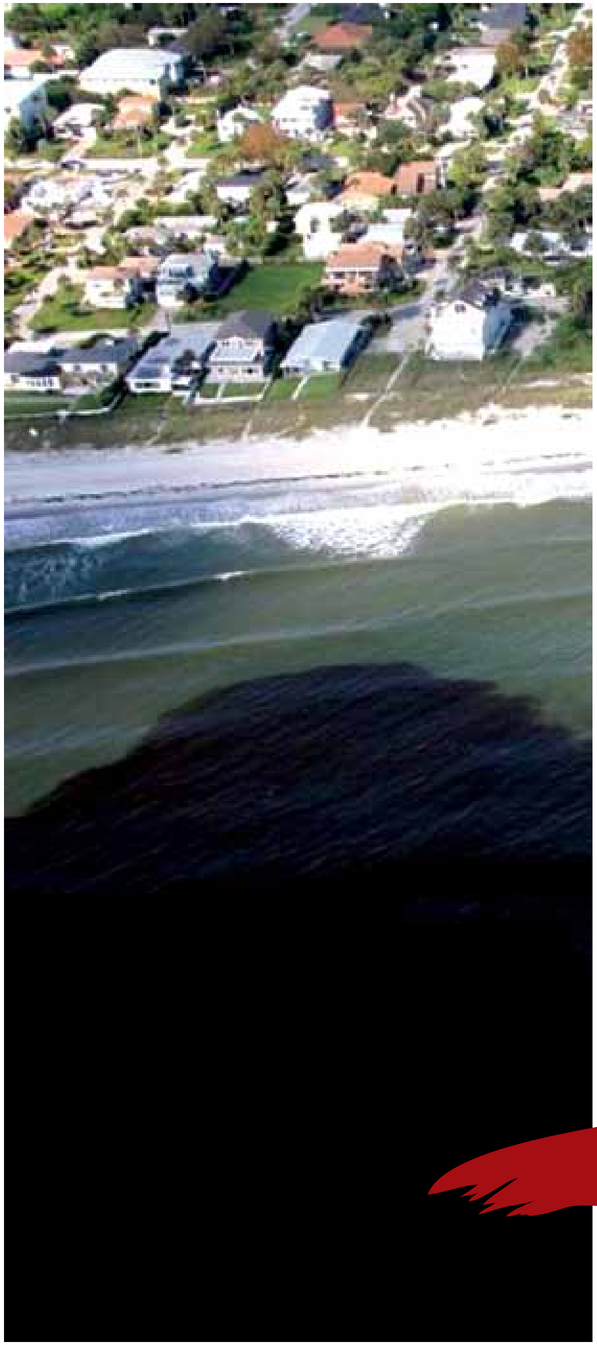

THE RED TIDE
CONTROL & MITIGATION PROGRAM

REPORT TO STAKEHOLDERS

ABOUT THE PROGRAM

GIL McRAE, DIRECTOR
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
FISH AND WILDLIFE RESEARCH INSTITUTE

Although the first accounts of red tide in Florida come from the logs of Spanish explorers, inhabitants of the region have been living with the effects of red tide since they first came to the area thousands of years ago. As the coastal population of Florida has grown, so too has the awareness of red tide and its impacts on those living on or visiting our coast. Extensive red tides can create public health risks, affect production and revenue of several marine industries, affect the economy of local communities, and ultimately affect the quality of life of those impacted. Despite the importance of red tide to Floridians, there has been little concerted effort to explore options to control and mitigate the effects of the blooms. In 2007, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI) in partnership with the citizens' group START (Solutions To Avoid Red Tide), established the Red Tide Control and Mitigation Program. This competitive grant program funded a number of important projects designed to minimize the size, intensity, or duration of *Karenia brevis* blooms or reduce the environmental, economic, social, or public health impacts of future red tides in Florida. Proposals were reviewed by a panel consisting of scientists, managers, and citizens representing FWC-FWRI, START, Florida Department of Agriculture and Consumer Services, Florida Department of Environmental Protection, Florida Department of Health, Collier and Lee county governments, University of South Florida, Sierra Club, and the Sanibel Sea School.

Between 2007 and 2009, the program funded 12 projects addressing numerous topics including effects on human health; outreach and education strategies; economic impact investigations; and biological, chemical, or physical control of red tide blooms or their toxins. This report presents overviews of projects funded through 2009 and represents a significant contribution to our understanding of red tide impacts and how to deal with them in Florida. My sincere thanks go out to our many partners in this effort, and I look forward to our continued collaboration as we work together to address these complex issues.

Barbara Kirkpatrick

CONTENTS

INTRODUCTION

4 What is red tide?

7 The Red Tide Control and Mitigation Program

OVERVIEW OF RED TIDE CONTROL AND MITIGATION PROJECTS:

ALLEVIATING HUMAN HEALTH IMPACTS

8 Expansion of the Beach Conditions Reporting System to Collier County: reducing the public health impacts from Karenia brevis aerosols

10 Poison control, podcasts, and partnerships

12 Measuring the airways inflammation in asthmatic children during red tide exposure

14 Effects of brevetoxin exposure on signal transduction pathways in immune cells

16 Examination of fetal uptake and potential developmental effects of brevetoxin in mice

OUTREACH AND EDUCATION STRATEGIES

18 Production of a film documentary on Florida red tides for TV broadcasting

20 Red tide mitigation through strategic education and outreach

ECONOMIC IMPACT INVESTIGATIONS

22 Estimating the socio-economic costs of mitigating respiratory ailments caused by Florida blooms of *Karenia brevis*

BIOLOGICAL, CHEMICAL, OR PHYSICAL CONTROL OF BLOOMS AND THEIR TOXINS

24 Biological control of *Karenia brevis* toxicity

26 Parasitic *Amoebophrya* sp. in *Karenia* species: examining its presence and role in natural bloom decline, and its potential as a biological control agent

28 Mitigating the harmful effects of Florida red tides using brevetoxin-specific complexing agents

30 Nutrient controls contributing to *Karenia brevis* blooms in the Gulf of Mexico

APPENDIX

32 Principal Investigator contact information and list of collaborators

FWC

Karenia brevis (scanning electron microscope photo)

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Aerial view of a *Karenia brevis* bloom

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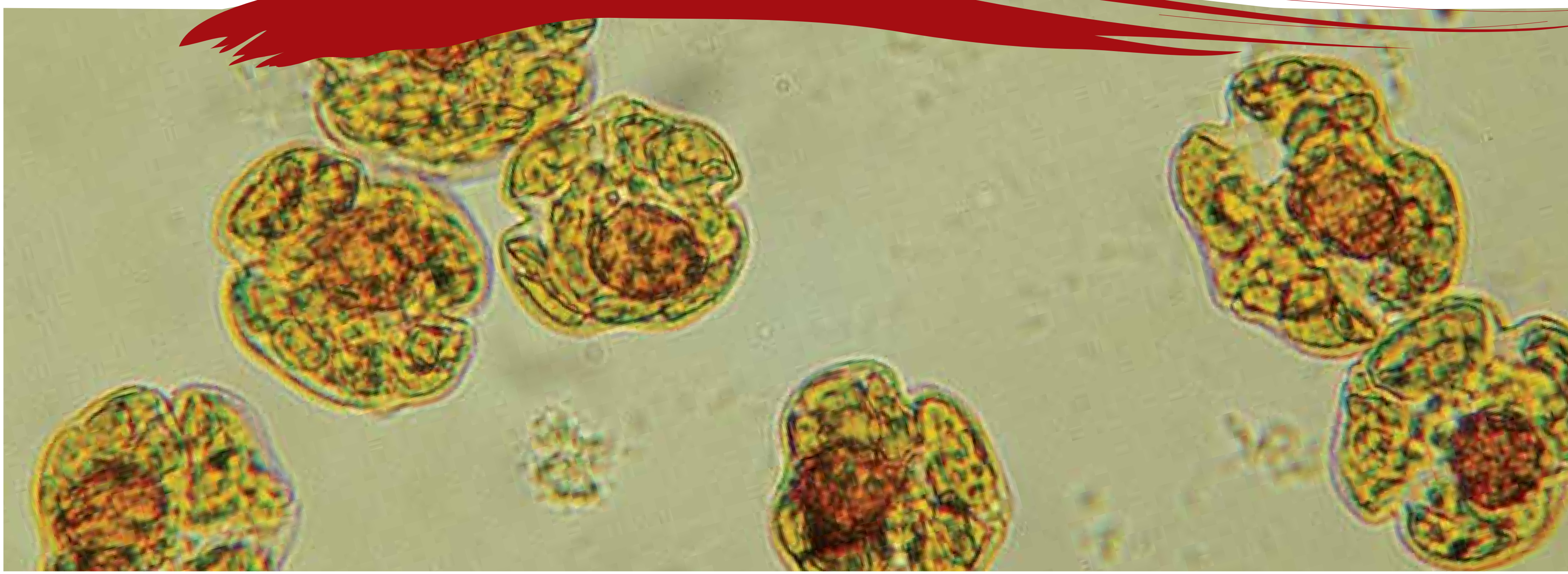
Scientists conducting offshore red tide sampling

WHAT IS RED TIDE?

"Red tide" is a general term used worldwide to describe many different kinds of harmful algal blooms or **HABs**. However, the term is misleading because these blooms are not always red (they can be brown, blue, green, yellow, and more), and they have nothing to do with the tide. Algal blooms are higher-than-normal concentrations of algae. Harmful algal blooms are blooms of toxic or nuisance algal species that may pose a serious and recurrent threat to human health, wildlife, marine ecosystems, fisheries, coastal aesthetics, and our economy.

Their **harmful** or negative effects may be visible or hidden. Some are visible, such as dead or dying fish floating on the water or washed up on the shore. Other effects are hidden: blooms can disrupt the food chain by killing organisms that fish and shellfish eat, and habitat can be lost when blooms smother aquatic plants and deprive them of light. HABs may make people sick when they eat contaminated seafood or inhale toxic seaspray.

Algal can refer to either microscopic (seen only under a microscope) plant-like cells or larger aquatic plants that can be seen with the unaided eye, such as "sea lettuce." Both types of algae can be found in seawater, brackish water, or fresh water. The term "algal" suggests plants that have chlorophyll, as land plants do. Almost all HAB species can be classified as plant-like microalgae that need light and carbon dioxide to make their own food using chlorophyll.



Mote Marine Laboratory

A **bloom** is a higher than normal amount of algae in the water. What concentration of algae constitutes a bloom is different for each algal species. For one species it may be 200 algal cells per liter of seawater and for another it may be 2 million cells per liter. Blooms occur when algal growth exceeds losses (e.g., cells dying or being eaten) or when conditions result in the physical concentration of algal cells.

Harmful algal blooms are produced by flagellates, diatoms, and blue-green algae, organisms that are members of the **phytoplankton** community. "Phyto" means "plant," and "plankton" means that they drift with the currents. **Flagellates** are single cells with whip-like appendages (flagella) that enable them to move up and down in the water column, traveling up to 15–20 meters a day. This group includes dinoflagellates (armored flagellates). Approximately 70 percent of HAB species are **dinoflagellates**, and some of these produce toxins that are among the most potent known to man. **Diatoms** are organisms with a cell wall of glass (silica) that can be individual cells or attached in chains. They can float at the water's surface or sink to the depths of the ocean. **Blue-green algae** (also called Cyanobacteria) are among the oldest bacteria found on earth. They have plant pigments like algae, but they do not have an internal microstructure like that of the diatoms and flagellates. Individual cells, filaments, or colonies often float at the surface of the water and generally appear blue-green.

WHAT IS FLORIDA RED TIDE?

Florida red tide refers specifically to one of the most troublesome HAB species in the Gulf of Mexico and along Florida's Atlantic coast -- the dinoflagellate ***Karenia brevis*** (shown on page 4). The toxins produced by *Karenia brevis*, called **brevetoxins**, are **neurotoxins** that cause damage to nerve cells or tissues. Brevetoxins can kill large numbers of fish, birds, and other marine animals. Filter-feeding shellfish consume *Karenia brevis* and brevetoxins and can retain the toxins, making the shellfish poisonous for humans to eat. Red tide toxins are released into the air (**aerosolized brevetoxins**) through seaspray. People that inhale aerosolized brevetoxins suffer from respiratory symptoms or illness including itchy and watery eyes, wheezing, shortness of breath, coughing, and chest tightness. The effects of Florida red tide are seen almost every year, driving coastal residents and tourists from beaches and impacting local and state economies.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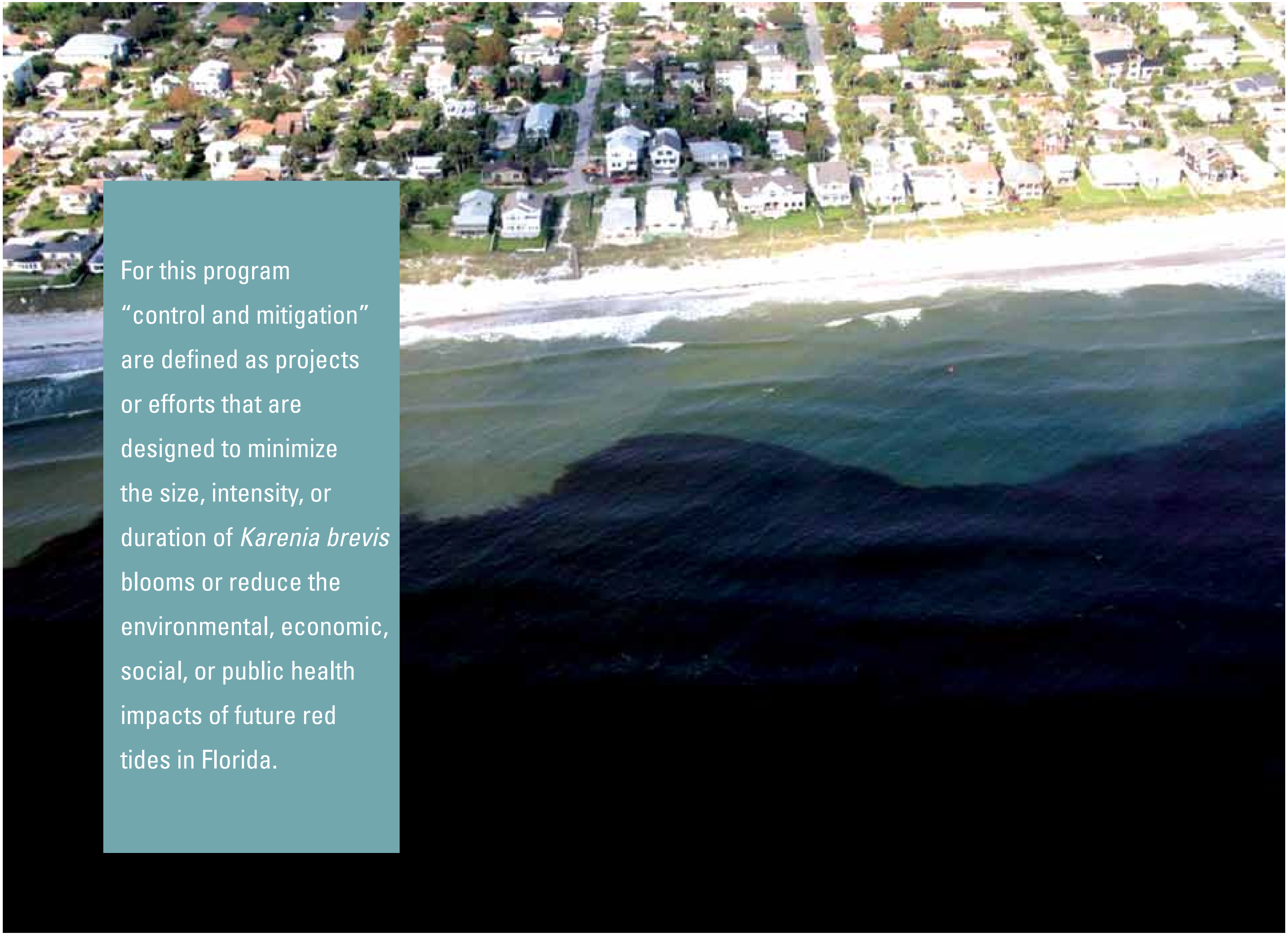

For this program "control and mitigation" are defined as projects or efforts that are designed to minimize the size, intensity, or duration of *Karenia brevis* blooms or reduce the environmental, economic, social, or public health impacts of future red tides in Florida.

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THE RED TIDE CONTROL AND MITIGATION PROGRAM

One of the first attempts to manage harmful algal blooms was directed at Florida red tide in the 1950's, and there is now a global effort to manage many different HABs. These efforts can focus on removing the organisms or their toxins directly (**control**) or on ways to minimize their impacts (**mitigation**).

As a result of increased funding for red tide research provided by the Florida Legislature, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI) directed $1,000,000 each year between 2007 and 2009 to explore environmentally acceptable techniques or technologies to control or mitigate *Karenia brevis* red tide blooms and their effects in Florida.

To do this, the FWC-FWRI established a competitive grant program called the **Red Tide Control and Mitigation Program**. Proposals were requested for projects or efforts designed to minimize the size, intensity, or duration of Florida red tides or reduce the environmental, economic, social, or public health impacts of future Florida red tides.

Grant proposals were submitted to FWC-FWRI but were evaluated by an independent panel of partners and stakeholders. The nine-member Red Tide Control and Mitigation Panel, composed of representatives from local and state government, universities, and nonprofit organizations, provided expert reviews of the submitted proposals and made funding recommendations to the FWC-FWRI Grants Committee. The FWC-FWRI Grants Committee then considered the Panel reviews and made final grant award recommendations.

A Red Tide Control and Mitigation grant was also issued to Solutions To Avoid Red Tide (START) to promote and publicize the Red Tide Control and Mitigation Program. START is a nonprofit organization dedicated to promoting efforts for control and mitigation of Florida red tide in an environmentally responsible manner. START is committed to education outreach as its primary mitigation strategy.

In all, the Red Tide Control and Mitigation Program funded 12 projects that addressed Florida red tide control and mitigation from many different angles including alleviating human health impacts; outreach and education strategies; economic impact investigations; and biological, chemical, or physical control of blooms or their toxins. This report presents overviews of projects funded through 2009. As a result of state budget cuts that began in 2008, the program was ended and its reinstatement is uncertain.

EXPANSION OF THE BEACH CONDITIONS REPORTING SYSTEM TO COLLIER COUNTY: REDUCING THE PUBLIC HEALTH IMPACTS FROM *Karenia brevis* AEROSOLS

MOTE MARINE LABORATORY,
BARBARA KIRKPATRICK

PROJECT SNAPSHOT

Mote Marine Laboratory used funds from the Red Tide Control and Mitigation Program to expand the Beach Conditions Reporting System to several beaches in Collier County, adding to existing systems in Pinellas, Manatee, Sarasota, and Lee counties.

INTRODUCTION

Because inhaling brevetoxins harms human health, there is a need to minimize human exposure to these airborne toxins. The Beach Conditions Reporting System is a real-time reporting system that helps decrease human exposure to Florida red tide. Park rangers, lifeguards, and other volunteers on Florida's Gulf beaches report beach conditions twice a day. Reports include information such as whether dead fish are present, whether beachgoers are having respiratory irritation, and the water color and wind direction. Beachgoers can access this information about their favorite beach by calling a hotline (941-BEACHES) or from Mote Marine Laboratory's Web site (www.mote.org/beaches). This system allows beach visitors to make informed decisions on which beaches have minimal exposure to brevetoxins.

PROJECT GOALS

The goal of this project was to expand the Beach Conditions Reporting System by establishing and maintaining new sites in Collier County.

FINDINGS AND ACCOMPLISHMENTS

The Beach Conditions Reporting System was set up for several sites in Collier County and went "live" January 10, 2008 (see Figure 1, Collier County splash page). At the request of users, an e-mail subscription service was also developed that provides users with twice-daily reports, saving the step of having to go to the Web site directly. The e-mail service began July 1, 2008, in time for the Fourth of July holiday. Conditions are also e-mailed every Monday to the National Oceanic and Atmospheric Administration for use in their Gulf of Mexico Harmful Algal Bloom bulletins. The NOAA HAB Bulletins (http://tidesandcurrents.noaa.gov/hab/bulletins.html) provide bloom location, forecast of short-term bloom movement, and likelihood of adverse health effects due to Florida red tide.

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As seen in Figure 2, users of the Beach Conditions Reporting System are located all over the United States.

POTENTIAL APPLICATIONS

Through the "contact us" button as well as a brief, voluntary user survey on the Web site, feedback has been overwhelmingly positive about the usefulness of the information that the system provides. Although the system was started to minimize the health impacts of toxic Florida red tide aerosols, users also find the information on surf conditions, water clarity, and presence of red drift algae and other macroalgae extremely helpful in maximizing their experience at the beach. Expanding the Beach Conditions Reporting System to provide this information for all of Florida's public beaches will help minimize red tide exposures and maximize beach enjoyment in the future.

FOR MORE INFORMATION PLEASE READ:

Workshop Leads to Local Red Tide Data Collection in Florida. 2008. Coastal Services magazine, p. 2-3. Available: http://www.csc.noaa.gov/magazine/2008/02/article1.html

See Appendix for Principal Investigator contact information and project collaborators.

FIGURE 1 Beach Conditions Reporting System, Collier County

FIGURE 2 Beach Conditions Reporting System users throughout the United States

POISON CONTROL, PODCASTS, AND PARTNERSHIPS

FLORIDA DEPARTMENT OF HEALTH, ANDREW REICH

PROJECT SNAPSHOT

This project takes a multi-prong approach to protecting human health from the effects of Florida red tides by providing up-to-date and accurate information to the public, medical professionals, and resource managers through a Distance Learning Program, presentations and educational materials; by production of a Public Service Announcement; and by maintaining and upgrading a 24-hour Aquatic Toxins Hotline.

INTRODUCTION

In the past 20 years, more people have been moving to the Florida coast, and coastal vacationers and recreation have increased. The growing population at risk of exposure to Florida red tides through eating seafood, having skin contact, and inhaling brevetoxins creates a need for consistent public health communication and education strategies. The Florida Department of Health worked closely with partners such as Mote Marine Laboratory, Solutions To Avoid Red Tide, and the Florida Poison Information Center-Miami to tackle this challenge.

PROJECT GOALS

This project focused on developing and implementing up-to-date training materials for health care professionals (such as physicians, nurses, and toxicologists) to help them identify, diagnose, and report illness related to Florida red tide. Other efforts involved outreach and education for residents and visitors by training coastal managers and parks workers. Finally, the project aimed to expand public knowledge of the Aquatic Toxins Hotline and to improve its services.

FINDINGS AND ACCOMPLISHMENTS

This project developed and coordinated a Distance Learning Program on HABs and Florida red tide for health professionals. "Florida Red Tide and the Healthcare Provider" was broadcast from WFSU studios to 545 viewers. A DVD of the program was created, and the PowerPoint presentations from this broadcast are available on-line at the Florida Poison Information Center-Miami's Web site (http://www.med.miami.edu/poisoncontrol/x57.xml) and the Florida Department of Health's Aquatic Toxins Website (http://www.myfloridaeh.com/medicine/aquatic/Education_and_Outreach_Materials.htm).

Florida Poison Information Center – Miami

Specialist in Poison Information, Florida Poison Information Center, Miami

Florida Poison Information Center – Miami

"Florida Red Tide and the Healthcare Provider" (Left to right: Dr. Lora E. Fleming, Andrew Reich, and Wendy Stephan)

Dr. Richard Weisman of the Florida Poison Information Center presented information on Florida red tide and its potential human-health impacts at five South Florida hospitals, training 60 health-care professionals to recognize and treat marine-toxin illness.

The Florida Department of Health and project partners met with coastal managers involved with Florida red tide issues to find out what types of information they would find useful, and materials were distributed to managers of protected marine resources and state and local parks, as well as other coastal managers and their staff. Each was also given a computer memory stick with Florida red tide-related information and contacts.

The Aquatic Toxins Hotline (1-888-232-8635) is a toll-free, automated information system operating 24 / 7 / 365. The Hotline serves both the public and health professionals, providing current information on Florida red tide and other marine toxins. Project funding enabled the Aquatic Toxins Hotline to continue informing callers of the locations of *Karenia brevis* blooms and giving them the option of speaking to a Specialist in Poison Information at the Florida Poison Information Center -Miami. The Specialists in Poison Information are physicians, nurses, and pharmacists certified by the American Association of Poison Control Centers in poison management who give personalized treatment and prevention advice. The Aquatic Toxins Hotline also upgraded its automated menu and recorded information system to improve caller satisfaction and ease of use. Additionally, a series of Hotline ads was made for use during Florida red tide blooms.

POTENTIAL APPLICATIONS

The products developed by this project are great sources for keeping the public informed about Florida red tide. The Distance Learning Program can easily be adapted for the general public to educate communities at risk of brevetoxin exposure. Continued evaluation and improvement of the Aquatic Toxins Hotline will help to minimize human health impacts from Florida red tide exposure.

See Appendix for Principal Investigator contact information and project collaborators.

MEASURING THE AIRWAYS INFLAMMATION IN ASTHMATIC CHILDREN DURING RED TIDE EXPOSURE

UNIVERSITY OF SOUTH FLORIDA,
MORNA DORSEY

PROJECT SNAPSHOT

What are the effects of red tide exposure to asthmatic children? Scientists studied airway inflammation in asthmatic children who had spent an hour on the beach during periods with no red tide. By comparing this data to airway inflammation in these children during a red tide, scientists hope to provide recommendations regarding appropriate medications for asthmatic children during red tide blooms.

INTRODUCTION

With the growing rate of asthma, particularly in children, there is increasing concern over things in the environment that may trigger an asthma attack. In experiments with animals, inhaling brevetoxins caused significant bronchoconstriction (reduced airflow to the lungs from muscle tightening). People, particularly those with asthma, also report large increases in respiratory symptoms such as coughing or difficulty breathing after being near *Karenia brevis* red tides. Some human-health research has looked at how asthmatics over the age of 12 respond to red tide exposure. However, not much is understood about the response of younger children.

PROJECT GOALS

The goal of this study was to see whether the airways of children with asthma became inflamed when exposed to brevetoxins. If the respiratory effects of brevetoxins are due not to airway inflammation but rather to a mechanism of the nervous system, the medications that doctors advise their patients to take for prevention or treatment of symptoms may be different. Measuring exhaled nitric oxide is a noninvasive means of determining whether airways are inflamed and of assessing a person's response to anti-inflammatory medications.

FINDINGS AND ACCOMPLISHMENTS

This project planned to conduct a field study during a *Karenia brevis* bloom followed by a non-bloom field study and to compare results. However, only a non-bloom field study was done because a *Karenia brevis* bloom did not occur during the study period.

Scientists measured levels of exhaled nitric oxide in 22 healthy children and 14 asthmatic children at St. Petersburg Beach before and after a 1-hour beach walk. Water samples were analyzed to ensure the lack of red tide. The study data showed that the average level of nitric oxide exhaled by asthmatic children was significantly higher than that of healthy children. For both the healthy and asthmatic children, there was little change in exhaled nitric oxide after the 1-hour beach walk (see Table2).

The non-bloom field study showed that simply being exposed to the beach and active walking for one hour does not increase airway inflammation or worsen bronchoconstriction in asthmatic children. Because no changes were seen in this control study, these factors (being at the beach and active walking) can be excluded as contributing to any changes in nitric oxide levels that may be measured in children in a future study that will be performed during a Florida red tide.

POTENTIAL APPLICATIONS

Researchers have recruited an additional 36 children to perform the same tests during a *Karenia brevis* bloom. Results from non-bloom and bloom studies can then be compared, and researchers will be able to better describe how exposure to brevetoxins creates breathing problems for children with asthma.

The results of this work will help in giving health advice to the parents of asthmatic children on the best medications for them to take during red tide blooms. It will also allow families with asthmatic children to better plan their days at the beach.

See Appendix for Principal Investigator contact information and project collaborators.

	Asthmatic	Healthy
Number of patients	14	22
Age range (median)	6-8 (10)	7-17 (11)
Male:Female	9:5	10:12

TABLE 1 Patient demographics

	Asthmatic		Healthy	
	Pre-walk	***Post-walk***	***Pre-walk***	***Post-walk***
Exhaled nitric oxide (ppb) (mean ppb)	***9.6 – 65.3 (38.4)***	***8.2 – 68.6 (42.2)***	***4.3 – 15.6 (12.1)***	***4.6 – 16.1 (13.7)***

TABLE 2 Data showing that exhaled nitric oxide levels (in parts per billion or ppb) were higher in asthmatic children than healthy children and that nitric oxide levels before and after a one-hour beach walk did not change for either group.


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EFFECTS OF BREVETOXIN EXPOSURE ON SIGNAL TRANSDUCTION PATHWAYS IN IMMUNE CELLS

MOTE MARINE LABORATORY,
CATHY WALSH

PROJECT SNAPSHOT

Previous research suggests that brevetoxins may affect the human immune system. This study using human immune cells demonstrated that brevetoxins enhance the ability of calcium to enter the cells and may alter signaling pathways responsible for initiating immune cell functions.

INTRODUCTION

Many reports show that after brevetoxins are inhaled, they travel throughout the body. A recent emergency room study also reported an increase in pneumonia patients during Florida red tides. These observations suggest that respiratory problems experienced during a red tide may be only one consequence of inhaling brevetoxins and that there may be long-term health problems.

To understand whether there are long-term effects from inhaling brevetoxins, detailed studies of cell mechanics are needed. Knowing how human immune cells respond to brevetoxins will help researchers to know whether inhaling red tide toxins decreases immune function.

PROJECT GOALS

The primary focus was to discover how brevetoxins may impact human immune cells. Healthy immune response has many components. This research focused on calcium signaling, which activates many important immune-cell pathways needed to start immune responses.

FINDINGS AND ACCOMPLISHMENTS

In laboratory experiments, researchers used Jurkat cells, cultured human T cells that are widely used in medical research. Human T cells are a type of white blood cell that is central to immune function. Jurkat cells were treated with PbTx-2, a brevetoxin commonly present in high amounts in red tide blooms and seaspray, in order to learn how brevetoxins affect the ability of calcium to enter immune cells and whether brevetoxins affect signaling pathways responsible for initiating immune cell functions. When Jurkat cells were exposed to brevetoxin (PbTx-2), expression of a calcium channel (SK2) and the amount of calcium entering the cell increased. One signaling pathway (ERK1/2) was not affected, but another (Src kinase) was activated.

Calcium channels, such as SK2, and calcium transport into cells are important in activating cell signaling pathways, such as ERK1/2 or Src kinase, that are involved in immune response. Because calcium channel expression and the amount of calcium entering the cell were increased (see Figure 1), researchers investigated whether brevetoxins affected pathways that respond to calcium. Components of the signaling pathways are key enzymes that regulate and are involved in a range of cellular functions required by our immune system to generate effective responses. Results indicated significant activation of Src kinase in Jurkat cells (see Figure 2). The fact that the Src pathway was affected, but not the ERK1/2, provides information about specific molecular targets of brevetoxins.

Exposing immune cells to brevetoxin (PbTx-2) in cell culture produced several changes in immune

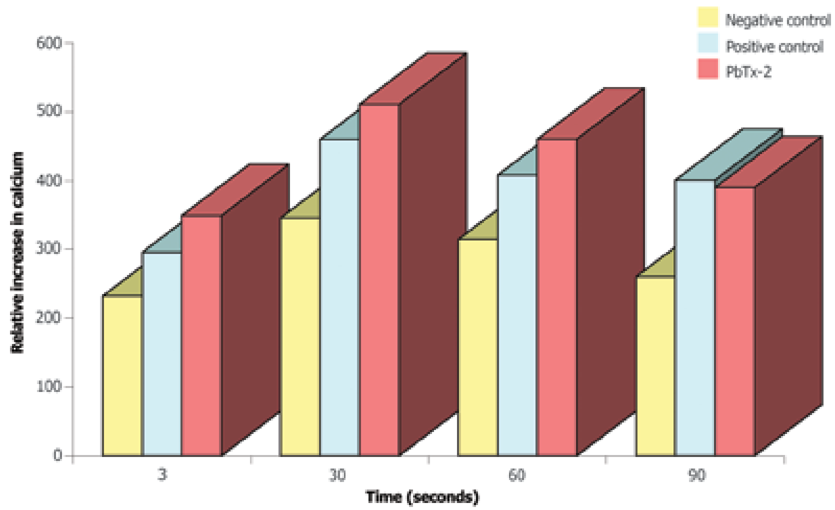


FIGURE 1 Graph displaying the effect of brevetoxin (PbTx-2) on the influx of calcium into Jurkat cells showing that within seconds of exposure, the calcium inside the Jurkat cells increased. Bars represent the average result of six repeated experiments.

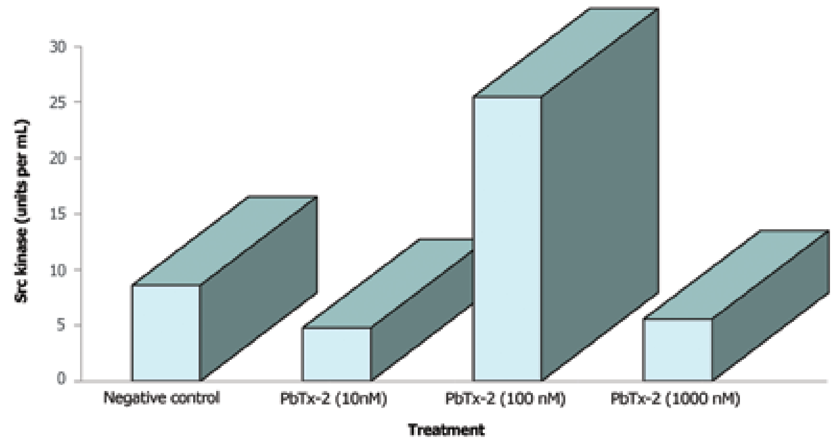


FIGURE 2 Graph displaying that at a certain concentration (100 nanomolar) brevetoxin (PbTx-2) turned on the Src kinase immune cell signaling pathway in Jurkat cells. Bars represent the average result of four repeated experiments.

system components needed for healthy immune response. Further studies are needed to determine whether these changes are also seen after environmental exposure to aerosolized brevetoxins.

POTENTIAL APPLICATIONS

This research contributes significantly to knowledge of the long-term impacts of red tide toxins on human health and helps lay the foundation for future human health studies on environmental brevetoxin exposure.

To successfully treat or reduce health effects related to red tide exposure, it is critical to identify cellular targets of brevetoxins within the immune system. When specific targets are known, efforts to prevent or treat the human health effects from brevetoxin exposure can begin. For example, the SK2 calcium channels have been considered as drug targets for treating various diseases, including sickle cell anemia, cystic fibrosis, graft-versus-host disease, rheumatoid arthritis, inflammatory bowel disease, and multiple sclerosis. Confirming the role of SK2 channels in health effects associated with brevetoxin exposure may lead to new ways of preventing or treating brevetoxin-related health effects.

See Appendix for Principal Investigator contact information and project collaborators.

Mote Marine Laboratory

EXAMINATION OF FETAL UPTAKE AND POTENTIAL DEVELOPMENTAL EFFECTS OF BREVETOXIN IN MICE

LOVELACE RESPIRATORY RESEARCH INSTITUTE, JANET BENSON

PROJECT SNAPSHOT

Is it safe for pregnant women to be at the beach during red tide? Using mice as a mammalian model, researchers found that brevetoxins are passed to unborn mice but did not observe problems with pregnancy, fetal viability and growth, or any external malformations of the fetal mice.

INTRODUCTION

Every year, about 22,000 pregnant Florida residents may inhale seaspray containing brevetoxins because they live or work near red tide-affected beaches. Studies have shown brevetoxins to be toxic to some fish larvae and to sea urchin embryos. Other studies have suggested that brevetoxins may cross the placenta in pregnant mice and pass into the fetus. Nothing is yet known about the potential health consequences from brevetoxin exposure during pregnancy in humans.

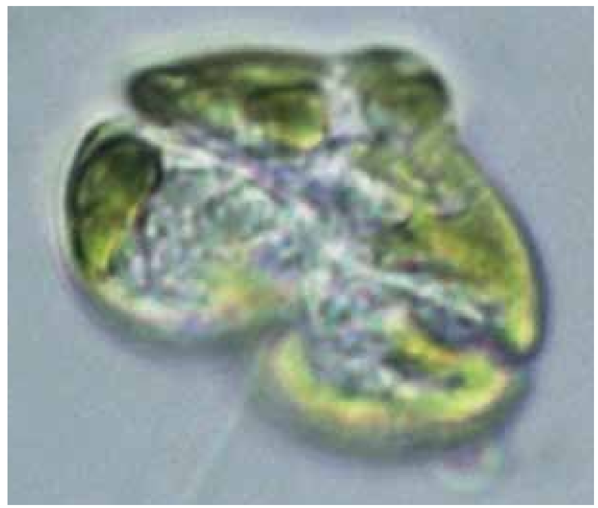
PROJECT GOALS

The main purpose of this study was to work towards answering the question, Is it safe for pregnant women to be at the beach during red tide? The project goals were to see whether low-level exposure to brevetoxins affects development of fetal mice and to see how much brevetoxin can be found in maternal and fetal organs after 14 days of exposure. The tested mice represented pregnant women who are recreationally exposed to red tide for short periods (low-level) and coastal residents who are exposed to low levels of red tide toxins over a period of time (14 days).

FINDINGS AND ACCOMPLISHMENTS

Researchers used osmotic pumps to slowly expose pregnant mice to brevetoxins from gestation through fetal organ development. The total daily dose was approximately 200 times higher than pregnant women are exposed to during one 2-hour visit to a beach where Florida red tide is present. A similar number of control mice (not exposed to brevetoxins) were compared to the brevetoxin-exposed mice. At term, mice pups were examined for soft tissue and skeletal abnormalities, as well as amounts of brevetoxins or metabolites in maternal and fetal tissue.

Exposure to brevetoxins did not seem to cause toxicity in the mothers or cause death to mothers or pups. Pregnant mice had healthy body-weight gain during pregnancy and healthy organ weights. There were no differences in the percentage of males per litter or in the average body weights of male and female pups. No major abnormalities or effects on hearts were seen in either the exposed or the control groups.



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Karenia brevis (light microscope photo)

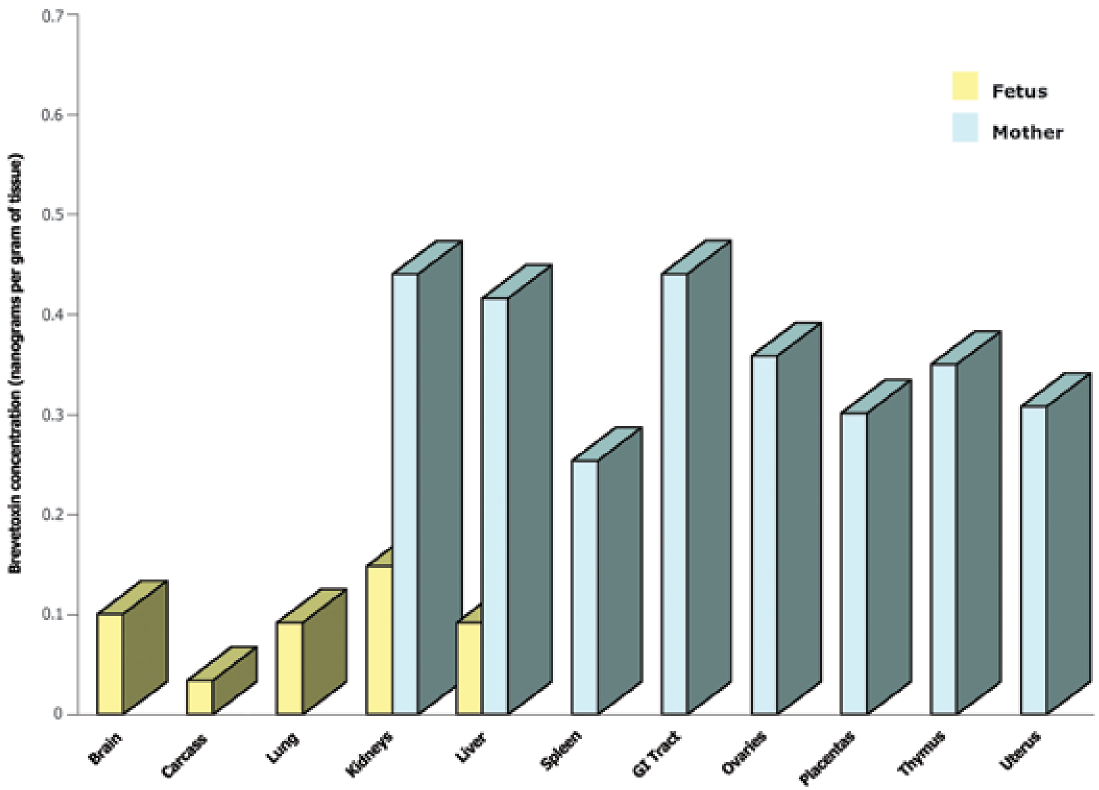

FIGURE 1 This graph displays the average brevetoxin concentrations found within organ tissues of fetal mice and mothers, showing that brevetoxins were transferred to fetal mice. However, concentrations of brevetoxins in the fetal mice were much lower than those found in the mothers.

In both groups, extra ribs in the lower back were sometimes seen. One brevetoxin-exposed pup had a cleft palate, and one unexposed pup had a malformed head. All of these defects are common to this strain of mouse and are not believed to be linked to study conditions.

Small amounts of brevetoxins were found in fetal organs and bodies. Concentrations were much lower than those found in maternal organs (see Figure 1).

POTENTIAL APPLICATIONS

This research lays the foundation for discovering whether inhaling brevetoxins will harm pregnant women or their unborn children. Although no negative effects were seen, more research is needed. Future studies will focus on whether fetal exposure harms the immune and nervous systems of newborn and juvenile mice.

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See Appendix for Principal Investigator contact information and project collaborators.

PRODUCTION OF A FILM DOCUMENTARY ON FLORIDA RED TIDES FOR TV BROADCASTING

LES FILMS DE L'ESPIGAOU,
JULIEN NAAR

PROJECT SNAPSHOT

Wildlife documentary film director Julien Naar hopes to help ease the effects of Florida red tide through an educational documentary film. Julien is working with red tide scientists and affected citizens to help tell the red tide research story through film.

INTRODUCTION

The story of Florida red tide and the progress that science has made over the years are fascinating. Although the Florida public is very interested and deeply concerned about red tide, they are often misinformed. Stories about Florida red tides are almost always exaggerated, if not totally false. The reality of the red tide phenomenon is harmful enough to Florida's businesses and wildlife, and the public's misconceptions only worsen the problem. The scientific community's knowledge needs to be made widely available to the public to reduce people's fears and misunderstandings.

Education and outreach are great ways to minimize the social and economic impacts of Florida red tide. To reach this goal, however, the information has to be true, accessible, understood, and provided in formats that the community can use in meaningful ways. Televised nature and wildlife documentaries have tremendous success in sharing information and educating the public on environmental issues.

PROJECT GOALS

This project aimed to use the combined expertise of a red tide scientist, a film producer, and a wildlife documentary director to produce a high-quality film on Florida red tide.

The project's main goal was to create a film that would educate the public about Florida red tides, reducing their harmful social and economic impacts. The film would differ from TV news reports by clearly and thoroughly describing and explaining the sources and impacts of Florida red tides. In order to maximize viewers, this film would be formatted for local television and broadcasting throughout Florida.

FINDINGS AND ACCOMPLISHMENTS

The film follows an array of scientists through an investigation of a red tide-related manatee mortality, guiding the audience through the complexity of the phenomenon. While watching the investigation unfold, viewers also learn about other Florida red tide impacts and related research that is being conducted.

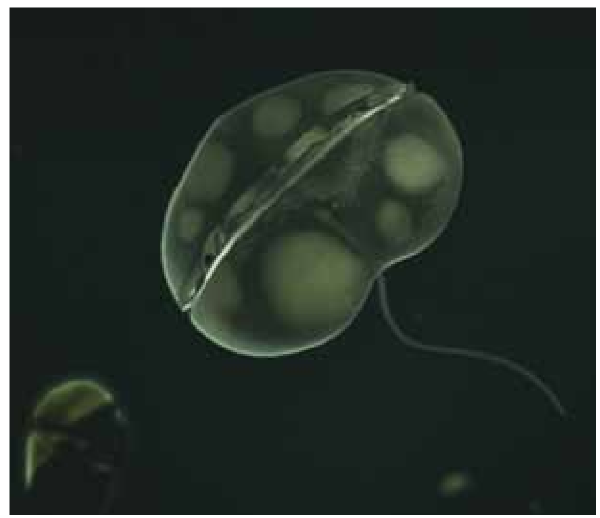

FIGURE 1 3-D animated representation of *Karenia brevis*

Les Films de L'Espigaou

Les Films de L'Espigaou

Filming of manatee health assessments at Crystal River

Les Films de L'Espigaou

Production shot of laboratory filming

Filmmakers originally planned a 26-minute film, but upon learning from local TV stations that a 52-minute film would be more marketable, they secured additional funding. Filming finished in 2009, and the film is in “final cut.” The script is in final review for scientific accuracy.

Although the effects of red tide are easily seen, *Karenia brevis* itself is extremely difficult to observe. A unique element of this film is high-quality 3-D animation representing the microscopic world of *Karenia brevis* (see Figure 1). With the help of experts, key parts of the *Karenia brevis* life cycle are shown at a level of detail that has not been shown before.

POTENTIAL APPLICATIONS

This film shares clear information on Florida red tide and will give the public a better understanding of the phenomenon. Information about the progress that science has made and how this is being used to reduce the impacts of red tide will give the public a way to assess the significance of these efforts and their results. Clearly explaining red tide health risks, such as shellfish poisoning, will raise public awareness and promote safe behavior, reducing the potential for illnesses during red tides.

This film offers an excellent educational platform for reducing the social and economic impacts of red tide. Because of the public’s strong interest in this subject, this high-quality documentary will be heavily publicized and reach many more people than other current outreach strategies.

See Appendix for Principal Investigator contact information and project collaborators.

RED TIDE MITIGATION THROUGH STRATEGIC EDUCATION AND OUTREACH

UNIVERSITY OF FLORIDA,
SHERRY L. LARKIN

PROJECT SNAPSHOT

This project aims to develop communication strategies that will help natural resource managers foster public trust, under-standing, and meaningful participation in decision making regarding potential options for red tide control and mitigation.

INTRODUCTION

Public discussions about Florida red tide can be heated. Knowing how the public feels about the different approaches being considered to potentially control Florida red tide blooms and lessen their impacts is important. By making sure the public is informed and addressing their concerns, the selected approaches for addressing the effects of Florida red tide will be more accepted and have greater economic value.

PROJECT GOALS

This project's main goals were to measure the knowledge of the public and find out how they feel about some of the methods being considered to potentially control or reduce the impacts of Florida red tide blooms, to estimate the economic value the public places on these approaches, and to determine the best ways of sharing red tide information with the public.

FINDINGS AND ACCOMPLISHMENTS

In the first year of the project, meetings of small focus groups were held to learn how different forms of information change people's views and understanding of red tide science, prevention, control, and mitigation. There were 38 participants in each focus group from four different coastal areas of Florida (the panhandle, east coast, central west coast, and southwest coast). Participants included commercial fishermen, local political leaders, resource managers, environmental activists, citizens, and business leaders. Participants responded to red tide questionnaires and were videotaped during group discussions.

Results showed that participants think Florida red tide is a very important issue because of the economic impacts on the community (60%), the environmental impacts (42%), the health impacts (37%), beach closings (35%), and the negative visual impacts (21%). When asked about desired

University of Florida

Meeting of a red tide focus group

solutions for dealing with red tide, 54% supported bloom prevention, 41% supported monitoring and mitigation strategies, 13% supported bloom control, and 9% thought that nothing should be done.

A list of participant comments and opinions about red tide control and mitigation strategies was also compiled.

Researchers are now working on a formal survey for Florida residents and visitors. The survey will provide data to measure the public's knowledge, perceptions, and preferences of different red tide control, prevention, or mitigation strategies.

POTENTIAL APPLICATIONS

It is important that the public clearly understand the costs, benefits, and risks of different red tide control and mitigation strategies for them to trust and accept these response actions. This work will help coastal managers, scientists, and policy makers understand the most effective ways of informing the public about red tide research and management in order to encourage public support of response actions and to meet long-term coastal management goals.

FOR MORE INFORMATION PLEASE VISIT:

http://plaza.ufl.edu/slarkin

See Appendix for Principal Investigator contact information and project collaborators.

University of Florida

Red tide focus group participants completing questionnaires

ESTIMATING THE SOCIO-ECONOMIC COSTS OF MITIGATING RESPIRATORY AILMENTS CAUSED BY FLORIDA BLOOMS OF *Karenia brevis*

WOODS HOLE OCEANOGRAPHIC INSTITUTION, PORTER HOAGLAND

PROJECT SNAPSHOT

What are the costs of red tide-related respiratory irritation? Researchers at the Marine Policy Center at Woods Hole Oceanographic Institution tackled this problem by looking at economic damages and management costs associated with human respiratory irritation during Florida red tides. They developed models to estimate rates of illness due to aerosolized brevetoxins and used these models to estimate a cost-of-illness range for respiratory ailments due to Karenia brevis *blooms.*

INTRODUCTION

Socio-economic cost analysis looks at both the social and economic impacts of a Florida red tide bloom. For example, breathing aerosolized brevetoxins may cause respiratory problems (coughing, sneezing, itchy and watery eyes) for beachgoers. Because they will not enjoy themselves as much as usual, this is a social impact or cost. The same bloom may cause those beachgoers to leave without dining in the area, and this lost business is an economic impact or cost. It is important to estimate the socio-economic costs of *Karenia brevis* blooms for two reasons. First, the scale of the costs will help decision-makers decide on the scale of policy responses needed. Second, knowing the incidence of costs (who is affected) will allow decision-makers to target policy responses.

PROJECT GOALS

The main goal of this project was to estimate the economic costs of human respiratory illnesses associated with *Karenia brevis* blooms. A second goal was to create a framework for decision-makers to choose the most cost-effective policies for responding to human respiratory illnesses associated with *Karenia brevis* blooms.

FINDINGS AND ACCOMPLISHMENTS

Researchers developed a statistical model (called an exposure-response model) to try to predict how many reported respiratory illnesses are due to *Karenia brevis* blooms. The model was tested using data on Sarasota Memorial Hospital emergency room visits; the amount of *Karenia brevis* present in the area; and measures of pollen, pollutants, respiratory disease (including flu outbreaks), and population changes (including tourist visits) (see Figure 1).

Researchers estimated that Florida red tides can cause huge economic costs. The cost of treating respiratory illnesses in Sarasota County alone

Mary Ellen Seyle - designWorks advertising associates

Sarasota Memorial Hospital ER

averages $200,000 per year. The costs of emergency room visits are only a conservative estimate of the total economic and social costs.

Researchers classified the main types of policy responses and identified when each response could be implemented as red tide becomes a hazard. A framework was made for evaluating the potential net benefits of policy responses to the toxic effects of *Karenia brevis* blooms, along with a method of estimating how useful policy responses must be to "break even" in economic terms. For example, two policy responses -- a Beach Conditions Reporting System and an Aquatic Toxins Hotline -- were assessed. Because it costs less to run and is just as effective at reducing costs of illness from aerosolized brevetoxins, the Beach Conditions Reporting System was more cost-effective than the Hotline.

POTENTIAL APPLICATIONS

This research is the first step in understanding the most cost-effective ways to use policies to reduce the harmful effects -- on both public health and the economy -- of respiratory illness caused by brevetoxins. More research building on these results is needed to describe the costs of illness from *Karenia brevis* blooms along the entire Florida Gulf coast. Research is also needed to measure how effective the different policies are. A policy not only must inform people but also must lead to a behavior that removes them from harm's way. Finally, social science research is needed to understand how people respond to information and how those responses may be damaging. Changes in behavior may lead to additional costs, such as lost tourism business and lost recreational benefits. These effects need to be considered in theory, but they are difficult to measure.

In general, the results of this research will increase the likelihood that decision-makers will choose cost-effective ways to respond to red tides in order to minimize their social and economic impacts in Florida.

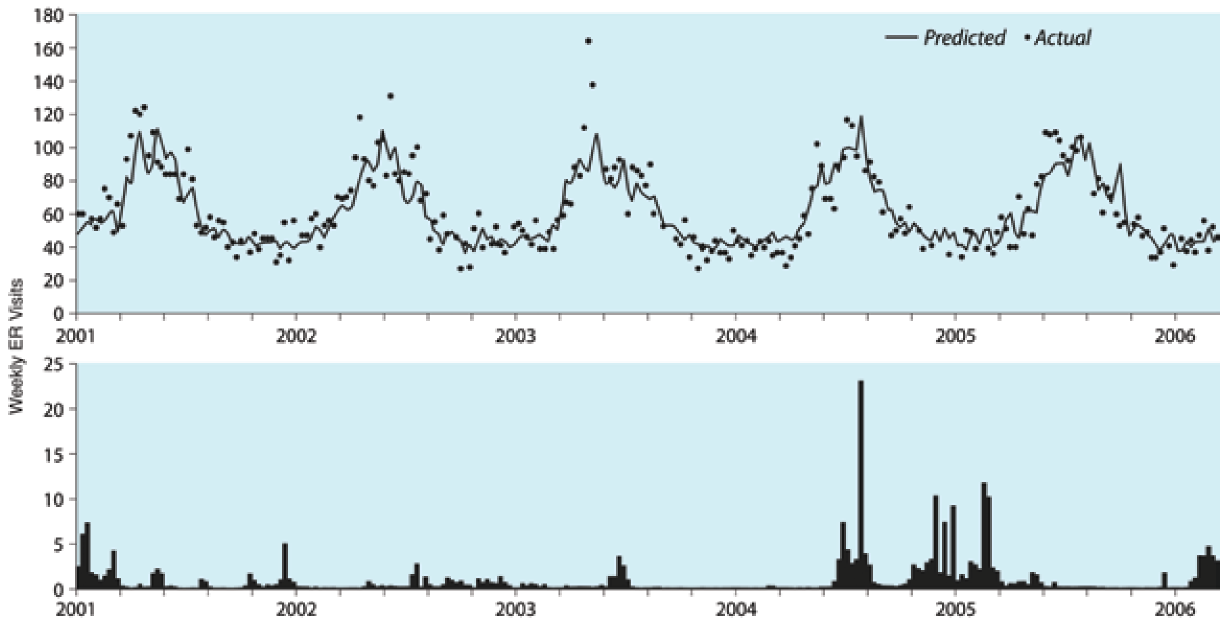

FIGURE 1 Exposure-response model for Sarasota County, Florida. The top panel compares the model predictions (solid line) with actual data (dots) on the number of weekly emergency room (ER) visits for all respiratory illnesses, demonstrating that the model accurately predicts the number of ER visits. The bottom panel shows the number of predicted weekly ER visits for respiratory illnesses associated specifically with red tides. The predictions of red tide-related ER visits are used to estimate the economic costs of illness.

FOR MORE INFORMATION, PLEASE READ:

Hoagland, P., D. Jin, L.Y. Polansky, B. Kirkpatrick, G. Kirkpatrick, L.E. Fleming, A. Reich, S.M. Watkins, S.G. Ullmann and L.C. Backer. 2009. The costs of respiratory illnesses arising from Florida Gulf Coast *Karenia brevis* blooms. *Environ. Health Persp.* 117:1239-1243.

See Appendix for Principal Investigator contact information and project collaborators.

BIOLOGICAL CONTROL OF *Karenia brevis* TOXICITY

GEORGIA INSTITUTE OF TECHNOLOGY, JULIA KUBANEK

PROJECT SNAPSHOT

Can other organisms break down red tide toxins? This study demonstrated that native Gulf of Mexico phytoplankton species are capable of detoxifying waters containing red tide. The phytoplankton do not kill Karenia brevis *cells, but they remove brevetoxin from the water column.*

INTRODUCTION

Growing concern over Florida red tide impacts has motivated researchers to understand how blooms work and how to lessen their effects. There are several forms of brevetoxin (PbTx) produced by *Karenia brevis*. Researchers at Georgia Institute of Technology have shown the amount of the most abundant Florida red tide toxin, PbTx-2, in water is reduced 50-90% when competitive phytoplankton species are present. Further understanding how this process occurs is an important step towards developing a biological control for red tide toxicity.

PROJECT GOALS

The main goals were to identify which phytoplankton competitors can degrade waterborne brevetoxins and to understand how this degradation occurs. Researchers aimed to determine whether adding live phytoplankton could be a natural biological control of *Karenia brevis* toxicity and whether this method could also benefit marine life.

FINDINGS AND ACCOMPLISHMENTS

Researchers learned that many phytoplankton competitors (across taxonomic groups, including diatoms, cryptophytes, and dinoflagellates) can remove waterborne PbTx-2 (see Figure 1). Testing for removal of other brevetoxins by the diatom *Skeletonema costatum* showed that the detoxifying effect depends on the specific form of brevetoxin (for example, PbTx-2 and -1 were removed, but PbTx-3, -6, and -9 were not removed), suggesting that enzymes play a role in the removal of brevetoxins by competitors.

By adding brevetoxins to killed cultures of *Skeletonema costatum* and finding no loss of toxin, researchers learned that live cells are required to remove brevetoxins from the water column, and that the toxin does not simply stick to cellular debris associated with the competitors. However, compounds (probably proteins) exuded by competitors are responsible for some toxin breakdown or removal.

Tests of how much *Skeletonema costatum* is needed to remove brevetoxins from the water showed that the quantity of competitor cells present has only a small impact on toxin removal. What is most important is the presence of competitor cells.

Experiments with marine invertebrates were also done to learn whether the effects of toxins on marine life could also be reduced. Tests with brine shrimp (*Artemia salina*) showed that *Skeletonema costatum* reduced brevetoxins and removed all toxic effects on the brine shrimp at environmentally realistic concentrations. Tests with the sea anemone *Aiptasia pallida* included observing physical and behavioral responses as well as toxin levels. Results showed that *Skeletonema costatum* reduced, and in some cases completely protected against, the physiological damages of brevetoxin exposure.

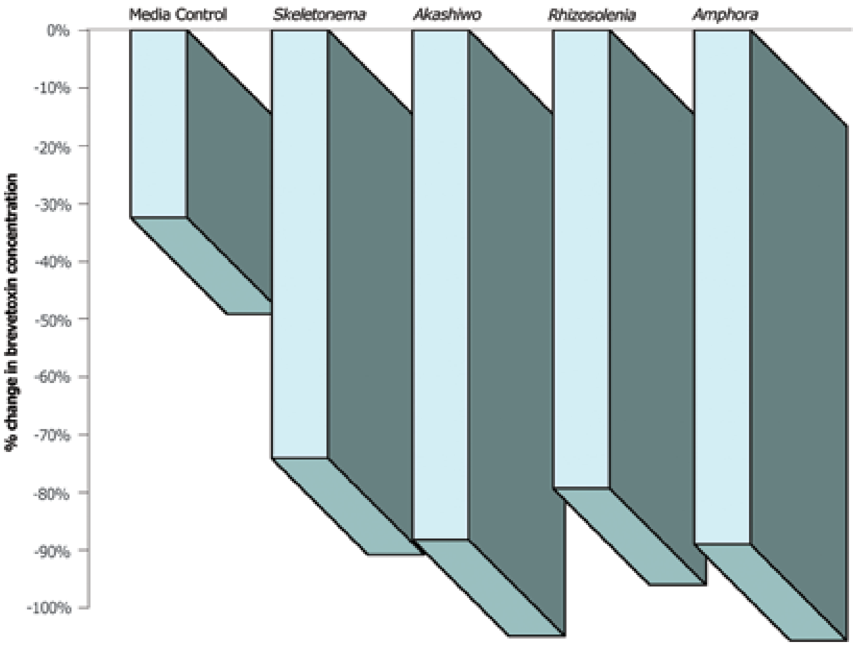

FIGURE 1 This graph shows the decrease in brevetoxin concentration observed after incubation with different phytoplankton species for 24 hours, demonstrating that many phytoplankton species can effectively remove waterborne brevetoxins.

FWC

Phytoplankton cultures grown in the laboratory

POTENTIAL APPLICATIONS

The project results give information that will help design a biological control strategy for *Karenia brevis* red tides in the Gulf of Mexico that could be tailored to different local area needs, maximizing cost-benefits. For example, because a range of phytoplankton species can remove brevetoxins, species appropriate for the local area -- those that can survive in that environment -- can be used, reducing costs of repeated applications. Knowing which brevetoxins can be removed by competitor species also gives a more realistic idea of the potential reduction. Knowing that live competitor cells in any density provide maximal removal saves both time and labor costs, as competitor phytoplankton would not have to be grown to high concentrations over long periods of time before they could be used.

Results also show that proteins and enzymes may play a key role in toxin removal. This finding could lead to developing an enzyme-based additive or a protein-adsorbent resin to remove waterborne brevetoxins.

The finding that *Skeletonema costatum* can reduce the toxic effects of brevetoxins on marine invertebrates supports using competitor phytoplankton species as control agents for *Karenia brevis* -- a mitigation strategy that not only will reduce waterborne brevetoxin levels but also could reduce negative impacts on ecosystems and marine wildlife.

See Appendix for Principal Investigator contact information and project collaborators.

PARASITIC *Amoebophrya* SP. IN *Karenia* SPECIES: EXAMINING ITS PRESENCE AND ROLE IN NATURAL BLOOM DECLINE, AND ITS POTENTIAL AS A BIOLOGICAL CONTROL AGENT

SMITHSONIAN INSTITUTION,
MARIO SENGCO

PROJECT SNAPSHOT

The goals of this project were to find out if parasites found in some harmful algal bloom species are also found in Karenia brevis *and whether these parasites could be used as a bloom control method. Although researchers did not observe the parasite enter* Karenia *cells in experiments, they found possible evidence of the parasites in natural* Karenia brevis *bloom samples.*

INTRODUCTION

Amoebophrya is a parasitic dinoflagellate that infests and kills other dinoflagellate hosts. Parasitic dinoflagellates may play a role in the ecology of bloom-forming dinoflagellates. *Amoebophrya* outbreaks in various marine systems have been linked to declining dinoflagellate blooms. Although *Amoebophrya* has not been reported to infest *Karenia* species, it has been found in related dinoflagellates. *Amoebophrya* may be the perfect candidate for controlling Florida red tide blooms.

PROJECT GOALS

The main goal was to find *Amoebophrya* in samples of *Karenia brevis* blooms. If found, *Amoebophrya* would be isolated and maintained in *Karenia* cultures to examine its biology and potential for controlling *Karenia brevis* blooms.

FINDINGS AND ACCOMPLISHMENTS

During two years, many *Karenia brevis* cultures were obtained from other laboratories. Researchers checked the weekly Florida red tide status reports, but no significant *Karenia brevis* blooms occurred during the project. During the second year, a few samples were obtained from a dense bloom off Charlotte Harbor.

Amoebophrya is not usually found without a host, so chances are best when the host is blooming or in high concentration. With no major *Karenia brevis* blooms in Florida, the project focused on the preserved Charlotte Harbor bloom samples and on laboratory experiments in which *Karenia brevis* was exposed to *Amoebophrya* parasites from other dinoflagellate species.

The preserved *Karenia brevis* cells from a bloom showed possible infestation by an *Amoebophrya*-like parasite. Bloom samples were stained with a chemical called protargol that makes it easier to see the parasite inside the *Karenia brevis* cell. Along the edge of the *Karenia brevis* cell were small "inclusions" having the size, shape, and appearance of *Amoebophrya* (see Figure 1). In the *Karenia* cell shown in Figure 2, the nucleus is no longer present,

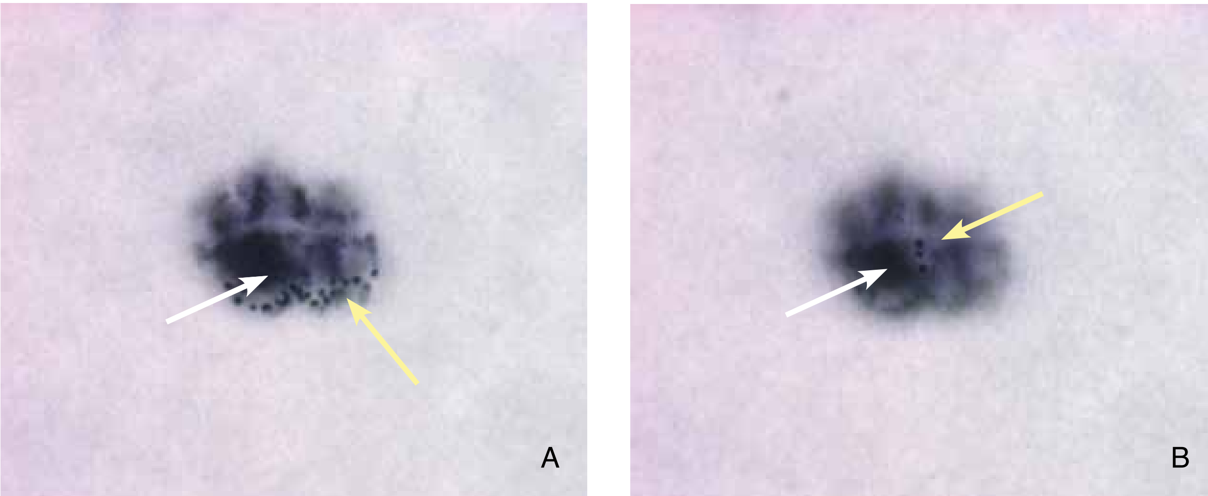

FIGURE 1 *Karenia* cells from the Charlotte Harbor bloom after staining. White arrows indicate the host nucleus. (A) Many cells in the sample show the presence of "inclusions" along the periphery of the host (yellow arrow) that have characteristics of *Amoebophrya* parasites. (B) Inclusions appear to be membrane-bound in the cytoplasm (yellow arrow).

FIGURE 2 Possible infected *Karenia* cell at late stage.

and the inclusions appear similar, but not identical, to the typical "beehive" arrangement of the parasite in its late life-stages. It may be a later stage when the parasite is close to emerging from the host. More observations are needed to confirm these results.

Experiments were done to see whether *Karenia brevis* can be infested by *Amoebophrya* found in *Alexandrium tamarense,* another toxic, bloom-forming dinoflagellate. To see whether the parasite can enter, develop, and complete its life cycle in *Karenia brevis,* the parasites were grown in *Alexandrium tamarense* and one *Amoebophrya* for every ten dinoflagellates was added to *Karenia brevis* cultures. Samples were examined over four days. Parasite infestations were tried with other dinoflagellate species as controls for comparison.

Although the "beehive" arrangement of parasites was seen in control samples of other dinoflagellate species, the parasite did not enter or develop in *Karenia brevis,* even when aspects of the environment, such as temperature and light, were changed. Because the parasite from another dinoflagellate host did not appear to enter *Karenia brevis* cells, some degree of specificity probably influences parasites' choice of hosts. The results suggest that species of *Amoebophrya* taken from other hosts will not necessarily attack *Karenia brevis.*

POTENTIAL APPLICATIONS

More observations are needed to confirm the results of this study, along with more tests using living samples from high-density *Karenia* blooms. If an *Amoebophrya*-like parasite is isolated from *Karenia*, it could be a natural solution for controlling Florida red tide. Parasites can stop host cells from dividing, causing cell death in possibly as few as two to three days.

See Appendix for Principal Investigator contact information and project collaborators.

MITIGATING THE HARMFUL EFFECTS OF FLORIDA RED TIDES USING BREVETOXIN-SPECIFIC COMPLEXING AGENTS

UNIVERSITY OF NORTH CAROLINA AT WILMINGTON, JEROME NAAR

PROJECT SNAPSHOT

On the heels of their discovery that the amino acid cysteine can detoxify brevetoxins, researchers investigated how long such a treatment was effective in seawater and what doses were needed. Although treating blooms directly would be too costly, their experiments revealed a promising use of cysteine to reduce shellfish toxicity during Florida red tides.

INTRODUCTION

Ways to reduce the harmful effects of Florida red tides should be cost-effective and environmentally friendly. Researchers at the University of North Carolina at Wilmington are targeting red tide toxins rather than the toxin-producing organism. They have discovered that the amino acid cysteine and related compounds can react with brevetoxins and act as detoxifying agents.

PROJECT GOALS

This project aimed to learn more about the detoxifying effects of cysteine and related compounds and how practical their use would be to reduce the harmful impacts of *Karenia brevis* blooms. The main goals were to find out how much compound is needed to treat bloom toxicity, to see how long the compounds last in seawater, and to study the effects of these compounds on marine life. Finally, researchers wanted to evaluate how compounds could be dispersed for open-water treatment and how much that would cost.

FINDINGS AND ACCOMPLISHMENTS

Researchers confirmed that cysteine and related compounds can detoxify brevetoxins. In particular, cysteine methyl ester was found to be more effective than cysteine at reducing the toxicity of brevetoxins. They determined what doses of cysteine and related compounds were effective in treating brevetoxins and how long the treatment works. Unfortu-

J. Naar, University of North Carolina Wilmington

Clams pre-treated with cysteine and non-treated control clams were bagged and exposed to a *Karenia brevis* red tide

Julien Naar

Photo of clam filter-feeding

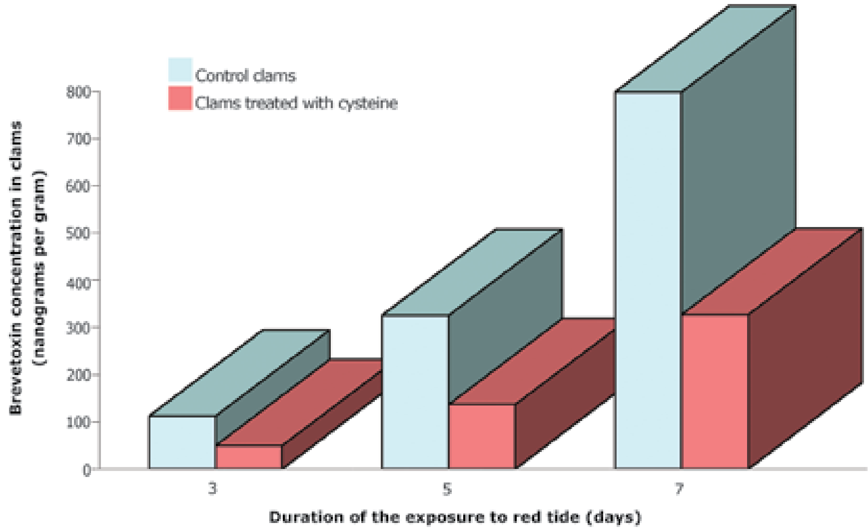

FIGURE 1 Brevetoxin concentrations in clams exposed to a Florida red tide for 3, 5, and 7 days. The percentages shown indicate the reduction of brevetoxin contamination as a result of pre-treatment with cysteine. Clams that were treated with cysteine before exposure accumulated much less brevetoxin -- less than half of what accumulated in the clams that were not treated.

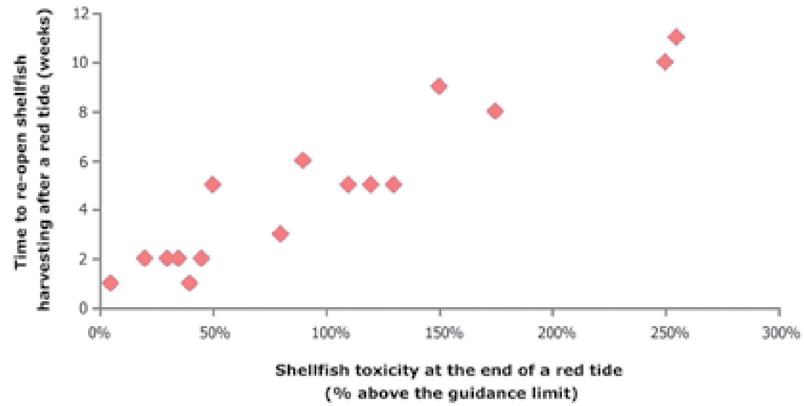

FIGURE 2 Relationship between shellfish toxicity at the end of a red tide and the duration of the shellfish harvesting area closure. This graph clearly illustrates that the more toxins the shellfish have accumulated during the red tide the longer it takes for them to return to safe levels.

nately, because such large amounts of cysteine or cysteine-like compounds would be needed, treating open-water blooms directly would be too costly to implement.

A more realistic use of these detoxifying compounds may be to reduce shellfish toxicity during red tides. Researchers treated shellfish with cysteine before exposure to a *Karenia brevis* bloom. The treatment reduced the toxicity of the shellfish by more than 50 percent (see Figure 1). This application required far less cysteine than directly treating a bloom and thus could be a cost-effective approach. Because cysteine would not need to be added directly to marine waters, there would be no chance of negative environmental impacts.

POTENTIAL APPLICATIONS

There is a strong relationship between how toxic shellfish become during a Florida red tide and how long shellfish harvesting areas are closed after a red tide (see Figure 2). The more toxic the shellfish have become, the more time is needed for the shellfish to remove the brevetoxins from their tissues and reach a level at which they may be safely eaten. Therefore, reducing the amount of brevetoxins that accumulate in shellfish during a red tide would result in shorter shellfish harvesting bans.

Researchers talked with shellfish farmers in southwest Florida and found that they are interested in using cysteine to prevent shellfish from becoming toxic. Working with this farming community and further investigating the potential use of cysteine and its derivatives to minimize shellfish toxicity may help reduce the impacts of Florida red tide on the shellfish industry. This would benefit not only the shellfish farmers but also Florida's economy and restaurants and diners everywhere.

See Appendix for Principal Investigator contact information and project collaborators.

NUTRIENT CONTROLS CONTRIBUTING TO *Karenia brevis* BLOOMS IN THE GULF OF MEXICO

UNIVERSITY OF SOUTH FLORIDA, JASON LENES

PROJECT SNAPSHOT

This project addresses one piece of the nutrient puzzle related to red tide. Researchers used computer models and experiments to show that increasing the amount of the nutrient silica in an ecosystem may favor the growth of more beneficial phytoplankton species rather than Karenia brevis.

INTRODUCTION

Understanding how Florida red tide blooms start, grow, and maintain themselves is key to finding ways to stop or reduce their impacts. *Trichodesmium,* a nitrogen-fixing marine microorganism, and rotting fish killed by brevetoxins are primary food sources for *Karenia brevis* in the eastern Gulf of Mexico. These nutrient sources provide nitrogen and phosphorus but not silica. Large amounts of silica continually enter the Gulf from Florida's rivers. Although *Karenia brevis* does not need silica to grow, competitive and faster-growing organisms in the Gulf do. In the early stages of a bloom, organisms that are close to sources of silica may be able to compete more effectively for nutrients. This competition may help slow the growth of *Karenia brevis* and its potential prey.

PROJECT GOALS

The project used laboratory and field experiments and computer simulation models to test the role of silica in *Karenia brevis* growth. Researchers wanted to know how different types and amounts of nutrients available to *Karenia brevis* may favor growth of more beneficial species. This information can help explain how *Karenia brevis* blooms grow and maintain themselves in the Gulf, and possibly how altering types and amounts of nutrients might be used to control blooms.

FINDINGS AND ACCOMPLISHMENTS

Researchers studied how *Karenia brevis* interacts with other organisms, such as *Trichodesmium*, and with prey (such as bacteria as well as some algal species) found on the West Florida Shelf and how *Karenia brevis* uses nutrients common to the Gulf. Results showed that *Karenia brevis* ingests prey to maintain balanced growth. When more nutrients, such as nitrogen, were present, *Karenia brevis* ate less prey.

Researchers developed the computer model HABSIM, which uses 27 variables to test how each potential nutrient source supports red tide blooms on the West Florida Shelf. To test whether HABSIM was working properly, the model ran using actual data from a 2001 *Karenia brevis* bloom. The model was run using data from a one-year period (January 1, 2001 through December 31, 2001), to examine

Old Dominion University

Co-investigator Margaret Mulholland (Old Dominion University) performing field experiments whether the model accurately predicted the start of the *Karenia brevis* bloom. To see whether the presence of silica resulted in competition for food sources, two test cases were run: (1) normal initial silica concentrations and (2) elevated initial silica concentrations.

In case 1, a *Karenia brevis* bloom began in June (see Figure 1a) in response to the "new" nitrogen provided by *Trichodesmium*. In late July, the bloom reached levels that would kill fish, which gave it nutrients from the rotting fish. The maximum *Karenia brevis* level predicted by HABSIM in early October was similar to what was seen in the 2001 bloom. Case 2 showed a similar pattern, but the higher concentrations of silica led to an increase in diatoms, which decreased the predicted overall *Karenia brevis* concentration by about 50 percent (see Figure 1b).

POTENTIAL APPLICATIONS

The project results and HABSIM are great starting points for bloom prediction. Future experiments will test how nutrients with and without silica can alter natural shore samples and will help show competition and dominance among co-occurring Gulf of Mexico phytoplankton species. These results will be used to further test HABSIM as a prediction tool. If models continue to show that increases in silica reduce *Karenia brevis* concentrations, then ways of changing the nutrient regime to treat and reduce blooms can be considered.

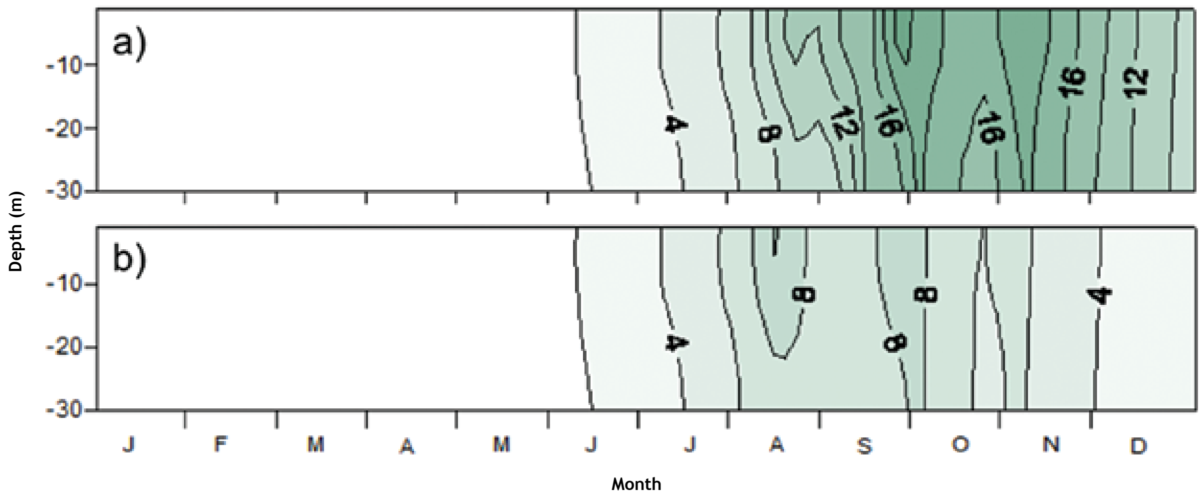

FIGURE 1 Model simulated 2001 *Karenia brevis* concentrations (in micromoles of carbon per liter) for a) case 1 and b) case 2. By increasing the initial silica concentration in the model (case 2), the predicted maximum *Karenia brevis* concentration was decreased by about 50 percent.

See Appendix for Principal Investigator contact information and project collaborators.

FWC

Trichodesmium bloom overlying a *Karenia brevis* bloom

APPENDIX

Principal Investigator contact information and list of collaborators

Alleviating Human Health Impacts

1) Expansion of the Beach Conditions Reporting System to Collier County: reducing the public health impacts from *Karenia brevis* aerosols
Principal Investigator: Barbara Kirkpatrick, Senior Scientist, Environmental Health – Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236
Email: bkirkpat@mote.org, P: 941-388-4441, ext 226
Collaborators: Robert Currier, Mote Marine Laboratory
Kate Nierenberg, Mote Marine Laboratory

2) Poison control, podcasts, and partnerships
Principal Investigator: Andrew Reich, Coordinator: Aquatic Toxins Program – Florida Department of Health, 4052 Cypress Way, Bin A08, Tallahassee, FL 32399
Email: andy_reich@doh.state.fl.us, P: 850-245-4444, ext 2295
Collaborators: Lora E. Fleming, University of Miami
Richard S. Weisman, University of Miami and Florida Poison Information Center
Wendy Stephan, Florida Poison Information Center

3) Measuring the airways inflammation in asthmatic children during red tide exposure
Principal Investigator: Morna Dorsey, University Assistant Professor, Division of Allergy, Immunology & Rheumatology – University of South Florida, 801 Sixth Street South, Box 9350, St. Petersburg, FL 33701
Email: mdorsey@health.usf.edu, P: 727-767-4470
Collaborators: John W. Sleasman, University of South Florida

4) Effects of brevetoxin exposure on signal transduction pathways in immune cells
Principal Investigator: Cathy Walsh, Senior Scientist and Program Manager, Marine Immunology Program and Center for Shark Research – Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236
Email: cjwalsh@mote.org, P: 941-388-4441, ext 302

5) Examination of fetal uptake and potential developmental effects of brevetoxins in mice
Principal Investigator: Janet Benson, Senior Scientist, Lovelace Biomedical and Environmental Research Institute – Lovelace Respiratory Research Institute, 2425 Ridgecrest Drive SE, Albuquerque NM 87108
Email: jbenson@lrri.org, P: 505-348-9749
Collaborators:
Anne Hall, Lovelace Respiratory Research Institute
Julie Hutt, Lovelace Respiratory Research Institute

Outreach and Education Strategies

6) Production of a film documentary on Florida red tides for TV broadcasting
Principal Investigator: Julien Naar, Member and Representative – Les Films de L'Espigaou, 13 rue de Pichauris Domaine de L'Oliveraie, 13013 Marseille, France
Email: juliennaar@yahoo.fr, P: 33 6 60 62 40 64
Collaborators:
Jerome Naar, University of North Carolina at Wilmington
Bertrand Loyer, Saint Thomas Productions, Aix En Provence Cedex 03 France

7) Red tide mitigation through strategic education and outreach
Principal Investigator: Sherry Larkin, Associate Professor, Food and Resource Economics Department – University of Florida, P.O. Box 110240, Gainesville, FL 32611-0240
Email: Slarkin@ufl.edu, P: 352-392-1845, ext 431
Collaborators:
Charles M. Adams, University of Florida
Marybeth Bauer, National Oceanic and Atmospheric Administration, National Ocean Service
Linda L. Lampl, Lampl-Herbert Consultants
Chris Pettit, New College of Florida, Mote Marine Laboratory
Mario R. Sengco, Smithsonian Institute
John M. Stevely, University of Florida
Patricia Tester, National Oceanic and Atmospheric Administration, National Ocean Service

Economic Impact Investigations

8) Estimating the socio-economic costs of mitigating respiratory ailments caused by Florida blooms of *Karenia brevis*
Principal Investigator: Porter Hoagland, Research Specialist, Marine Policy Center – Woods Hole Oceanographic Institution, Mail Stop 41, Woods Hole, MA 02543
Email: phoagland@whoi.edu, P: 508-289-2867
Collaborators:
Barbara Kirkpatrick, Mote Marine Laboratory
Di Jin, Woods Hole Oceanographic Institution
Lora Fleming, University of Miami
Steven G. Ullmann, University of Miami

Biological, Chemical, or Physical Control of Blooms and Their Toxins

9) Biological control of *Karenia brevis* toxicity
Principal Investigator: Julia Kubanek, Associate Professor, School of Biology and School of Chemistry and Biochemistry – Georgia Institute of Techonology, 310 Ferst Drive, Atlanta GA 30332-0230
Email: Julia.kubanek@biology.gatech.edu, P: 404-894-8424
Collaborators:
Clare H. Redshaw, Georgia Institute of Technology
Denise A. Sutter, Georgia Institute of Technology
Krista Lim-Hing, Georgia Institute of Technology
Tracey L. Myers, Georgia Institute of Technology
Jerome Naar, University of North Carolina at Wilmington

10) Parasitic *Amoebophrya* sp. in *Karenia* species: examining its presence and role in natural bloom decline and its potential as a biological control agent
Principal Investigator: Mario R. Sengco, Ecologist, Smithsonian Environmental Research Center – Smithsonian Institution, PO Box 28, 647 Contees Whart Road, Edgewater, MD 21037
Email: sengco.mario@epamail.epa.gov, P: 202-566-2676

11) Mitigating the harmful effects of Florida red tides using brevetoxin-specific complexing agents
Principal Investigator: Jerome Naar, Research Associate Professor, Center for Marine Science – University of North Carolina Wilmington, 5600 Marvin K. Moss Lane, Wilmington NC 28409
Email: naarj@uncw.edu, P: 910-962-2367, 910-962-2368

12) Nutrient controls contributing to *Karenia brevis* blooms in the Gulf of Mexico
Principal Investigator: Jason Lenes, Associate in Research, College of Marine Science – University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL 33701
Email: lenes@marine.usf.edu, P: 727-553-1150
Collaborators:
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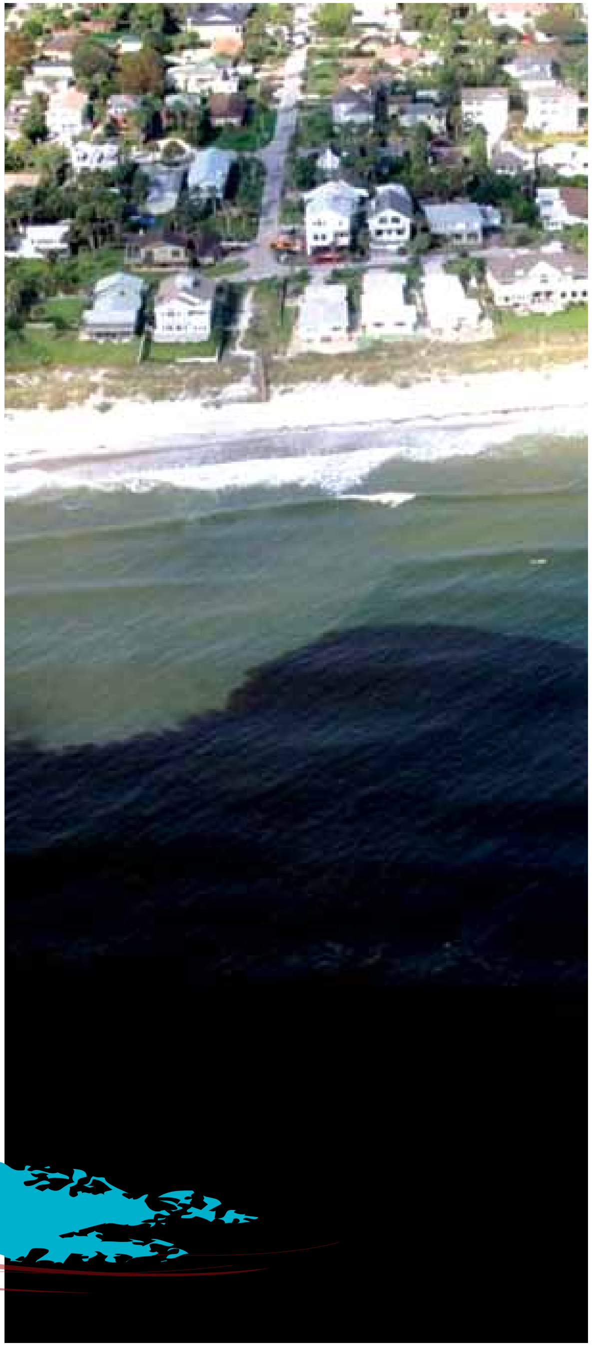
Brian P. Darrow, University of South Florida
Leo A. Procise, Old Dominion University



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