

Toxic Golden Algae (*Prymnesium parvum*)

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WHAT ARE GOLDEN ALGAE?

Algae are primitive, mainly aquatic photosynthetic organisms that contain chlorophyll and lack true stems, roots, and leaves. Algal blooms (an explosive increase in the population of algae) are common in aquatic environments, and harmful algal blooms (HABs) can cause substantial problems to marine and freshwater resources.

Prymnesium parvum, commonly referred to as “golden alga,” is a microscopic (about 10 µm), flagellated alga that is capable of producing toxins that can cause extensive fish kills. This algal species is found worldwide (Edvardsen and Paasche, 1998) and is most often associated with estuarine or marine waters, but it can also occur in inland waters that have a relatively high mineral content. Salinity appears to be the main factor controlling its distribution (Nicholls, 2003).

The first confirmed blooms of *P. parvum* in North America were identified in Texas in 1985 on the Pecos River (James and De La Cruz, 1989). Since then, fish kills caused by golden algae blooms have occurred in 33 reservoirs in Texas along major river systems, including the Brazos, Canadian, Rio Grande, Colorado, and Red Rivers, and have resulted in more than an estimated 34 million fish killed and tens of millions of dollars in lost revenue (Sager et al., 2008; Southard et al., 2010). *Prymnesium parvum* has invaded reservoirs and river systems in 23 other states, including all southern regions of the USA and more recently some northern states, including Colorado, Wyoming, Nebraska, Iowa, Washington, Pennsylvania, West Virginia, and Maine (Sager et al., 2008; Roelke et al., 2016).

In New Mexico, *P. parvum* was first reported in the 1980s (New Mexico Department of Game and Fish [NMDGF], 2004). From 2002



Figure 1. *Prymnesium parvum*. Photo courtesy of Texas Parks and Wildlife Department © 2006 (Greg Southard, TPWD).

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to 2007, *P. parvum* blooms caused extensive fish kills in Brantley, Bataan, and Carlsbad Municipal Reservoirs in the lower Pecos River (New Mexico Aquatic Invasive Species Management Plan, 2008). Blooms were also reported in isolated ponds near Eunice and Roswell (NMDGF, 2004, 2005), and toxic golden algae blooms led to fish kills in McAllister Lake in Las Vegas (S. Hopkins, personal communication, January 22, 2009).

WHAT DO GOLDEN ALGAE LOOK LIKE?

These single-celled organisms are ellipsoid or oval in shape, with cells ranging from 8 to 11 µm in length and 4 to 6 µm in width (Green et al., 1982). Each *P. parvum* cell has two equal “tails” called flagella and a short, flexible peg-like organelle called a haptonema (Figure 1). The flagella are used for motility and the haptonema may be used for attachment or feeding. *Prymnesium parvum* cells have two saddle-shaped chloroplasts that are usually yellow-green to olive in color. Microscopic examination of subsurface water samples (*P. parvum* is light sensitive and avoids the water surface) at magnifications of 400 to 1,000× is required for identification, and confirmation requires the examination of the scale morphology using electron microscopy or molecular-based techniques (Galluzzi et al., 2008). Proper identification of this alga requires experience.

HOW DO GOLDEN ALGAE KILL FISH?

Golden algae are believed to produce a number of toxins, collectively known as prymnesins, which include an ichthyotoxin, or fish toxin (Ulitzer and Shilo, 1966); a cytotoxin (a substance that is toxic to cells) (Ulitzer and Shilo, 1970); and a hemolysin (a protein that causes the destruction of red blood cells) (Ulitzer, 1973). The ichthyotoxin adversely affects gill-breathing organisms such as fish, bivalves, crayfish, gilled amphibians, and also some species of plankton. The toxin damages the permeability of gill cells, which then makes them susceptible to any toxins present in the water, including the *P. parvum* toxin itself (Olli and Trunov, 2007). The gills lose their ability to exchange water and absorb oxygen and bleed internally, resulting in death of the organism by asphyxiation.

ARE GOLDEN ALGAE HARMFUL TO HUMANS OR OTHER ANIMALS?

Prymnesium parvum blooms are not considered a public health threat. Unlike red tide, another toxic alga, toxins that golden algae produce do not appear to have a negative effect on other wildlife, livestock, or humans. However, scientists have stressed that there is currently insufficient scientific evidence to conclusively state that there are no health risks to terrestrial organisms or humans. As a common sense precaution, dead or dying fish should not be consumed.

UNDER WHAT CONDITIONS DO GOLDEN ALGAE BLOOMS OCCUR?

Although it can exist in waters without causing harm, under certain environmental conditions, *P. parvum* can gain a competitive edge over other algal species, and algal blooms can be initiated. The presence of blooms of *P. parvum* does not necessarily mean the algae will produce and secrete prymnesins into the water, and in fact studies suggest that bloom density and toxicity are not strongly correlated (Shilo, 1981). Toxicity appears to be enhanced by temperatures lower than 86°F (30°C) (Shilo and Ashner, 1953), by pH greater than 7.0, and when cells are grown under nutrient-limited conditions (Dafni et al., 1972; Granéli and Johansson, 2003; Hambright et al., 2014). Studies have shown not only that *P. parvum* becomes more toxic when nutrients are limited but also that toxicity was reduced when nutrients were added to natural plankton communities undergoing *P. parvum* blooms (Kurten et al., 2007; Roelke et al., 2007; Errera et al., 2008).

In the south-central USA, golden algae blooms and associated fish kills almost always occur during the cooler winter and spring months (Hambright et al., 2010; Southard et al., 2010; VanLandeghem et al., 2014; Hambright et al., 2015). This is the time of year when environmental conditions (cooler temperatures, limited nutrients) are not favorable to other algae, and it appears to give golden algae an advantage. However, the exact environmental conditions favoring toxic algal blooms are not clear, and even though factors such as water temperature and salinity are somewhat helpful in predicting future blooms, there are many exceptions that have been reported. For example, if golden algae become



Figure 2. Foam is characteristic of *P. parvum* blooms. Photo courtesy of Texas Parks and Wildlife Department © 2006 (Joan Glass, TPWD).

abundant in the overall algal community, they can persist all year despite rising temperatures, and fish kills can occur during summer months, as has happened in some Texas lakes and rivers. It does appear that the most important factor influencing the toxicity of *P. parvum* blooms is the relative amount of nitrogen and phosphorus found in the water, with toxicity increasing when both of these nutrients are limited (Johansson and Granéli, 1999; Roelke et al., 2007, 2016; Errera et al., 2008; Hambright et al., 2014).

SIGNS OF GOLDEN ALGAE BLOOMS AND FISH INTOXICATION

Appearance of the Water

When the population of golden algae increases during a bloom cycle, the water may begin to turn yellowish, yellow-copper, or a copper-brown tea color. Another sign of *P. parvum* blooms can be foaming at the water surface if agitated or aerated, such as where there is wave action (Figure 2). However, it is important to note that these conditions can be caused by other sources, and fish kills have been reported in waters where these visual conditions were not apparent.

Signs of Intoxication

Fish affected by *P. parvum* toxins behave erratically. They may swim slowly below the surface, accumulate in the shallows, or show no normal avoidance of



Figure 3. Appearance of gills of a dying largemouth bass during an algal bloom. Photo courtesy of Texas Parks and Wildlife Department © 2006 (Greg Southard, TPWD).

human presence or other disturbance. They may try to leap from the water to avoid the toxins. If clean water flows into the affected body of water, fish will often accumulate around this freshwater source. Signs of intoxication include redness or bleeding in the gills, at the base of the fins, around the mouth area, and along the belly, and the fish may be covered with mucous (Figure 3). Young fish are often more sensitive to the toxins than adults. In the early stages of intoxication, the effects are reversible if the fish can move to uncontaminated water. Ecological impacts will vary depending on the length and severity of the toxic bloom. In larger water bodies with access to fresh water, toxic blooms may not kill all the fish present. However, in shallow hatchery ponds, the entire population of fish may be killed if the toxic bloom is not treated promptly.

MANAGING GOLDEN ALGAE

Monitoring for Presence

In New Mexico, the Department of Game and Fish (NMDGF) currently monitors bodies of water for the presence of *P. parvum* and investigates the causes of its spread. Water samples are collected and examined microscopically to determine if the alga is present. Once the presence of *P. parvum* is confirmed, cell counts are conducted to estimate the density of algal cells in the water. Recently, a rapid test for the detection of *P. parvum* using a specific monoclonal antibody and solid-phase cytometry

(the counting of cells) was developed by West et al. (2006). In another study, a method using real-time quantitative PCR (a molecular technique used to produce large quantities of DNA) was developed for the rapid detection and quantification of *P. parvum* (Galluzi et al., 2008).

Estimating Toxicity of Golden Algae

The presence of golden algae does not necessarily mean toxins will be produced. To test for the presence of toxins and estimate toxicity, a bioassay (a test to measure biological activity or potency of a substance) can be used (Ulitzer and Shilo, 1964). This test can identify waters that have high enough concentrations of the toxin to pose a risk to fish, and can help to decide if treatments are warranted. The bioassay involves exposing test fish to various dilutions of the water in question amended with a chemical solution known as a cofactor. This cofactor enhances the potency of the ichthyotoxin, which enables the detection of sub-lethal levels of the toxin. The bioassay currently used by Texas Parks and Wildlife Department (TPWD) has been adapted from the Israeli test, and the methods can be found in Appendix B at the following link: http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_t3200_1138_appendices.pdf.

Treatments

Management guidelines and treatments for controlling golden algae in ponds and small reservoirs are covered in detail by the TPWD (Sager et al., 2007). In aquaculture pond facilities, *P. parvum* blooms are currently controlled primarily by the addition of chemicals possessing algicidal properties. These include ammonium sulfate (Barkoh et al., 2003) or copper-based algacides to reduce population densities, and potassium permanganate to reduce toxicity (Dorzab and Barkoh, 2005; Barkoh et al., 2010). Adding nutrients has also been shown to suppress population growth and production of toxins in aquaculture ponds (Kurten et al., 2010). However, all these approaches have some drawbacks. The concentrations of ammonium sulfate required to control *P. parvum* may produce concentrations of un-ionized ammonia that can be toxic to some fish (Barkoh et al., 2003, 2004). Copper sulfate is effective in reducing the number of algal cells, but has no effect on their toxicity (Sager et al., 2007) and may kill desirable algae along with the golden algae,

as well as large numbers of invertebrate food organisms such as rotifers and cladocerans (Boyd, 1990). Excessive additions of nutrients can lead to pH and dissolved oxygen problems. In addition to using ammonium sulfate and copper sulfate to control *P. parvum*, Chinese carp breeders have used suspended solids (mud), the addition of fertilizer (manure), and reduced salinity with varying degrees of success (Guo et al., 1996). Ultraviolet light and ozonation have been successfully used to control *P. parvum* in small volumes of water, but these treatments may not be feasible for ponds and reservoirs due to the cost and required equipment (Sager et al., 2007).

Other methods, including ultrasonic vibrations, barley straw, and probiotics, were investigated by TPWD to determine their effectiveness at controlling *P. parvum* blooms and toxicity, but were deemed ineffective (Grover et al., 2007; Sager et al., 2007).

When deciding to apply any algacide, it is important to first obtain all regulatory approvals and permits. Only those treatments approved by the U.S. Environmental Protection Agency and the New Mexico Department of Agriculture can be used in New Mexico. It is also important to follow all label instructions and restrictions to comply with federal law.

While these chemical methods may be successful in controlling *P. parvum* blooms in aquaculture facilities, their use in natural systems is problematic because of regulatory restrictions and the high risk of negative impacts on non-target species. Furthermore, while ponds and smaller reservoirs (less than a few hundred acres) can be successfully treated with these chemicals, it is simply not financially or logistically feasible to apply algacides to larger lakes, reservoirs, and rivers. For these reasons, feasible management techniques are currently not available for large bodies of water in New Mexico, such as the Pecos River, and golden alga is currently virtually impossible to eradicate from such natural systems. One possible avenue to pursue for long-term control of *P. parvum* may be to reduce salinity to levels that are below tolerance levels of the alga, either by source attenuation or dilution of the water through manipulations of water levels and flow, or some combination of the two (S. Hopkins, personal communication, January 22, 2009). Addition of nutrients is a strategy that has proven to be effective in suppressing growth of

P. parvum during in-lake mesocosm experiments (Roelke et al., 2007; Errera et al., 2008), and large-scale fertilization to help control blooms of *P. parvum* has been considered, but that could lead to other ecological problems (S. Denny, personal communication, January 9, 2009). The use of clay minerals to flocculate (form into a lumpy, aggregated mass) and sediment algal blooms from the water column has shown some promise in laboratory and field trials (Sengco and Anderson, 2005). The practice involves adding clay slurries directly over an algal bloom, which subsequently form aggregates of algal cells and clay that settle out of the water column. Algal cell removal efficiency appears to be best when clays and chemical flocculants are combined (Sengco and Anderson, 2005).

WHAT CAN I DO TO HELP PREVENT THE SPREAD OF GOLDEN ALGAE?

Dead or dying fish or large numbers of fish behaving erratically should be reported to authorities as quickly as possible. In New Mexico, fish kills are investigated by the New Mexico Environment Department (NMED) in collaboration with NMDGF Regional Offices. Contact the Surface Water Quality Bureau of NMED at <http://www.nmenv.state.nm.us/swqb/FishKills>, or one of the NMDGF Area Operations Regional Offices at <http://www.wildlife.state.nm.us/home/contact/location-map/>, with as much information as you can provide (species, size, approximate number of fish affected, and location where fish were observed).

To prevent the spread of golden algae from one body of water to another, the following precautions should be taken.

- Before leaving a lake or other body of water, drain all water from the bilge, live wells, and any other water-holding device of your watercraft.
- Rinse out the boat, bilge, live wells, and equipment with fresh water and, if possible, allow the equipment to dry for two to three days before using it at another body of water.
- For an extra precaution, it is recommended to spray the surface of equipment with a 10% bleach solution, allowing a 15-minute contact time before rinsing the area with clean water free of algae and allowing it to dry.

- Never move water, live animals, or plants from one body of water to another because you may also transplant undesirable species such as *P. parvum*.

WHERE CAN I LEARN MORE ABOUT GOLDEN ALGAE?

The TPWD has a Golden Alga Task Force that works with researchers, other agencies, and interested stakeholders within and outside Texas to better understand, monitor, and control *P. parvum*. To find out more about golden algae, bloom status reports, and research and management of *P. parvum*, visit the TPWD website at www.tpwd.state.tx.us/landwater/water/environconcerns/hab/ga/.

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