

Arizona HAB Meeting – Responding To Harmful Algal Blooms

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Meeting Report Summary

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Meeting Participants

Arizona Game and Fish Department: Larry Riley, Marc Dahlberg, Kirk Young, Eric Swanson; **Applied Biochemists:** Paul Westcott, Jim Schmidt, Harry Knight; **Texas Parks and Wildlife Department:** Joan Glass, Greg Southard, Dennis Smith; **Clemson University:** Dr. John Rogers, B. Maurice Duke; **Aquatic Consulting and Testing, Inc.:** Dr. Rick Amalfi, Doug Crow; **University of Arizona:** Dr. Dave Walker; **Arizona Department of Environmental Quality:** Susan Fitch, Timothy Franquist; **Salt River Project:** Brian Moorhead, Gregg Elliott; **Arizona State University:** Dr. Milton Sommerfeld, Dr. Qiang Hu; **U.S. Fish and Wildlife Service:** Denise Baker, Dr. Kevin Reynolds; **Central Arizona Project:** Steve Rottas; **U.S. Bureau of Reclamation:** Mary Reece

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Arizona HAB Meeting – Responding To Harmful Algal Blooms

In the United States, harmful algae blooms (HABs) have triggered fish and wildlife mortalities, placed severe restrictions on recreational water usage and threatened domestic water supplies. In Arizona, golden alga as a cause of fish mortalities was first discovered in February 2005. Over the next five months, additional fish kills were confirmed from 11 other waters, half public and half private. As public, media and management interest and concerns increased over golden alga impacts in Arizona, it became clear that more information and coordination was needed to develop appropriate response strategies and approaches.

Thanks to the generous support of Applied Biochemists, represented locally by Paul Westcott, golden alga and HAB experts from Texas Parks and Wildlife Department and Clemson University were flown in for the Arizona HAB meeting. Eric Swanson with Arizona Game and Fish Department served as the meeting co-coordinator and facilitator. Developing specific strategies for effective monitoring and control of HABs was the focus of this multi-agency meeting with key stakeholders in Arizona. Particular emphasis was directed towards recent experiences, strategies and research on golden alga, *Prymnesium parvum*, in Arizona and Texas.

What are Harmful Algal Blooms (HABs)? Rapid reproduction of planktonic, toxin-producing algae species (one or more) resulting in high algal cell concentrations that dominate the algal community.

HAB Issue and Problem Overview – Paul Westcott, Applied Biochemists

- Harmful Algal Blooms attract media attention. Headlines use words such as “toxic algae, fish dying, water supply threatened, and killer algae.” The loss of large numbers of fish, especially catchable-sized sport fish, often attracts extensive media coverage and generates public alarm.
- Threats and problems associated with HABs include: human health and safety; threats to domestic animals and wildlife; taste, odor and toxin impacts to drinking water supplies; fish and aquatic life mortalities; management, monitoring and treatment costs; property value depreciation; tourism and recreation industry losses.
- While more HAB research and study are needed, there are response and treatment strategies that can be applied.
- Early detection of HABs and a rapid response targeting known algae species with the most effective algaecide can prevent serious problems.
- The “no response” option can lead to severe environmental and economic impacts, as well as elevate risks to human health.
- Algaecide applications must take into account the target species, algae concentration levels and distribution, and water quality.

Review of Golden Alga in Texas – Joan Glass, Texas Parks and Wildlife

What is golden alga?

- A microscopic (8-15 μm) yellow-green algae
- Motile using two whip-like flagella. Also has one haptonema (like a short, stiff flagella – $\frac{1}{2}$ cell size).
- Has characteristic swimming patterns.
- Mixotrophic. Both photosynthetic and heterotrophic (capable of eating bacteria, other algae, and protozoans).
- Produces two toxins, prymnesin I and prymnesin II, that affect gill-breathing fish and mollusks. No evidence or theoretical reason to believe toxins are harmful to humans, domestic animals or wildlife.
- Toxin toxicity is increased as alkalinity and cation ratios increase
- *Prymnesium parvum* cells have one C-shaped or saddle shaped chloroplast.
- Cells can vary in motility, shape, color and content.
- Life cycle includes a dormant cyst stage that can reside in water or sediment

History of golden alga

- First described in the scientific literature in 1937 in Scandinavia
- Now found worldwide in bays, estuaries and freshwater systems in Japan, Sweden, Denmark, England, Australia, Israel, and United States.
- First identified in Texas in 1985 in the Pecos River. Now found at over 30 locations statewide.
- As of 2005, golden alga has been confirmed from 12 states: Texas, Nebraska, Oklahoma, North Carolina, South Carolina, Georgia, Arkansas, Alabama, Wyoming, Colorado, New Mexico, and Arizona

Impacts of Golden Alga in Texas

- 21 lakes in Texas have experienced golden alga events (blooms and fish kills)
- Over 24 million fish killed
- Two warm-water hatcheries affected. One with an extreme fish kill and both have had to take drastic management measures to control and contain *P. parvum*
- Fisheries management changes and elevated costs
- Increases in monitoring and research costs

List of Active and Recent Research Projects in Texas

- Development of a DNA-based Assay and Partial Genome Analysis of *Prymnesium parvum*
- Statewide Survey for *Prymnesium parvum*
- Historic Data Assessment of Golden Alga Fish Kills
- Concentrated Monitoring of a *Prymnesium parvum* Bloom
- Effects of Barley Straw and Liquid Live Micro-Organisms on Density and Ichthyotoxicity of *Prymnesium parvum* in Hatchery Ponds
- Developing a Predictive Understanding of *Prymnesium parvum* Toxic Bloom Formation and its Control
- Estimating the Economic Impacts of Golden Algae (*Prymnesium parvum*) on Recreational Fishing at Possum Kingdom Lake

- Testing and Evaluation of Clays and Chemical Flocculants for Management of *Prymnesium parvum* Blooms in Texas

Funding for HAB Work in Texas

- Texas Parks and Wildlife base operating funds
- State Wildlife Grant funds from USFWS
- Legislatively designated or authorized funds

TPWD HAB Management Strategies

- Golden Alga Task Force – comprised of TPWD staff from various programs and areas of expertise and management
- Investigation and monitoring of all fish kills and toxic algae blooms – Kills and Spills Team (KAST)
- Algae control in two State Hatcheries (Dundee and Possum Kingdom) using ammonium sulfate to elevate un-ionized ammonia during warmer months with water temperatures >15°C, then using the copper-based algacide Cutrine in winter months.
- Management and restocking of impacted reservoirs
- Communications and outreach strategy – media, contacts, website development
- Statewide survey for presence of golden alga
- Assess fishery losses by quantifying numbers and species of fish killed by water and calculating an economic value for the mortalities. [Note: both fish kill counts and valuation methods follow American Fisheries Society guidelines.]
- Continue to coordinate with other agencies, states, managers and researchers to address the issues.
- TPWD is considering organizing another international meeting on golden alga in 2007

What We Know About Golden Alga

- It is widespread in Texas. Golden alga can be spread from water to water by a wide range of human, water management, wildlife, waterfowl, and natural means.
- It needs an “advantage” to bloom (e.g., rapid temperature change, low or high temperature, high salinity, rapid increase or decrease in nutrient loading, etc.)
- The toxin and toxicity is affected by water quality. Natural systems with pH <7 rarely have toxic conditions. Other factors include the cation:anion ratio, salinity, conductivity.
- There is no clear or consistent correlation between toxin amount, cell counts, water quality, bloom condition and toxicity to fish.
- A single drop of water may contain as many as 500,000 cells of *P. parvum*!
- Golden alga can develop a resistant cyst that can survive in the wet or dried dirt of a pond bottom

Promising Research and Management Findings

- The toxin prymnesin has been chemically isolated
- Toxicity can be roughly quantified by fish bioassay
- Chelated copper sulfate treatments are highly successful, but not species specific.

- Potassium permanganate can be effective as a primary treatment followed by a copper-based algacide application.
- Ammonia sulfate can be successfully used to elevate un-ionized ammonia that will lyse (burst) the golden alga cell, but will not adversely affect beneficial algae needed for fish production.
- Ozone and UV sterilization can be used to kill golden alga in small volumes of water such as for fish hauling. Ozone appears to have a neutralizing affect on toxins in the water, although the mechanism is unknown.

What We Need To Know

- What gives the golden alga a competitive advantage to bloom and what sustains it?
- How to predict and/or prevent toxic blooms
- What are the range of treatment options for rivers, canals, small ponds, lakes and large reservoirs?
- An easier, cost effective monitoring method and instrumentation.

Golden Alga Research, Management and Control in Texas Fish Hatcheries – *Greg Southard and Dennis Smith, Texas Parks and Wildlife*

Massive fish kills occurred at both Dundee and Possum Kingdom state fish hatcheries in 2001. Both hatcheries receive supply water from golden alga infested reservoirs.

TPWD established a golden alga Task Force to develop strategies to effectively and efficiently control *Prymnesium parvum* to ensure fish production. Literature reviews were conducted and experts contacted to understand how blooms occur, what causes production and release of prymnesin toxins, and what would be the best control strategies.

A *P. parvum* management plan for the hatcheries was developed that included:

1. Algae sampling and identification methods
2. Methods to monitor alga density
3. Methods to monitor toxin levels
4. Mitigation and control approaches
5. Strategies to prevent dispersal during stocking operations

Monitoring *P. parvum* Densities

- Cell counts determined with $\geq 400X$ magnification using a compound light microscope and a hemacytometer
- Samples are fixed with Lugol's solution
- Hemacytometer counts are in increments of 10,000 cells/mL
- Other enumeration techniques using other counting chambers provide more refined cell counts, however they take significantly more time and effort.

Monitoring *P. parvum* Toxin Levels Using Bioassay

- Mix water sample with cofactor solution
- Fathead minnows are the test organism
- Minnow mortality is monitored in three solution concentrations for 2 hours at 28°C

- This methodology is time consuming and not a very reliable measure of impending blooms or toxic events

About *P. parvum* Toxins

- Toxicity is independent of cell density (no correlation)
- Toxicity is independent of toxin levels
- There are various *P. parvum* strains, some have been isolated, some have been found without toxins, others have very high toxin levels
- Toxins rapidly degrade, especially when exposed to sunlight
- A simpler, quicker, more accurate method/instrument is needed for toxicity monitoring and estimating *P. parvum* concentrations

Treatments of *P. parvum* can be grouped as either Physical or Chemical methods

Physical Treatments Include

- Ultraviolet Sterilization – successful
- Ozonation – successful
- Barley Straw – unsuccessful
- Sonication - unsuccessful
- Biological control – unsuccessful

Ultraviolet Sterilization treatments destroyed all *P. parvum* cells, reduced toxicity, but did not eliminate toxins at higher levels. This method is not suitable for large scale water treatment, but is effectively used to treat water for fish transport trucks at *P. parvum* positive hatcheries.

Ozonation is used to control *P. parvum* cell counts and reduce toxicity for hatchery water used for hatchery egg incubation systems, and all incoming water to hatcheries. Effective ozonation treatment rates include ozone dosing at ≥ 1.2 mg/L with a contact time of ≥ 4 minutes.

Chemical Treatments Include

- Ammonium sulfate – successful
- Copper-based algaecides – successful
- Potassium permanganate - beneficial
- Other Oxidative compounds – other compounds are untested
- Nitrogen:Phosphorus ratio manipulation – untested
- Acids – unsuccessful using hydrochloric or sulfuric acids when pH >7

Ammonium sulfate has proven highly effective at both Texas warmwater hatcheries. It acts as a prophylactic treatment elevating un-ionized ammonia to a desired range of 0.14 – 0.25 mg/L. This inexpensive method is most effective at water temperatures from 15°C to 28°C. Un-ionized ammonia levels must be monitored daily to ensure maximum levels are not exceeded. Un-ionized ammonia at the proper levels causes *P. parvum* cells to lyse (burst) while not affecting other, beneficial algae essential for primary production to support fingerling fish growth. This chemical is not recommended for waters with temperatures below 15°C, low pH, high ambient NH₃, sensitive fish species, or delicate fish life stages.

- Increases total ammonia nitrogen (T.A.N.) and un-ionized ammonia levels (U.I.A.)
- Un-ionized ammonia levels ≥ 0.2 mg/L cause *P. parvum* cells to lyse
- Must use temperature, pH and T.A.N. values to calculate U.I.A. concentration
- Treatment is fairly selective in controlling *P. parvum* while not affecting green algae. Extra nitrogen loading may benefit primary productivity
- Low cost per treatment
- Fish are more tolerant to high U.I.A. levels when water has high alkalinity and hardness

Citrine® Plus (chelated form of CuCO_3) is highly effective in killing *P. parvum* cells at treatment levels of 0.2 mg/L as total copper. Citrine® Plus is federally registered and has no label restrictions in fisheries or drinking water supplies. Treatment levels ≥ 0.4 mg/L can cause mortality in rainbow trout. Citrine® Plus is used during cooler, winter months to control all algae species. It is a broad spectrum algaecide that inhibits primary productivity.

Potassium permanganate (KmnO_4) has been used to remove toxins from water and alleviate stress to fish. It does not kill *P. parvum* by itself, but in combination with algaecides it eliminates cells and reduces toxicity. Potassium permanganate is an oxidizer, so measures should be taken to ensure the oxidative demands of water are met during an application. Treatment levels of about 2 mg/L KmnO_4 are used in hatcheries.

General Notes

- Algaecides and chemicals dissipate more rapidly from earthen ponds than lined ponds.
- *P. parvum* seems to be particularly virulent in lined hatchery ponds
- Algal population dynamics appear to be very different in hatchery ponds vs. reservoirs.
- Diligence and a lot of time are needed to monitor, treat and test water at *P. parvum* infected hatchery ponds
- Algal blooms do not occur at high temperatures in hatchery ponds

TPWD has developed Hazard Analysis and Critical Control (HACCP) plans for state hatcheries to prevent dispersal of *P. parvum* from affected hatcheries. The HACCP plan includes the following procedures:

- *P. parvum*-free water (UV treated or well water) used to fill hauling unit tanks
- Production fish are rinsed twice in *P. parvum*-free water to rinse any cells away.
- Water samples from hauling tank units are checked microscopically for alga.
- Tanks are flushed with *P. parvum*-free water if *P. parvum* detected.

Harmful Algae Blooms In Arizona – Marc Dahlberg, AZ Game and Fish

From January through June 2005 fish kills associated with *P. parvum* blooms were documented from the following 12 Arizona waters

- Large Reservoirs: Saguaro Lake, Canyon Lake and Apache Lake
- Small public lakes and ponds: Water Ranch Lake, Cortez Lake, Kearny Lake
- Small private lakes and ponds: Val Vista Lakes, The Lakes, Garden Lakes, Summit Lakes, Chandler West Lake, The Islands

Golden alga have only been documented in Arizona since 2004 and were first associated with fish kills in 2005. Soon after golden alga were confirmed in Arizona waters in spring 2005, the Arizona Game and Fish Department (AGFD) prepared a press release and conducted various media interviews to inform and advise the public. A series of Frequently Asked Questions, modeled after the TPWD web site, was prepared and posted on the Game and Fish Department web site at azgfd.gov. A phone number and email address were provided for the public to report fish kill observations to AGFD.

Saguaro, Canyon and Apache Lakes are a series of reservoirs ranging in size from 950-2,600 surface acres on the Salt River. Approximately 15 miles downstream of Saguaro Lake, river flows are fully diverted into a network of Salt River Project canals. This 135-mile canal system is supplemented with pumped groundwater and water from the Central Arizona Project canal to meet all downstream water user demands. The Salt River Project canals deliver water to over 100 municipal, recreational and home-association ponds and lakes ranging in size from 0.1 acres to over 50 acres.

Monitoring *P. parvum* – *Dr. Rick Amalfi, Aquatic Consulting and Testing, Inc., Tempe, AZ*

Aquatic Consulting and Testing, Inc. (ACT) provides lake consulting and management services to various private property owners primarily in Maricopa County. Laboratory services are provided statewide for a wide range of water quality and biological tests including algae identification, enumeration, and toxin bioassay.

Monitoring Plan For Client Lakes

- Sample various lake locations to test for *P. parvum*
- Perform site visits weekly to observe conditions and collect samples
- Keep water samples cool and analyze quickly. Do not preserve samples.
- Report all positive results immediately and enact action/treatment plan

Action Plan For Lakes Positively Identified With *P. parvum*

- Act immediately to treat
- Treat with chelated copper algaecide at 0.2-0.5 ppm as Copper in entire photic zone across entire lake
- Re-sample and analyze in 48 hours
- Re-test weekly thereafter for up to a month

Tips for Microscopic Identification of *P. parvum*

- Concentrate sample by centrifugation
- Look for flagellates (swimmers) at 200-400X magnification
- Use multiple aliquats to ensure representative sampling results

- Try proto-slow or similar product for better viewing
- Be aware that cell color, shape, content and mobility is variable
- Use 1,000X magnification to make positive identification of paired flagella and haptonema

Toxicology of Harmful Algal Blooms – *Dr. John Rodgers, Clemson University, SC*

Best Approach to Harmful Algal Blooms and Toxicology Management

- Determine identity and distribution of toxic algae
- Assess probable risks
- Determine what can be done and what will be done
- Do it!
- Monitor and learn

Issues and Risks Associated With HABs

- Fishery impacts (fish toxicity, Invertebrate and mollusk toxicity, reduced fish productivity)
- Alter water characteristics (increase pH, decrease DO, decrease clarity)
- Taste and odor problems (MIB, geosmin)
- Toxin production (neurotoxins, hepatotoxins)
- Aesthetics (property value, tourism)
- Angling recreation (reduced angler catch rates and angling use)
- Other water-based recreation (boating, swimming, etc.)
- Economic impacts (recreation, property values, tourism)
- Treatment costs and labor-intensive options
- Public health and safety fears and reactions

Action Plan For Lakes With HABs

- Conduct risk assessment to determine if problem is significant (helps to focus decisions)
- A no action decision IS a decision to accept possible risks and consequences
- Consider all available treatment options: (1) chemical, (2) biological, (3) physical, (4) mechanical, (5) combination of the above
- Multiple treatments and monitoring are often required
- Notes: (1) success of treatments often depends on applicator skill and equipment, and (2) timing of treatments can be important

Chemical Control Options

- Copper formulations: Algimycin®-PWF, Earth Tec, Cutrine® Plus, Cutrine® –Ultra, Clearigate
- Peroxide formulations: Green-Clean®, Green-Clean® PRO, PAK™ 27
- Endothal formulations: Hydrothol®191, Aquathol®
- Diquat bromide: Reward®

Biological Control Options

- Grass carp
- Filter feeding bivalves

Physical Control Options

- Dyes
- Aeration
- Manipulate lake levels, water operations, and water supply

Mechanical Control Options

- Rakes
- Filters

Site-specific Management of a Problematic Alga (*P. parvum*) Using a Copper-containing Algaecide – B. Maurice Duke, Clemson University, SC

***Prymnesium* Toxicity Experiment**

- *P. parvum* samples treated with Cutrine® Plus at five concentrations (0.2, 0.4, 0.6, 0.8, 1.0 mg/L of Cu)
- Samples held in 250 ml Erlenmeyer flask for 96 hours
- Observed daily
- At conclusion, cell counts measured (hemacytometer) and chlorophyll *a* measured (spectrofluorometer)
- Treatments with Cutrine® Plus at 0.2 mg/L were just as effective as all other higher treatment concentrations in killing off *P. parvum* cells and reducing chlorophyll *a*

Field applications of Cutrine® Plus in Arizona waters have been successful with no reoccurrence of *P. parvum* associated fish kills after two months.

HAB Research in Arizona – Dr. David Walker, University of Arizona

Algal Toxin Monitoring in Arizona

- Studies conducted on watersheds surrounding Phoenix area since 2000
- Quarterly sampling for the following toxins: microcystin, anatoxin-a, cylindrospermopsin, and saxitoxin
- Other sampling included algal ID and counts, and various physico-chemical and chemical variables
- Development of a large, comprehensive database

Highlights of Toxin Research

- Over 140 µg/L of anatoxin-a found in Saguaro Lake (8/2000)

- Toxin tests of bluegill and threadfin shad stomachs found toxic levels of anatoxin-a in 33% of all fish and microcystin in 67%. However, no anatoxin-a was found in aqueous samples.
- During fish kill event, numbers of potentially toxic species were relatively low
- All cylindrospermopsin results (with the exception of a concentrated plankton tow) were non-detects
- Numbers of potentially toxic algal species increased after toxic events
- Anatoxin-a is readily degraded by sunlight and alkalinity (half-life may only be a few hours in lakes during warmer months)

List of Potentially Toxic Cyanobacteria/Algae Found in Salt River Reservoirs

Algae Species	Algal Toxin
<i>Aphanizomenon flos-aquae</i>	Anatoxin-a
<i>Anabaenopsis circularis</i>	Anatoxin-a, Microcystin
<i>Anabaena laxa</i>	Anatoxin-a, Microcystin
<i>Anabaena shremetievi</i>	Anatoxin-a, Microcystin
<i>Anabaena torulosa</i>	Anatoxin-a, Microcystin
<i>Anabaena variabilis</i>	Anatoxin-a, Microcystin
<i>Cylindrospermopsis raciborskii</i>	Cylindrospermopsin
<i>Merismopedia elegans</i>	Microcystin, nodularin
<i>Microsystis</i> sp.	Anatoxin-a, Microcystin
<i>Pseudanabaena</i> sp.	Anatoxin-a, Microcystin
<i>Oscillatoria aghardii</i>	Anatoxin-a
<i>Oscillatoria limnetica</i>	Anatoxin-a
<i>Prymnesium parvum</i>	Prymnesin I and Prymnesin II
<i>Gymnodinoids</i>	Saxitoxin, Brevetoxin
And several more...	

Golden Alga Findings in Arizona

- Found in lower three Salt River reservoirs in spring 2005
- Large fish kills occurred in early June of 2004 and 2005
- Small kills noticed beginning in March of 2004 and 2005
- Highest observed kills were found in the upper, riverine portion of Saguaro Lake that receives hypolimnetic releases from Canyon Lake upstream
- Canyon Lake has pump-back storage operations
- Nitrogen is usually lacking in riverine sections of reservoirs in spring
- Release of hypolimnetic waters high in ammonia/ammonium may trigger a decrease in toxin production

Common Misconceptions About HABs

- There is a correlation between numbers of toxic species present and the amount of toxin produced
- Algal species produce constant or fixed amounts of toxin
- Environmental conditions for toxin production are well known and predictable
- Algal toxins exert their influence in isolation

- Genes coding for toxin production are known
- No new or novel toxins exist

New Approaches To Toxicity Testing

- Collect composite samples
- Identify all algae to species level
- Isolate all suspect species into axenic cultures
- Conduct bioassays to screen for toxin producers
- Quantify toxins
- Examine the role of bioactive peptides
- Examination of “novel” toxins (Euglenoids, Gymnodinoids)
- Perform genomic fingerprinting of known toxin producers
- Isolate site-specific algal strains to determine toxin toxicity or lack of

HAB MODERATED SESSION

Meeting attendees participated in a moderated afternoon session to identify, share and develop guidelines and “best management practices” for harmful algal bloom prevention, early detection, rapid response, bloom monitoring and impact assessment, impact reporting and outreach strategies.

I. PREVENTION STRATEGIES

- Hazard Analysis and Critical Control (HACCP) plans for all water transfer, fish stocking, boating, and water contact operations. Programs and activities needing plans include: hatcheries, fish transport and stocking, and boating operations (fish management, law enforcement, water quality sampling, research). Note: TPWD has prepared HACCP plans for state hatchery operations in Texas.
- Public guidelines and outreach to encourage draining live wells and bilges of boats, cleaning boats and trailers, dumping bait buckets, washing off waders and fishing gear, etc.
- Guidelines and permits for private aquaculture and fish transport/hauling and stocking operations within the state and across state lines.
- “Sanitizing” gear with 10% bleach or other products such as “Quat” (quaternary ammonia).
- Outreach tools include use of web-based information, public advisories shared with media and posted at waters, links to Aquatic Nuisance Species and Protecting Your Waters national and statewide efforts.
- Large-scale watershed management or pollution controls to reduce nutrient loading and eutrophication.
- Artificial, man-made lakes and ponds require ongoing management and maintenance. Unfortunately, small municipal waters are often a neglected component of the urban landscape.

Preventing golden alga or other HABs from inhabiting a body of water is extremely difficult. Golden alga can be dispersed by: (1) human activities that carry water or wet equipment from one water to another; (2) water delivery systems that include interbasin transfers or mixing of water supplies; (3) fishing and boating recreationists and equipment moving from water to water; and (4) migrating or mobile waterfowl, herons, egrets, cormorants or other wading birds. Some literature suggests that golden alga may even be dispersed through the air by wind currents. The resting cyst stage of golden alga may remain in a viable state in sediments even during dry-up periods.

II. EARLY DETECTION STRATEGIES

Routine Monitoring (weekly, monthly, other)

- Collect water samples for plankton identification, cell counts, and species composition. Use grab sample methods as plankton nets can cause physical damage to golden alga cells making identification difficult. Keep samples cool and unpreserved when submitting to labs.
- Other water quality parameters to measure include: temperature, pH, dissolved oxygen, nitrate-nitrogen, nitrite-nitrogen, kjeldahl nitrogen, total phosphorus, ortho-phosphorus, secchi depth, salinity, conductivity
- Visual observations of water color, fish kills and odd fish behavior should be recorded

Resources Available For Algae Identification and Quantification

- Texas: TPWD has staff and laboratory facilities.
- Arizona: AGFD has staff and facilities to determine golden alga presence in public waters. Algae samples from private waters can be tested by Aquatic Consulting Testing, Inc (private) for either golden algae presence or comprehensive algae identification and quantification. Researchers affiliated with both ASU and UA also conduct algae and algal toxin testing.
- Support from ASU was offered to provide training in HAB identification and enumeration.
- Testing for toxins is challenging since golden alga toxins degrade rapidly and toxin levels fluctuate rapidly in waters. Bioassay methods using water samples, cofactor agents and fathead minnows can be used to test for toxins. Aquatic Consulting and Testing, Inc. can provide bioassay testing in Arizona.

Visual Signs or Indicators of Golden Algae to Look For FISH and FISHING

- Dead fish or clams.
- Declining catch rates by anglers
- Fish appearance indicators include: redness or hemorrhaging in fins; redness around mouth area or around head region; hemorrhaging in and around gills; sores on body; cloudy eyes
- Unusual fish behavior, characteristics or other observations include: fish observed in lethargic, weak state in shallows and along shorelines; fish lying along the bottom in shallow areas with delayed or no escape response to human presence; fish concentrated around areas of freshwater inflow, or in deeper sections of the lake with lower toxin concentrations; fish may exhibit “piping” behavior at water surface or in extreme cases, fish may actually try to jump out of the water to escape high toxicity.
- Fish seek to avoid areas of high toxicity by moving out of high bloom areas and into other lake zones or deep areas. In some instances in Texas, bass anglers have discovered the locations of bass “sanctuaries” and have experienced high catch rates from these areas.

WATER

- Color changes to yellowish, yellow-brown, copper or golden. Most noticeable in shallow zones.
- During blooms, foam may be observed forming in areas where water is highly agitated by inflow, wave and wind action along the shoreline, aeration, or other activities such as boating that create water turbulence.
- There are no documented incidences where golden alga blooms adversely affect the normal range of water quality parameters such as pH or dissolved oxygen, unlike most other algae blooms.

“Typical” Sequence of Fish and Aquatic Species Killed by Golden Alga Toxins

1. Filter feeding aquatic organisms such as clams or mollusks
2. Filter feeding fish, particularly forage fish such as shad
3. Fish with higher toxin sensitivity such as trout. Experience has shown that smallmouth bass are also extremely sensitive, but tend to “disappear” rather than float at the surface when dead.
4. Near-shore fish such as bass, bluegill and crappie. Small fish are killed first and eventually all sizes may die.
5. Pelagic fish such as striped bass, white bass and yellow bass
6. Bottom dwelling fish such as catfish, carp and suckers.

III. RAPID RESPONSE STRATEGIES

Texas Parks and Wildlife Department has an HAB Response Plan that establishes guidelines and protocol for the monitoring, sampling, testing, analysis and reporting of HAB occurrences. Development and implementation of an established, consistent statewide response strategy is a good planning and management practice. Arizona’s resource and land management agencies must join together in a coordinated, collaborative multi-agency effort to respond appropriately and strategically to HAB incidents.

For HAB affected waters, the most effective treatment can be accomplished using copper-based algaecides. Golden alga are particularly susceptible to Cutrine® Plus. However, as with all algaecide treatments, all algae species are affected, not just harmful or undesirable species.

Best Practices For Algaecide Application

- It is always best to identify the algal types and relative abundance before treating
- Test the water to determine temperature, pH, dissolved oxygen, alkalinity and hardness since all of these water quality parameters can impact algaecide performance and control results
- Be aware that: (1) algaecide sensitivity varies by species, and (2) algal abundance can affect dosage rate
- Treating the algae, not the water, is the most economical and effective approach to algal control
- Must use a Certified Applicator

- Select the proper algaecide to use under the existing water quality and algae conditions. All copper algaecides are not chelated equal.
- Calculate the quantity of algaecide needed based on the entire lake volume, not just the photic zone
- Carefully follow all chemical label instructions making sure to use only EPA registered products to comply with Federal law (FIFRA).
- Apply the algaecide as a diluted solution rather than straight from the container.
- Apply the diluted algaecide as an even application at a moderate to light level on the first pass across the lake, then repeat with another application
- Use criss-cross application patterns to mix well. Utilize prop wash from boats and take advantage of winds and currents to assist in mixing the chemical across and within the lake.
- Mixing dye or lake colorants to algaecide solution may help to visually determine good chemical coverage.
- Algaecide treatments are best conducted in the morning hours, when winds are minimal and treatment can be monitored throughout the day.
- Monitor dissolved oxygen before and after application

Algaecide Treatment Costs

- Products such as Cutrine® Plus, Cutrine® Ultra, Algimycin® - PWF, Earth Tec, typically cost from \$18-30 per gallon as concentrated product.
- Algaecide treatment costs may range from \$200-\$400 per acre-foot depending on chemical prices and application costs.
- Because of moderately high costs of algaecide treatment, this method may not be considered practical for larger lakes and reservoirs. The largest lake treated with algaecide for golden algae blooms in Arizona is 50 acres. It is a private, home-association lake in Tempe, AZ. In other parts of the country, reservoirs in excess of 1,500 acres are routinely treated every year for algae blooms.

Algaecide treatment costs associated with large lakes and reservoirs can be significant and in some cases impractical. However, strategic application of algaecides to coves, bays or sections of lakes with the heaviest, concentrated HAB blooms may have merit. Additionally, treatment of protected coves or lake areas with low HAB blooms may serve to reduce toxins in these areas so they can serve as “sanctuaries” for fish seeking to avoid high toxicity areas during bloom events. In addition to treatment cost and funding, a range of additional considerations such as permitting, agency coordination and responsibility, downstream water uses, application logistics, outreach, etc., must be considered on a case by case basis to determine the feasibility of this control method.

Other Algaecide Considerations

- Algaecide treatments must be approved by the landowner. For public waters (especially those under Federal ownership and management), the approval and permitting process can be complex, lengthy and costly requiring extensive coordination and collaboration and may involve a formal or informal public notification and comment process.
- Copper toxicity in water, sediments and fish is a common concern. The chelated forms of copper in most algaecides is Federally approved for applications in fishing waters and drinking water supplies. The form of copper used is not bioavailable

within water systems and generally settles into the bottom sediments in an inert state.

- For any algaecide treatment, the affected public should be notified and an outreach strategy adopted.

Other Chemical Options

- Potassium permanganate
- PAK™ 27
- Phycomycin™ SCP

IV. BLOOM MONITORING AND IMPACT ASSESSMENT STRATEGIES

Determining Fish Kill Totals and Values

- Follow American Fisheries Society methodologies for fish kill assessment. *Sourcebook For Investigation and Valuation of Fish Kills*, supplement to American Fisheries Society Special Publication 24, 1993.
- Another helpful publication is *Field Manual for the Investigation of Fish Kills*, U.S. Department of Interior Fish and Wildlife Service, Resource Publication 177, 1990.
- Field methods for counting fish mortalities in large lakes include assignment of crews to designated sections of the lake. Experienced crew members must be able to properly identify fish species and gather information on the sizes and number of fish. Mortality counts at each location are done three times to obtain a reliable estimate. Areas of lake are segmented by low, medium and high fish counts and surface acreage values assigned. Counts are conducted weekly until fish kill event is over. Larger fish such as carp are marked with paint so they are not double counted the next week.
- TPWD does not remove dead fish. Fish removal is the responsibility of the pond or lake owner or management agency.
- A recently completed report (October 2005) was prepared by Bob Ditton (Texas A&M University) that describes a method to estimate economic losses and impacts associated with fish kills.

Toxin Testing and Analysis

- Specialized laboratories are required to analyze HAB toxins from water samples.
- Methods of detection include the use of PCR and DNA.

Impacts to Waterfowl and Domestic Ducks

- Numerous reports in Texas and Arizona indicate high waterfowl and domestic duck mortalities following major fish kills from golden alga.
- Mortalities are symptomatic of botulism. As ducks feed on dead and decaying fish carcasses, they are subject to episodes of botulism.
- In a couple cases, entire populations of domestic ducks have died within a span of a couple weeks.
- Lake and pond owners should remove all dead and dying fish and ducks as quickly as possible.

V. HAB INCIDENT REPORTING

Gathering and compiling HAB incident reports is important to monitor HAB distribution, impacts, bloom and occurrence trends, and assess local and statewide fisheries, recreation, and economic impacts.

TPWD has full-time monitoring crews that travel statewide to sample for HAB occurrence and sample lake conditions during algae blooms and fish kills. Quarterly summary reports are prepared to assess statewide trends and impacts.

VI. OUTREACH, INFORMATION & EDUCATION STRATEGIES

A variety of outlets should be used to share information about HABs, golden alga and fish kills with the public, key stakeholders, and the media.

- Web site – include Frequently Asked Questions (FAQs), press releases, advisories, prevention strategies, and known information of HABs. Emphasize what we are doing and what the public can do.
- Press releases
- Public meetings
- Provide advance notification to public when possible before fish kill events happen. Forecast probable events and seasonal occurrences.

Develop a focused, consistent message that everyone can deliver and reinforce. Be proactive by providing as much information as possible immediately, rather than waiting for complete or perfect information. Anticipate distrust and skepticism from the general public. Expect media to sensationalize the issue. Be concise, be simple and stick to the facts. Communicate the issue regularly and frequently update all FAQ, web site and other information sources available to the media and public.

“Messages to Communicate About Golden Alga”

- Golden alga blooms are NOT a public health threat
- While golden alga is not a human health problem, people should not pick up dead, or dying fish for eating.
- Golden alga toxins can kill gill-breathing aquatic organisms including clams and fish
- HABs and golden alga impacts may be minor or severe, but they are temporary
- This is potentially a big problem affecting thousands of anglers and businesses
- There are treatment solutions for smaller lakes and ponds, but these same algaecide treatment strategies are impractical in larger lake and river systems.
- Golden alga and other HABs can exist in waters without causing fish kills or other problems.
- The problems and solutions are complex; learning is continuous, and we have a lot to learn.

Multi-agency collaboration, networking and coordination will be vital to communicating a clear and responsive message to the public.