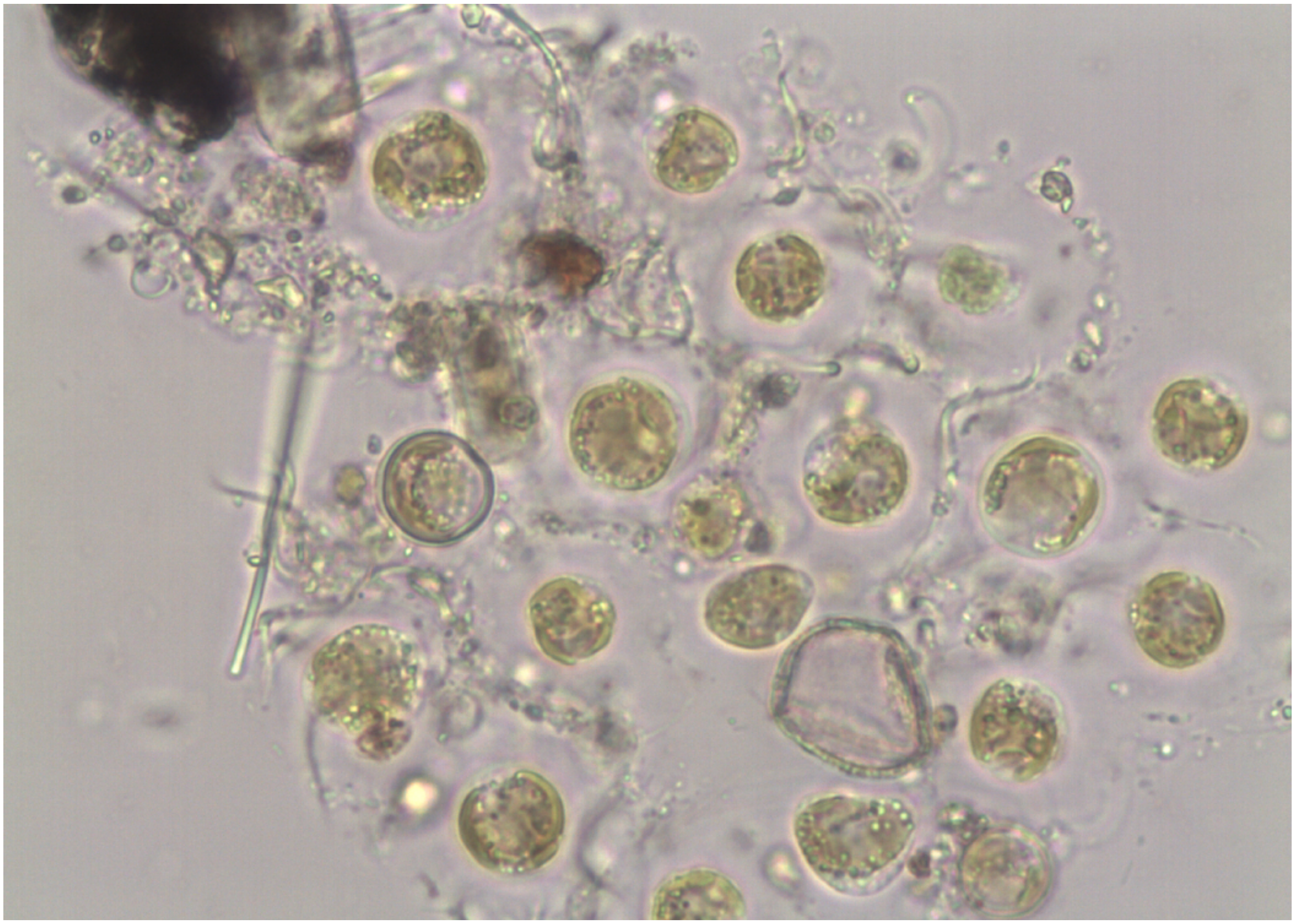
Golden Algae: The Hidden Fish Killer

PRYMNESIUM PARVUM IS RESPONSIBLE FOR MANY FISH DEATHS, BUT THERE ARE SOLUTIONS.



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Introduction

Of the thousands of algal species known to man, only a few seem to capture people's attention and make it into mainstream media. The toxin-producing golden algae Prymnesium parvum is undoubtedly one of those species. P. parvum has been documented and implicated in numerous large-scale fish kills worldwide, resulting in major monetary and ecological losses. Since 2000, P. parvum has caused the loss of tens of millions of U.S. dollars in natural resource damages and has killed thirty-four million fish in the state of Texas alone. Many Texan fish managers no longer stock sport fish in lakes with repeated, fish-killing P. parvum blooms (Brooks et al. 2011). In Florida, P. parvum has caused numerous fish kills and has led the Florida Fish and Wildlife Commission (FWC) to begin a community-based P. parvum watch to help better predict and understand when a bloom will occur. From 2005 to March 2013, the Florida FWC and the community monitoring program documented twelve toxic blooms of P. parvum. Most occur in small ponds in residential areas, golf courses, and the Intracoastal Waterway. This monitoring program also found that the blooms occurred when temperatures were below 30^{o}C (winter months), and salinities were between 1 and 5 parts per thousand (ppt) (http://myfwc.com).

Identification, Classification, and History

P. parvum is an uninucleate, unicellular flagellate with an ellipsoid or narrowly oval cell shape (Lee 2008). Identification of P. parvum is particularly challenging even for a trained phycologist. This is because P. parvum is extremely small (8-10µm) and fragile, and its morphology can be distorted by using preservatives. Identification can be achieved at 400 to 1,000x magnifications, but for species confirmation, an electron microscope looking at scale morphology or molecular-based techniques using polymerase chain reaction (PCR) assays are required (Galluzzi et al. 2008). If using a compound microscope, some of the key characteristics to look for are: 1) the presence of a haptonema (a filamentous appendage arising between two smooth flagella), 2) two elongated chloroplasts yellow to green in color, and 3) equally sized flagella (12-15µm long) (Lee 2008). Overall, P. parvum poses as a difficult species to identify. Not only is it very small but it requires expensive equipment in the identification process, perhaps making it that much more of a challenge to manage.

The holotype (the single specimen designated as the type of a species by the original author at the time the species name and description were published) of the genus Prymnesium is Prymnesium saltans Massart (Carter 1937). P. parvum belongs to the group Prymnesiophyta, which is comprised of approximately five hundred living species in fifty genera. Like Chrysophyta, the group is recognizable by its golden or yellow-brown accessory pigments (primarily fucoxanthin). Prymnesiophyta has two membranes of chloroplast endoplasmic reticulum, as do the Cryptophyta and Heterokontophyta, but differ in having flagella without mastigonemes (hair-like structure). The most distinguishing feature of the Prymnesiophyta group is the presence of a haptonema, superficially similar to a flagellum. Still, it differs in the arrangement of microtubules and function, being implicated in attachment or capture of prey (Lee 2008). The classification of Prymnesiaceae was originally called Haptophyceae, based on the haptonema structure, but was later changed by Hibberd (1976) to be based on the genus Prymnesium. It's important to note that the literature still uses both classification names.

Interestingly, the Prymnesiophyta group was not studied in detail until greater magnification could be achieved using the electron microscope. Irene Manton (1904-1988) and her colleagues at Cambridge University were the first to describe the haptonema structure and recognize Prymnesiophyta as a distinct group. Advances in molecular techniques in the 1990s further supported Dr. Manton's early research and confirmed that Prymnesiophyta are indeed distinct from Cryptophyta and the Heterokontophyta (Lee 2008).

Biology

Environmental requirements

P. parvum is a predominantly marine species but can handle a wide range of salinities, allowing it to inhabit inland brackish waters. Larsen et al. (1998) found that P. parvum could survive in salinity ranging from 3 to 30 parts per thousand (ppt) and had an optimal growth at 8 ppt. Macêdo et al. 2023 found that more than 1900 µS/cm conductivity encouraged the rapid growth of P. parvum. P. parvum temperature tolerance is between 5 and 30^{0}C, with optimal growth around 15-26^{0}C. Lysing of the cell wall occurred when temperatures rose above 34^{0}C, and when temperatures fell below 10^{0}C growth was severely limited (Larsen et al. 1998).

P. parvum is a mixotroph and can switch from autotrophic to heterotrophic depending on light intensity and nutrient availability. This ability may give P. Parvum a competitive edge over other algal species that are obligate phototrophs. Wynne and Rhee (1986) found a positive correlation between light intensity and phosphorus (P) uptake. As light intensity increased, P. parvum increased its phosphate uptake speed from the environment, suggesting light intensity may also have a profound effect on competition. However there seems to be a balancing mechanism with respect to light intensity, since excessive light intensity actually caused growth inhibition. Rahat and Jahn (1965) were the first to describe P. Parvum as having heterotrophic growth in the dark but noted that growth only occurred if high concentrations of glycerol were available. Once energy reserves were depleted, growth was slowed substantially, suggesting photosynthesis is the preferred metabolic pathway for bloom formation.

The nutrient requirements for P. Parvum seem to go against conventional wisdom in that reducing nutrients (nitrogen and phosphorus) will not necessarily reduce P. Parvum growth. This pertains to P. Parvum's ability to obtain nutrients from both photosynthesis and by consuming prey (mixotrophy). Brooks et al. (2011) have described, "Individual cells can aggregate in ''feeding swarms,'' where they encircle and consume a prey organism already debilitated by toxins. Such predatory behavior tends to occur late in a bloom cycle as a strategy to obtain nutrients under depleted conditions (Brooks et al. 2011)." This is a competitive and aggressive species that is fit for survival in nutrient-depleted habitats, making management difficult.

Prymnesin toxin

P. parvum secretes a potent exotoxin called prymnesin. The toxin is soluble in water and is not restricted to release during death or lysis of the cell. The harmful effects of Prymnesin are due to its ability to increase cell membrane permeability and disrupt the cellular ion balance (Brooks et al. 2011). The toxin causes acute toxicity to any gill-breathing species such as fish, mollusks, arthropods, and to the gill-breathing stage of amphibians. It has also been demonstrated that compounds released by P. parvum are allopathic and can potentially change an entire phytoplankton community. Fistarol et al. (2003) found that cyanobacteria, dinoflagellates, and diatom cultures subjected to prymnesin all showed suppressed growth, with diatoms being the most sensitive. P. parvum has also been shown to secrete more toxins when grown in nitrogen (N) and P-limiting conditions (Johansson and Graneli 1999). This may be another mechanism by which P. parvum can obtain nutrients when they have become limiting.

Control Options

P. parvum has evolved to thrive in a variety of ecological niches, as outlined above. This unique ability to adapt to different environmental conditions, along with its ability to manipulate food webs by producing prymnesin, makes management particularly difficult. However, at Natural Lake Biosciences, we are actively researching P. parvum control strategies in the lab and the field. The best control methods thus far have been the use of algaecides mixed with biocatalysts (Pondzilla and Aquasticker) for short-term control. Probiotics such as Muckbiotics, Temperature-Driven Solutions, and MetaFloc can help prevent blooms from occurring and/or prolong algaecide treatments. Watershed management of ions in a lake (maintaining well under the freshwater threshold of 1,200 µS/cm conductivity) greatly reduces the risk of P. parvum blooms.

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Notes

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