immotile forms of *G. breve* in culture and was the first to suggest the possibility of a sexual cycle for this species. Additionally, Steidinger, Davis, and Williams (7) and Steidinger and Williams (8) described three significant morphological differences from Davis' original description.

Nutrition of G. breve

The importance of chelators in making seawater more suitable for *G. breve* growth was first demonstrated by Wilson (9). He attributed this to two possible factors: chelators 1) reduce toxicity of heavy metals and 2) make trace metals and minor nutrients more available to the organism. Following this, studies were conducted to determine distribution and concentration of naturally occurring chelators and trace metals in west coast Florida rivers and their possible correlation with red tide outbreaks (10, 11).

Gymnodinium breve is a unicellular planktonic alga and requires specific nutrients and growth factors. Two such requirements, phosphorus and vitamin B_{12}, were studied from a field and laboratory approach. At the time of our initial studies, phosphates were a major concern and some researchers suggested that excess discharge of phosphates might be a triggering mechanism. However, extensive culture analyses by Wilson (9) produced results which, when compared with field data, showed there were more than sufficient quantities of phosphates in nearshore waters to support a bloom year round and that increased phosphates merely supported a higher cell population per volume of seawater. Stewart, Wahlquist, and Burket (12) showed that over a seven-month period, inshore seawater samples collected from Tampa Bay to Cape Romano contained sufficient vitamin B_{12} to support a *G. breve* bloom; however, this species did not bloom during the sampling period. These results indicate that although *G. breve* requires phosphates and vitamin B_{12} for growth, sufficient quantities of each is not a triggering factor.

Biological, Chemical, and Physical Factors

Since 1955, FDNR sampling programs during red tide and non-red tide years have helped establish the distribution of *G. breve* and associated phytoplankton in the eastern Gulf and adjacent waters relative to basic oceanographic parameters. Much of this information is published (1, 8, 13, 14, 15, 16) and all of the raw data is on file. *Gymnodinium breve* is a coastal species and under normal conditions is restricted by low salinities from entering estuaries where shellfish are harvested. However, during droughts which cause higher salinity regimes in bays, *G. breve* red tides once transported inshore have a greater chance of survival and shellfish exposed to the organism or the toxin in seawater can become toxic (17, 18). Field data indicate that shellfish toxicity disappears one to two months after a red tide has terminated. Steidinger (19) described the probable sequence of red tides. *Gymnodinium breve* blooms are initiated 16 to 64 km offshore. Then favorable conditions, such as sufficient nutrients and growth factors and optimal salinities and temperatures, support the bloom which is maintained and concentrated by such physical mechanisms as winds, currents, and convergence areas. This offshore bloom may also be transported to inshore waters. In addition to transport, physical conditions may influence the severity of red tide effects. For example, during the unusual 1971 spring-summer red tide (18), some patch reef communities off Sarasota sustained heavy mortalities which were due indirectly to a red tide apparently confined to bottom water beneath a thermocline (20).

PREDICTION

Prediction or early detection of red tides would obviously be of assistance in forewarning public officials of potential public health hazards and needs for fish removal. Three methods have been suggested based on past research. Ingle and co-workers (21) suggested aerial surveillance to determine locations of discolored water and fish kills. Such information coupled with meteorological and current predictions could be sufficient in approximating where dead fish, irritation, and/or fish kills could be expected over the next few days. A second method is the iron index proposed by Ingle and Martin (22). Reviewing 25 years data, they found that major red tides occur off the Charlotte Harbor area when 235,000 pounds of iron are potentially delivered in Peace River discharge over a three-month period. They did not specify iron as a triggering factor, but considered it a measurable indicator of stimulatory factors in the water. A third method suggested was regular monitoring programs to detect coastal increases in *G. breve* populations (1). This method, based on actual cell counts, could give a two- to four-week forewarning of possible fish kills. However, cell counts alone cannot be used to determine duration or path of the bloom.

CURRENT RESEARCH

Present research basically covers eight projects in three areas: biology of the causative organism and zone of initiation, pathological and ecological effects of *G. breve*, and prediction and amelioration of Florida red tides. Our goal, then, is to determine why *G. breve* blooms occur, predict their path and duration, and lessen the economic impact to affected Florida communities.

Biology of G. breve and Initiation Zone

Electron microscopic studies of *G. breve* have begun and will be used to clarify its taxonomic position, characterize different life stages and determine the presence or absence of endosymbionts. Such studies may also assess why culture specimens are apparently more fragile than field specimens. Electron microscopy of cells exposed to different light qualities is planned as part of an experiment currently being performed to test the use of fluorescent bulbs other than cool white in culturing *G. breve*.

The major thrust biologically is to determine the life cycle of this dinoflagellate. Research by Wall and Dale (23) confirms the existence of benthic resting cysts for a variety of marine dinoflagellates, and von Stosch's work (24) on dinoflagellate sexual cycles suggests that such cysts may be benthic zygotes. Such stages may exist in the life cycle of *G. breve* (25), therefore, we have initiated a program to determine the presence or absence of benthic resting stages and, if they are found to exist, map their distribution. Pyle and Wallace (26) are examining the possibility of a relationship between the presence of underground marine springs and the location of initial *G. breve* blooms. Contractual arrangements are being made to determine if relationships do occur and emphasis will be placed on possible locations of *G. breve* resting or "seed" populations.

Pathological and Ecological Effects

Shellfish toxicity and aerosol irritation can occur even though no *G. breve* cells are apparent in water samples (17, FDNR unpublished data). Therefore, field samples were collected during and after the recent 1974 red tide. Mouse bioassays are being completed to determine relative longevity of neurotoxicity in inshore waters.

Also during the 1974 winter-spring red tide, necropsies of 13 species of affected fishes were performed by FDNR pathologists (27). Several abnormalities, particularly hematological, were associated with *G. breve*—killed fish. Consequently, laboratory and field studies are in progress to determine causes of marine animal mortalities and the degree of susceptibility among different animals. Standard pathological techniques will be performed as well as electron microscopy of tissues of animals exposed to *G. breve* toxin in nature and under laboratory conditions.

Red tides most certainly influence marine populations, but the overall results and consequences have not been evaluated. In years following red tides, increased catches of shrimp and crabs are frequently reported. These observations suggest a beneficial influence of red tides by reducing predators. Contrarily, isolated patch reef kills have been documented. Consequently, a survey project to assess the effect of red tides on various vertebrate and invertebrate populations is planned. Repopulation studies are extremely important to such an endeavor and one such project continues today. In the laboratory, we will evaluate the effect of *G. breve* toxin on various developmental stages of fishes and invertebrates.

Prediction and Amelioration

Methods developed over the last several years should be pursued along with new methods such as temperature patterns (28) and remote sensing. Coupled with prediction is amelioration of economic hardships imposed by red tides. When dead fish or potential fish kill areas are located and their direction of movement determined, municipalities advised to expect dead fish could remove them quickly. A better solution would be to remove floating dead fish before they are beached. With this object in view, contractual funds have been designated to design and build harvesting and processing equipment for dead fish. Blogoslawski and co-workers (29) have developed oxidation techniques to deactivate the toxin in contained seawater aquaria systems. Such developments are important to the continued operation of commercial marine aquataria and research laboratories using coastal or bay waters affected by red tides.

CONCLUSIONS

Red tides are recurring, natural phenomena. As such, they have been influencing west Florida shelf communities for decades. Isolated communities which have been almost annihilated by red tide appear to re-establish themselves in several years. Possibly, prevention of blooms could have serious consequences on overall community interrelationships. Presently, control is not feasible and would be very difficult. Once a red tide is established, treatment and retreatment of any location would be necessary. However, if methods of prevention or control were developed, we should seriously consider whether or not to use them. We should first assess how and to what extent *G. breve* blooms affect Gulf marine communities.

Undeniably, Florida red tides create hardships through loss of revenue from such industries as tourism and sports fisheries. The economic impact can be lessened by reducing or eliminating the undesirable results of red tides such as floating or beached dead fish along our shorelines. Predicting when and where problems may arise and being prepared to meet them will greatly ease economic difficulties.

Another aspect to consider is public health; red tides are a health hazard because people can suffer from respiratory irritation and mildly toxic shellfish. Potentially, these problems can be solved through further research. Efficient fish removal will be facilitated by early detection. Medical research is being considered by the Florida Department of Health and Rehabilitative Services and the National Institute of Environmental Health Services and could result in treatments to reduce respiratory irritation during red tides.

Red tide will probably not be controlled, although theoretically, the greatest chance of success for control would arise during the initiation stage before the red tide became so geographically extensive. Of course, this would be dependent on localized sites of initiation which have not been verified, but it emphasizes the need for basic biological studies of *G. breve*. Nevertheless, Florida red tides are a current problem and require immediate solutions. Therefore, we must approach the problem of red tide practically by promoting an extensive public education program and eliminating those factors which cause undesirable economic and public health difficulties.

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