Toxic Golden Algae in Texas

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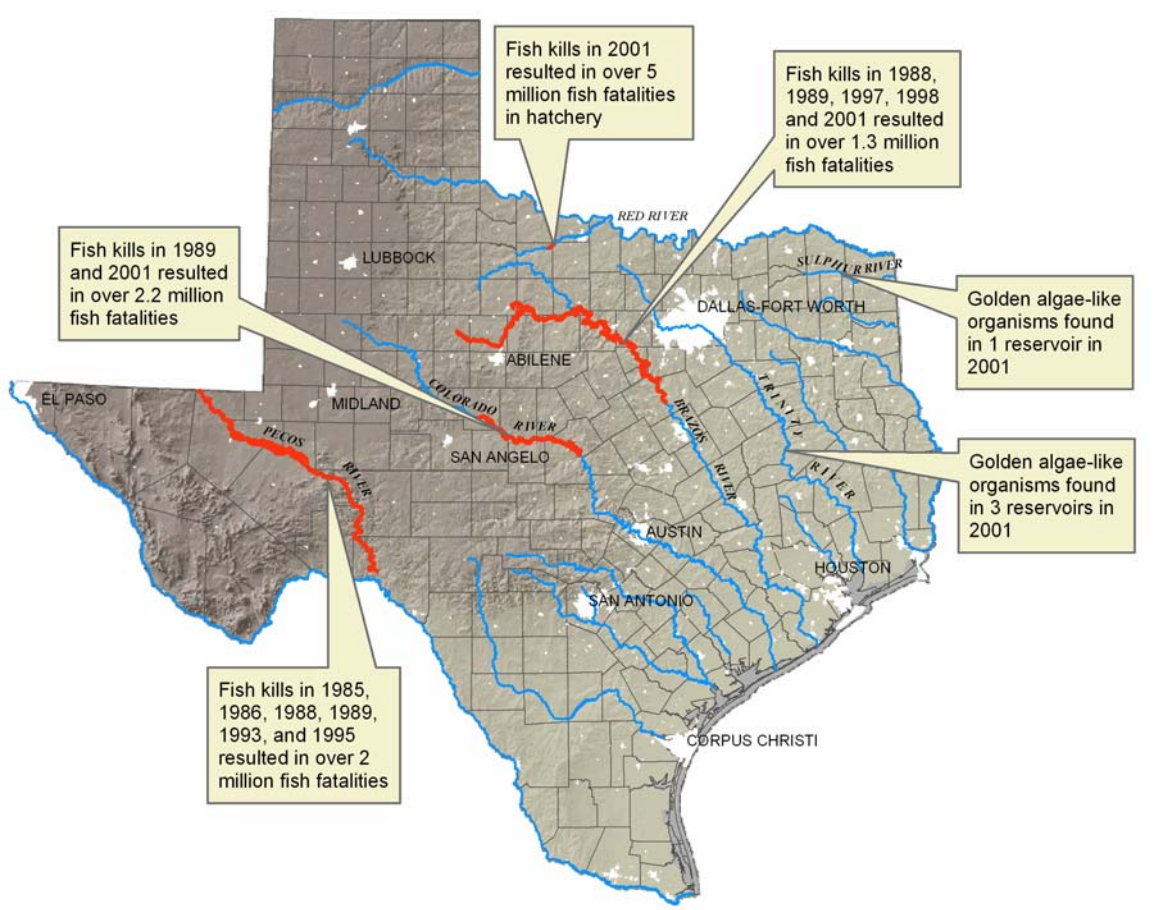
Toxic Golden Algal Impacts in Texas



Toxic Golden Algae in Texas (Understanding and Managing the Toxic Golden Algal Problem)

Golden Alga Threatens Texas Lakes, Rivers, and Fish Hatcheries

At the request of Representative Keffer, potential research and management strategies for toxic golden algal blooms are presented. Toxic golden algae have killed millions of fish since 1985. If successful, these proposed research and management options will protect the economic and ecological values of our watersheds.

Partners

Brazos River Authority

Tarleton State University

Texas A&M University

Texas Agricultural Experiment Station

Texas Department of Health

Texas Parks and Wildlife Department

University of Texas

U.S. Geological Survey

Toxic golden algae have killed millions of fish in Texas, resulting in the loss of millions of dollars of dead fish, lost revenues to local economies, and lost time and resources involved in responses to the fish kills. Golden algae will continue to cause problems in Texas in the future. Problems associated with toxic golden algal blooms in Texas include the following:

- Losses to local economies during the 2001 winter fish kills are estimated to exceed $18 million;
- More than 12 million fish worth nearly $4.5 million have been killed in Texas lakes, rivers, and fish hatcheries;
- Game fish such as largemouth bass, smallmouth bass, striped bass, catfish, crappie, and rainbow trout, and threatened species including blue suckers and Rio Grande darters have been killed;
- Fish kills have occurred in reservoirs on the Brazos River system, Colorado River system, Pecos River system, and Red River system; and
- Golden algae-like cells have been identified in four additional reservoirs in the Trinity River and Sulphur River systems.

Actions to Manage Golden Algal Impacts

Potential work essential to controlling golden algae covers five broad areas over four years. Each area of work completes a different piece of the puzzle and is needed to understand how golden algal populations grow and become toxic, and how their impacts can be managed. The actions include the following:

- Understanding the biology of toxic blooms of the golden alga;
- Monitoring Possum Kingdom Reservoir to compare conditions with toxic blooms to conditions without toxic blooms;
- Investigating control options through the development, validation, and application of a sound mathematical model;
- Communicating effectively with the public about current research and management strategies; and
- Detecting, preventing, and controlling golden algal blooms in fish culture.

Problems caused by golden algae are not likely to be easily or quickly solved. Controls, particularly in lakes and rivers, may involve large-scale changes in nutrients and salt concentrations in the impacted watersheds.

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Toxic Golden Algae in Texas: An Overview

Problem:

Toxic golden algal blooms have killed over 12 million fish in Texas since 1985, resulting in the loss of millions of dollars worth of dead fish, lost revenue to local economies, and lost time and resources involved in responses to the fish kills. Blooms are projected to continue and to expand into other river basins in Texas. At the request of Representative Keffer, the Harmful Algal Bloom Workgroup created this report to detail potential actions needed to understand how golden algal populations grow and become toxic, and how they can be managed in our lakes, rivers, and fish culture facilities. Problems caused by golden algae are not likely to be easily or quickly solved. Controls, particularly in lakes and rivers, may involve large-scale changes in nutrients and salt concentrations in the impacted watersheds.

Description:

The golden alga is a microscopic, free-floating, yellow-green algae. Algae are plants that are usually aquatic and lack true stems, roots, and leaves. The golden alga, whose scientific name is *Prymnesium parvum* ("perm-knee-z-um parvum"), lives in brackish water. Large concentrations of the golden alga (an algal bloom) color the water yellow to coppery-brown and may release the toxin prymnesin. Little is known about the cause of the blooms and toxin production. The toxin disrupts the functioning of the gills in fish and clams, killing them after extended exposure. Previous toxic blooms in Texas have killed hundreds of thousands of fish at a time, although aquatic insects, birds and mammals have not been impacted. The Texas Department of Health has stated that the golden alga is not known to harm humans; however, people should not collect dead or dying fish to eat.

Historical Exposure:

This toxic alga has killed fish on five continents. Evidence suggests that the golden alga probably caused fish kills in Texas as early as the 1960s, but it was first confirmed in Texas during a 1985 fish kill on the Pecos River. Since 1985 the range and impact of this organism has increased to include portions of the Brazos River, the Colorado River, and the Red River basins.

Recent Events:

During the winter and spring of 2001, significant fish kills caused by the golden alga occurred on three Brazos River lakes (Possum Kingdom Reservoir, Lake Granbury, and Lake Whitney) and on one lake in the Red River basin (Diversion Lake). Texas Parks and Wildlife Department's (TPW) Dundee Fish Hatchery, which uses water from Diversion Lake, experienced a total loss of fish production due to the golden alga twice during 2001. In October 2001, golden algal fish kills occurred in E.V. Spence Reservoir on the upper Colorado River and in Moss Creek City Lake near Big Springs. The U.S. Geological Survey has identified golden algae-like cells in four additional lakes in Texas (Bardwell, Navarro Mills, Grapevine, and Cooper), although fish kills from toxic golden algal blooms have not been reported in these areas.

Controls:

Several methods to control the golden alga and its toxin have been tried in fish culture ponds with mixed success. Fish culture treatments may pose threats to sportfish and other organisms if used in public waters. Available treatments do not offer effective or feasible methods for the control and management of golden algal blooms in Texas waters.

Ecological Impacts:

More than twelve million fish have been killed by toxic golden algal blooms in Texas since April 1985; over 7.6 million fish were killed in lakes and rivers, and 5.1 million fish were killed at the Dundee Fish Hatchery during the 2001 production season. Many economically important fish have been affected, including largemouth bass, smallmouth bass, striped bass, catfish, crappie, and rainbow trout. In 1986 on the Pecos River, approximately 200 blue suckers and 3,600 Rio Grande darters were killed; both of these fish are on the Texas list of threatened animals. Several other state or federally endangered or threatened fish occur in areas of previous golden algal fish kills, and future blooms may affect these protected animals. Despite killing large numbers of fish, golden algal blooms do not permanently poison the water. Although many fish were killed in Possum Kingdom Reservoir in 2001, post kill monitoring showed shad reproducing well and large catfish still being caught. Few largemouth bass older than one year were found, however, indicating that the entire recovery process may take years.

Economic Impacts:

According to an August 2001 article in a Possum Kingdom area newspaper, the Possum Kingdom Chamber of Commerce predicted four year losses of $18 to $20 million for the area's economy. These losses result from cancelled travel plans, lost bait and tackle sales, and reduced demand for fishing guides. In 2001 the number of fishing guides dropped by more than half.

The value of the fish losses in Texas since 1985 is nearly $4.5 million in current dollars. At the Dundee Fish Hatchery, the loss in 2001 was approximately $680,000. ($426,000 was the value of dead fish, and $254,000 was the cost to acquire and transport new stock from other states.) Other economic impacts which are difficult to measure include costs associated with the investigation of fish kills, the restocking of lakes, decreased attendance in state parks, and decreased revenue from fishing license sales.

Actions:

The public demanded action to control the golden alga. This demand led to a public meeting in the Possum Kingdom area in the summer of 2001. As a result of this meeting, TPW began coordinating the effort to address golden algal threats in Texas. The effort continues under the legislatively-established Toxic Substances Coordinating Committee's Harmful Algal Bloom Workgroup comprised of representatives from several state agencies and universities. This report, prepared by the Harmful Algal Bloom Workgroup, outlines potential research and management options for the golden alga in Texas waters. Although TPW coordinated this report, the majority of work described would be performed by other agencies and universities. TPW neither has the funds or resources necessary to accomplish these tasks. TPW is interested in performing the fish culture management work but cannot support it within its current budget.

Potential Work:

Potential work in five areas is needed to achieve the goal of managing impacts of the golden alga in Texas. The work focuses on golden algal problems in lakes and rivers and in fish culture facilities, which require different management approaches. Each element of work completes a different piece of the puzzle and is needed to understand how golden algal populations grow and become toxic, and how their impacts can be managed. Although some of the work can occur simultaneously, some of the goals described are dependent on the success of other goals. The five areas of work are summarized below with estimated costs, although operational costs and budget numbers are likely to change over time. Specific budgets for each major area of work are available upon request.

Biology of the Golden Alga:
Establishing laboratory cultures of the Texas golden alga will allow experiments to be conducted on what makes it grow, what allows it to outcompete other algae, and what stimulates its toxin production. Methods to efficiently monitor golden algal abundance and toxicity during blooms must be developed to help understand what factors stimulate blooms and toxicity outside the lab. Historical records of blooms will be analyzed to identify physical, chemical, and biological variables of past blooms. (Projected Cost: $2,010,000)

Possum Kingdom Reservoir Monitoring:
A multi-year reservoir monitoring program with intensive sampling over space and time will allow comparisons between toxic bloom periods and non-bloom periods. Factors influencing bloom creation, bloom maintenance, and bloom disappearance will be studied. (Projected Cost: $3,635,000)

Investigation of Control and Mitigation Options:
A model will be developed and validated to explore golden algal management options for Possum Kingdom Reservoir and other lakes. The model will simulate golden algal growth patterns and different management strategies in Possum Kingdom Reservoir. The model development will use knowledge gained from the laboratory experiments and reservoir monitoring of the golden alga. (Projected Cost: $515,000)

Public Outreach and Involvement:
Communicating with the public about golden algal impacts and management options will help address public concerns. The public needs adequate information about the golden alga in order to participate in developing plans for controlling and mitigating impacts of golden algal blooms. (Projected Cost: $80,000)

Management of the Golden Alga in Fish Culture:
Evaluating strategies for the detection of the golden alga, the prevention and control of golden algal blooms, the prevention of toxin excretion and accumulation, and the destruction of golden algal toxin in fish culture facilities will allow effective control methods to be developed. (Projected Cost: $1,660,000)


photo by Brazos River Authority

A. Biology of the Golden Alga

Establishing laboratory cultures of the Texas golden alga will allow experiments to be conducted on what makes it grow, what allows it to outcompete other algae, and what stimulates its toxin production. Methods to efficiently monitor golden algal abundance and toxicity during blooms must be developed to help understand what factors stimulate blooms and toxicity outside the lab. Historical records of blooms will be analyzed to identify physical, chemical, and biological variables of past blooms.

I. Issue: Is the golden alga in Texas the same organism throughout the state?

Goal: Establish single-species cultures of the Texas golden alga growing under constant, repeatable conditions.

Research Needs:

- Collect and transport golden algal samples from blooms to research facilities.
- Isolate and maintain golden algal cells in culture.

II. Issue: Is the golden alga in Texas the same as golden algae in other parts of the world?

Goal: Identify the cultures of the Texas golden alga and compare to golden algal cultures from other parts of the world.

Research Needs:

- Identify microscopic ultra-structural and internal characters of the golden alga.
- Characterize the Texas golden alga through molecular and genetic analysis. If genetic variations exist among different samples of the golden alga, study the specific toxin strains of the golden alga for correlations to genetic variations. Develop molecular and gene probes for rapid detection of the golden alga.
- Develop computer chip-based biosensors utilizing molecular probes to detect and identify the golden alga.
- Isolate and characterize golden algal toxins through liquid chromatography mass spectrometry methods (LC-MS).
- Compare the Texas golden alga to golden algae from different states and countries using phenotypic characters, genetic markers, and chemical composition.
- Develop field tests for detecting the golden alga and its toxicity.
    1. Grow the golden alga under nutrient-limited conditions to determine growth patterns. Characterize its toxins under these conditions.
    2. Characterize hybridization with fluorescently-labeled gene probes or with chip-based biosensors.
    3. Isolate and characterize pigments for the golden alga.
    4. Analyze alkenone production in the golden alga and in sediments of lakes and rivers with recent blooms to determine if the golden alga leaves a chemical or physical record of occurrence.

III. Issue: What factors allow the golden alga to grow rapidly and outcompete other algae?

Goal: Determine growth kinetics and competitive ability of golden algae from various Texas locations.

Research Needs:

- Determine growth parameters for laboratory and field populations of the golden alga under varied conditions.
- Estimate net growth rates under varying in-lake conditions using dilution bioassay experiments. These experiments will measure the effects of nutrients and zooplankton consumption on the golden alga within a natural plankton community.
- Conduct competitive exclusion experiments using natural plankton communities in Possum Kingdom Reservoir inoculated with golden algal cultures.

IV. Issue: What factors cause the golden alga to produce toxins?

Goal: Describe conditions under which the golden alga becomes toxic.

Research Needs:

- Measure toxin production by nutrient-limited cultures of the golden alga through the population growth experiments. Additionally, measure toxin levels from cultures experiencing unlimited growth.
- Estimate golden algal impacts on aquatic food webs before, during, and after blooms. Determine zooplankton survival and reproduction for animals grazing on nutrient-limited cultures of toxic golden algae. Combine with results from growth rate bioassays to predict conditions in the field that lead to golden algal toxicity for zooplankton.

V. Issue: What are the physical, chemical and biological conditions that have occurred during past blooms of the golden alga?

Goal: Determine environmental factors that are related to the cause of historical golden algal blooms in Texas in order to recognize and potentially manage future bloom conditions.

Research Needs:

- Identify the location and timing of previous golden algal blooms and the impacts of each bloom. Compare bloom locations to lakes and rivers with similar characteristics but which have never had blooms.
- Characterize the watersheds identified above by gathering present and historical information from different local, state, and federal sources. Maintain data in a Geographic Information System.
- Analyze present and historical watershed information to identify possible correlations with golden algal blooms. Identify gaps in information that may need to be addressed in future monitoring of golden algal blooms.

VI. Issue: Where does the golden alga presently occur in Texas?

Goal: Develop field and paleo-limnological tools to map the distribution of the golden alga in Texas.

Research Needs:

- Develop and test field methods for detecting the golden alga and its toxicity using pigment analysis and toxin identification.
- Develop paleo-limnological tools to map golden algal presence and relative abundance in reservoirs with recorded blooms.

Total Budget for the Proposed Work on the Biology of the Golden Alga:

Year One:	$535,000
Year Two:	$835,000
Year Three:	$640,000
TOTAL:	**$2,010,000**

Golden Alga, *Prymnesium parvum*

photo by Carmelo Tomas, Univ. North Carolina

B. Possum Kingdom Reservoir Monitoring

Understanding both the mechanisms that cause blooms of the Texas golden alga and the conditions that lead to healthy lake environments (where golden algal blooms are less likely to occur) are critical to the development of management options. Bloom-initiating mechanisms of harmful algal blooms (HABs) in general are highly diverse and may occur over very short time intervals or in limited areas. Reports of bloom-initiating mechanisms for golden algal events around the globe are contradictory, incomplete, and of limited use for the development of management options in Texas. Additional field sampling is required. A four year sampling regime is proposed that focuses on both widespread spatial sampling and closely spaced sampling over time in a single lake system of ecological and socioeconomic importance where golden algal blooms have occurred in the past (Possum Kingdom Reservoir). The physical, chemical, and biological parameters that will be sampled have been linked to bloom-initiation and formation; they also influence conditions under which a lake ecosystem is considered healthy. Sustaining this field effort over four years will improve the ability to account for variability between years.

Issue: What are the physical and chemical conditions associated with golden algal blooms in nature?

Goal: Identify the location of golden algal bloom-initiation "hot-spots" and areas of high plankton dynamics throughout the year, and correlate golden algal distribution, abundance, toxicity, and growth dynamics to physical and chemical conditions.

Research Needs (Bi-Weekly):

- Sample at fifteen locations along the central axis of Possum Kingdom Reservoir during each bi-weekly sampling trip, where each location will consist of one near-shore station and one station at a mid-way point between shorelines, and measure nutrients, water quality parameters, toxin concentrations, phytoplankton, zooplankton and bacteria.

Research Needs (Daily/Monthly Sampling):

- Evaluate nutrient sources, sinks, and budgets in Possum Kingdom Reservoir by measuring external and internal nutrient loading. Two moorings will be deployed (one mooring at the upper reaches of the reservoir and the other between the dam and hatchery) to sample nutrients daily, measure water flow, and measure the water quality parameters of pH, dissolved oxygen, conductivity, and temperature. Estimate the hydraulic residence time of the lake. Measure the exchange of nutrients between the sediments and water column monthly by retrieving and incubating sediment cores from three locations. Estimate sediment bacterial activity.

Research Needs (Quarterly):

- Conduct in-field dilution bioassays to understand food web interactions.

Research Needs (Near-Continuous):

- Deploy a solar-powered mooring at a single location perceived as a "hot spot" for golden algal bloom-initiation to detect short-period phenomena that might influence bloom-initiation. Collect data every minute and measure changing nutrient concentrations; water quality parameters; phytoplankton biomass, concentration, and composition; air temperature and humidity; and wind speed and direction through instruments on the mooring.

Total Budget for the Proposed Work on the Possum Kingdom Reservoir Monitoring:

Year One:	$1,170,000*
Year Two:	$ 815,000
Year Three:	$ 820,000
Year Four:	$ 830,000
TOTAL:	**$3,635,000**

(* = The first year of the project includes the purchase of many of the new technologies to be utilized during the four-year project.)

photo by Texas Parks and Wildlife

C. Investigation of Control and Mitigation Options

A predictive model of golden algal population growth will be developed and validated utilizing information about the biology of the golden alga gained from laboratory experiments and reservoir monitoring. The model will be applied to Possum Kingdom Reservoir and will explore golden algal management options for this lake and, after slight alterations, for other lakes.

Issues: What physiological parameters allow the golden alga to successfully outcompete other algae? How does golden algal physiology vary with temperature and salinity? What processes influence the biology of Possum Kingdom Reservoir? What management activities can be used to control the golden alga?

Goal: Develop a model to simulate golden algal growth patterns in a reservoir, and use the model to develop potential management options.

Research Need (Numerical Model Simulation):

- Build and validate a time-dependent one-dimensional model where populations of simulated organisms change as a result of naturally occurring processes. Base model design on laboratory experiments and reservoir monitoring.

Total Budget for the Proposed Work on the Investigation of Control and Mitigation Options:

Year One:	$125,000
Year Two:	$125,000
Year Three:	$130,000
Year Four:	$135,000
TOTAL:	**$515,000**

photo by Texas Parks and Wildlife

D. Public Outreach and Involvement

Communicating with the public about golden algal impacts and management options will help address public concerns. The public needs adequate information about the golden alga in order to participate in developing plans for controlling and mitigating impacts of golden algal blooms.

I. Issue: How can we address public concerns about the possible impacts of the golden alga on humans, wildlife and fish?

Goal: Ensure that the public has adequate information about the golden alga, its impacts and its management through a public information program.

Research Needs:

- Develop and maintain a project website.
- Develop an information packet about the golden alga and the lack of human health impacts.

II. Issue: How can impacted communities determine and implement actions to manage the blooms of the golden alga while mitigating any impacts?

Goal: Develop a public plan for managing and mitigating impacts from golden algal blooms.

Research Needs: Create stakeholder committees for impacted watersheds to evaluate impacts and to propose management and mitigation actions.

- Identify economic impacts to human, wildlife and fish communities.
- Identify possible management alternatives based upon historical data, laboratory experiments, reservoir monitoring, and modeling results.
- Evaluate feasibility of alternatives based on economics, environmental impacts, and community needs.

Total Budget for the Proposed Research on Public Outreach and Involvement:

Year One:	$20,000
Year Two:	$20,000
Year Three:	$20,000
Year Four:	$20,000
TOTAL:	**$80,000**

photo by Texas Parks and Wildlife

E. Management of the Golden Alga in Fish Culture

The golden alga becomes prevalent whenever it appears in fish culture settings; for this reason, effective control strategies must be implemented to make fish production possible. Although control methods in the literature include the destruction of the alga or its toxin, controlling blooms to prevent toxin accumulation is the preferred strategy. Different characteristics of the alga and its toxins need to be examined to determine reliable and cost-effective management plans. Several strategies will be evaluated, including timely detection of the algal presence, prevention and control of blooms, prevention of toxin excretion and accumulation, and destruction of toxins.

I. Issue: How can pond operators rapidly identify and count the golden alga?

Goal: Improve golden algal detection and counting techniques.

Research Needs:

- Develop a portable vacuum filtration system and colorimetric scale to facilitate quick detection of the alga in the field.
- Test fluorescence microscopy for the detection of the alga in low densities.
- Test whether or not flow cytometry is useful for quantifying the golden alga using either fluorescence or size sorting criteria.

II. Issue: How can current methods of testing toxicity in the field be improved for use in large-scale fish culture situations?

Goal: Improve methods of field ichthyotoxin detection.

Research Need:

- Shorten the current field bioassay protocol from two hours to less than ½ hour. Explore alternative cost-effective methods of testing toxicity in the field.

III. Issue: What physical, chemical and biological factors influence golden algal blooms in fish culture ponds?

Goal: Investigate factors that inhibit golden algal blooms.

Research Needs:

- Experiment with varying nutrient concentrations, algae composition, and destratification of water in ponds to control the golden alga.
- Investigate bacterial formulations known to control algae for effectiveness and feasibility in a fish culture setting.
- Test the ability of ultraviolet light and ozone generators to kill the golden alga in the source water before it enters the ponds.
- Promote growth of nontoxic algae which outcompete the golden alga.

IV. Issue: What substances and devices can control the golden alga in ponds and protect the fish being cultured?

Goal: Identify types and amounts of chemicals and other devices that effectively control golden algal blooms.

Research Needs:

- Investigate the following chemicals for effectiveness in controlling the golden alga: ammonium sulfate, aqua-ammonia, copper sulfate, potassium permanganate, acetic acid, ozone, and others.
- Investigate other devices for effectiveness in controlling the golden alga, including level of acidity, ultraviolet light, and aquasonic equipment.

V. Issue: What factors influence the production, accumulation, and destruction or deactivation of golden algal toxins?

Goal: Identify factors that cause production and release, accumulation, or destruction of toxins in the golden alga.

Research Needs:

- Investigate factors that may trigger increased synthesis and release of toxins, including nutrient ratios.
- Investigate strategies for preventing the accumulation of toxins.
- Investigate soap eaters, bacteria, peroxides and acids for control of the toxins.

Total Budget for the Management of the Golden Alga in Fish Culture:

Year One:	$ 850,000*
Year Two:	$ 270,000
Year Three:	$ 270,000
Year Four:	$ 270,000
TOTAL:	**$1,660,000**

(* = The first year of the project includes the purchase of many of the new technologies to be utilized during the four-year project.)

photo by Texas Parks and Wildlife

APPENDICES

photo by Brazos River Authority

Appendix I: Events Involving the Golden Alga in Texas

(not including Hatchery Losses)

Date		Location		Loss Totals	
Start	**End**	**County (ies)**	**Affected Waterbody (ies)**	**Count**	**Value ($)**
04\21\1985	4\27\1985	Loving	Red Bluff Reservoir (off the Pecos R)	10,125	71,401
10\31\1985	11\10\1985	Crockett, Pecos, Terrell, Val Verde	Pecos River	110,968	85,875
11\19\1985	11\20\1985	Val Verde	Pecos River	300	89
11\20\1986	12\12\1986	Pecos, Terrell, Val Verde	Pecos River	263,879	** 2,140,534
10\25\1988	11\06\1988	Haskell, Throckmorton	California, Paint Creek (off the Brazos R)	35,526	9,877
11\05\1988	11\16\1988	Reeves, Loving, Ward, Pecos, Crane, Crockett	Red Bluff Reservoir, Pecos River	1,580,320	337,246
04\24\1989	05\16\1989	Haskell	Paint Creek (off the Brazos R)	15,168	54,145
08\12\1989	08\29\1989	Runnels	Colorado River	1,723	
08\30\1989	09\15\1989	Coke	Colorado River	8,545	
12\06\1989		Reeves	Pecos River	50	
11\03\1993	11\21\1993	Pecos, Terrell, Val Verde, Crockett	Pecos River	33,124	22,927
12\05\1995		Crockett, Terrell	Pecos River	7,733	22,023
10\05\1997	10\10\1997	Young	Brazos River	640,647	75,326
06\25\1998	7\20\1998	Fisher	Clear Fork of the Brazos River	33,874	9,558
01\11\2001	08\30\2001	Palo Pinto	Possum Kingdom Res.(off the Brazos R)	200,027	257,371
01\27\2001	08\30\2001	Hood	Lake Granbury (off the Brazos R)	409,952	370,243
04\13\2001	06\21\2001	Hill, Bosque	Lake Whitney (off the Brazos R)	9,596	37,337
03\12\2001	Still Active	Baylor	Lake Diversion (off the Red R)	309	
10\20\2001	10\30\2001	Coke	Lake Spence (off the Colorado R)	2,200,000	481,000
10\16\2001	10\30\2001	Howard	Moss Creek Lake (off the Colorado R)	6400	
11\24\2001	Still Active	Runnels	Colorado River	2,100,000	465,000
			Total	**7,668,266**	**$4,439,952**

** Value of fish lost and additional value of lost Threatened & Endangered fish, $500 per fish (232 blue suckers & 3682 RioGrande darters = $1,957,000)

Appendix II: Sources for More Information

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Appendix IV: Acknowledgements

Numerous people from many different affiliations have been involved in this report. We wish to acknowledge the effort and interest of the following individuals, and we apologize in advance for any individual inadvertently not included.

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