Guidelines for Golden Alga *Prymnesium parvum* Management Options for Ponds and Small Reservoirs (Public Waters) in Texas

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Figure 1. Golden alga cells photographed by Dr. John La Claire II (UT - Austin), image used with permission.

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The golden alga *Prymnesium parvum* is a toxic organism capable of causing extensive kills of aquatic animals. Rivers, ponds and reservoirs in north-central and west Texas have been susceptible to these toxic algal events (Figure 2). These guidelines were developed to provide information and describe management options presently available for controlling golden alga toxic events in ponds and small reservoirs in public waters. The information is provided to help cities, water utilities, river authorities, and others evaluate options for addressing toxic events. Texas Parks and Wildlife Department (TPWD) is not funded or staffed to treat algal problems. However, TPWD wants to provide information for entities that manage affected waters should they decide to address toxic algal events.

Numerous groups are concerned and involved with decisions on possible management efforts for toxic golden alga events in Texas public waters. These groups include regulatory agencies such as the Texas Commission on Environmental Quality (TCEQ), U.S. Environmental Protection Agency (USEPA), and the Texas Department of Agriculture (TDA); water utilities and other water controlling authorities such as drinking water suppliers and river authorities; and water users such as irrigators, recreational users, and landowners. The TCEQ regulates water quality standards for the state including water quality and drinking water standards. The TDA and USEPA regulate the use of pesticides in the state including the use of algaecides in public waters. Water suppliers transport water for industry, agriculture, and public consumption. There are numerous users of public waters including recreational fishers and boaters, irrigators, industry, and water utilities. Additionally, TPWD serves an important role in guiding decisions regarding nuisance aquatic vegetation in public waters. All these stakeholders should be considered when making management decisions for toxic golden alga events. These guidelines provide information to facilitate information exchange and coordination among the stakeholders. It may well be beneficial to pre-plan management options for areas where golden alga events are likely. The amount of coordination necessary to implement treatment options can take time and having action plans in place with this coordination already initiated could save considerable time for implementing treatments.

Golden Alga Overview

History

- The golden alga was first described in 1937 in England.

- *P. parvum* is widely distributed, being found on every continent except Antarctica, reported from at least 14 countries, and is most often associated with estuarine or marine waters but can exist in inland waters.
- *P. parvum* was first found in inland waters in the Middle East where it caused fish mortalities in aquaculture facilities.
- The alga was first identified in the U.S. in water samples from a 1985 fish kill on the Pecos River, Texas. Since then four additional Texas river systems, the Brazos, Canadian, Colorado, and Red, have been affected (Figure 2).
- *P. parvum* has been reported in 15 U.S. states.
- Since 2001, *P. parvum* has been a persistent problem in Texas waters affecting at least 29 reservoirs and killing over 27 million fishes, while communities associated with reservoirs experienced losses in their recreational based incomes.
- *P. parvum* also has been problematic in two Texas state freshwater fish hatcheries killing brood fishes and production fingerlings.

As a result of these problems, TPWD is developing management options and coordinating research efforts concerning this toxic alga. These guidelines were developed using information gathered by Texas and Arizona agencies who evaluated numerous treatment options.

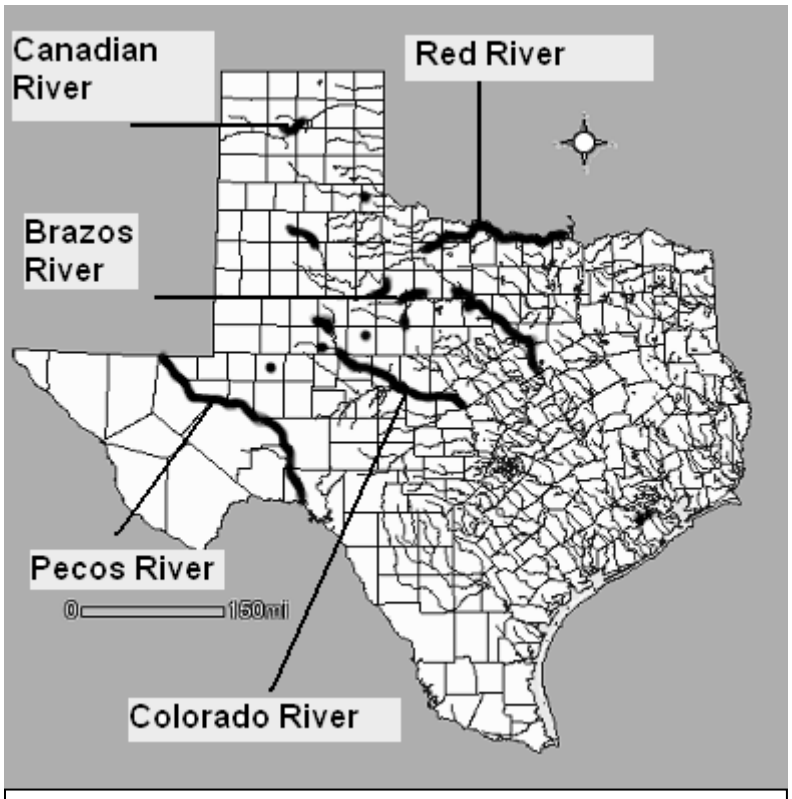

Figure 2. Shaded areas indicate where golden alga fish kills have been identified in public waters in Texas.

Description

- *P. parvum* is sub-spherical to elongate and approximately 8-15 µm long with 2 flagella and a shorter haptonema arising from a pit (Figure 3). The haptonema is about half the cell length, flexible but non-coiling, and can be used to attach the cell to a surface.
- Two large yellow-green chloroplasts are situated laterally and parietally and are often deeply lobed, which may result in a c-shaped appearance.
- The alga exhibits a characteristic swimming motion of moving forward while spinning on its longitudinal axis.
- Microscopic examination of subsurface water samples (e.g., ≥ 6-inch depth) is required for identification since *P. parvum* is ultraviolet-light inhibited and avoids the water surface. Magnifications of 400 - 1000x are required for a presumptive identification, while confirmation of visual identifications requires electron microscopy to examine scale morphology. Corroborative identification by experienced individuals is recommended when first becoming familiar with this organism.
- *P. parvum* can form dormant cysts when stressed or conditions become unfavorable for the alga.

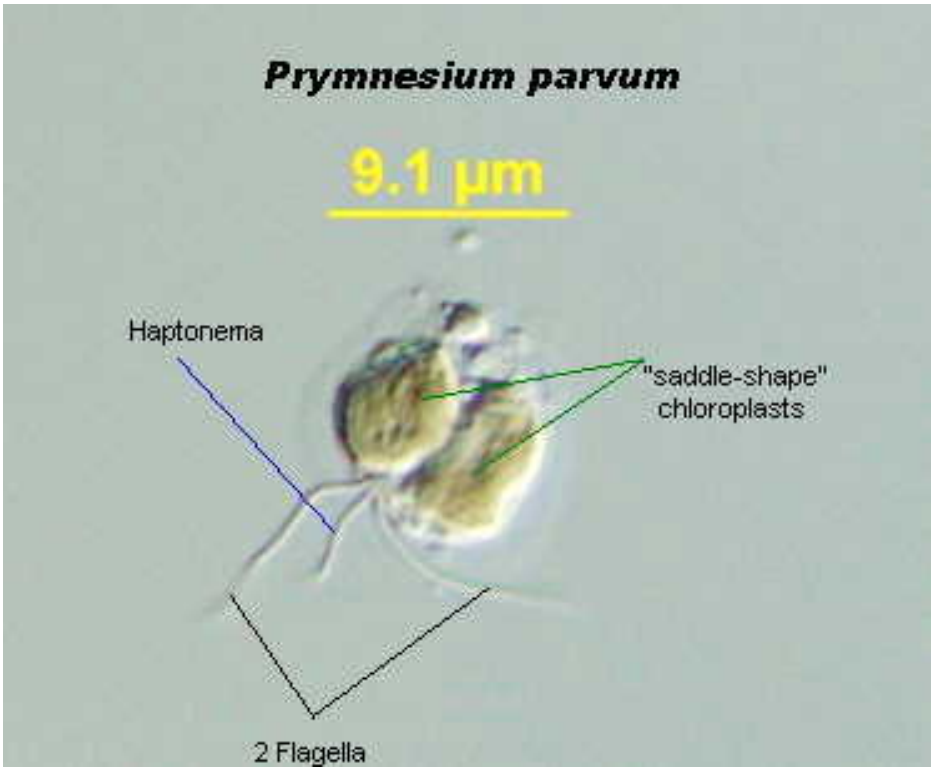

Figure 3. A microscopic picture of a golden alga cell (1000X magnification). Photo by Greg Southard, TPWD

Toxicity/Impacts

- Toxins released by *P. parvum* are called prymnesins and affect gill breathing organisms; most aquatic insects appear unaffected and adverse impacts to higher vertebrates have not been documented.
- Although a variety of toxic effects have been attributed to prymnesins, the ichthyotoxicity is best known. Prymnesins affect gill breathing organisms by causing hemorrhaging and interruption of the selective permeability of cells in the gills. Cells of other exposed tissues can also be damaged.
- All species of Texas fish are susceptible, as well as bivalves, crayfish, gilled amphibians, and certain plankton species.
- Fish kill investigations in Texas indicate a general progression of fish mortality during a toxic event. Commonly, small forage fishes are initially killed, especially planktivorous species such as threadfin shad *Dorosoma petenense* and gizzard shad *D. cepedianum*. Freshwater drum *Aplodinotus grunniens* are affected relatively early. The next group impacted includes shallow water fishes such as juvenile and young adult sunfish, minnows, and cichlids. As the bloom expands and refugia disappear, larger, more mobile fishes, such as stripers and striper hybrids *Morone* spp. and catfish, succumb. Carp *Cyprinus carpio*, gar *Lepisosteus* spp., and buffalo *Ictiobus* spp. usually are affected last. This sequence may vary according to the order habitats are affected by changes in water circulation carrying the alga cells and toxins.
- Ecological impacts depend on the length and severity of the toxic conditions, with impacts ranging from minor reductions in forage fish populations to major declines in fisheries.
- Forage fishes generally are rapidly replenished through natural reproduction, while higher trophic species may require considerable stocking effort and years to recover naturally.
- Reservoirs with repeated fish kills have had their recreational fisheries decimated.
- Threatened and endangered species, or species of concern, may lack sufficient numbers to recover from kill(s).
- Fish kills have adverse effects on recreational economies associated with reservoirs and relate directly to reduced fishing and recreational use of the waterbody due to poor aesthetics.
- *P. parvum* fish kills in 2001 resulted in a conservative estimate of millions of dollars lost to the local economy around Possum Kingdom Reservoir.

Treatments

General Successful Treatments

- There are many algal control treatments available but not all can successfully control the golden alga. Additionally, some treatments may not be effective or appropriate for public waters.

- Treatments to control *P. parvum* were first developed in Israel in aquaculture ponds using ammonia or ammonium sulfate to lyse cells.
- In laboratory tests, prymnesin toxicity has been mitigated using substances such as oxidants, adsorbents, bacteria, and antibiotics.
- Reducing pH to 6.0-6.5 decreases toxicity, suggesting a potential treatment. In TPWD laboratory experiments, acid applications reduced pH, toxicity, and density of viable *P. parvum* cells, but pH returned to pretreatment levels within 18-28 hours in the highly buffered waters typically associated with *P. parvum* events.
- Copper sulfate, a wide spectrum algaecide, is effective in reducing cells but has no effect on toxicity.
- Reducing salinity in brackish water ponds has been used to control *P. parvum* events.
- To successfully rear sport fish at affected hatcheries, TPWD has used, modified, and examined a variety of treatments. Copper-based algaecides are effective at temperatures below 15ºC (59˚F) but may negatively affect important food sources and sensitive fish species. Ammonium sulfate provides un-ionized ammonia nitrogen (UIA-N), which causes osmotic imbalance leading to cells lysing. The un-ionized fraction of total ammonia is positively correlated to temperature and pH, and treatments are not successful at temperatures below 15°C (59°F) or pH below 7.0. Treatments are usually unnecessary at TPWD hatcheries at temperatures ≥ 30°C (86°F), when the golden alga does not seem to become a problem.
- TPWD freshwater hatcheries treat with a minimum concentration of UIA-N near 0.16 mg/L. This UIA-N concentration may have adverse effects on early life stages and sensitive fish species. Concentrations of UIA-N > 0.25 mg/L appear to have substantial negative effects on striped bass *Morone saxatilis* production. Intensive monitoring of pond pH, temperature, and ammonia concentrations is required to maintain UIA-N concentrations between these upper and lower thresholds.
- Two UIA-N treatment strategies are currently under evaluation at TPWD hatcheries. One strategy monitors cell densities and applies ammonium sulfate when *P. parvum* cells are found, while the other strategy maintains a minimum of 0.16 mg/L UIA-N whenever pond temperatures are between 15˚C (59˚F) and 30˚C (86˚F).
- Concentrations of potassium permanganate near the demand may temporarily reduce acute toxicity due to *P. parvum* and ≥ 2 mg/L above the demand may control cell density.
- Hydrogen peroxide lyses *P. parvum* cells in 24 hours at 62.5-500 mg/L, in 1 hour at 3,125 mg/L, and in 15 minutes at 12,500 mg/L. Higher concentrations can be used to disinfect equipment but are likely to be harmful to fishes.
- Additional studies on oxidizing compounds, especially those labeled as algaecides, are planned by TPWD.
- Ultrasonic vibrations, barley straw, and probiotics (e.g., bacteria inoculants) were studied by TPWD for efficacy against *P. parvum* blooms and toxicity but were not successful.

- For small water volumes, as in recirculating incubation systems and fish hauling units, TPWD has used ultraviolet light and ozone treatments to destroy cells and reduce toxicity. Ozone at 5 mg/L for 15 minutes is the current method to treat egg incubation and hatching system water at TPWD fish hatcheries. These treatments may not be practical for large water volumes.
- Studies indicate that toxicity may be related to nutrient limitation. TPWD research suggests nitrogen and phosphorus applications may control *P. parvum* cells and toxicity. While nutrient enhancement shows promise, higher pH may result and must be addressed to make this a viable control option for sensitive aquatic species.
- When *P. parvum* was found in Arizona, the Arizona Game and Fish Department (AGFD) worked with universities and industry to examine treatment alternatives. A 2005 workshop led to the development of response guidelines for toxic events in Arizona. The Arizona guidelines include alga control using copper-based algaecides (e.g., Cutrine® Plus and Earth Tec) in Urban Fishing Program waters.

Treatments Approved for Use in Public Waters

- Not all algal treatments have been approved for use in United States public waters. Only those treatments approved by the USEPA and the TDA, the federal and state regulatory agencies, can be used in Texas public waters. Care must be taken to ensure the treatment is approved and any use restrictions are followed.
- Ultraviolet light treatments and ozonation have been successful in treating small quantities of water. However, these treatments may be impractical for ponds and reservoirs due to the cost and equipment required.
- The most successful treatments using approved chemicals have been with copper-based algaecides, especially chelated copper compounds. Copper-based algaecides are effective at temperatures below 15ºC (59°F) but may negatively affect important species, including plankton and sensitive fish.
- Approved copper-based algaecides include Algimycin®-PWF, Earth Tec, Cutrine®Plus, Cutrine®Ultra, and Clearigate.
- Copper-based treatments that include delimeamine (e.g., Clearigate) have a greater possibility of injuring sensitive fish species. These treatments should only be selected if other options are not available.
- As an example, Cutrine®Plus kills golden alga cells at treatment levels $\geq$0.2 mg/L as total copper. Label instructions call for the use of 0.6 gallons of concentrate per acre-foot of water. Cutrine®Plus is federally registered and has no label restrictions in fisheries or drinking water supplies. Treatment levels $\geq$0.5 mg/L can cause mortality in sensitive fish species such as rainbow trout if alkalinity levels are low. Cutrine®Plus can be used during cooler, winter months to control algae. It is a broad-spectrum algaecide that inhibits primary production (algal production).

Issues to Consider To Determine Whether to Treat or Not

Are you sure the problem is a golden alga toxic event? Investigate and coordinate with TPWD and other agencies to make sure that golden alga is the problem (see information below under Determining if Golden Alga is a Problem).

- Is the treatment approved for use in public waters by the USEPA? Is it effective for controlling the golden alga? Answers to both of these questions limit choices at this time.
- Are there any use restrictions for the selected treatment? Any use restrictions (see label instructions) must be followed.
- Are there treatment limitations for the affected site due to water quality conditions (e.g., water temperature, hardness, alkalinity, etc.)?
- Will the treatment reduce damage to the system or will it result in more harm than good? Broad scale ecosystem impacts need to be considered before implementing a treatment. If only forage fish are affected, treatment may not be necessary since forage species can naturally replace themselves quickly. If numerous fish species or a greater percentage of the fisheries community is impacted by a toxic alga, the ecosystem may recover more slowly or require assistance to recover.
- Are there threatened and endangered species or species of concern present in the waterbody? If yes, the treatment might be more harmful than the golden alga bloom. Any action should be coordinated with the U.S. Fish and Wildlife Service (USFWS) and TPWD Wildlife Diversity Program to avoid potential problems.
- Is the treatment financially feasible? The total cost of the treatment includes the cost of the chemical, the costs to distribute the treatment into the water and to monitor its concentration and effectiveness.
- Will the area need to be re-treated? The cost evaluation needs to include the potential need to re-treat the water if the golden alga problem returns.
- Are any permits required, or are there any state and/or local regulations prohibiting this treatment? Coordination with TCEQ, TDA, and local authorities should be undertaken to address this question and get their input. Potential effects to other aquatic vegetation and habitat must also be considered. TPWD has a guidance document Aquatic Vegetation Management in Texas for vascular plants (not algae); this document should be reviewed for state contact information and procedures may be used if appropriate. It is available on the TPWD web site at: www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_pl_t3200_1066.pdf .
- If the treatments selected are likely to affect vascular plants the above document should be followed and an Aquatic Vegetation Treatment Proposal submitted to TPWD.

Once the above information is gathered, the technical, environmental, and fiscal feasibility of treating the water can be determined.

Suggested Actions and Issues for Treatment Decisions

Preventing the Spread of the Golden Alga

- The golden alga may be spread from site to site via water and equipment that moves from one waterbody to another such as boats and trailers. It is a wise strategy to prevent transporting the golden alga through equipment cleaning efforts whenever leaving a waterbody with golden alga present.
    - After leaving the water, drain the bilge, live wells and any water-holding device.
    - Thoroughly rinse out the boat, bilge, live wells, etc. with clean freshwater (not lake water but water from a well or water supply company). Use hot water (>104°F) for this rinse if possible.
    - Allow the equipment to dry for 2 to 3 days before putting it into the water again, if possible.
    - For an extra precaution you can wash the equipment with a 10% bleach solution making sure the contact time with the bleach solution is at least 5 minutes. Rinse the bleach solution off the equipment but do not discharge this water into the waterbody.
- Never transplant live animals or plants from one waterbody to another as you may also transplant unwanted organisms such as the golden alga.
- Empty your bait bucket on land before leaving the lake area. Never release live bait into a waterbody from a different waterbody.

Determining if Golden Alga is the Problem

- Visual indications of a dominant *P. parvum* event may include abnormal yellow or gold to rust-colored water and foaming where the water is agitated.
- Stressed, lethargic, or dead fishes may be present, with fishes bleeding from the gills, showing reddening of the skin particularly at the fins, opercula (gill covers), mouth, and eyes. Affected fish also may generate a heavy mucus layer.
- Fish behavior can vary widely, and although fish typically swim slowly, lie on the bottom, or congregate near the shore, they may crowd around a fresh water source such as springs or actively leap out of the water onto the shore.
- Mussels die and their soft bodies may be seen floating apart from their shells.
- Most adult and larval aquatic insects apparently are not affected.
- Microscopic examination is required for a presumptive identification (see earlier description for key characteristics). Visual identification, along with the field characteristics of a golden alga toxic event, is usually sufficient to determine the presence of a golden alga problem.
- If it is determined that a toxic golden alga event and/or a fish kill is occurring, please notify the TPWD Kills and Spills Team (KAST, see the attached sheet for contact information).

Coordination and Approval for Treatments Selected

- Once it is determined that golden alga is the problem and a treatment application is feasible, any required approvals and permits must be obtained.
- Contact and coordinate with the appropriate controlling authorities to obtain any required approvals and permits. These authorities include the agency in charge of the waterbody (such as cities, river authorities, U.S. Army Corps of Engineers, etc.), the TCEQ for possible permits and restrictions, TDA for pesticide use coordination, and any water supply companies that may convey water from the waterbody for municipal, agricultural, or industrial use to make sure there are no conflicts with these uses and the treatment(s). If other aquatic vegetation or habitat may be affected by treatments, the TPWD Aquatic Habitat Enhancement Program should be contacted and consulted. Care must be taken for this coordination as it may require contacting different groups within agencies.
- If threatened and endangered species, or species of concern, are present coordination should be undertaken with the USFWS and TPWD Wildlife Diversity Program to make sure any concerns are addressed.
- Include the TPWD KAST when coordinating these efforts to facilitate monitoring or data collections to evaluate treatment effectiveness. KAST would appreciate a report of the treatment undertaken, its effectiveness, and data collected. This information would be used to help groups that may want to treat golden alga events in the future, as well as to modify guidelines.

Treatment Applications

- As noted previously, the treatment must be USEPA-approved and registered for this use (i.e., approved algaecides). All label restrictions and instructions must be followed.
- A certified aquatic applicator for pesticide use may be required. Check with the TDA for the latest requirements.
- Water quality parameters should be analyzed prior to, during, and after the treatment to determine potential interactions with the treatment and to document any changes during the treatment period. These parameters should include air and water temperature, pH, dissolved oxygen, alkalinity, hardness, and any other parameters of concern for the treatment chosen. These parameters may affect dosage rates and the success of the treatment. Various agencies or paid consultants may be able to help with this monitoring.
- Apply the treatment as a diluted solution rather than straight from the container to help ensure an even distribution over the entire area to be treated.
- Apply the diluted treatment as an even application at a light to moderate level on the first pass over the treatment area so several passes can be made to help assure even distribution of the treatment.
- Use criss-cross application patterns to distribute the treatment evenly.
- If possible, use prop wash from boats and take advantage of water currents to assist in the mixing of the treatment across the area and into the water column of the waterbody.

- Treatments are best done in the morning to take advantage of reduced winds and so the treatment can be monitored throughout the day.

Pre-planned Treatment Options

For areas where the possibility of toxic golden alga events is high it would be beneficial to pre-plan and develop treatment options prior to events occurring. When a toxic golden alga event occurs there is little time to implement treatment actions to prevent the event from becoming worse and impacting the higher trophic levels of the aquatic ecosystem. Coordinating with the stakeholders noted in the previous sections to agree to management options will greatly decrease the time from a toxic event starting to implementing a treatment. Such a plan can be documented in a management plan (action plan, treatment plan, or other suitable name) for the waterbody. This plan would develop monitoring efforts to identify an event and document approved treatment options and actions to be taken by the entities involved. This plan could address all the issues noted earlier in the document for monitoring, final coordination and agreement once a golden alga event is found, implementing an approved treatment option, and monitoring whether the treatment is successful.

Determining the Risk of a Toxic Golden Alga Event

There are several triggers noted in the previous sections that can be used to determine if the waterbody in question is in a high risk area for golden alga events including:

- Have previous toxic golden alga events taken place?
- Is golden alga known to be present in the waterbody?
- Is the waterbody in the region of the state where toxic golden alga events are common (See Figure 2)?
- Alkaline soils and high pH (>7.0) waters have been found to be more susceptible to toxic events in Texas. This is probably due to a higher presence of the cations (e.g., dissolved metals) in the water required for the toxin to form. Are these conditions present for the waterbody in question?
- Does the waterbody have fairly salty water (high conductivity)? The salty waters in central and west Texas appear to be more suitable for the golden alga (an estuarine species in most of the world).
- Coordination with TPWD staff can help answer some of these questions.

Potential Monitoring Efforts and Triggers

- Golden alga presence (see previous sections on identification). This requires microscopic examinations by someone familiar with the golden alga.
- Water quality monitoring (water temperature, salinity or conductivity, pH, etc.). This requires water samples and water quality analyses via chemical analysis kits or water quality meters.
- Algal community (Is the golden alga starting to dominate the other algae?). This also requires microscopic examination.

- Does the waterbody exhibit the characteristics of a golden alga event noted previously such as yellow to rust colored water and foaming when the water is agitated?
- Fish toxicity (Are fish stressed or dying and showing characteristic golden alga toxicity symptoms?).

Planning Document

A complete plan should consider all the suggestions below but can include more or less information depending on the needs for the waterbody and desires of the stakeholders.

- Discuss goals and objectives for the plan.
- Outline monitoring plans and implementation.
- Discuss coordination and approvals developed through the plan and required for treatment implementation.
- Discuss approved treatment options and decision criteria for deciding which option to implement.
- Note stakeholders and contact/coordination requirements.
- List treatment pre-calculations and stock-piled treatments or treatment supply sources.
- Plan post-treatment monitoring and assessment.

Resource Information (Contacts and Literature)

TPWD

- Golden alga information on the TPWD web site (www.tpwd.state.tx.us/landwater/water/environconcerns/hab/ga/)
- Golden Alga Task Force
  - Dr. David Sager 512-912-7150
  - Liz Singhurst 512-912-7050
- Kills and Spills Team (see attached contact list)
- Wildlife Diversity Program (Threatened and Endangered Species) 512-912-7011
- Aquatic Habitat Enhancement, Dr. Earl Chilton 512-389-4652

TCEQ

- Water Quality Assessment
  - Christine Kolbe 512-239-5831
  - Sidne Tiemann 512-239-4606
- Public Drinking Water Section/Source Water Assessment and Protection
  - Greg Rogers 512-239-4782
- Website www.tceq.state.tx.us

TDA

- Pesticide Programs Division 800-835-5832
- Website www.agr.state.tx.us

USFWS

- Threatened and Endangered Species
    - Austin Office 512-490-0057
- Website www.fws.gov

USEPA

- Pesticide Program
    - Greg Weiler 214-665-7564
- Website www.epa.gov

Acknowledgements

The information provided in this document originates from several sources. In particular, research on potential treatment options conducted at TPWD fish hatcheries were instrumental in developing the information provided. The editors compiled the results of numerous studies on treatment options undertaken by TPWD hatchery and research staff members and a guidance document developed for the Urban Fishing Program of the Arizona Game and Fish Department. Publications for these research and management efforts are listed in the Literature Reference Section of this document.

Kills and Spills Team (KAST) Regions

Austin Headquarters - 24-hr Communication Center
4200 Smith School Road
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Houston Area - 24-hr Communication Center
117 East Avenue A
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(281) 842-8100

(Vacant)/Coastal Coordinator
Office: (512) 912-7013
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Radio: 813

Jack Ralph/Inland Coordinator
Office: (512) 912-7153
Mobile: (512) 422-8054
FAX: (512) 912-7160
Pager: (800) 299-4099 PIN: 2667
Radio: 812

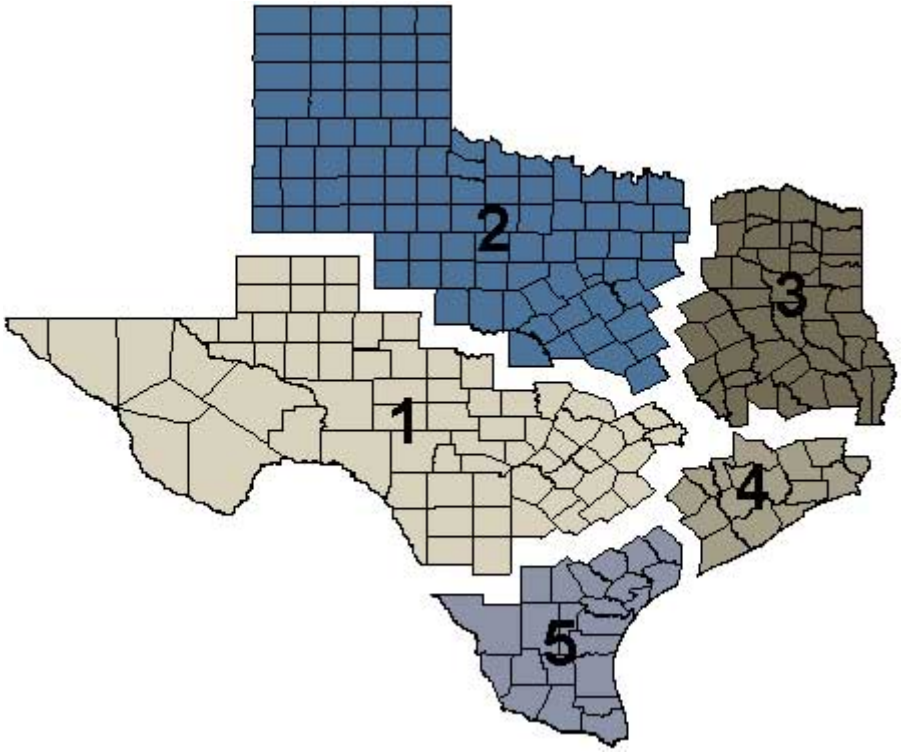

Figure 4 - Map of Texas Counties and KAST Regions

Region 1
A.E. Wood Fish Hatchery
505 Staples
San Marcos, Texas 78666

Stephen Twidwell
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Jennifer Bronson
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Radio: 03806

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Radio: 03803

Adam Whisenant
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Radio: 03807

Region 4
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Dickinson, Texas 77539

Winston Denton
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Region 5
TAMUCC
Natural Resources Center
6300 Ocean Drive, NRC Suite 2501
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Radio: 03805

http://www.tpwd.state.tx.us/landwater/water/environconcerns/kills_and_spills/

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