P. parvum Bloom in a Nevada Reservoir

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Preliminary Report on Aquatic Food Web Impacts from a Toxic Haptophyte

Harmful algal blooms (HABs) in U.S. coastal and freshwaters have received much greater attention in recent decades. While blooms from bluegreen algae (cyanobacteria) are more widely recognized, a member of the haptophytes, *Prymnesium parvum*, produces toxins that can kill fish and other aquatic biota, resulting in substantial water quality degradation. This article reports the first bloom of *P. parvum* in Nevada and impacts on fish, zooplankton, and quagga mussels in Lake Las Vegas, a man-made lake near Las Vegas (Figure 1).

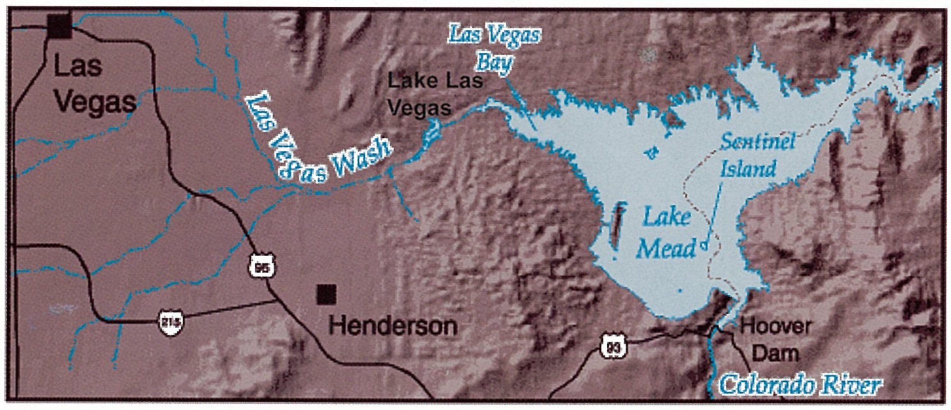

Figure 1. Lake Las Vegas area map.

Lake Las Vegas

Lake Las Vegas is a 130 ha warm monomictic reservoir located adjacent to the Lake Mead National recreational area boundary in Henderson, Nevada. Construction began in 1989 with a 1.6 m long earthen dam within the Las Vegas Wash channel (Figure 2). The wash flows of about 300 c.f.s. are bypassed under the reservoir via two 2.13 m diameter concrete pipes. The bypass was designed to keep high-nutrient, low-quality runoff water out of the lake. Only in storm events of greater than three-year frequency does the Wash water flow into the reservoir. Construction of the dam and its three spillways was completed in May 1991 and filling began with 0.004 km^3 of Lake Mead water. At full elevation, the reservoir is 3.2 km long and one mile wide. The maximum depth is 43 m with average depth 10 m and an average storage capacity of 0.013 km^3. Untreated Lake Mead water is the primary source of makeup water to the reservoir with evaporation losses of about 0.002 km^3 annually (Weber 2006).

Lake Las Vegas water chemistry is influenced by a number of natural and anthropogenic sources. Natural influences such as flood events discharge periodically into the reservoir and influence water chemistry and plankton communities. Depending on the magnitude of these events, the change may be short-lived or last for several years when the lake's volume is completely replaced or flushed as in a July 1999 event when 0.06 km^3 passed through the lake.

The reservoir is a unique urban lake providing recreation and irrigation storage for a large master-planned community, including three 18-hole golf courses. The management and staff of the reservoir conduct monthly water quality. monitoring of physical, chemical, and biological constituents. While management of the reservoir has changed since 1991, water quality monitoring and analytical methods have been consistent since the reservoir was constructed.

Prymnesium parvum

P. parvum is a haptophyte or golden alga with two flagella and a unique flagellum-like organ called a haptomena (Figure 3). The species belongs to the same group as the non-toxic and common species in lakes, reservoirs, and ponds, *Chrysochromulina parva*. *P. parvum* specimens in Lake Las Vegas were about 10 µm x 6-7 µm and identified and enumerated with an inverted microscope under phase contrast microscopy in Lugol's preserved samples.

The species was first reported in the U.S. in the 1980s and has been found in Texas, Arizona, New Mexico, Colorado, Wyoming, North Carolina, South Carolina, Georgia, Arkansas, and Alabama, and likely others. *P. parvum* has been reported at concentrations exceeding 100,000 cells/mL and blooms may occur in inland waters at salinity of 1-2 psu with lower growth at < 1psu. Blooms in low salinity coastal and inland waters have been reported worldwide. The species inhibits the growth of competing

Figure 2. Lake Las Vegas map.

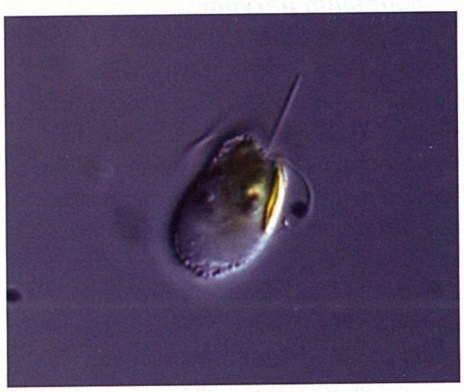

Figure 3. Photomicrograph of Prymnesium parvum *at 100x magnification.* Photo by Karie Holtermann, Metropolitan Water District of southern California).

algae, especially cyanobacteria and dinoflagellates and completely suppresses diatoms.

In Texas, 12 million game and threatened fish were killed in various water bodies from 1985-2001 with an estimated value of tens of millions of dollars. The incidence of *P. parvum* blooms in Texas has increased dramatically since 2001. While fish are the most visible casualty of a *P. parvum* bloom, the toxins released kill other gill-breathing organisms, invertebrates, planktonic algae, and bacteria.

The appearance of *P. parvum* is a potential challenge to lake managers. The species is equipped with an arsenal of of toxins; cytotoxiins, ichthyotoxicins, and neurotoxicins, substances that are antibacterial and allelopathic, acting to inhibit the growth or even kill other phytoplankton, zooplankton and fish. These toxins provide *P. parvum* with a competitive advantage over competing algal species for nutrients and may also reduce their grazing losses from zooplankton and planktivorous fish, enabling it to completely dominate the phytoplankton community under suitable environmental conditions.

The complex life cycle, physiology, and ecological niche requirements and strong survival attributes of *P. parvum* give this species a strong advantage to out-compete other phytoplankton and zooplankton for available food and resources. *P. parvum,* as in most algae, produces energy through photosynthesis, but in addition is mixotrophic and capable of using both inorganic and organic and dissolved nutrient sources. Its ability to ingest bacteria and other algae is known as "phagotrophy."

The species' ability to persist in both nutrient limited environments as well as nutrient excess systems further enhances its competitive advantage. Unlike some cyanobacteria that can fix nitrogen from the atmosphere during periods of nutrient depletion, *P. parvum* can consume phytoplankton, zooplankton, and bacteria to meet energy needs.

Toxicity may be influenced by environmental conditions; phosphorus and nitrogen limited growth are among the factors that may promote toxin production. Other conditions such as pH, salinity, and temperature have also been found to influence the toxicity of the *P. parvum*. These toxins can serve to directly remove algae competitors of *P. parvum* for nutrients and create an environment where the decaying organic matter and subsequent bacterial colonies provide particulate nutrient sources for *P. parvum's* mixotrophic mode of nutrition.

Short History of Algal Introductions

Since the lake began filling in 1991, reservoir managers and staff have conducted extensive water quality monitoring of physical, chemical, and biological constituents. This record provides a unique data set especially regarding the plankton community where the same phycologist (Janik) and methods have been utilized for nearly 20 years. The phytoplankton composition is strongly influenced by inflow from Lake Mead and the Colorado River, the primary source of water for the lake. For example, during the past ten years, a number of species have been introduced, likely from Lake Mead source water inflows. These species may dominate for a few seasons and often then become minor components of the algal community. An example is the green alga, *Pyramichlamys dissecta.* This species was observed in 1996, 1997, 1998, and 2001 in the inner Las Vegas Bay. During 2001, *P. dissecta's* population exploded and expanded into an extensive algae bloom that persisted for nearly six months. *P. dissecta* became the dominant species in Lake Las Vegas soon after the Lake Mead bloom and has persisted at low densities until approximately 2006 and is now found in low numbers. The cyanobacterium and toxin producer, *Cylindrospermopsis raciboskii* was first reported in Lake Las Vegas in July 2007 and has remained a notable component of the late summer and fall assemblage. In January 2007, quagga mussels were first reported in Lake Mead. Within a few months, quagga mussels were reported in several of the golf course ponds in the resort supplied by Lake Mead via Lake Las Vegas. The discovery of *P. parvum* in December 2009 is the latest and likely the most significant of the introductions on the lake plankton ecology. While its presence at this time is unconfirmed in Lake Mead, the species has been reported in low abundance in the downstream reservoir, Lake Havasu (personal communication, Karie Holtermann, 2010, Metropolitan Water District of southern California).

Table 1. A Comparison of Biological Diversity Before and After the Introduction of *P. parvum*.

	Jan.-Feb. 2009	Jan.-Feb. 2010
Phytoplankton		
Assemblage	*Rhodomonas minuta*, *Cryptomonas* spp., *Cyclotella* spp., *Chrysochromulina parva*	*P. parvum* (99% biomass)
[1] No. Common species	4-7	1
Biomass (mg/m^3)	200-400	15,000-20,000
Zooplankton		
Assemblage	Mixed: *Daphnia*, copepods, rotifers	Copepod nauplii
[2]Taxonomic richness	4-6	1
Abundance (per L)	25 - 75	0.5 - 2
Quagga Mussels	Present	Absent
Fish (dead) /day	0	1-697 (Avg. 91)
Average Secchi (m)	4.9	1.0

[1] Common species – contributing 5% or more to biomass.
[2] Taxonomic richness – total number of taxa identified.

The Great Competitor: Impacts to the Food Web

Phytoplankton. *P. parvum* was first identified in Lake Las Vegas in December 2009. The winter phytoplankton community is typically characterized by relatively low biomass (less than 400 mg/m^3) and composed of a mixed assemblage of cryptophytes, diatoms, and the commonly occurring *Chrysochromulina. parva* (Table 1). The lake managers were immediately notified of the potential for fish kills when *P. parvum* was first identified. In the Lake Las Vegas Early Detection Monitoring Program, samples are analyzed within seven days of collection with results and recommendations immediately provided to lake management. The presence of the species triggered higher frequency weekly sampling and a factsheet was prepared and distributed to lake stakeholders. Cell abundance of *P. parvum* remained at about 1000 cells/mL until late January 2010, when inflows from a large storm event substantially elevated the total P concentration in the lake to greater than 30 µg/L. Abundance in mid-February then increased to 35,000 cells/mL (Figure 4). Within two weeks, in early March, *P. parvum* jumped to more than 80,000 cells/mL and peaked at 96,000 cells/mL on March 11. *P. parvum* has maintained bloom levels to the last sample collected on April 13, 2010.

Zooplankton. The zooplankton community during January to April is typically characterized by rotifers, copepods, and cladocerans (*Daphnia pulex*) with total density from 25 to 75/L, When *P. parvum* abundance reached 50,000 cell/mL in mid-February, zooplankton were abruptly reduced in about two weeks from 60/L to 1/L with only copepod naulpii remaining. At the time of this article, *P. parvum* remained at more than 70,000 cell/mL and copepod nauplii were the sole representative of zooplankton at less than 1/L.

Quagga mussels. Southhard et al. (2010) reported that *P. parvum* might have influenced the decline of Asiatic clams, *Corbicula fluminea*, in the Pecos River system in Texas. Similar impacts to mollusks in Lake Las Vegas have been observed. In 2007, quagga mussels were found in Lake Mead, Clark County, Nevada and subsequently spread to Lake Las Vegas. Since the identification of *P. parvum* in Lake Las Vegas, quagga mussels have not been seen on pelagic substrate samplers that were previously heavily colonized. In addition, golf course maintenance staff reported the shedding of quagga mussels from within their irrigation systems that receive water from Lake Las Vegas.

Fish. Fish mortality was first observed approximately 30 days after the first occurrence of *P. parvum* in December. Since the first dead fish was found, maintenance workers collected dead fish every day with an average of 91 fish collected daily with a range of one to 697 removed over a 58-day period. These statistics are skewed so that during the peak biomass of *P. parvum*, a greater number of dead fish were observed with significantly fewer observed after the peak of the bloom.

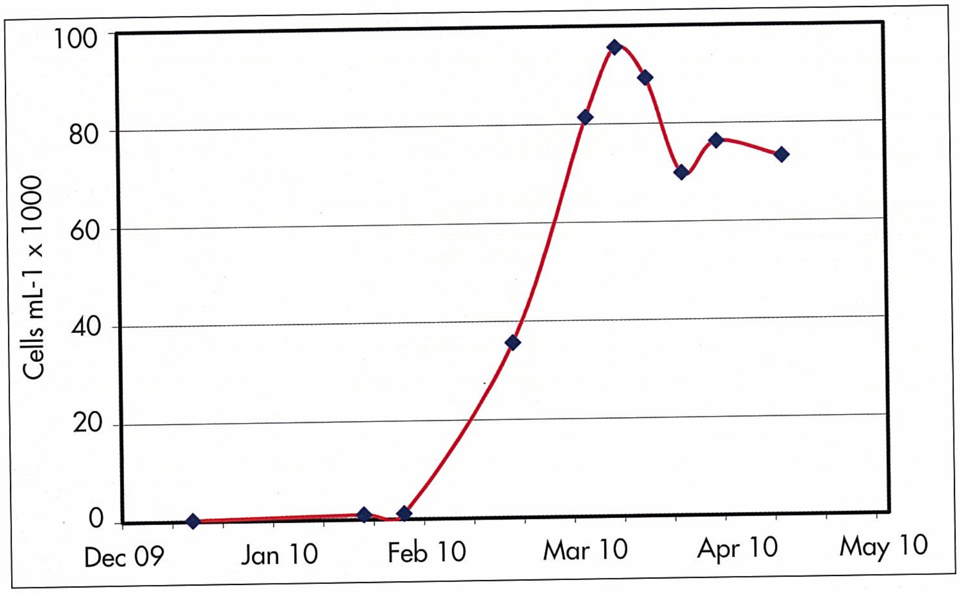

Figure 4. Prymnesium parvum *abundance during the 2009-2010 bloom.*

The common carp (*Cyprinus carpio*) was by far the dominant species affected by the presence of *P. parvum* making up over 80 percent of the collected dead fish (Figure 5). In addition, largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus),* and bluegills (*Lepomis macrochirus)* also were affected; at 11 percent, 5 percent, and 4 percent of the total, respectively. In this case, the influence of the common carp's feeding habit within the shallow littoral reaches of the reservoir possibly impacted this species more readily than other pelagic feeding game fish such as the largemouth bass since the life cycle of *P. parvum* includes a non-flagellated cyst form that may be present at high concentrations on the lake sediments. In most previously reported fish kills from *P. parvum* toxicity, game fish were the most common group. In contrast, rough fish were the primary fish lost in Lake Las Vegas.

Management of the Problem – Early Detection

In 2009, the American Water Resource Association sponsored a symposium that focused on the current research knowledge base on *P. parvum* and management strategies, and a number of the important papers were published (Barkoh and Fries 2010). Early detection is key to determining if a treatment method is suitable for a specific lake or pond. A number of treatment options have been found effective in reducing *P. parvum* including copper compounds (Rogers et. al. 2010). The concept of whole lake treatment can be daunting for many lake managers. Geographic influences and economic impacts play a large role in determining the best action as it relates to control of *P. parvum*. Regionally, the definition of what constitutes a lake versus a pond can vary, but in general the concept of whole system treatments are more easily applied to ponds or lakes that are less than 25 acres in area. Larger lakes (>100 acres) typically have more complex limnological dynamics and, in turn, have much higher cost associated with treatment. In any case, the label recommendations of the selected algal control chemical must be closely followed.

Summary

While the *P. parvum* bloom is still ongoing in Lake Las Vegas, the preliminary lessons learned from this event are: *P. parvum* is unpredictable and very quickly attained high densities with devastating effects on the "normal" biota; the literature is inconsistent and varies by geography; limited and cost effective control options are available on large lakes and reservoirs; and *P. parvum* is a strong competitor and will likely have long-term impacts to lake ecology. Preparation of full response plans may be unnecessary for each potential invasive species, but lake managers should prepare preliminary plans that address actions if, for example, chemical treatment is identified as a possible control measure. What is the lead time to acquire necessary permits, purchase chemicals and secure a contract with certified aquatic herbicide applicator? Often state and municipal

Figure 5. Source water inlet structure in background with specimen of dead common carp in foreground.

agencies must deal with a lengthy process to obtain these services, while the problem species, requiring no permit, rapidly overruns your lake.

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