The Ecology of the Plankton Communities of Two Desert Reservoirs

by

Tyler R Sawyer

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved July 2011 by the
Graduate Supervisory Committee:

Susanne Neuer, Chair
Daniel L. Childers
Milton Sommerfeld

ARIZONA STATE UNIVERSITY

August 2011

ABSTRACT

In 2010, a monthly sampling regimen was established to examine ecological differences in Saguaro Lake and Lake Pleasant, two Central Arizona reservoirs. Lake Pleasant is relatively deep and clear, while Saguaro Lake is relatively shallow and turbid. Preliminary results indicated that phytoplankton biomass was greater by an order of magnitude in Saguaro Lake, and that community structure differed. The purpose of this investigation was to determine why the reservoirs are different, and focused on physical characteristics of the water column, nutrient concentration, community structure of phytoplankton and zooplankton, and trophic cascades induced by fish populations.

I formulated the following hypotheses:

1) Top-down control varies between the two reservoirs. The presence of piscivore fish in Lake Pleasant results in high grazer and low primary producer biomass through trophic cascades. Conversely, Saguaro Lake is controlled from the bottom-up. This hypothesis was tested through monthly analysis of zooplankton and phytoplankton communities in each reservoir. Analyses of the nutritional value of phytoplankton and DNA based molecular prey preference of zooplankton provided insight on trophic interactions between phytoplankton and zooplankton. Data from the Arizona Game and Fish Department (AZGFD) provided information on the fish communities of the two reservoirs. 2) Nutrient loads differ for each reservoir. Greater nutrient concentrations yield greater primary producer biomass; I hypothesize that Saguaro Lake is more eutrophic, while Lake Pleasant is more oligotrophic.

Lake Pleasant had a larger zooplankton abundance and biomass, a larger piscivore fish community, and smaller phytoplankton abundance compared

to Saguaro Lake. Thus, I conclude that Lake Pleasant was controlled top-down by the large piscivore fish population and Saguaro Lake was controlled from the bottom-up by the nutrient load in the reservoir. Hypothesis 2 stated that Saguaro Lake contains more nutrients than Lake Pleasant. However, Lake Pleasant had higher concentrations of dissolved nitrogen and phosphorus than Saguaro Lake. Additionally, an extended period of low dissolved N:P ratios in Saguaro Lake indicated N limitation, favoring dominance of N-fixing filamentous cyanobacteria in the phytoplankton community in that reservoir.

ACKNOWLEDGEMENTS

Funding for this project came in the form of The Research and Training Initiatives Office Facilities Initiative Grant for Grads (RTI FIGG) and from the Arizona State University School of Life Sciences as funding and support as a research and teaching assistant. Field sampling and laboratory assistance was contributed by Jessica Amacher, Charles Baysinger, and Aaron Robinson. Alissa Rickborn carried out the DNA analysis of the zooplankton guts. Natasha Zolotova provided assistance with the preparation and analysis of particulate nutrient samples in the W.M. Keck Laboratory. Analysis of dissolved nutrient samples was handled by Bill Clinton at the University of California Santa Barbara Marine Science Institute Analytical Lab. The staff of Scorpion Bay Marina at Lake Pleasant provided helpful information on reservoir levels, weather, and other extraneous data in addition to un-equaled enthusiasm about the project. Finally, I express gratitude and respect for my advisor, Susanne Neuer, and to my supervisory committee for their insight and consideration.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Page

Introduction

A community is defined as “the sum of all of the interacting populations in a habitat” (Lampert and Sommer, 2007). In aquatic ecosystems, the community consists of primary producers (phytoplankton), grazers (herbivorous zooplankton), second order consumers (carnivorous zooplankton and planktivore fish), and third order consumers (piscivorous fish) (Kormondy, 1996). The assemblage and interaction of the organisms forms a food web.

A food web is defined as community organization “in which species are linked together through complex feeding relationships” (Primack, 2006 and Yodzis, 2001). Food webs contain relationships that are more complex than a linear food chain. These relationships depict the flow of energy through the community, on the basis of predator/prey schemes. In aquatic communities, two distinct food webs can be found: the two-dimensional, and the three-dimensional. Benthic communities on the lake bottom are considered two-dimensional as the community occupies a single horizontal plane. Pelagic communities are considered to be three-dimensional, as the community occupies the horizontal plane as well as the vertical plane. Typically, three-dimensional food webs are more complex than two-dimensional ones (Kormondy, 1996).

Man made reservoirs differ ecologically from natural lakes. Establishment of community structure through succession in reservoirs spans time measured in human lifetimes, while succession in natural lakes spans time measured evolutionarily or geologically (Dumont, 1999). Reservoir community structure is also determined by the natural biota that inhabited the river system prior to damming. The organisms found in reservoirs commonly possess the ability to

tolerate a broad range of physiological conditions, due to frequent, abrupt perturbations in the ecosystem(Agostinho et al., 1999).

In 1958, A.C. Redfield reported a ratio of 106:16:1 that described the molar ratio of carbon, nitrogen, and phosphorus (C:N:P) in the biomass of marine phytoplankton. This ratio was also reflected in the nutrient ratio of the sea water. The Redfield Ratio is important as it can indicate nutrient limitations for primary productivity. When nutrient ratios are above the Redfield Ratio (for example: N:P > 16), this indicates that primary production in the ecosystem is limited by phosphorus availability. In contrast, ratios below the Redfield Ratio (N:P <16) indicate nitrogen limitation. Nitrogen limitation is particularly favorable for many filamentous cyanobacteria as they are able to readily fix nitrogen from the atmosphere, giving them an ecological advantage (Wiedner et al., 2007). In a book on ecological stoichiometery published in 2002, Sterner and Elser, reported that most freshwater phytoplankton exhibited N:P ratios of 30:1, thus deviating from the Redfield Ratio. Elser et al. (2000) also found that freshwater zooplankton herbivores had N:P ratios of 22:1. Additionally, while nitrogen concentrations remained somewhat constant across different groups of zooplankton, phosphorus concentrations varied up to a factor of five. The cladoceran grazer *Daphnia* was found to be particularly phosphorus rich, with a C:P ratio of 80:1 (Elser et al., 2000)

Field Data Collection Sites

Data and samples were collected at Saguaro Lake and Lake Pleasant in Central Arizona. Both reservoirs are drinking water and municipal use reservoirs for the metropolitan Phoenix area. Additionally, both reservoirs produce hydroelectric power by releasing water from the dams.

Saguaro Lake is located at approximately 33.57º N by 111.52º W. The reservoir, created in 1930 by damming the Salt River with Stewart Mountain Dam, is approximately 33 meters deep (Salt River Project, 2011), with a central deep channel running east to west, and wide shallower shoals on either side (Figure 1).

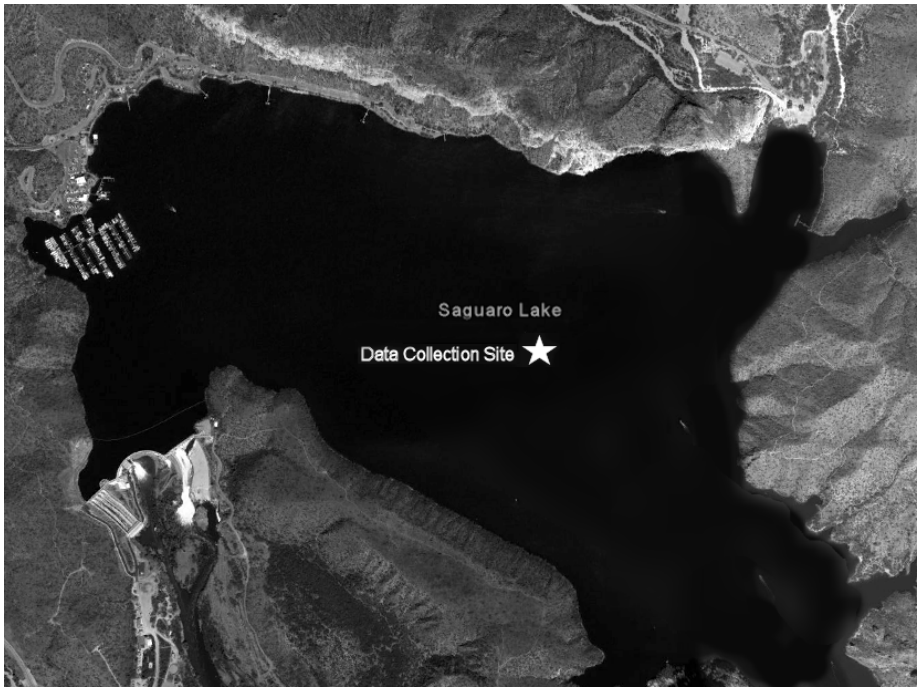


Figure 1: Surface Map of Saguaro Lake (Google Earth, 2011)

Lake Pleasant (Figure 2) is located at approximately 33.86º N by 112.26º W. The reservoir was initially created in 1895 by the construction of the Camp Dyer Diversion Dam (Beardsley Dam) on the Agua Fria River. The reservoir subsequently increased in size in 1926 and 1992 when the Waddell and New Waddell Dams, respectively, were completed (Bureau of Reclamation, 2009). The reservoir has a maximum depth of approximately 86m (CAP, 2011), while the maximum observed depth at the sampling site was approximately 55m. During the 2010 time series, the recorded reservoir water depth (recorded via

sonar each month) changed frequently, from a high during December of 69m, to a low during August of 49m at the sampling site.

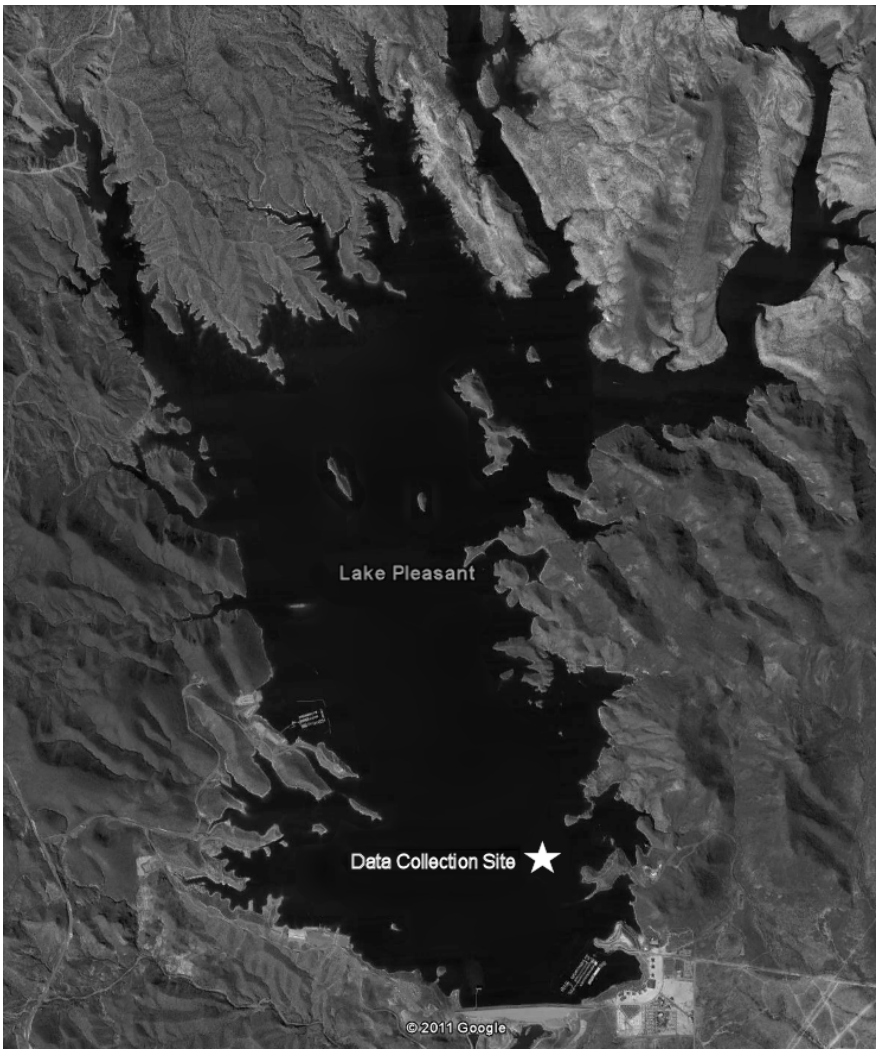


Figure 2: Surface Map of Lake Pleasant (Google Earth, 2011)

Previous Work

Previous work in Saguaro Lake and Lake Pleasant was carried out by local government agencies (AZGFD and DEQ) in addition to the Neuer, Sommerfeld, and Westerhoff Laboratories at Arizona State University. Existing data from the Neuer Lab initially inspired the current investigation.

In the late 1970's, a study was conducted on Canyon Lake (upstream from Saguaro Lake) to determine the effect of back-pumping on the clutch size of copepods (McNatt, 1977). This study focused on the calanoid copepod *Diaptomus*. In addition, data were also collected on water parameters (temperature, dissolved oxygen) and the zooplankton community. Zooplankton were specifically identified taxonomically and quantified to identify which species were present in the reservoir. Spatial distributions of zooplankton were also examined, utilizing several reservoir transects.

Work by the Department of Environmental Quality focused on parameters of temperature, conductivity, dissolved oxygen, pH, concentrations of nitrogen/phosphorus, coliform bacteria, and metals (Darren Sversvold, ADEQ, personal communication). The Arizona Fish and Game Department has examined water parameters in addition to community analysis with a focus on management for recreational usage (Stewart et al., 2008)

The Westerhoff Lab at Arizona State University has been continually monitoring Saguaro Lake and Lake Pleasant during the last decade. The laboratory focuses on research pertaining to drinking water quality, with specific interest in the algae in the reservoirs that are responsible for taste and odor (T&O) issues in drinking water. Parameters that have been measured include dissolved organic carbon, conductivity, temperature, dissolved oxygen, total nitrogen, total phosphorus, MIB (2-Methylisoborneol, responsible for musty smell in drinking water), Geosmin (responsible for earthy taste in drinking water), among other contaminants (Westerhoff et al., 2010). The Sommerfeld lab has also investigated the algal populations in these lakes over many years, particularly in context with water quality issues in the Central Arizona reservoirs

(Westerhoff and Sommerfeld, 2005). A relationship of declining cyanobacterial blooms in fall and the occurrence of T&O compounds was found by Tarrant et al. (2009).

Tarrant et al. (2010) investigated the use of MERIS (MEdium Resolution Imaging Spectrometer) and MODIS (Moderate-resolution Imaging Spectroradiometer) satellite sensors to infer the amount of total suspended matter in Lake Pleasant, Saguaro Lake, Bartlett Lake (an impoundment of the Verde River), and Roosevelt (the most-upstream impoundment of the Salt River). The Tarrant et al. investigation was part of a larger ecological investigation of the reservoirs carried out by the Neuer Lab, beginning in 2007.

Data from Saguaro Lake and Roosevelt Lake were collected by the Neuer lab from 2007 to 2009. Data from Lake Pleasant and Bartlett Lake on phytoplankton abundance, chlorophyll *a*,, nutrient composition, and hydrology were available from 2008-2009. During that time period, the data indicate that phytoplankton community composition differed between Saguaro Lake and Lake Pleasant. Saguaro Lake was dominated by filamentous cyanobacteria in the summer, while Lake Pleasant was dominated by the cocci-shaped *Synechococcus* in the spring and prymnesiophytes (Class: *Prymnesiophyceae*) in the summer. Although the two reservoirs were dominated by different types of cyanobacteria, occurance of pyrmnesiophytes and diatoms was consistent between the two (Figure 3). Additionally, phytoplankton biomass was greater in Saguaro Lake than Lake Pleasant by an order of magnitude, using chlorophyll *a* concentrations as a proxy for biomasss (Figure 4).

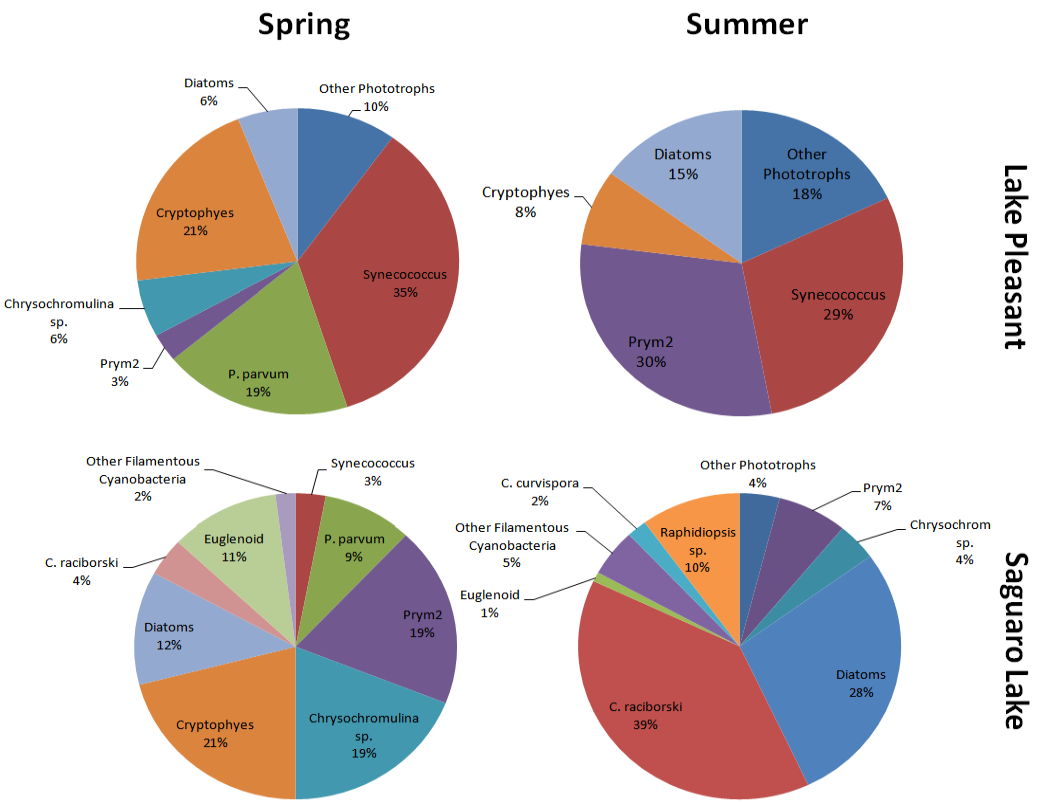


Figure 3: Phytoplankton community structure of Lake Pleasant and Saguaro Lake in 2009. Data are depicted for the summer (June through October) and spring (February through May), showing seasonal shifts in community composition as well as differences between both reservoirs (Neuer et al., unpublished).

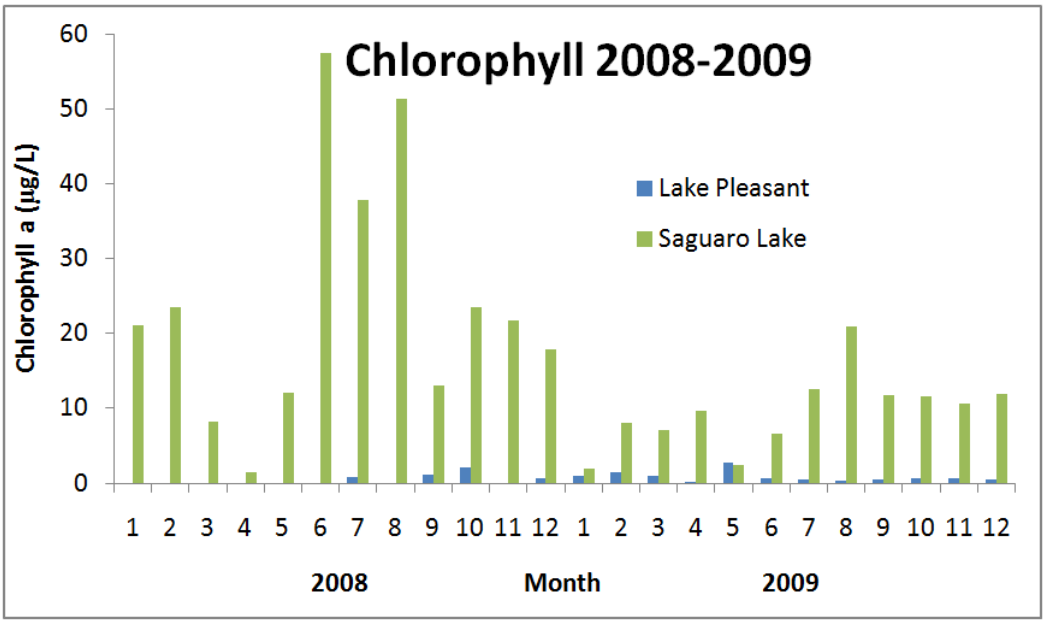


Figure 4: Chlorophyll *a* data from Saguaro Lake and Lake Pleasant (2008-2009).

Hypotheses

The objective in this thesis was to answer the central research question *Why do the phytoplankton communities of Lake Pleasant and Saguaro Lake differ?* With each hypothesis, I list the planned test, and the results which are most consistent with the respective hypothesis.

1) *Top-down control varied between the two reservoirs. The presence of a piscivore in a reservoir determines the amount of grazer and primary producer biomass through trophic cascades.*

    - This hypothesis was tested by measuring the abundance and composition of zooplankton, and phytoplankton biomass as chlorophyll *a*. DNA based molecular gut analyses of the zooplankton indicated prey preference, while particulate elemental concentrations determined the nutritional value of phytoplankton in each reservoir.

Data from AZGFD provided information on the fish communities of Lake Pleasant and Saguaro Lake. It was expected that high amounts of zooplankton would indicate top-down control mechanisms. Top-down control mechanisms would also be indicated by high biomass of upper level consumers. This high biomass of upper level consumers (piscivores) would prey heavily upon the next trophic level (planktivores), reducing their numbers. Reduced biomass of planktivores would allow zooplankton to flourish, placing increased grazing pressure on the primary producers (phytoplankton). Subsequently, phytoplankton biomass would be reduced due to the grazing pressure from the large zooplankton population. I hypothesized that Lake Pleasant was controlled from the top-down as there was a low amount of phytoplankton biomass indicated in previous work (Figure 4b). Additionally, I hypothesized that Saguaro Lake was controlled from the bottom-up as there was a high amount of phytoplankton biomass indicated in previous work (Figure 4a). DNA based molecular gut analyses of the zooplankton indicated prey preference, while particulate elemental concentrations determined the nutritional value of phytoplankton in each reservoir. Data from AZGFD (Arizona Game and Fish Department) provided information on the fish communities of Lake Pleasant and Saguaro Lake.

2) *Nutrient loads differ for each reservoir*. *Greater nutrient concentrations yield greater primary producer biomass.*

- This hypothesis was tested by measurement of inorganic dissolved nutrient data. I hypothesize that nutrient concentrations in Saguaro Lake were greater than those in Lake Pleasant, indicated by the greater biomass of primary producers in Saguaro Lake. Additionally, I hypothesize that nutrient ratios (N:P) were lower (N limiting) in Saguaro Lake than in Lake Pleasant. This was expected given the past phytoplankton community structure of Saguaro Lake (Figure 3) which was dominated by filamentous cyanobacteria able to thrive during N-limited conditions because of their ability to fix nitrogen.

Methods

Conductivity, Temperature, and Dissolved Oxygen

Conductivity determines the ability of a solution to conduct an electrical current as a function of dissolved ions, and is measured in micro-Siemens (YSI, 2009). All measurements were taken with a YSI 85 hand-held sensor. The conductivity readings were taken *in-situ* to a depth of 25 meters. The measurement range of the instrument was 0-4999µS, with an accuracy of 0.5%, and a resolution of 1µS (YSI, 2011). Calibration was performed using a solution of known conductivity, 1413µS.

Dissolved oxygen is a function of temperature, depth, primary production, respiration, and turbulence (Hach, 2006). Measurement of [DO] was carried out with a YSI 85 hand-held sensor. Readings were taken to a depth of 25 meters. All dissolved oxygen values were converted to percent saturation, through the use of an online calculator provided by the Aquaculture Network Information Center in collaboration with the Marine Fisheries Institute and NOAA. The measurement range was 0-20mg/L, with an accuracy of 0.3mg/L, and a

resolution of 0.01mg/L (YSI, 2011). Calibration took place using the factory-provided calibration sponge in the side of the instrument housing. The probe was placed into the side of the instrument housing with a wet calibration sponge for 15 minutes to reset the calibration for a specific altitude (1680 feet for Lake Pleasant and 1509 feet for Saguaro Lake). Waiting for 15 minutes to elapse allows the probe in the chamber in the side of the instrument to reach 100% saturation of dissolved oxygen. Temperature was also measured with the [DO] probe. The range of the instrument was -5 to 65°C, with an accuracy of 0.1°C, and a resolution of 0.1°C (YSI, 2011).

Water Collection

Water samples were collected in 1 gallon plastic bottles each month (Table 1). Surface samples were directly collected with the 1 gallon bottles. Deep samples were collected with a 3.6L acrylic Van Dorn alpha bottle (commercially available from Wildco) and transported to the laboratory in 1 gallon bottles. Samples were collected at four depths: surface, 3m (continuation of the existing time series), estimated bottom of the euphotic zone (see *Secchi Depth*, below), and below the thermocline. If any two depths were similar, for example the 3m and estimated maximum euphotic zone depth in Saguaro Lake, another depth deeper in the hypolimnion was chosen for collection. Collected water samples were analyzed for dissolved inorganic and particulate organic nitrogen/phosphorus/carbon, chlorophyll *a*, and phytoplankton composition. Only surface samples were analyzed for nutrients and particulate constituents. Samples for chlorophyll *a* and microscopy of phytoplankton were taken from every depth.

Sampling Dates	
Lake Pleasant	Saguaro Lake
1/5/2010	1/12/2010
2/2/2010	2/9/2010
3/2/2010	3/9/2010
4/6/2010	4/13/2010
5/4/2010	5/11/2010
6/2/2010	6/9/2010
7/7/2010	7/14/2010
8/4/2010	8/11/2010
9/1/2010	9/8/2010
10/6/2010	10/13/2010
11/3/2010	11/10/2010
12/1/2010	12/8/2010

Table 1: 2010 sampling schedule. Lake Pleasant was sampled the first week of every month, while Saguaro Lake was sampled in the second week.

Dissolved Constituents

Dissolved constituents (nitrogen and phosphorus) were analyzed at the University of California, Santa Barbara Marine Science Institute Analytical Lab. Water samples were filtered through Whatman GF/F filters, and kept frozen at -20 C in 50mL plastic centrifuge tubes prior to shipment. At UCSB, each sample was analyzed with a Flow Injection Analyzer from Zellweger Analytics Inc. Results were reported in concentrations of micro-moles per liter. Plastic is known to absorb phosphorus from water samples (UCSB MSI, 2011). In the future, it would be better suited to use glass containers for the handling and analysis of nutrient samples.

Particulate Constituents

Particulate constituents (Carbon, Nitrogen, and Phosphorus) were measured at the Arizona State University Campus. CHN samples were measured in the W.M. Keck Foundation Laboratory for Environmental

Biogeochemistry as part of a Research and Training Initiative grant. CHN samples were filtered onto pre-combusted Whatman GF/F filters to collect all particulate matter from the water column. Filters were dried, weighed, split, packed into tin capsules, and combusted in a Costech Instruments Elemental Analyzer. Combustion produced CO_2 from Carbon and N_xO_y from Nitrogen. These gasses were separated and collected, for processing through the Thermal Conductivity Detector (W.M. Keck Foundation Laboratory, 2007). Since the filters were split (in halves) in order to fit in the tin capsules, a total of two sample runs were required to ascertain the total amount of Carbon and Nitrogen on each filter.

Particulate Phosphorus (P from Phosphate) was determined by digestion and subsequent titration, modified after the total phosphorus protocol from the Standard Methods for the Examination of Waste Water (Franson, 1998). This titration measured P by creating a reaction that yielded a blue aqueous compound of Phosphate and Molybdenum which was then read by a spectrophotometer at 880nm. Modifications of the protocol included adjustment of standards to provide an optimal range for the expected P levels, and modification for using glass fiber filters. The use of glass fiber filters required pulverization by glass beads to remove all phosphate from the filter and centrifugation before reading by the spectrophotometer. This method was not sensitive enough to measure the small amount of P in either reservoir. In the future, it would be better to measure total P and dissolved P, then calculate POP.

Secchi Depth

Secchi depth was determined using a 15cm diameter solid white oceanic disc (Wildco). The Secchi depth was taken in the shade of the boat by lowering

the disc until it was no longer visible, raising the disc until visible again, and then taking an average of the two depths (Steel and Neuhausser, 2002). The Secchi depth was used to estimate the depth of the euphotic zone by doubling the recorded Secchi depth (Koenings and Edmundson, 1991).

Reservoir Depth

Reservoir depth was measured with commercially available vessel-mounted sonar units. For Lake Pleasant, a Lowrance X-4 was used (measurable depth 1-185m). For Saguaro Lake, a Lowrance Mark-5x was used (measurable depth 1-250m).

Chlorophyll a

50-250mL of water was filtered through 25mm Whatman GF/F filters in replicate, and extracted in 10mL of 90% acetone. After extraction, the acetone and extracted chlorophyll *a* was read on a Turner Designs TD-700 fluorometer. After accounting for extraction and filtration volumes, chlorophyll *a* was expressed in micro-grams per liter. Calibration took place with four calibration solutions of chlorophyll *a*. Solution concentrations were diluted to 1, 5, 10, and 100μg/L to establish a standard curve.

Phytoplankton Abundance

Volumes from 5 to 20mL were filtered onto 0.22μm black polycarbonate filters. Each volume was preserved with 0.1-0.2mL of 50% Gluteraldhyde and stained with 0.1mL of a solution of DAPI (4′,6-Diamidino-2-phenylindole dihydrochloride, 1 mg/100ml) (Neuer and Cowles (1994). The filters were fixed on a glass slide, sandwiched between drops of immersion oil and covered by a cover slip. Phytoplankton were examined via epifluoresence microscopy using blue and UV light excitation with a Carl Zeiss Imager.A1 compound microscope

at 1000x total magnification. Selected slides were examined based on peaks in chlorophyll and events observed in the zooplankton community, such as peaks or a rapid decline in abundance.

Zooplankton Abundance

Samples were collected with vertical net casts of a 15cm diameter towable net (75μm mesh size). Each vertical net cast (5m and 10m regularly, 20m and 30m on occasion) represented a filtered reservoir water volume of 353.25L (5m) or 706.5L (10m), respectively. Total filtered volumes were determined with a General Oceanics flow meter that was attached to the mouth of the net. All samples were preserved with a 2% final volume formalin solution. Samples collected from February-December contained a 6% sucrose (by weight) formalin solution. Addition of sucrose buffered the zooplankton against formalin corrosion (Haney and Hall, 1973). Samples collected from August-December were first anesthetized with CO_2 prior to fixation. Anesthesia via carbonated water prevents the expulsion of zooplankton guts and eggs when the animals undergo fixation (Gannon and Gannon, 1975). Monthly samples were quantified using a Carl Zeiss Discovery.V12 dissection microscope and a 6mL modified Bogorov tray. A total of five, 5mL subsamples were counted for each reservoir, each depth, and averaged. All data were converted to abundance per cubic meter of water. Identification of zooplankton was determined using the U.S. Geological Survey “Great Lakes Copepod Key” (2010) along with printed texts of *Fresh-Water Invertebrates of the United States* (Pennak, 1989) and *Ecology and Classification of North American Freshwater Invertebrates* (Thorp and Covich, 1991).

Zooplankton Biomass

Biomass estimates were made from an additional replicate count of each month using an Olypmus IMT-2 inverted microscope. Individual zooplankters were measured (and in the case of copepods examined for copepodite/adult morphology) to produce an average length of the monthly population, by group. Average lengths were compared against linear regression equations to convert length to biomass in units of micro-grams. Equations were derived from data produced by Dumont et al. (1975) of cyclopoids (copepodite and adult), calanoids, *Daphnia*, and *Bosmina*.

Rotifer Abundance

As per Chick et al. (2010), rotifers were collected from June to November in Saguaro Lake at two depths (surface and lower euphotic zone) via a discrete 2L van Dorn Alpha Bottle. Samples were filtered through a 25μm mesh, rinsed into 250mL bottles, and fixed with formalin (2% final concentration by volume). Monthly samples were quantified using a Zeiss Discovery.V12 dissection microscope and a 6mL modified Bogorov tray. A total of five, 5mL subsamples were counted for each reservoir, each depth, and averaged. All data were converted to abundance per cubic meter of water.

DNA Based Water Column and Gut Content Examination

For DNA based molecular analysis (organism identification and gut contents), zooplankton were collected by either a 100m or 200m horizontal net tow. Collected animals were anesthetized with carbonated water (commercially available seltzer water) to prevent expulsion of the guts due to stress or death (Gannon and Gannon, 1975). Animals were selected and divided into the following appropriate groupings: Cyclopoids, calanoids, *Daphnia*, *Bosmina*,

nauplii, and rotifers. An animal was picked from the environmental sample with forceps, washed three times in fresh double-distilled water, and placed in a micro-centrifuge tube containing 180µL of ATL buffer (proprietary buffer solution from Qiagen). After soaking for twenty minutes, 20µL of protinease-K was added to each tube to digest and lyse the cells. Samples were then stored (stable, after protinease-K digestion) up to two months, awaiting further extraction.

DNA based molecular analyses also took place on water column samples, filtered onto Whatman GF/F glass fiber filters. 200mL of reservoir water was filtered each month, and submersed in 600µL of lysis buffer. Samples were frozen and stored, awaiting further extraction. Water column samples were collected in order to compare occurrence of organisms in the water column to those found in zooplankton guts.

After storage, each sample (animal groupings, per reservoir, per month and water column samples) was then purified using the Qiagen DNeasy Mini Procedure by utilizing silica spin columns to bind, wash, and elute the DNA prior to PCR amplification (Qiagen, 2006). DNA was amplified using primers for a section of the eukaryotic 18S rRNA gene (Euk1A, Euk516r-GC) and cyanobacterial 16S rRNA gene (CYA359f-GC, CYA781r) (Diez et al., 2001; Medlin et al., 1988), however amplification from gut samples was not successful using cyanobacterial primers. Amplification took place in either a BioRad iCycler or Techne TC-312 Thermocycler according to the following Neuer Lab protocol: Each reaction contained 5 µL of 10X Takara Ex Taq buffer, 4 µL 200 µM dNTP, 1 µL 10% BSA (bovine serum albumin), 0.3 µL of appropriate 0.3 µM primer, 38.15 µL water, and 0.25 µL of Takara Ex Taq Polymerase plus template. The eukaryotic reaction underwent denaturation at 94°C/130s, 30 cycles at 94°C/30s

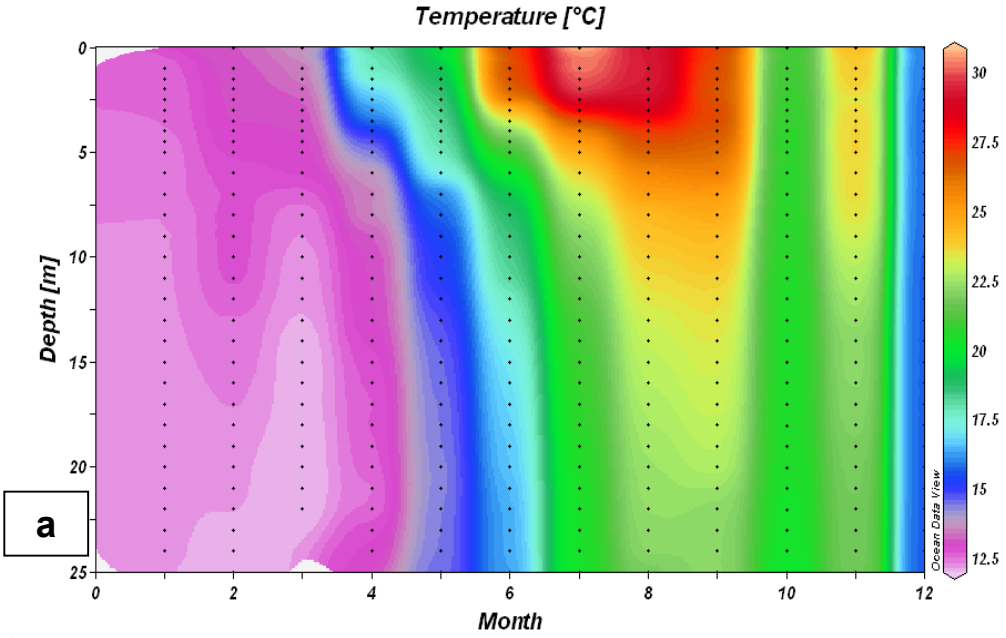
and 56°C/45s, 72°C/130s, and a final extension at 72°C/7min. The cyanobacterial reaction underwent denaturation at 94°C/5min, 30 cycles at 94°C/1min and 60°C/1min, 72°C/1min, and a final extension at 72°C/9min.

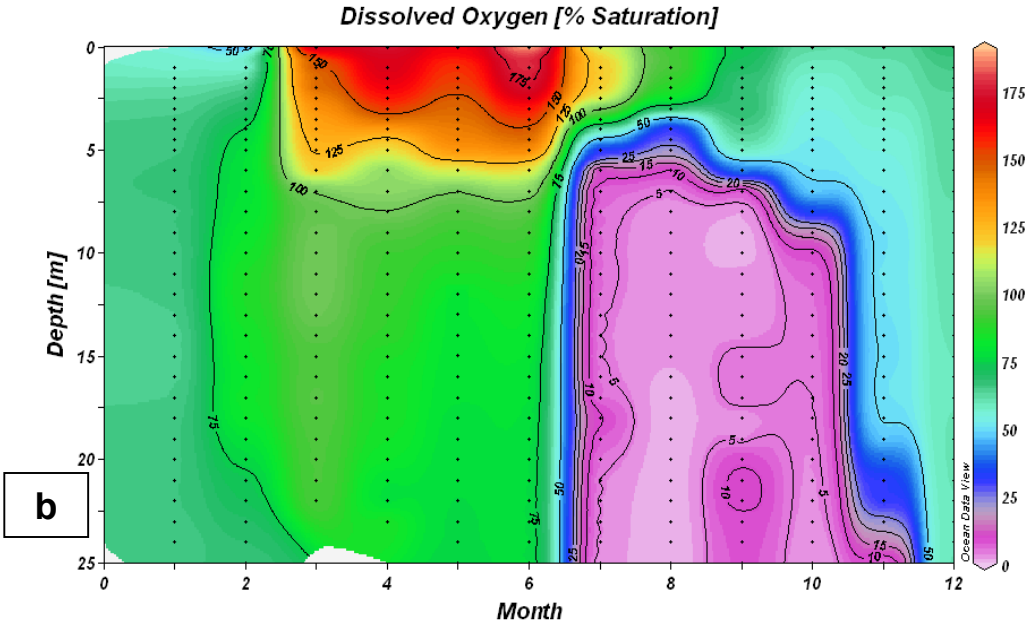
Amplicons were separated on a DGGE gel (Denaturing Gradient Gel Electrophoresis) in a BioRad DCode DGGE machine. The acrylamide DGGE allows separation of DNA by sequence. After staining each DGGE gel was imaged using a BioRad Fluor-S imager. The bands that could be most clearly visualized were then cut from each gel, and were re-amplified prior to sequencing.

Results

Temperature, Dissolved Oxygen, and Conductivity

Saguaro Lake





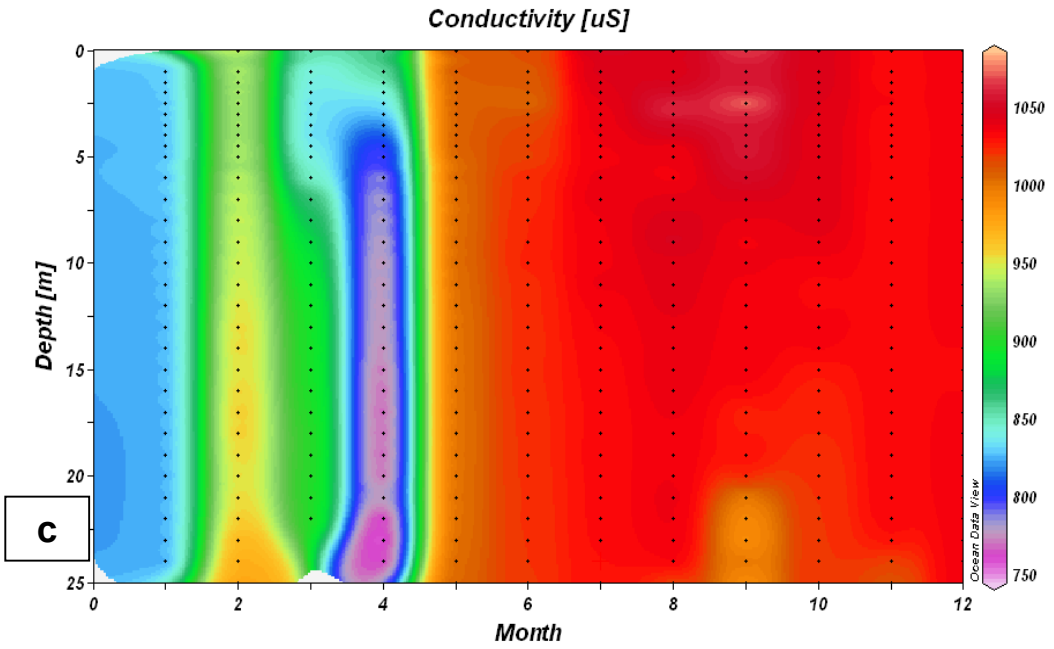


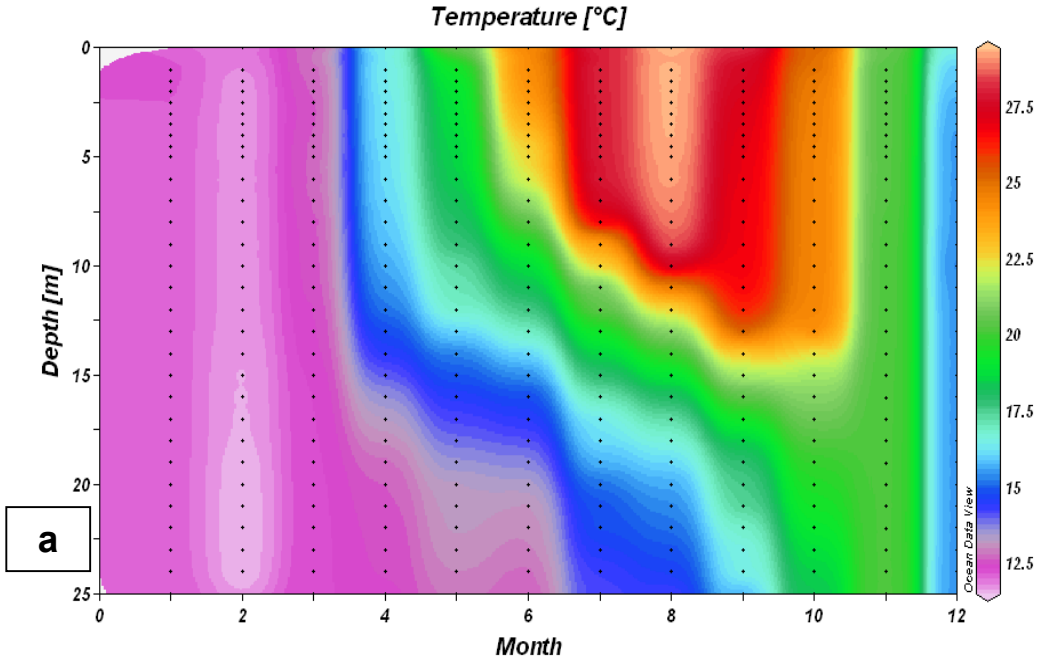
Figure 5 (a-c): Temperature (a), dissolved oxygen (b), and conductivity (c) of Saguaro Lake in 2010. Contour lines for dissolved oxygen (b) are positioned in 25 percent intervals of saturation. Red colors indicate a greater value, while blue or pink values indicate a lesser value.

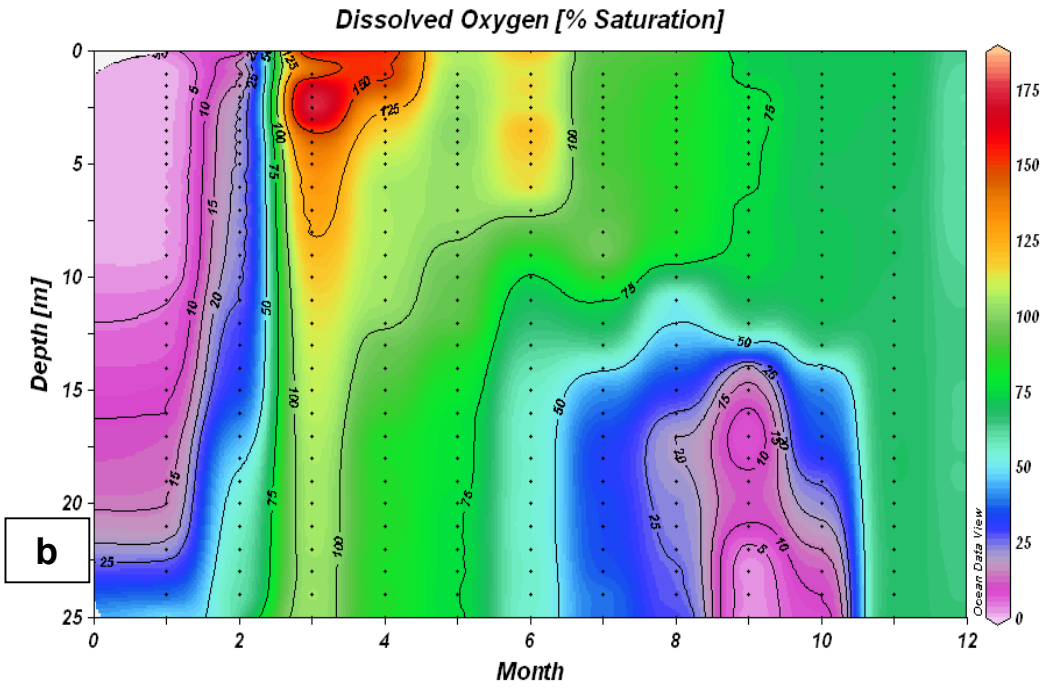
In 2010, temperature data in Saguaro Lake indicated that the water was well mixed in the months of January, and October through December. The reservoir was strongly stratified in the months of April through September (Figure 5a). The warmest surface temperature was recorded at 30.9ºC in July, while the coolest surface temperature was 12.8ºC in January. Overall, the two warmest months of the year were July and August.

Dissolved oxygen saturation values depict super-saturation in the surface water in the months of March through July (Figure 5b). This layer of oxygen super-saturation was measured to a depth of approximately 7 meters until the month of June. In July, the super-saturation of oxygen shoaled to depths of 4 meters or less. A large column of depleted oxygen water or anoxic water was found from July to October at depths greater than 7 meters.

Conductivity data show periods of fresh water intrusion in the spring (the month of April, notably), with higher conductivity levels later in the year (Figure 5c). Additionally, different vertical horizons of conductivity values were not measured in the reservoir.

Lake Pleasant




Dissolved Oxygen [% Saturation]
Depth [m]
Month
b
Ocean Data View

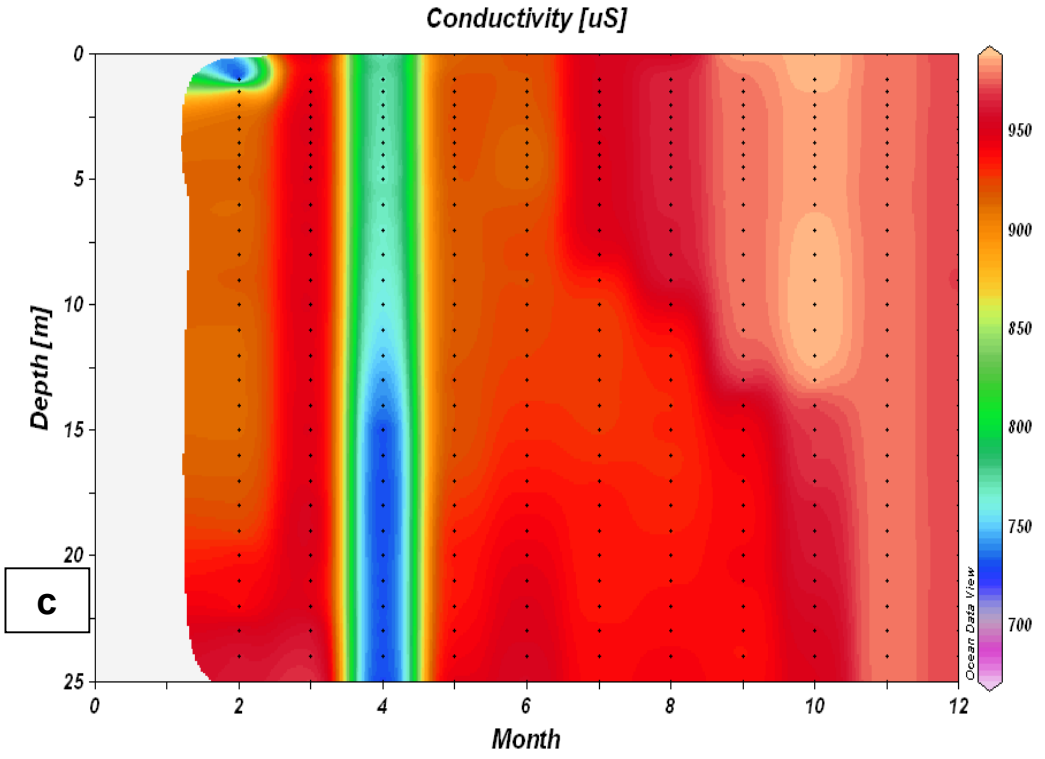

Conductivity [uS]
Depth [m]
Month
c
Ocean Data View

Figure 6 (a-c): Temperature (a), dissolved oxygen (b), and conductivity (c) of Lake Pleasant in 2010. Contour lines for dissolved oxygen (b) are positioned in 25 percent intervals of saturation. Red colors indicate a greater value, while blue or pink values indicate a lesser value.

In 2010, the surface water temperature in Lake Pleasant ranged from a low of 12.2°C in January, to a high of 29.4°C in August. During the winter months of January through March and November through December, the reservoir was well mixed (Figure 6a). Strong stratification was indicated during the summer months of April through October.

Dissolved oxygen saturation data show that the surface waters (to a depth of approximately 5 meters) were supersaturated with dissolved oxygen in the month of March (Figure 6b). Relatively anoxic conditions of less than 25% [DO] were measured throughout the column during the months of January and February, and at depths deeper than 15 meters in August through October.

Conductivity was highest in the latter part of the year, peaking in October (Figure 6c). As with Saguaro Lake, an intrusion of fresh water was measured in Lake Pleasant during the month of April.

Lake Pleasant and Saguaro Lake exhibited similar water conditions. Both reservoirs experienced strong thermal stratification in the summer and deep anoxic water late in the summer. Conductivity data were fairly consistent throughout the year in Lake Pleasant (except for the freshwater runoff in the spring), while conductivity in Saguaro Lake was higher during the latter part of the year (summer and fall) than during the winter and spring (January-April)

Secchi Depth

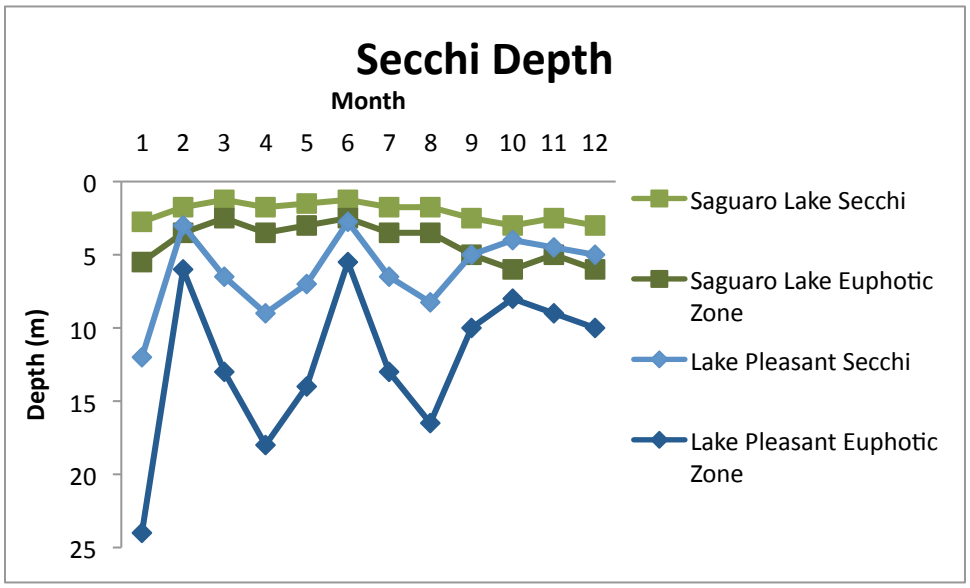


Figure 7: Secchi depth and estimated euphotic zone depth in Lake Pleasant and Saguaro Lake.

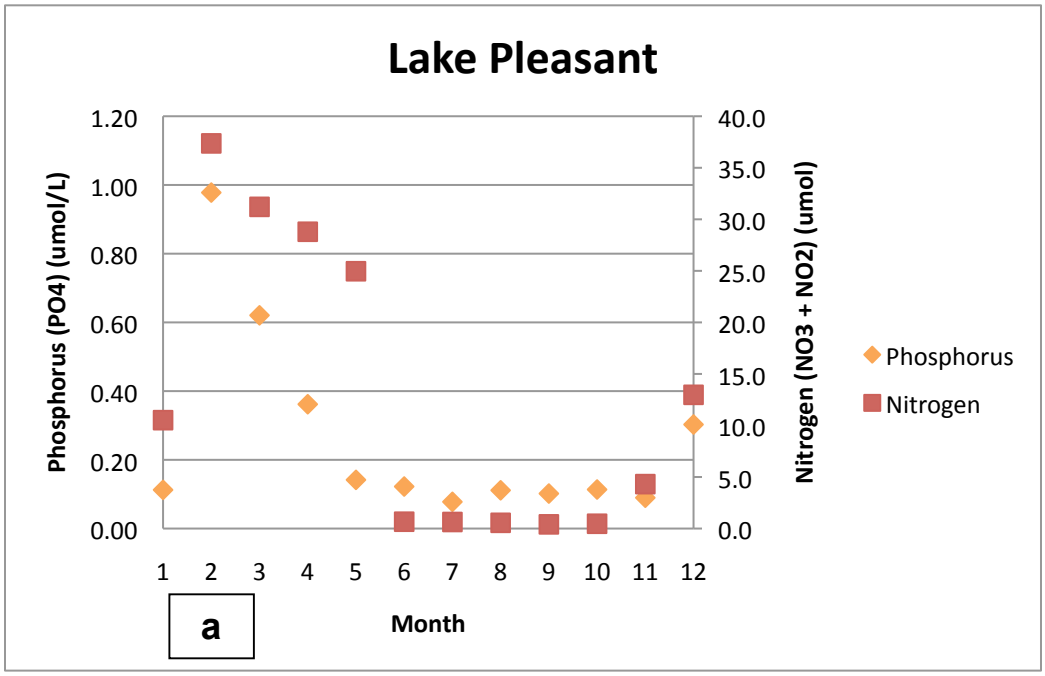
Recorded Secchi depth was consistently deeper in Lake Pleasant than Saguaro Lake (Figure 7). The deepest Secchi depth recorded in Saguaro Lake was 3m, the shallowest was 1.25, and the yearly average was 2.06m ± 0.64. In Lake Pleasant, the deepest recorded Secchi depth was 12m, the shallowest was 2.75m, and the yearly average was 6.125m ± 2.68.

Dissolved Inorganic Nutrients

		Lake Pleasant		Saguaro Lake	
		N	P	N	P
Month	1	10.5	0.11	1.94	0.09
	2	37.4	0.98	12.9	0.13
	3	31.2	0.62	35.0	0.24
	4	28.8	0.36	0.73	0.12
	5	25.0	0.14	0.41	0.15
	6	0.66	0.12	0.63	0.11
	7	0.64	0.08	0.45	0.12
	8	0.56	0.11	2.21	0.23
	9	0.41	0.10	2.54	0.12
	10	0.46	0.11	0.49	0.14
	11	4.31	0.09	0.35	0.19
	12	13.0	0.30	1.10	0.17

Concentrations in µmol/L

Table 2: Dissolved inorganic nutrient concentrations Lake Pleasant and Saguaro Lake



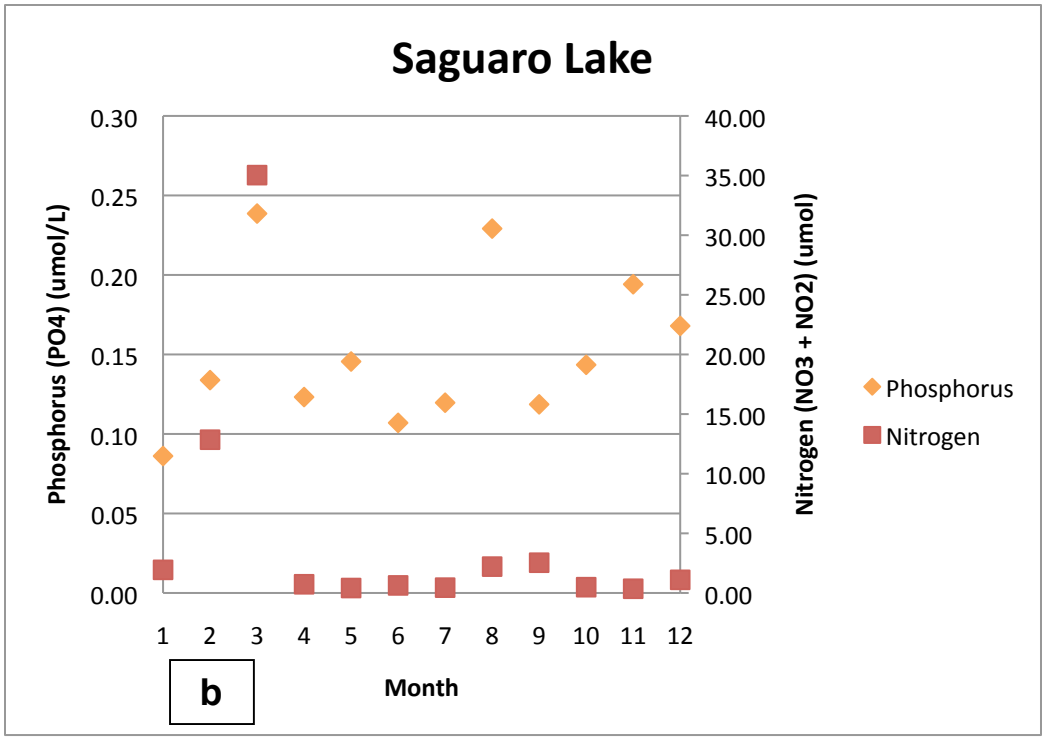


Figure 8 (a, b): Dissolved inorganic nutrient concentrations determined in the surface of Lake Pleasant (a), and Saguaro Lake (b). Concentrations are depicted in micro-moles. Note: Phosphorus and Nitrogen are plotted on separate axes.

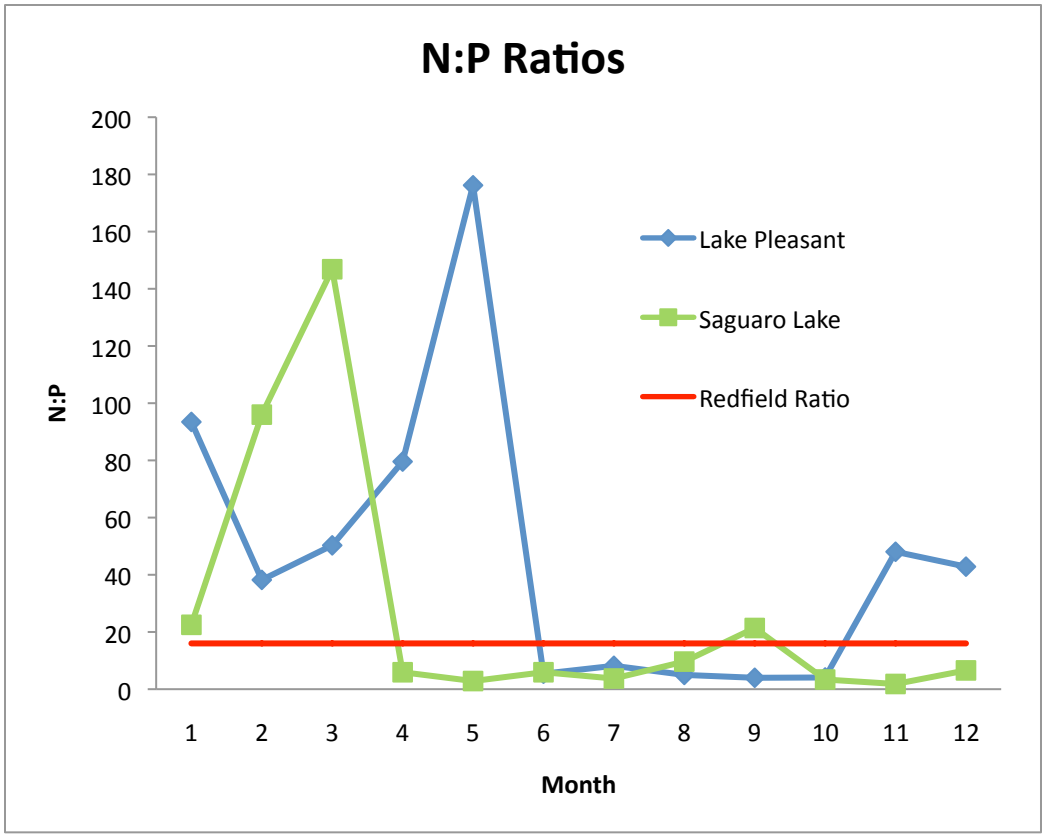


Figure 9: Molar nitrogen and phosphorus ratios plotted with the 16:1 Redfield Ratio (red). Lake Pleasant values are depicted in blue, and Saguaro Lake values are depicted in green.

In Lake Pleasant, dissolved nitrogen (as nitrate and nitrite) was highest during the month of February at 37.4µmol/L, and lowest during the month of September at 0.41µmol/L. Phosphorus (as phosphate) was recorded at a high of 0.98µmol/L during the month of February, and at a low of 0.08µmol/L during the month of July (Figure 8a, Table 2). In Saguaro Lake, N was highest during the month of March at 35.0µmol/L and lowest during the month of November at 0.35µmol/L. P was highest at 0.24µmol/L during the month of March, and lowest at 0.09µmol/L during the month of January (Figure 8b, Table 2). Generally, both reservoirs had peaks in N and P early in the spring. N and P peaks coincided with each other in each reservoir (February for Lake Pleasant, and March for

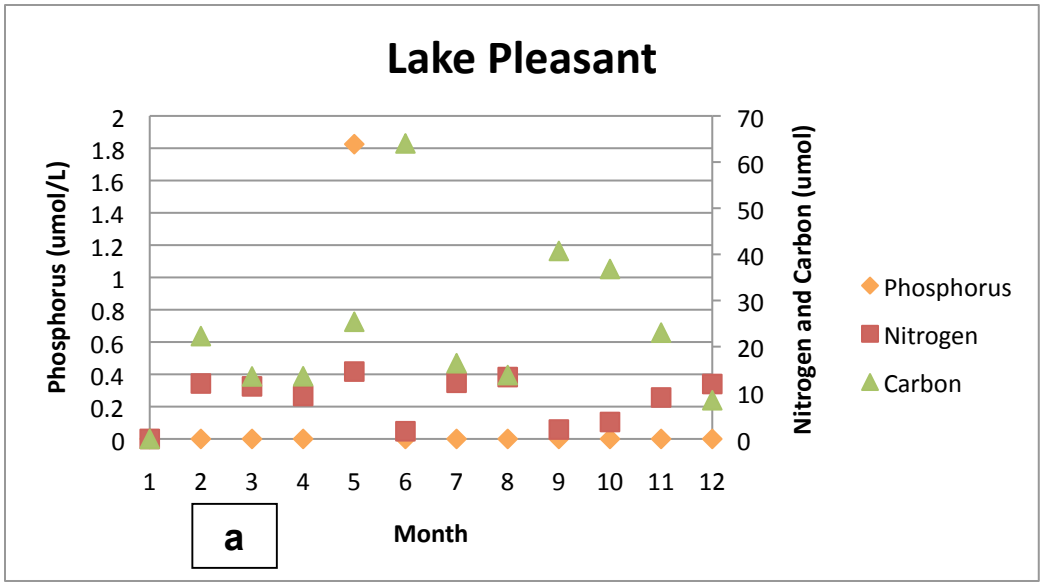
Saguaro Lake). N and P concentration peaks in Lake Pleasant declined throughout the months of March through May, and remained low throughout the remainder of most of the year. A small peak in N and P was measured at the very end of the year, during December. N concentrations in Saguaro Lake declined immediately after the peak during March, and remained low for the remainder of the year. P concentrations in Saguaro Lake fluctuated throughout the year, with two additional minor peaks measured during August and November.

Dissolved nitrogen and phosphorus ratios in Saguaro Lake were above the Redfield Ratio (Redfield, 1958) during the months of January through March and the month of September. Subsequently, N:P ratios were below the Redfield Ratio during the months of April through August and October through December. N:P ratios in Lake Pleasant were above the Redfield Ratio during the months of January through May and the months of November/December. N:P ratios were below the Redfield Ratio in the months of June through October (Figure 9). N:P ratios above the Redfield Ratio indicate P limitation, while those below the Redfield Ratio indicate N limitation.

Particulate Constituents

		Lake Pleasant			Saguaro Lake		
		C	N	P	C	N	P
Month	1	N/A	N/A	N/A	38.35	3.07	BDL
	2	22.28	12.01	BDL	141.17	2.19	BDL
	3	13.54	11.39	BDL	112.52	3.72	BDL
	4	13.58	9.31	BDL	125.96	1.58	BDL
	5	25.39	14.60	1.83	119.38	1.86	BDL
	6	64.04	1.67	BDL	171.43	2.08	BDL
	7	16.41	12.17	BDL	97.42	2.98	BDL
	8	13.84	13.40	BDL	130.45	1.27	BDL
	9	40.74	2.04	BDL	68.00	3.66	BDL
	10	36.83	3.68	BDL	67.32	3.55	BDL
	11	23.04	8.98	BDL	19.65	13.23	0.24
	12	8.35	11.90	BDL	47.08	5.50	BDL
		Concentrations in µmol/L					

Table 3: POC/PON/POP in Lake Pleasant and Saguaro Lake. BDL: Below Detection Limit.



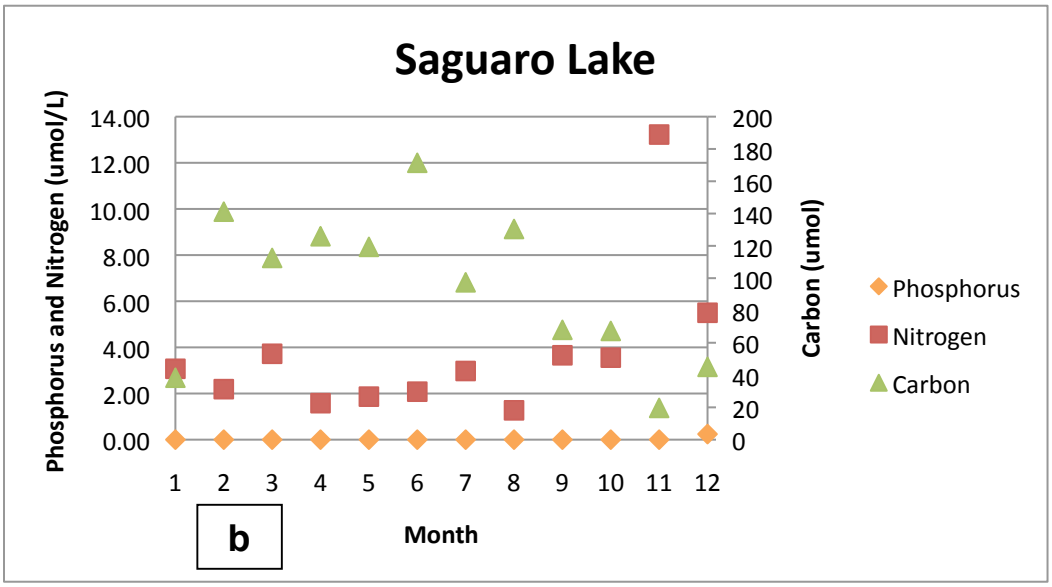


Figure 10 (a, b): Particulate P, N, and C values from the surface of Lake Pleasant (a) and Saguaro Lake (b).

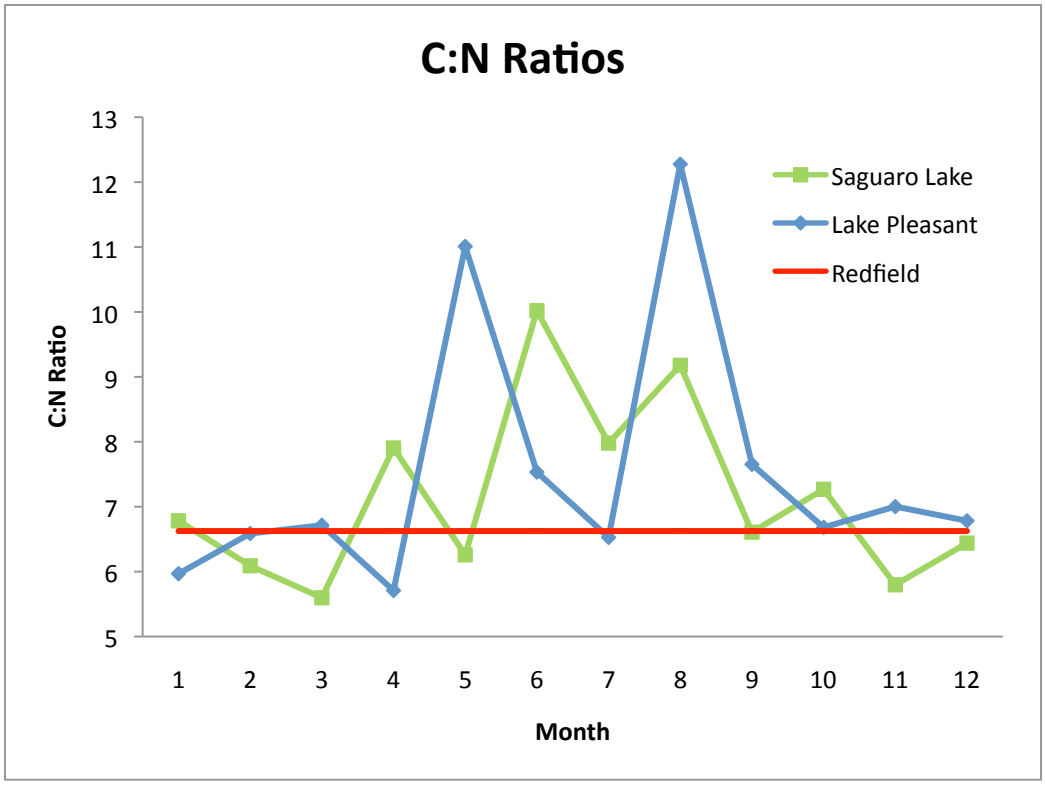


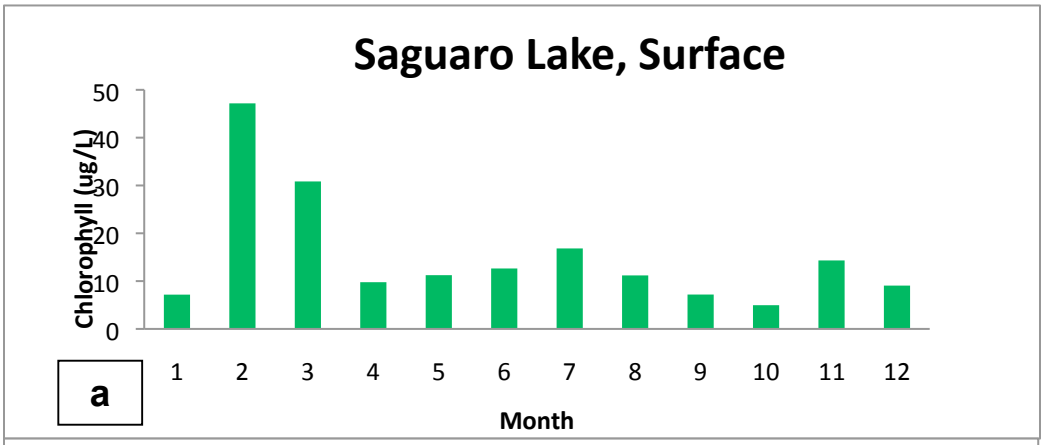
Figure 11: Ratios of particulate organic C and N. Lake Pleasant is depicted in blue, Saguaro Lake is depicted in green, and the Redfield Ratio is depicted in red.

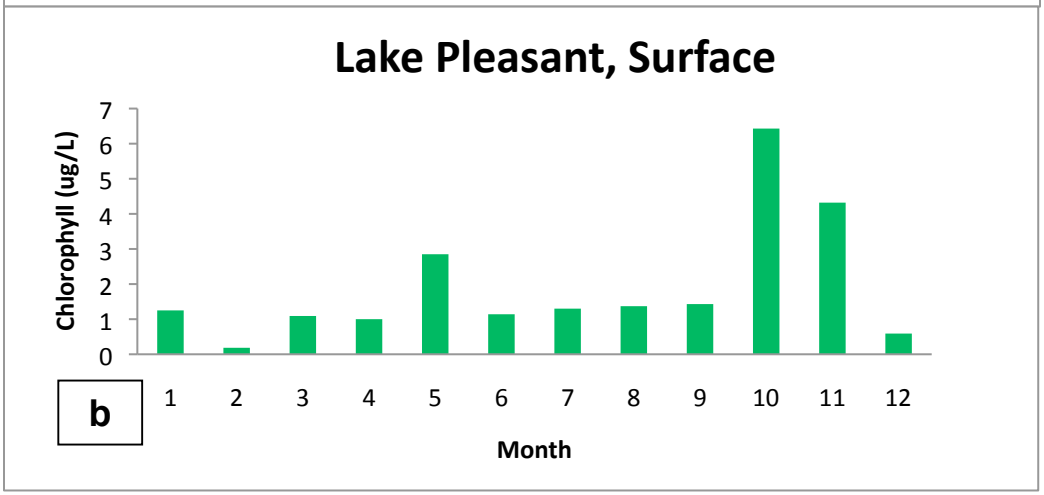
In Lake Pleasant, particulate carbon was recorded at a high of 64.05µmol/L during the month of June, and a low of 8.35µmol/L during the month of December. Nitrogen was highest during the month of May at 14.60µmol/L, and a low of 1.67µmol/L during the month of June. Phosphorus was only recorded above the background during the month of May, at 1.83µmol/L (Figure 10a, Table 3). POC and PON ratios typically were measured above the Redfield Ratio of 6.6:1, indicating C richness. However, in the months of January, February, April, and July, POC/PON ratios were measured below Redfield, indicating N richness. Large spikes in the ratio were measured in the months of May and August (Figure 11). I could only calculate

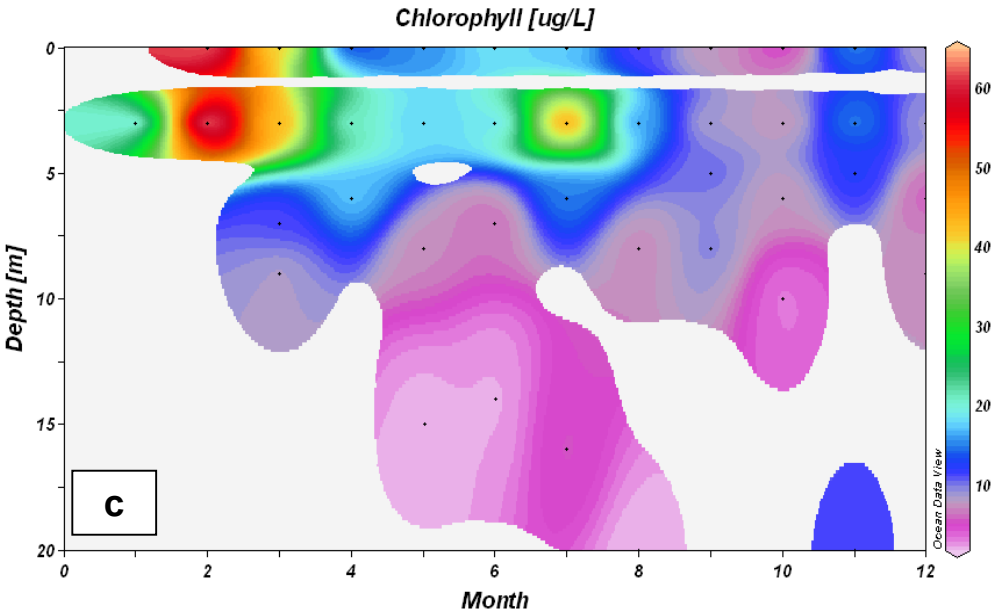
PON/POP ratios for the month of May, because POP was below detection limit for all the other months. During the month of May, the PON/POP ratio was 8:1, below both the Redfield (16:1) and “Elser” (30:1) ratios indicating relatively P rich particulate matter, which would be more nutritious for *Daphnia* (who require greater P, as they are P rich themselves).

In Saguaro Lake, POC was highest during the month of June at 171.43μmol/L and lowest during the month of November at 19.65μmol/L. PON was recorded at a high of 13.23μmol/L during the month of November, and a low of 1.27μmol/L during the month of August. POP was only recorded above the background during the month of November, at 0.24μmol/L (Figure 10b, Table 3). POC/PON ratios were above the Redfield Ratio for six months of the year: January, April, June through August, and October. The largest spike was measured in the month of June (Figure 11). PON/POP ratios could only be calculated for the month of November, due to the reason stated above. During the month of November, the PON/POP ratio was 54.8:1, above the Redfield and “Elser” ratios, indicating relatively N rich particulate matter.

Chlorophyll a







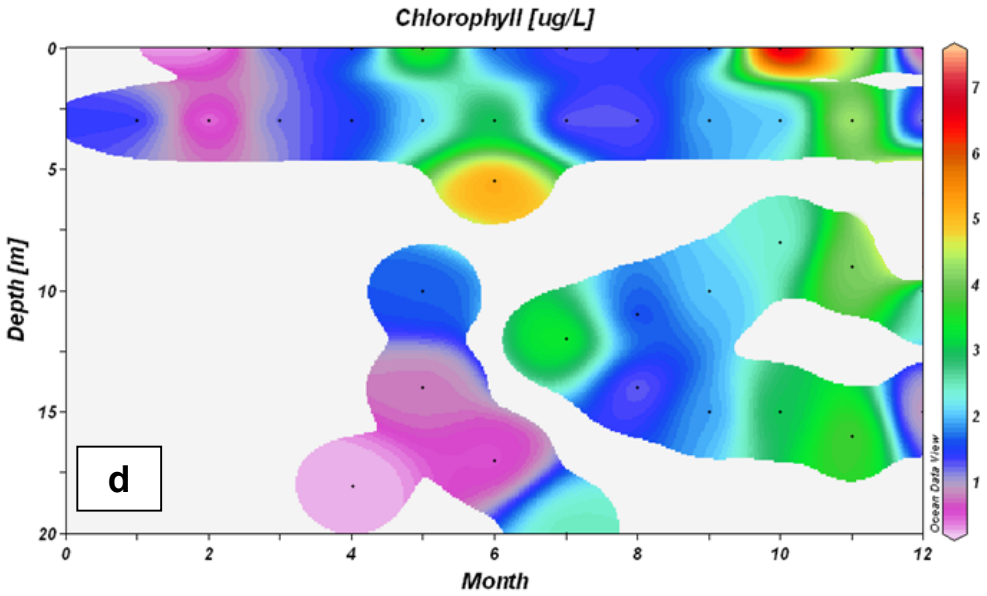


Figure 12 (a, b, c, d): Chlorophyll values for Saguaro Lake (a, c), and Lake Pleasant (b, d) in 2010. *From extracted chlorophyll values.*

Chlorophyll *a* concentrations in Saguaro Lake were consistently(on average) about an order of magnitude greater than the chlorophyll concentrations in Lake Pleasant. Saguaro Lake had one major peak in surface chlorophyll concentration in the month of February at a value of 47.17± of 2.23µg/L (Figure 12a). The average surface chlorophyll value for Saguaro Lake was 15.20± 12.54µg/L. In Lake Pleasant, two surface chlorophyll peaks were observed at 2.85± 0.27 µg/L and 6.43± 0.12 µg/L in the months of May and October, respectively (Figure 12b). The average 2010 surface chlorophyll concentration for Lake Pleasant was 1.91± 1.75µg/L.

Chlorophyll *a* concentrations at depth in Saguaro Lake were the highest during the month of February, at a depth of 3m at 48.95± 3.74µg/L. Concentrations were the lowest during the month of May at a depth of 15m at 1.51± 0.05µg/L (Figure 12c). The deep chlorophyll *a* peak during the month of

February coincides with the surface peak of chlorophyll *a* concentration. The deep minor peak during the month of July also coincides with a minor peak in surface concentrations during the same month. In Lake Pleasant, chlorophyll *a* concentrations at depth were the highest during the month of June at a depth of 5.5m at 3.69± 0.11µg/L. Concentrations were the lowest during the month of April at a depth of 18m at 0.16± 0.004µg/L (Figure 12d). The deep chlorophyll *a* peak during the month of June coincides with the estimated euphotic zone depth.

Phytoplankton Community

Reservoir	*Month*	*I.D.*	*Notes*
Lake Pleasant	March	Cryptophytes Centric Diatoms Pennate Diatoms	Peak in nauplii abundance
	May	*Synechococcus* (large aggregates) Cryptophytes Wood Fibers Prymnesiophytes	Peak in calanoid abundance Chlorophyll *a* minor peak
	July	Prymnesiophytes Cryptophytes *Synechococcus* (small aggregates)	All zooplankton abundances decrease
	August	*Synechococcus* (individual cyanobacteria) Cryptophytes Prymnesiophytes	Peak in nauplii abundance
	September	Chlorophytes Pennate Diatoms Prymnesiophytes *Synechococcus* (sparse individuals)	Nauplii abundance decrease
	October	Wood Fibers Pennate Diatoms	*Diaphanosoma* abundance peak Chlorophyll *a* peak
	November	*Synechococcus* (individual cyanobacteria) Cryptophytes Prymnesiophytes	All zooplankton abundances peak Chlorophyll *a* >4ug/L
Saguaro Lake	March	Centric Diatoms Prymnesiophytes Euglenoids Long Filaments	Copepod abundance peak Filaments fluoresce orange under blue light excitation Chlorophyll *a* >30ug/L
	April	*Synechococcus* (individual cyanobacteria) Cryptophytes Prymnesiophytes Thin Filaments	Nauplii abundance peak Filaments fluoresce green under blue light excitation
	July	*Cylindrospermopsis sp.* Prymnesiophytes *C. curvispora*	Copepod abundance decrease *Daphnia* abundance peak Chlorophyll *a* minor peak
	November	*C. curvispora* *Cylindrospermopsis sp.* *Prymnesiophytes* *Synechococcus* (individual cyanobacteria)	Late-year chlorophyll *a* minor peak

Table 4: Qualitative examination of phytoplankton communities in Lake Pleasant and Saguaro Lake. Specific months were selected due to coinciding events in zooplankton abundance and peaks in chlorophyll *a*.

In Lake Pleasant (Table 4), *Synechococcus* was relatively abundant in six of the seven months and was the most abundant phytoplankton during three of the months that it was present (May, August, and November). In May, the

cyanobacteria formed large aggregates. In August and November, the cyanobacteria occurred as individual cocci. Prymnesiophytes were present in five of the seven months (May through September, and November). Prymnesiophytes were the most abundant phytoplankton during the month of July, which experienced the greatest recorded decline of zooplankton abundance in 2010. Other abundant organisms included pennate diatoms, centric diatoms, cryptophytes, and chlorophytes. In the months of May and October, large bundles of wood fibers were found amongst the phytoplankton.

In Saguaro Lake (Table 4), prymnesiophytes were found in every month, but were never the most abundant phytoplankton. The community was varied throughout the year, also consisting of centric diatoms, euglenoids, cryptophytes, and filamentous cyanobacteria. The appearance of the potentially toxic filamentous cyanobacteria *Cylindrospermopsis* during the month of July coincided with a decrease in abundance of all zooplankton. *Cylindrospermopsis* remained abundant throughout the rest of the year, and zooplankton population abundance remained low as well.

Zooplankton Abundance

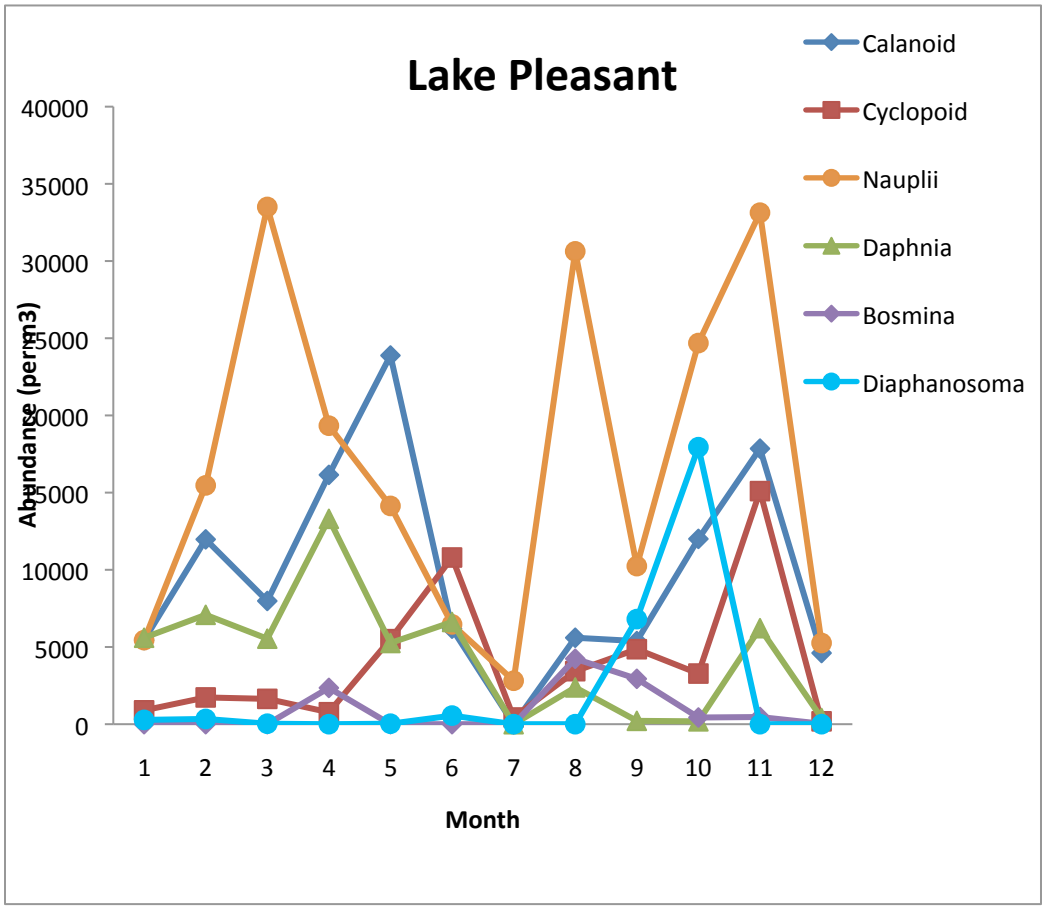


Figure 13: Abundance of zooplankton in the upper 5m of Lake Pleasant during 2010. Values depicted are of individuals per cubic meter.

In Lake Pleasant, zooplankton populations fluctuated over the year of 2010 (Figure 13). All populations experienced a decline in abundance in the month of July. Observed peaks varied by group. Peaks were measured for copepod nauplii (cyclopoids and calanoids) during March ($3.4x10^4 \pm 2116\ m^{-3}$), August ($3.06x10^4 \pm 4245\ m^{-3}$), and November ($3.31x10^4 \pm 3012\ m^{-3}$). Calanoid copepod peaks occurred in February ($1.20x10^4 \pm 1324\ m^{-3}$), May ($2.39x10^4 \pm 4407\ m^{-3}$), and November ($1.79x10^4 \pm 1982\ m^{-3}$). Cyclopoid copepod peaks were measured in June ($1.08x10^4 \pm 1997\ m^{-3}$) and November ($1.51x10^4 \pm 1579\ m^{-3}$). Abundance

of the Cladoceran *Daphnia* peaked in April ($1.33x10^4 \pm 1330\ m^{-3}$). The cladoceran *Bosmina* peaked in April ($2.35x10^3 \pm 668\ m^{-3}$) and August ($4.24x10^3 \pm 793\ m^{-3}$). The cladoceran *Diaphanosoma* peaked in October ($1.79x10^4 \pm 2588$). Nauplii were the greatest in abundance in the zooplankton community, with an approximate population of 3.3,x104 m^{-3} in the months of March and November.

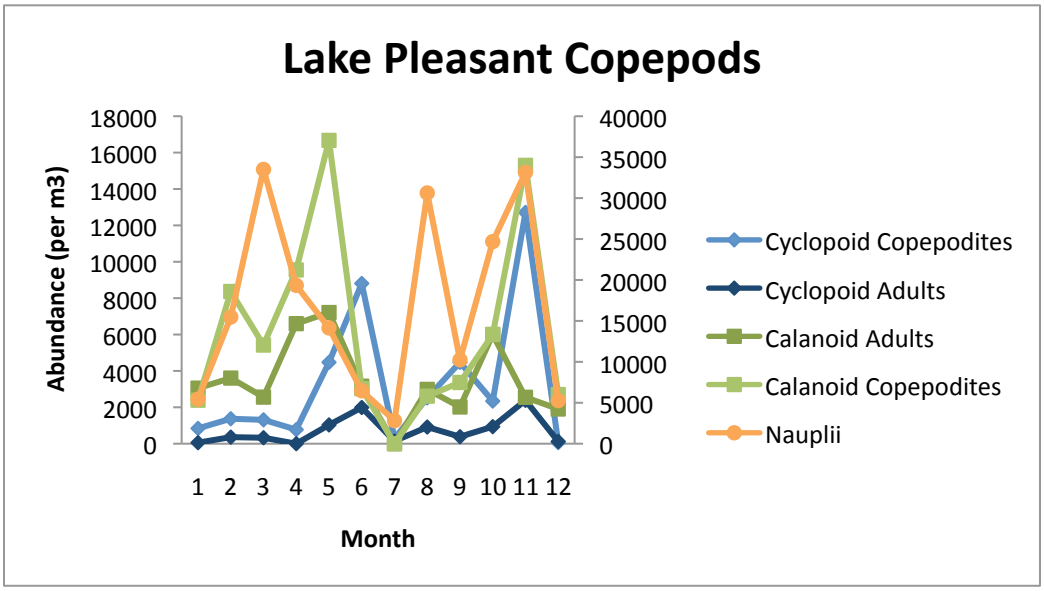


Figure 14: Copepodite and adult copepod populations from Lake Pleasant plotted on left axis. Nauplii plotted on right axis.

Calanoid copepod populations were (on average) composed of 38% adults and 62% copepodites. Seasonally, calanoid copepodites were more abundant than adults from January to May (62.2% copepodites, 37.8% adults) and November to December (72.5% copepodites, 27.5% adults), while copepodites and adults were relatively equal from June to October (57.2% copepodites, 42.8% adults). Cyclopoid copepod populations were (on average) composed of 22% adults and 78% copepodites. There was less of a factor of seasonality with cyclopoid copepodites than calanoids, as cyclopoid copepodites were always much more abundant than adults, with the exception of the month of

December, when the population was composed of 34% copepodites and 66% adults. Nauplii were not distinguished as either calanoids or cyclopoids due to difficulties in identifying the two groups. As a whole (averaged) nauplii made up 55% of the total copepod community throughout the year. Nauplii populations generally peaked during months of low abundance of other copepod copepodites and adults (March and August), with the exception of November, when nauplii abundance peaked along with both cyclopoid and calanoid copepodites (Figure 14).

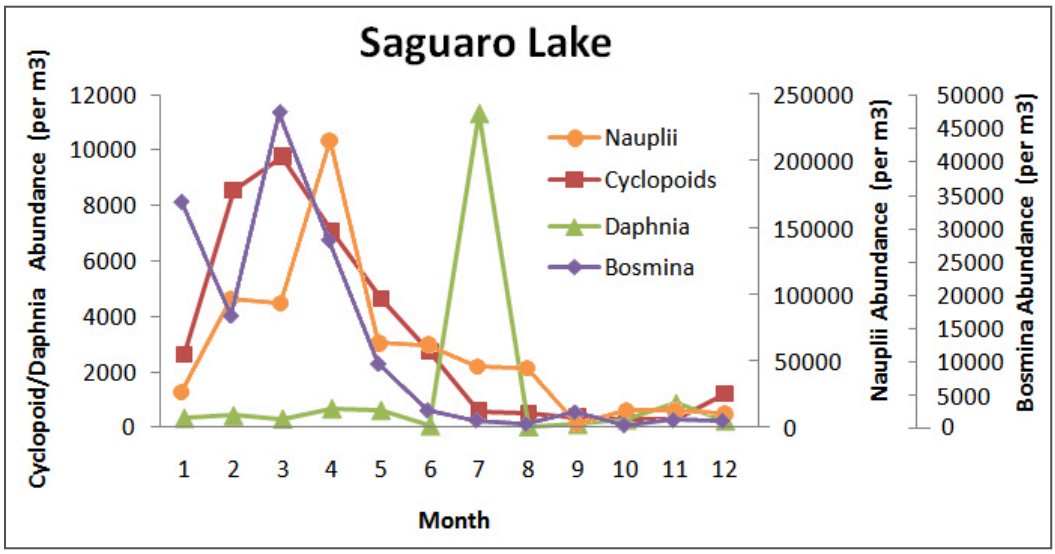
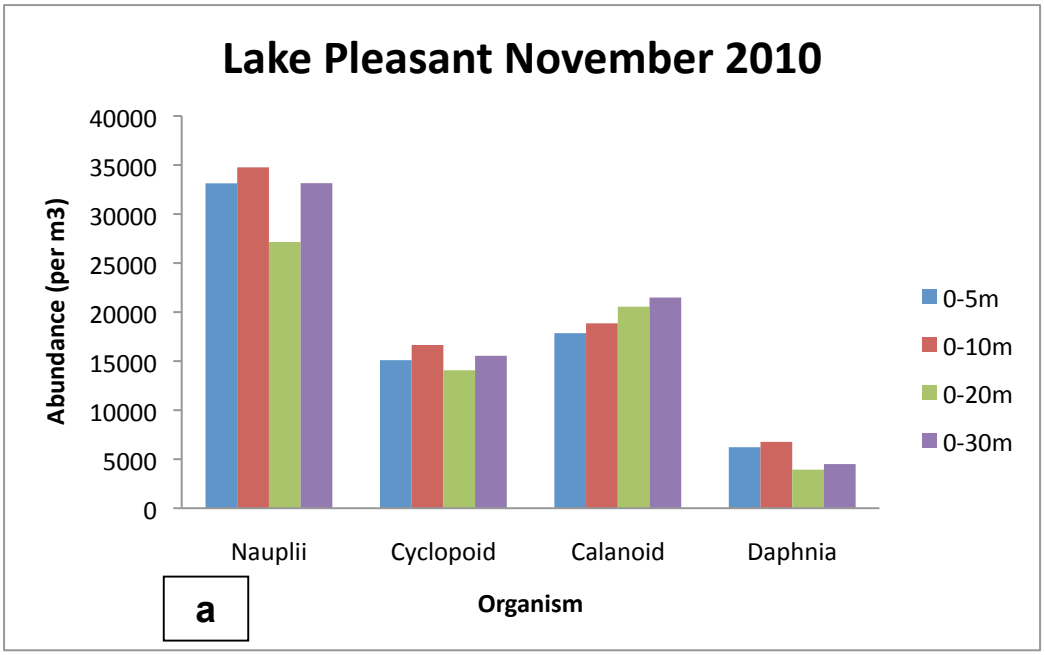


Figure 15: Abundance of zooplankton in the upper 5m of Saguaro Lake during 2010. Values depicted are of individuals per cubic meter. Note: Cyclopoids/*Daphnia*, nauplii, and *Bosmina* are plotted on different axes.

Saguaro Lake (Figure 15) had a less abundant copepod and *Daphnia* community than Lake Pleasant (Figure 13). However, nauplii and *Bosmina* in Saguaro Lake were more abundant (at their peak) than in Lake Pleasant. Saguaro Lake zooplankton populations were more abundant in the first half of the year (winter and spring), and began to decline steadily during the summer. Populations of cyclopoid copepodites ($9.78x10^3$ m^{-3} ±1 798), nauplii

(2.16x10^5 m^{-3} ± 7759), and the cladoceran *Bosmina* (4.72x10^4 m^{-3} ± 3965) peaked in the months of March and April. The cladoceran *Daphnia* (1.13x10^4 m^{-3} ± 119) peaked in the month of July.

Copepod populations were composed of either nauplii or copepodites, adult forms of cyclopoids were not found. To investigate if adult populations could be hiding at greater depths during the day, I conducted net casts to 20 m depth in both lakes. Adult cyclopoids were found but were sparse in the November 20m (Figure 16b) net cast, with only an occasional adult found in a 5mL subsample. Nauplii peaked at an order of magnitude greater than copepodite populations, approximately 200,000 m^{-3} individuals compared to 10,000 m^{-3}, respectively.



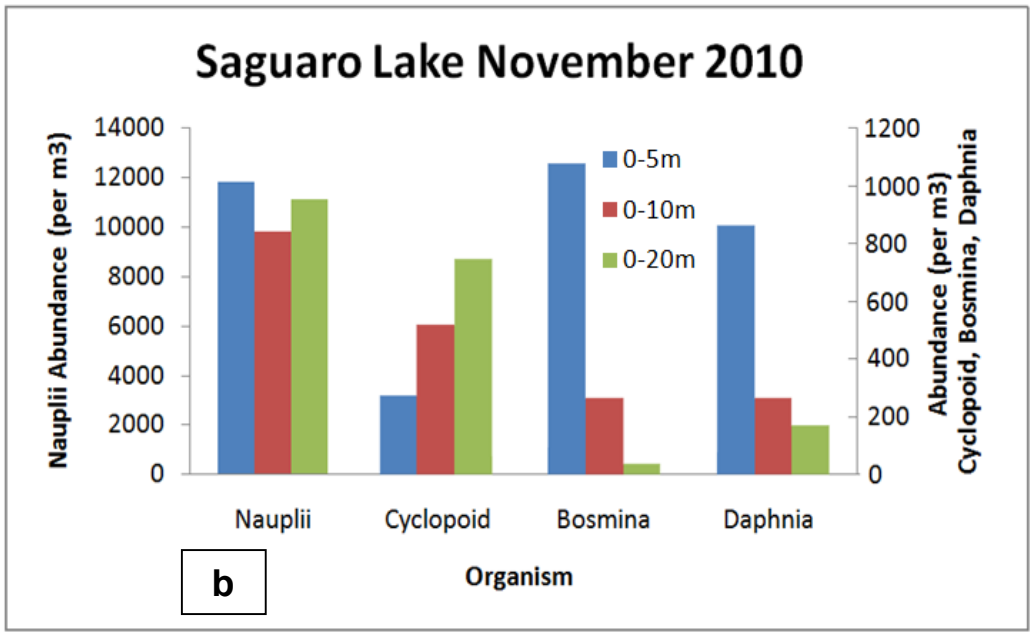


Figure 16 (a, b): Comparison of abundance estimates derived from casts of different depth intervals from Lake Pleasant and Saguaro Lake in November. Nested columns represent different organisms while each color represents a different depth interval. Copepod data represents combined adults and copepodites.

In Lake Pleasant (Figure 16a), abundance of nauplii was similar from 0-5m, 0-10m, and 0-30m. Nauplii from 0-20m were less abundant than the other three depths. Cyclopoid copepods were relatively well distributed throughout the water column. Calanoid copepods became more abundant as depth increased down to the maximum sample depth of the 30m net cast. The cladoceran *Daphnia* was most abundant from 0-5m and 0-10m, while less abundant from 0-20m and 0-30m. The cladoceran *Bosmina* was not present in significant numbers at any depth in the month of November.

In Saguaro Lake (Figure 16b) the nauplii population was distributed relatively equally in the upper 20m. Cyclopoid copepod abundance increased steadily with increasing depth, indicating that populations were more abundant in deeper depths. Cladocerans *Bosmina* and *Daphnia* both declined as sampling

reached deeper depths, indicating that they were more concentrated in the upper 5m of the water column.

Zooplankton Biomass

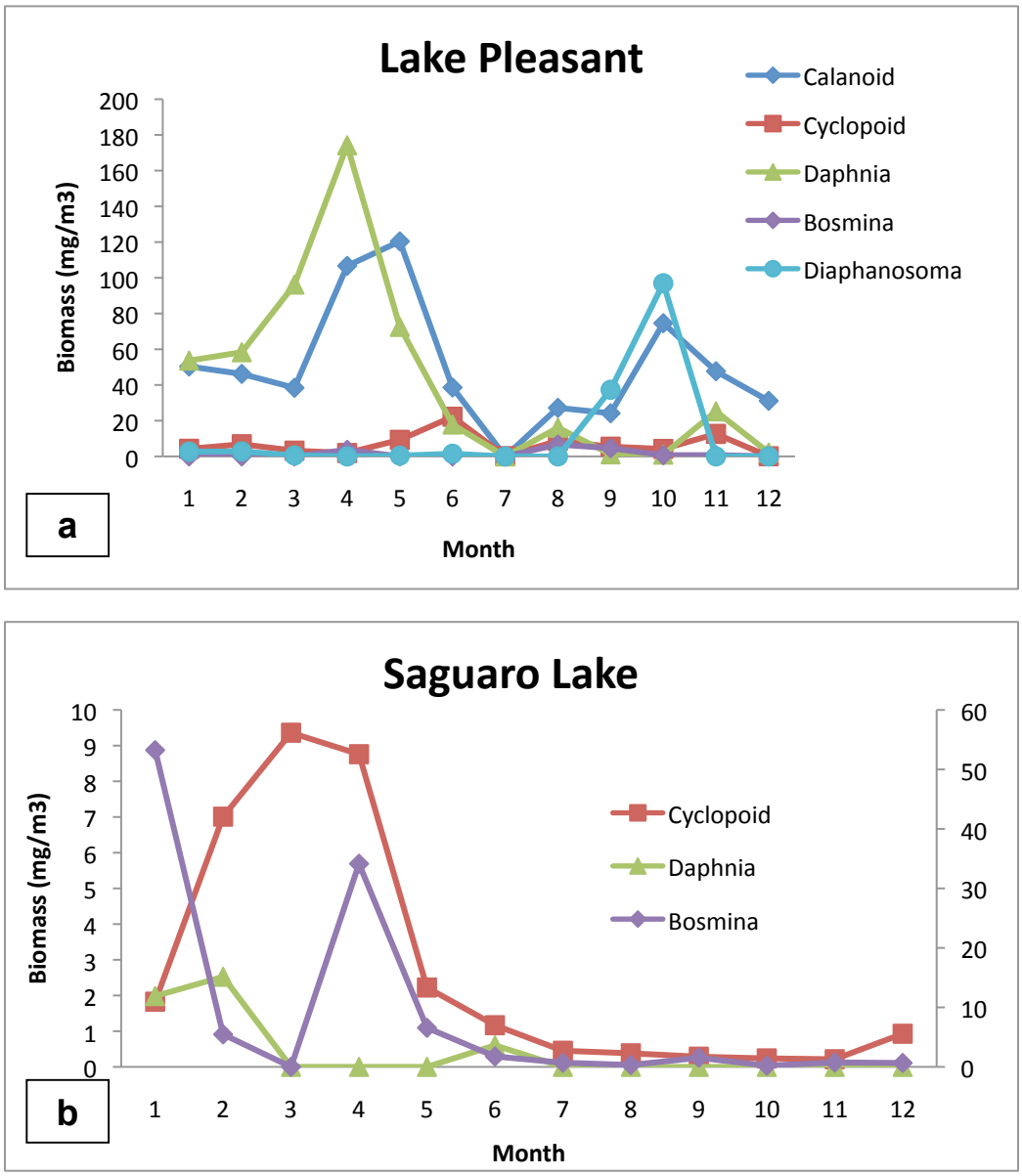


Figure 17 (a, b): Zooplankton biomass in Lake Pleasant and Saguaro Lake. Saguaro Lake *Bosmina* plotted on right axis (b).

Biomass of zooplankton in Lake Pleasant (Figure 17a) and Saguaro Lake (Figure 17) followed patterns similar to abundance figures (Figures 13 and 15). Two exceptions are the *Daphnia* populations in either reservoir. In Lake Pleasant, there was more *Daphnia* biomass than calanoid biomass during the month of April despite greater calanoid abundance. *Daphnia* in Lake Pleasant were very large throughout the year (body length average of 1200µm ± 112). In Saguaro Lake, *Daphnia* biomass also deviates from the pattern of abundance during the month of July. This is due to the small size of *Daphnia* during July with an average body length of 550µm ± 213 compared to the average body length during all other months of 900µm ± 239. In addition to the small size of *Daphnia* in Saguaro Lake, the helmets and tails of individuals formed elongated spikes, along with the spines on the carapace. The *Daphnia* of Lake Pleasant did not have any of these features.

Rotifer Abundance

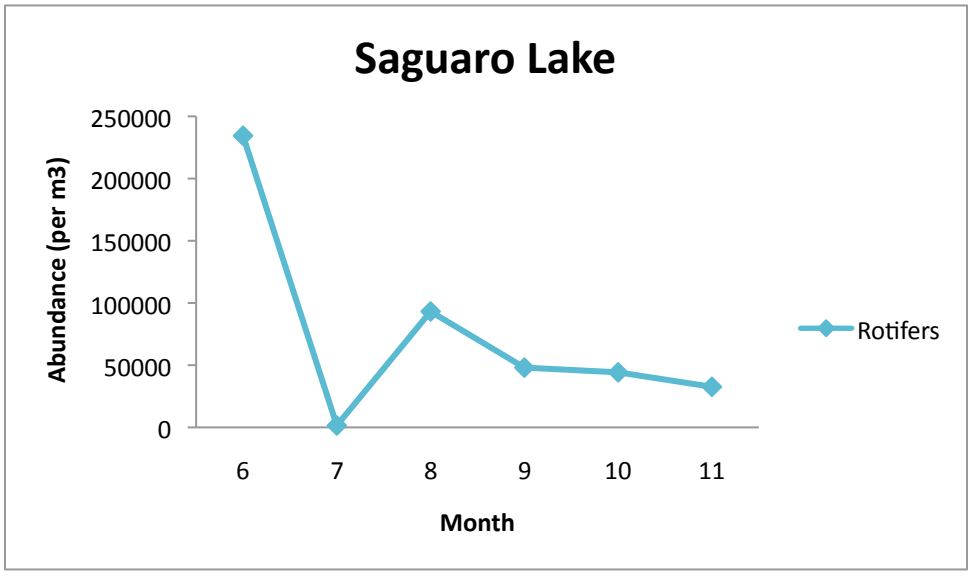


Figure 18: Rotifer abundance in Saguaro Lake from June to November of 2010.

Rotifer abundance of Saguaro Lake (Figure 18) was determined only during the months of June through November in the euphotic zone (Figure 7). They were the most abundant during the month of June ($2.34x10^5$ m^{-3} ± $3.32x10^4$), and least abundant during the month of July (3 m^{-3} ± 2.82). The average abundance of rotifers was 8.24 x 10^4 m^{-3} ± $8.28x10^4$ for the study period. The average from August through November was 5.27x 10^4 m^{-3} ± $3.91x10^4$.

Lake Pleasant Fish Community (AZGFD 2005 and 2008)

From data in two separate studies, the fish community of Lake Pleasant was composed of the following fish: Striped Bass (*Morone saxatilis*), White Bass (*Morone chrysops*), Largemouth Bass (*Micropterus salmoides*), Green Sunfish (*Lepomis cyanellus*), Bluegill (*Lepomis macrochirus*), Redear Sunfish (*Lepomis microlophus*), Sunfish Hybrid (*Lepomis sp.*), White Crappie (*Pomoxis annularis*), Black Crappie (*Pomoxis nigromaculatus*), Channel Catfish (*Ictalurus punctatus*), Flathead Catfish (*Pylodictis olivaris*), Tilapia (*Tilapia sp.*), Common Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Threadfin Shad (*Dorosoma petenense*), Golden Shiner (*Notemigonus crysoleucas*), Red Shiner (*Cyprinella lutrensis*), Mosquitofish (*Gambusia affinis*), Yellow Bullhead (*Ameiurus natalis*), and Sonora Sucker (*Catostomus insignis*) (Bryan, 2005; Stewart et al., 2008).

From 2000 to 2003, Arizona Game and Fish found that the average individual mass of Striped Bass decreased. From 2000 to 2006, average individual mass of Striped Bass (large piscivore), while the average individual mass of Threadfin Shad (planktivore) increased (Bryan, 2005) (Stewart et al., 2008).

Populations of Striped Bass individuals had the greatest mass in 2004 of 1334g (August specifically), and the lowest mass in 2005 of 333g (August

specifically). Populations of Threadfin Shad individuals had the greatest mass in 2006 (70g), and the lowest mass in 2000 (9g). The decreasing mass of individual Striped bass indicates that overall population abundance increased over time, due to intra-specific competition and stunted growth of the fish (Amundsen et al., 2007).

Saguaro Lake Fish Community

AZGFD (2011c) reports the following fish in Saguaro Lake: Rainbow Trout (*Oncorhynchus mykiss*), Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Yellow Bass (*Morone mississippiensis*), Crappie (*Pomoxis sp.*), Sunfish (*Lepomis sp.*), Channel Catfish (*Ictalurus punctatus*), Tilapia (*Tilapia sp.*), and Yellow Perch (*Perca flavescens*).

Saguaro Lake receives period stockings of the planktivore/insectivore/piscivore Rainbow Trout throughout the winter months. However, in 2010, stockings were scaled back (AZGFD 2011d). The large piscivores Largemouth and Smallmouth Bass are not stocked in Saguaro Lake, and are not found in the density of Striped Bass in Lake Pleasant. Furthermore, these piscivores are benthic and not pelagic, and occur mainly in the shallow parts of the reservoirs closer to the shore.

DNA Based Molecular Gut Analyses

Molecular examination yielded results from the gut content of selected animals and the water column. Results were quantified by the density of DGGE bands (denser bands indicate a higher concentration of DNA). Results labeled “Other” belong to DGGE bands that were not sequenced and do not have an equivalent band on the specific DGGE gel. The “Other” bands may be the

DNA of the animal itself, or unidentified prey bands. Cyanobacterial sequences were not obtained, due to insufficient extraction using the Qiagen kit.

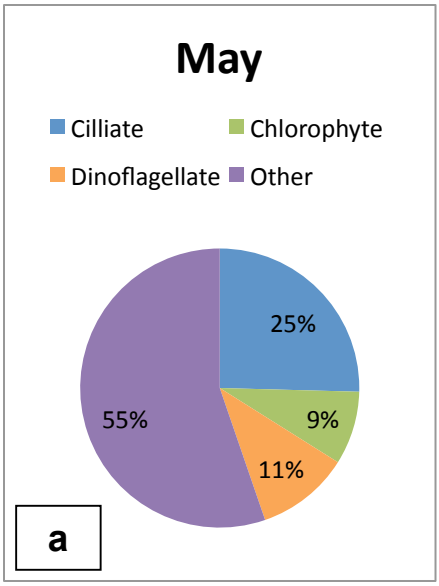
Saguaro Lake

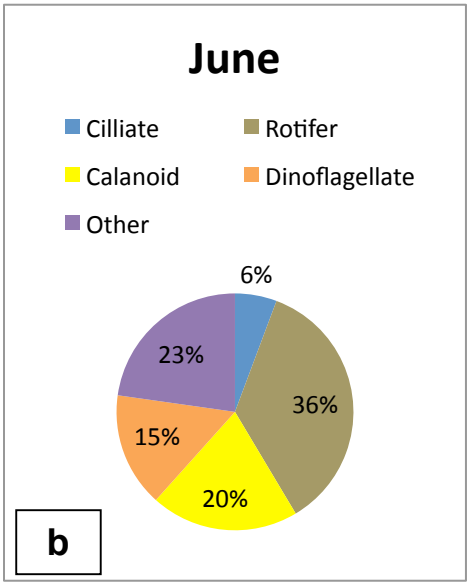
In Saguaro Lake, results were obtained from successfully amplified cyclopoid copepodite, cyclopoid nauplii and *Daphnia* guts. No DNA sequences were successfully amplified from *Bosmina* guts.

Saguaro Lake	Month	1	2	3	4	5	6	7	8	9	10	11	12
	Organism	Rotifera 98%	NR	NR	Rotifera 98% Ciliophora 92 Chlorophyta 84	NR	NR	NR	Amoeba 78% Ciliophora 91 Acanthocystidae (Protist) 78	Diatom 78% Ciliophora 96 Coccidian 87 Rotifera 92	Dinophyceae 82% Ciliophora 88 Prymnesiaceae 74	Fungi 77% Ciliophora 85 Chlorophyta 80 Dinophyceae 82	Ciliophora 93%

Table 5: Eukaryotic organisms found via DNA based molecular analysis of organisms in the water column of Saguaro Lake. Zooplankton selected for analysis were not included in the table. The % match is listed as similarity to the individual organism in the NCBI database (see Apendix).

In the Saguaro Lake water column (Table 5), the following common eukaryotic organisms were found: Ciliates (April, and August through December), rotifers (January, April, and September), chlorophytes (April and November), diatoms (September), dinoflagellates (November), and prymnesiophytes (October). Uncommon organisms include: Amoeba (August: Ichthyosporea, parasitic), Acanthocystidae (August: *Pterocystis*), *Coccidia* (September: *Cryptosproidium*), and Fungi (November: *Mortierella*). Although cyanobacteria comprise a large part of the phytoplankton community, data were not available due to difficulties in amplification.





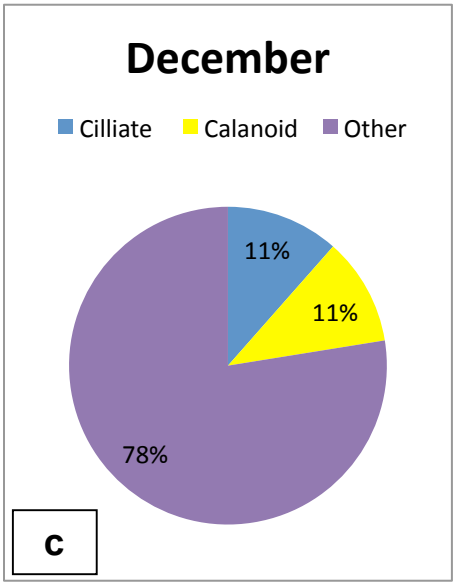
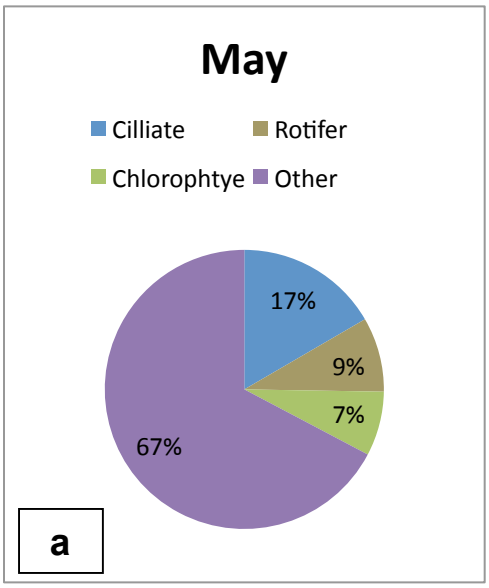
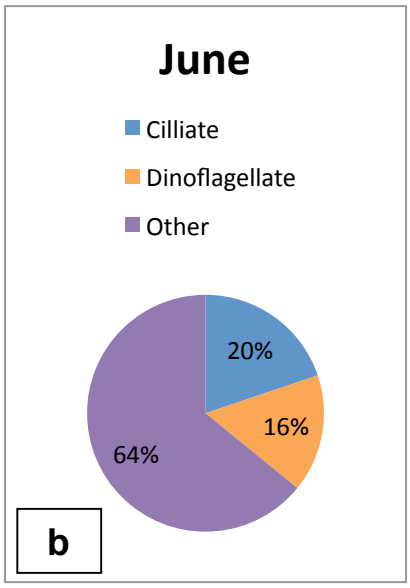


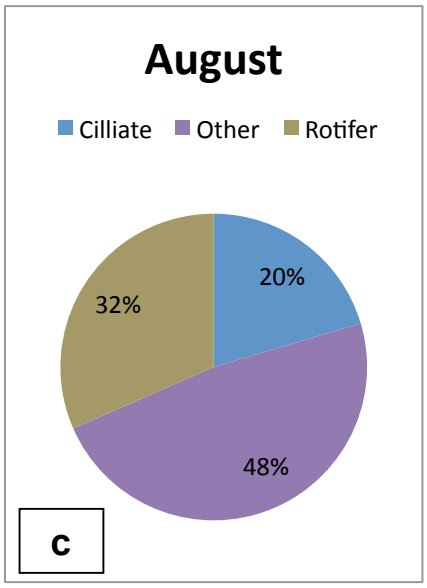
Figure 19 (a-c): Relative distribution of cyclopoid prey organisms in Saguaro Lake obtained from molecular gut analysis. Data were successfully obtained from samples collected in May (a), June (b), and December (c). Percentages represent DNA density.

Cyclopoid gut sequences were successfully amplified for three months: May, June, and December (Figure 19 a-c). In all three months ciliates were present in the gut data, comprising 6% to 25% of DNA density. In May and June, dinoflagellate sequences were found at approximately 13% (averaged). In June

and December, calanoid sequences represented 20% and 11% of DNA density, respectively. Chlorophytes were only found in the gut data in May (9%), while rotifers were only found in June (36%).







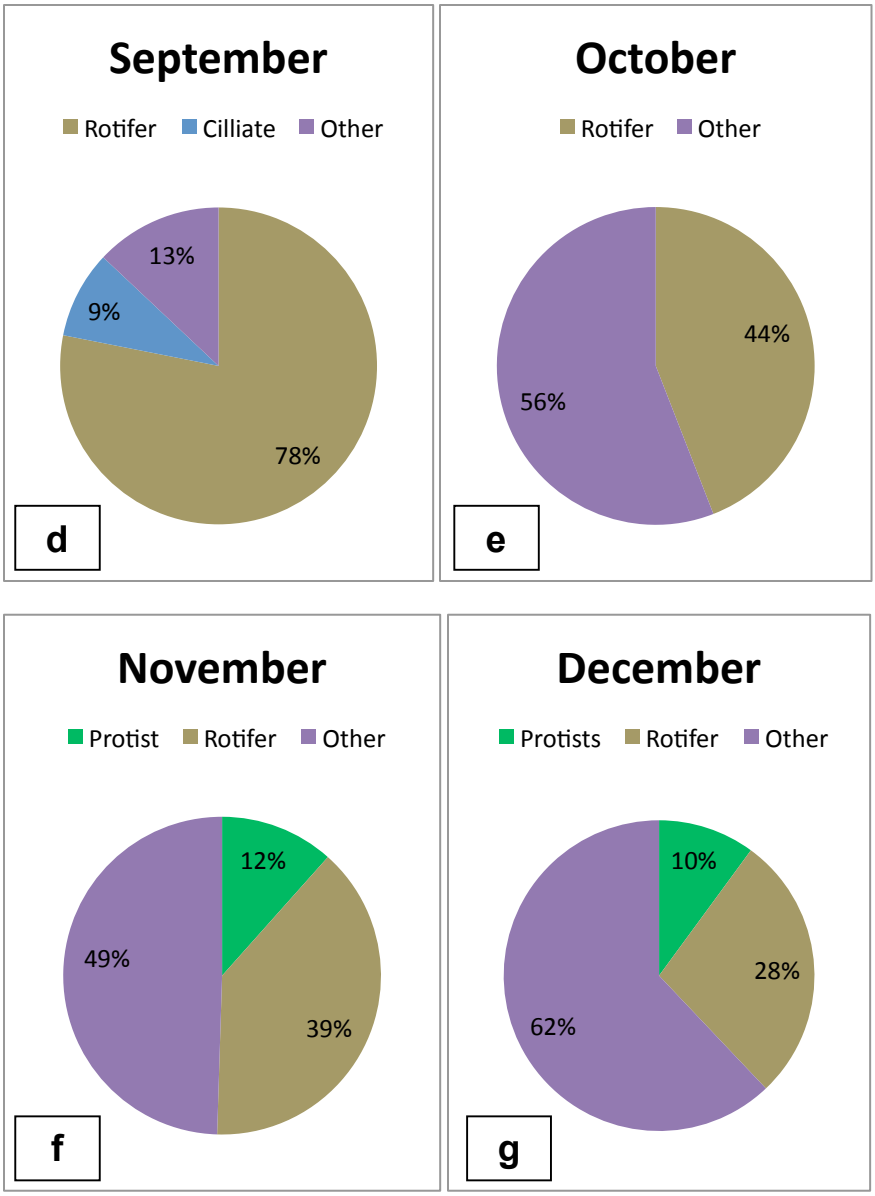


Figure 20 (a-g): Nauplii (Cyclopoid) prey organisms in Saguaro Lake. Data obtained from molecular gut analysis. Data were successfully obtained from samples collected in May (a), June (b), August (c), September (d), October (e), November (f), and December (g). Percentages represent DNA density.

Nauplii gut sequences were successfully amplified for the months of May, June, August, September, October, November, and December (Figure 20 a-g).

In the later months of 2010 rotifer sequences were abundant in the guts, and in September, 78% of all amplified DNA were rotifer sequences. Ciliate

sequences were found in four out of the seven months, no ciliate sequences were successfully amplified in October, November, or December. Chlorophyte sequences were found in May, while dinoflagellate sequences were found in June. Various other protists were found in November and December.

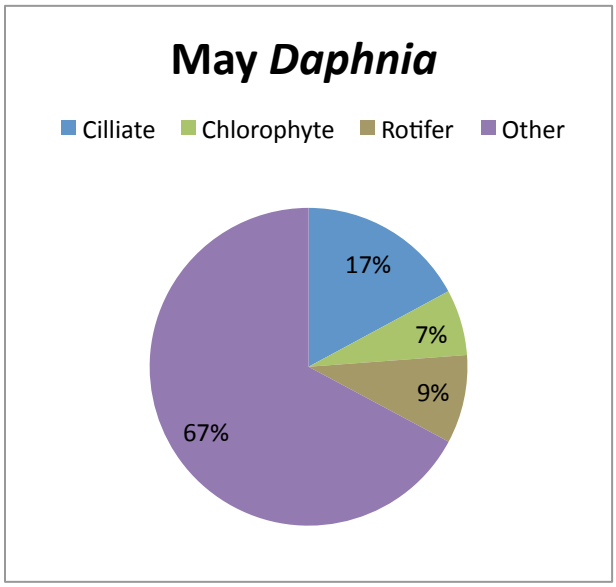


Figure 21: *Daphnia* prey organisms in Saguaro Lake. Data obtained from molecular gut analysis. Data were only successfully obtained from samples collected in May. Percentages represent DNA density.

Sequences from *Daphnia* guts were only successfully amplified in the month of May (Figure 21). Ciliates comprised of the majority of known sequences. Chlorophytes and rotifers were also found.

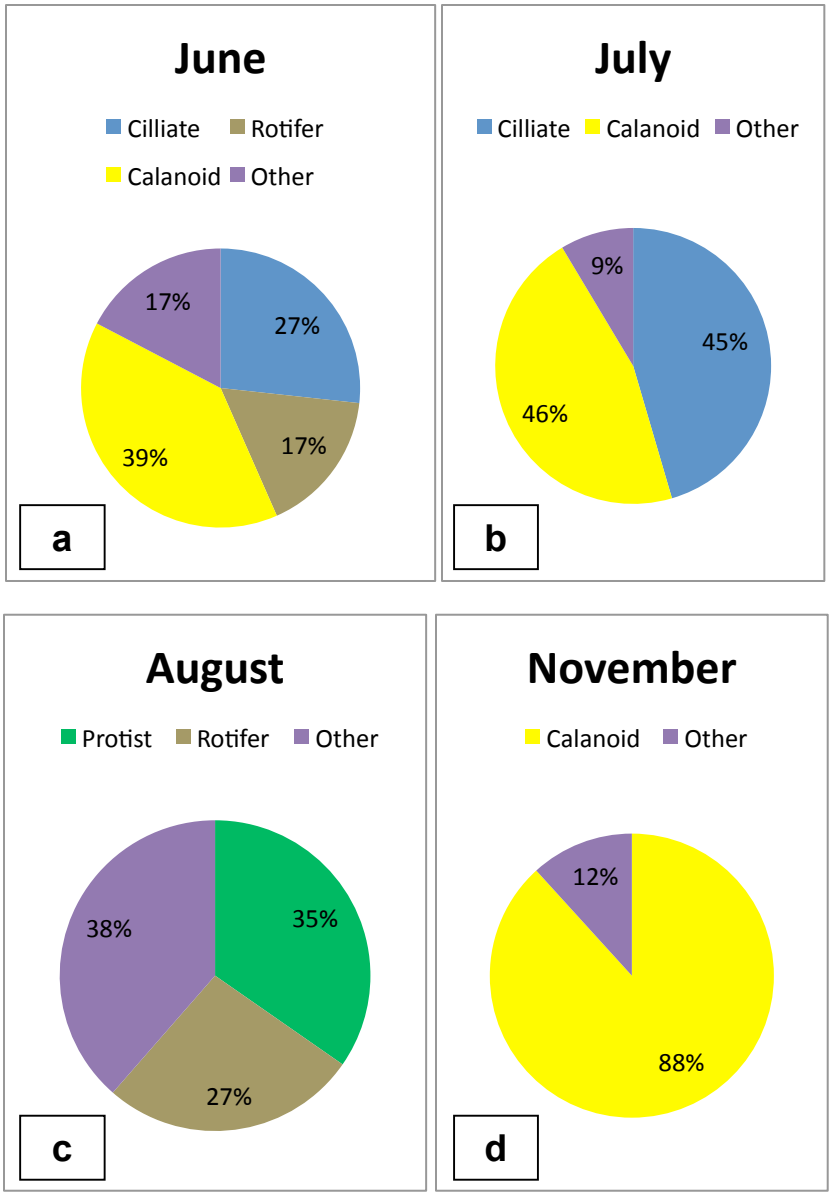
Lake Pleasant

In Lake Pleasant animals selected for examination were: Cyclopoids, calanoids, nauplii, *Daphnia*, *Diaphanosoma*, and *Bosmina*. Gut DNA was successfully amplified from cyclopoids, calanoids, nauplii, and Bosmina. Amplification of guts was not successful for Daphnia or Diaphanosoma.

	Month	1	2	3	4	5	6	7	8	9	10	11	12
Lake Pleasant	Organism	NR	Apicocomplexa 88% Chlorophyta 89 Ciliophora 97 Coccidian 74	NR	Ciliophora 92% Dinophyceae 87	NR	NR	Apicocomplexa 78% Fungi 80 Kinetoplastida 91 Spizellomycetales 70 Spermatophyta 93	Rhizidiomycetaceae 95% Bicosoecidae 83 Rotifera 89 Fungi 97 Dinophyceae 87 Ciliophora 89 Codonosigidae 96	Ciliophora 79% Fungi 97 Dinophyceae 92	Fungi 73% Diatom 89 Ciliophora 98 Stramenopiles 86 Chlorophyta 72 Prymnesiaceae 74	Ciliophora 98% Protozoa 83 Stramenopiles 87 Rhizaria 85 Fungi 94	Ciliophora 95% Choanoflagellida 80 Aveolata 92

Table 6: Eukaryotic organisms found via DNA based molecular analysis of the organisms in the water column of Lake Pleasant. Zooplankton selected for analysis are not included here. The % match is listed as similarity to the individual organism in the NCBI database (see Apendix).

In the Lake Pleasant water column (Table 6), the following common eukaryotic organisms were found: Chlorophytes (February), ciliates (February, April, and August through December), dinoflagellates (April, August, and September), rotifers (August), and diatoms (October). Uncommon eukaryotic organisms include: *Apicocomplexa* (February and September: parasitic phyla), *Coccidia* (February: *Cryptosporidium*), *Kinetoplastida* (July), *Spizellomycetales* (July: fungi), *Spermatophyta* (July: seed plants), *Rhizidiomycetaceae* (August: *Chromista*), *Bicosoecidae* (August), *Codonosigidae/Choanoflagellida* (August/December), stramenopiles (October and November: oomycetes), *Rhizaria* (November: *Cercomonadida*), and fungi (November: *Candida*). Although cyanobacteria comprise a large part of the phytoplankton community, data were not available due to difficulties in amplification.


June
Cilliate
Rotifer
Calanoid
Other
17%
27%
39%
17%
a
July
Cilliate
Calanoid
Other
9%
45%
46%
b
August
Protist
Rotifer
Other
38%
35%
27%
c
November
Calanoid
Other
12%
88%
d

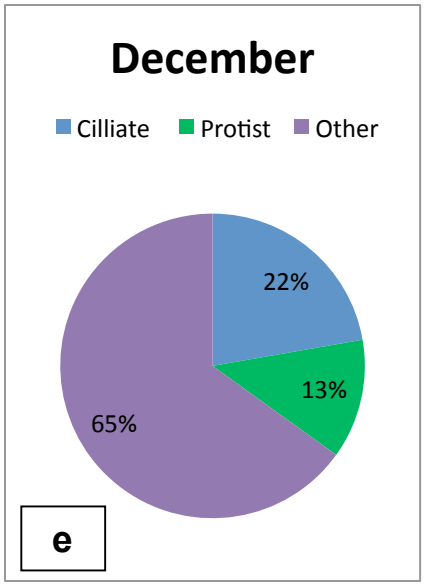


Figure 22 (a-e): Cyclopoid prey organisms in Lake Pleasant from molecular gut analysis. Data were successfully obtained from samples collected in June (a), July (b), August (c), November (d), and December (e). Percentages represent DNA density.

Cyclopoid gut data were amplified successfully for five months (Figure 22 a-e). In June, July, and November calanoid sequences made up the majority of sequences, indicating that the cyclopoids which are known carnivores, preyed either on pieces of adult or entire nauplii of the calanoids.. Ciliate sequences were found in June, July, and December. Rotifers were found in June and August, while various protists were found in August and December.

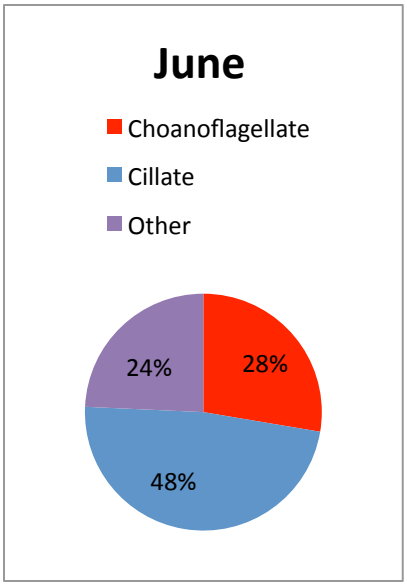


Figure 23: Calanoid prey organisms in Lake Pleasant from DNA based molecular gut analysis. Data were only successfully obtained from samples collected in June. Percentages represent DNA density.

Calanoid sequences only amplified in June (Figure 23). In June, ciliates made up 48% of the amplified DNA, with choanoflagellates making up 28%, and unknown (eukaryotic) DNA comprising the remaining 24% of the DNA density.

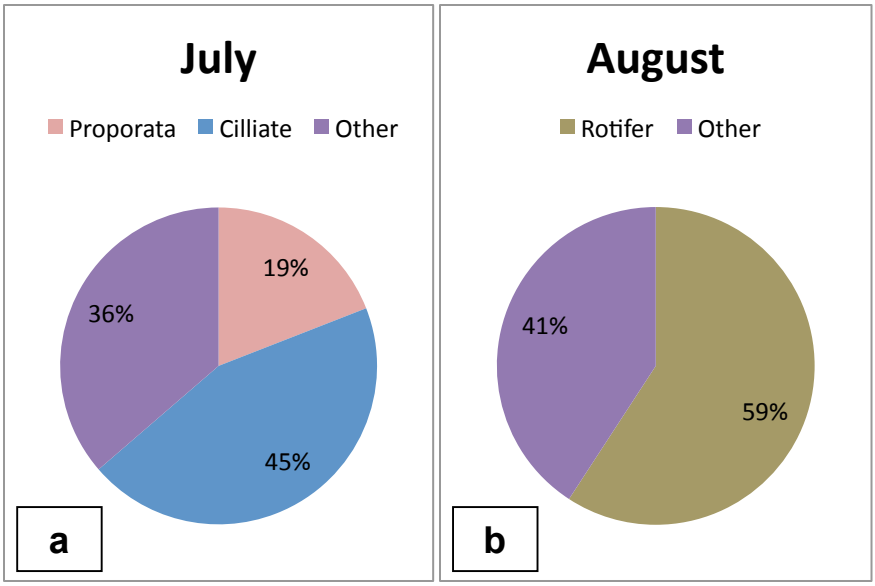


Figure 24 (a, b): Nauplii (Cyclopoid and Calanoid) prey organisms in Lake Pleasant from DNA based molecular gut analysis. Data were successfully obtained from samples collected in July (a), and August (b). Percentages represent DNA density.

Nauplii sequences were only successfully amplified in the months of July and August (Figure 24 a, b). In July, ciliates made up the majority of amplified DNA, while rotifers dominated in August.

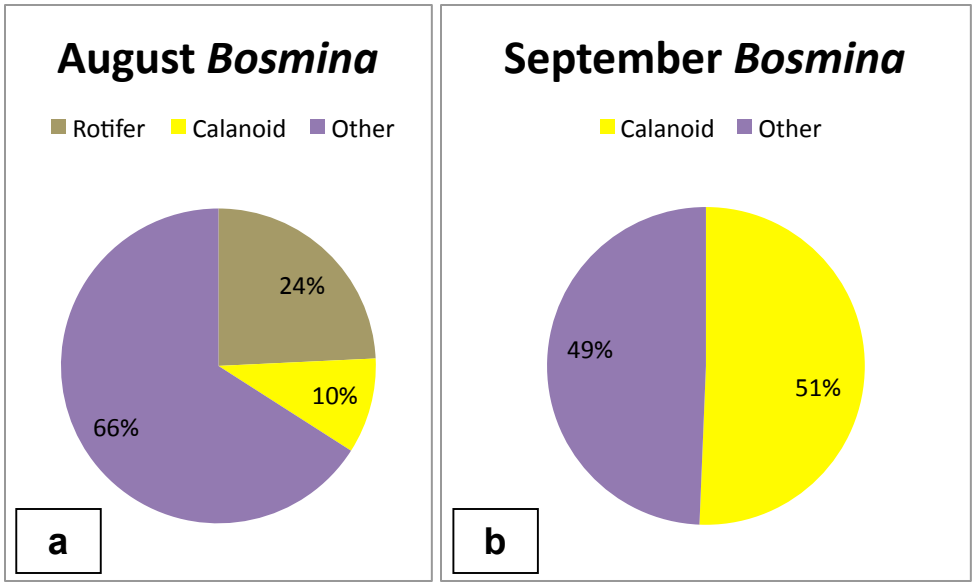


Figure 25 (a, b): *Bosmina* prey organisms in Lake Pleasant from DNA based molecular gut analysis. Data were successfully obtained from samples collected in August (a), and September (b). Percentages represent DNA density.

In Lake Pleasant, only *Bosmina* gut sequences were successfully amplified (Figure 25 a, b), there were no data for *Daphnia* guts. In *Bosmina*, rotifers were found in the month of August, while calanoids were found in August and September.

Discussion

Lake Pleasant and Saguaro Lake differed in the following four ways: 1) Lake Pleasant had a dissolved inorganic P concentration an order of magnitude greater than Saguaro Lake. Dissolved inorganic N concentration peaks were similar between the two reservoirs, but Lake Pleasant had high N concentrations after the initial peak for three months longer than Saguaro Lake. 2) Chlorophyll *a* concentrations (surface) in Saguaro Lake were approximately nine times greater than those in Lake Pleasant, and as a consequence, Saguaro Lake was more turbid than Lake Pleasant. Light is estimated to penetrate approximately five times deeper in

Lake Pleasant than Saguaro Lake. 3) Zooplankton abundance and biomass in Lake Pleasant was much greater than in Saguaro Lake. There are also a greater number of zooplankton groups in Lake Pleasant than Saguaro Lake. 4) Lake Pleasant contains the large pelagic piscivore Striped Bass. This species is not present in Saguaro Lake. The following discussion is split into six sections: 1) Hydrographical context. 2) Seasonal zooplankton variability in the reservoirs in relation to phytoplankton variability. 3) Food webs of the reservoirs derived from gut analyses and literature. 4) Controls of community structure. 5) Hypothesis evaluation. 6) Future work.

1. Hydrographical Context

In the Winter and early Spring of 2010 (January through March), Central Arizona experienced approximately 330mm (13 inches) of precipitation (NWS, 2011). This period of precipitation coincides with increased dissolved nitrogen levels and decreased conductivity in both reservoirs, possibly due to the influx of runoff of freshwater (as seen in the decreased conductivity, Figures 5c and 6c).

In the months of February and March chlorophyll *a* values in Saguaro Lake increased by an order of magnitude, coinciding with the increase in dissolved inorganic nitrogen. However, both reservoirs experienced turnover at this time, so the increased nitrogen may be due to mixing of nutrient-rich deep waters as well. Lake Pleasant did not see a simultaneous response in chlorophyll values coinciding with increased nitrogen or the increased runoff of winter and early spring.

In the spring and early summer of 2010 (March through May) incomplete stratification coincided with deep penetration of dissolved oxygen in Saguaro Lake and Lake Pleasant (Figures 5b and 6b).

In the summer and early fall of 2010 (June through October) strong thermal stratification prevented mixing of the water column with respect to dissolved oxygen. As a result, a large area of depleted oxygen or anoxic water developed at depth in the water column. In Lake Pleasant specifically, this area of anoxic water was found much deeper, due to the increased clarity of the water and penetration of solar radiation fueling primary production. The anoxic area was shallower by comparison in Saguaro Lake due to the inability of solar radiation to penetrate deep into the reservoir.

In the fall and early winter of 2010 (November and December) Lake Pleasant (Figure 26a) and Saguaro Lake (Figure 26b) turned over and became well-mixed. The mixing of nutrient-rich (both N and P) deep water at the surface did not lead to increases in chlorophyll in Lake Pleasant. In Saguaro Lake, however, the deep water mixing coincided with minor peaks in P concentration, and subsequent increases in chlorophyll *a*, with minor peaks during November and December. Chlorophyll values in Lake Pleasant began to decrease from the

peak measured in the month of October. During this November decrease in chlorophyll, the dissolved N:P ratio increased above the Redfield Ratio, indicative of phosphorus limitation. Phosphorus limitation limits primary production.

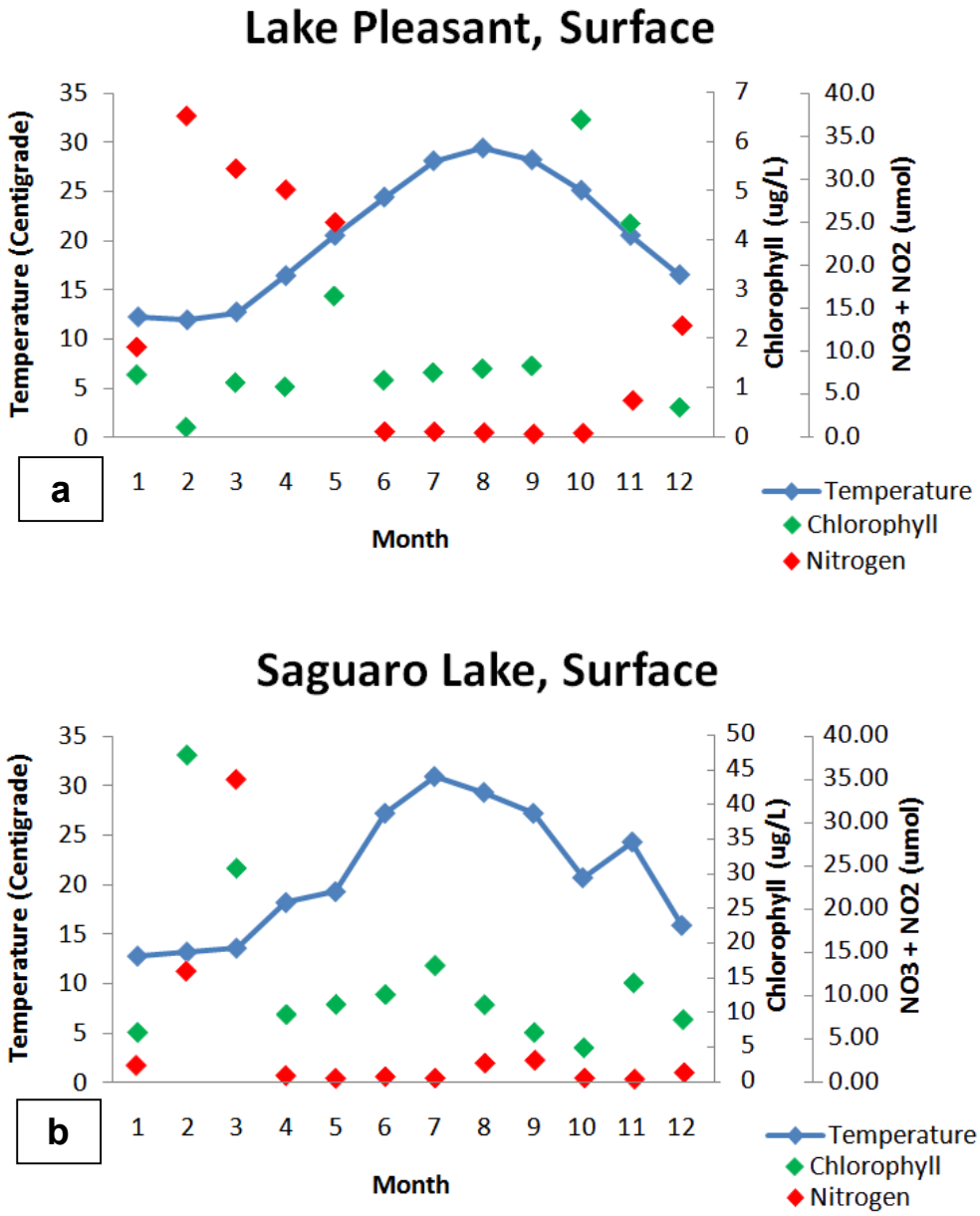


Figure 26 (a, b): Covariation of temperature, chlorophyll, and nitrogen in Lake Pleasant (a) and Saguaro Lake (b).

2. Seasonal Zooplankton Variability in the Reservoirs in Relation to Phytoplankton Variability

The zooplankton community in Lake Pleasant was more diverse than the community in Saguaro Lake, two additional groups of zooplankton (calanoid copepods and the cladoceran *Diaphanosoma*) were found in Lake Pleasant. Additionally, zooplankton biomass was higher in Lake Pleasant than in Saguaro Lake. Populations of zooplankton were found in abundance throughout 2010 in Lake Pleasant, while Saguaro Lake experienced a decline in the second half of 2010 (Figure 13 and 15).

In the month of July, all populations of zooplankton in Lake Pleasant decreased sharply. This might have been correlated with a seasonal variation in the phytoplankton population: 1) There was a prymnesiophyte bloom in July. The toxin produced by certain prymnesiophytes (*Prymnesium*, for example) may render them inedible or poisonous. This is consistent with results found by Remmel et al. (2011), reporting that populations of *Daphnia* began to decline after ten days of exposure to toxic prymnesiophytes. 2) The cyanobacteria *Synechococcus* was not forming aggregates, but was found in small clumps (three or four cells) or individually. When not in aggregate, the individual cells may be too small to consume.

The following might also contribute to the decrease of abundance observed in July in Lake Pleasant: 1) Predation on zooplankton by planktivorous fish such as the Threadfin Shad may have temporarily increased. DeVries et al. (1991) found that when Threadfin Shad populations peaked in Stonelick Lake, Ohio, zooplankton populations experienced massive declines. 2) Populations of zooplankton were possibly at a deeper depth than the deepest (10m) vertical tow

performed at the time of collection. Diel migration of the populations were not studied extensively; only one significantly deep tow (30m) was performed during the month of November. From the November deep results (20m and 30m), we see that large populations of zooplankton do occupy the water column well under the estimated euphotic zone (Figures 7 and 16a) in Saguaro Lake. Mcnatt (1977) found large diel migrations of zooplankton in Canyon Lake and Apache Lake of the Salt River chain.

After the month of April, all zooplankton populations in Saguaro Lake decreased from a peak in abundance in the month of March. From the months of July through December, all populations were very low in abundance. This might have been correlated with the following changes observed in the phytoplankton: Prymnesiophytes were found in greater abundance in the months of July through November. The effects of prymnesiophytes on zooplankton would be the same as listed above, for Lake Pleasant. Also in the time period of July through November, filamentous cyanobacteria (*Cylindrospermopsis*, *Aphanizomenon*) were abundant in the phytoplankton community. Existing literature indicates that these filamentous cyanobacteria release toxins to inhibit competition amongst phytoplankton and to inhibit grazing by zooplankton (DeMott and Moxter, 1991).

Variable N:P ratios of phytoplankton can have significant effects on a food web, as low phosphorus phytoplankton are considered to be of low nutritional quality for zooplankton- especially for the cladoceran *Daphnia* which has a high requirement for phosphorus (Elser et al, 2000). The difference in nutrient load and stoichiometric ratios of dissolved inorganic nitrogen to phosphorus (N:P) should influence the stoichiometric ratios (PON:POP) of phytoplankton and would constitute a form of bottom-up control of the plankton community. High dissolved

inorganic N:P ratios during the month of May in Lake Pleasant indicate P limitation. However, during the month of May, the ratio of PON:POP was 8:1 (Table 2), indicating P-rich phytoplankton. These P-rich phytoplankton would be excellent nutrition for *Daphnia* populations, but during the month of May, *Daphnia* abundance was only average (Figure 13). This may be evidence for bottom-up control or possibly an effect of competition, as there was also a peak in the population of calanoid copepods during the month of May. During the month of November in Saguaro Lake, the PON:POP ratio was 55:1, higher than the Redfield and "Elser" ratios, indicating N-rich phytoplankton. Dissolved inorganic N:P for November in Saguaro Lake was below the Redfield ratio indicating N limitation, which coincides with the presence of filamentous cyanobacteria (Table 2). This may be further evidence for bottom-up control of the community in Saguaro Lake. To further describe phytoplankton nutritional value, a more complete particulate P data set would be required.

3. Food Webs in the Reservoirs Derived from Gut Analyses and Literature

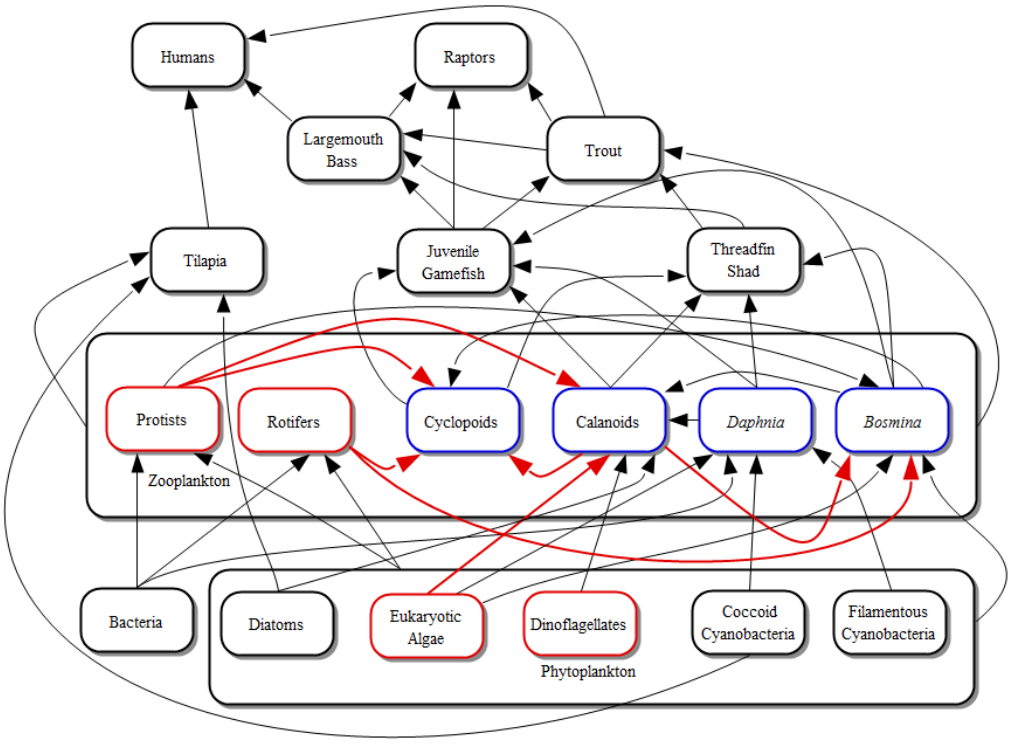


Figure 27: Hypothesized and inferred food web of Lake Pleasant. Black boxes and directional arrows depict relationships hypothesized from literature. Blue boxes depict taxonomic groups selected for DNA based molecular gut analyses. Red boxes depict prey organism groups found through DNA based molecular gut analyses. Red directional arrows represent inferred energy pathways, from DNA based molecular gut analyses. Larger groupings such as Zooplankton, Crustaceans, and Phytoplankton are presented based on descriptions of trophic interactions from literature.

In Lake Pleasant, five distinct trophic levels were identified (Figure 27). The lowest of these is made up of primary producer phytoplankton and bacteria. The first consumer level is made up of grazer zooplankton (first order consumers) and carnivore zooplankton (second order consumers). This second tier feed upon the first tier of producers (DeMott, 1982; Kagami et al., 2002; von Elert et al., 2003; Maly and Maly, 1974; Hansen and Hairston, 1998), and amongst itself in the case of carnivorous cycloploids and omnivorous calanoids

(DeMott, 1982; Kerfoot, 1987; Maly and Maly, 1974; Elser et al., 1995; Hansen and Hairston, 1998). This tier of zooplankton is more diverse in Lake Pleasant than in Saguaro Lake, with six (including nauplli, not pictured in Figure 27) groups of crustacean zooplankton. Saguaro Lake only possesses four (three pictured in Figure 28, nauplii are not pictured) groups of zooplankton. Note: all inferred trophic linkages (in red, from DNA based molecular analyses) are contained within the second tier of Figure 27. The third tier is comprised of planktivores (either second order consumers or third order consumers, based on the path of energy transfer through the tiers). The juvenile gamefish and Threadfin Shad feed upon the zooplankton of the second tier (Prophet, 1988), while the Tilapia feed on a mix of zooplankton and phytoplankton (Gu et al., 1997; Gido, 2001; Michewicz et al., 1972). The fourth tier is composed of large piscivore fish (Elser et al., 1995), the Largemouth Bass and Striped Bass. Currently, Striped Bass are very abundant in Lake Pleasant, to the point of out-competing the Largemouth Bass (Stewart et al., 2008) and drawing the attention of the Arizona Game and Fish Department. AZGFD has currently (as of 2011) lifted any sort of harvest limit on Striped Bass in an effort to manage their numbers (AZGFD, 2011b). The apex of the food web is occupied by piscivore raptors, the Osprey and Bald Eagle (Haywood and Ohmart, 1986) as well as humans.

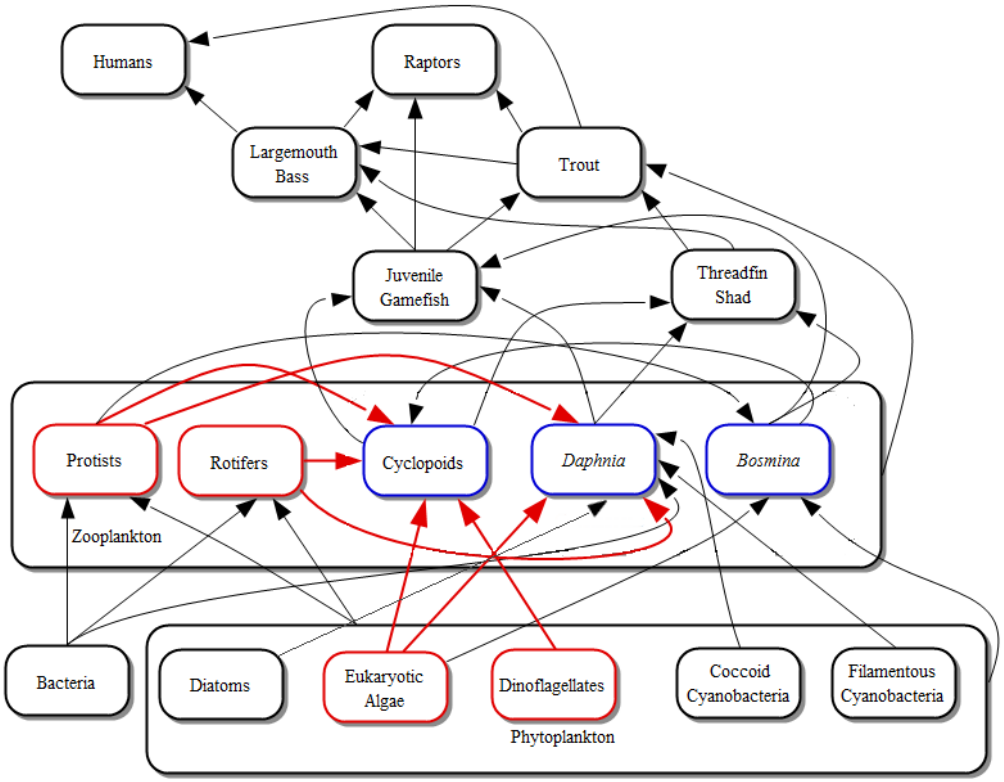


Figure 28: Hypothesized and inferred food web of Saguaro Lake. Black boxes and directional arrows depict relationships hypothesized from literature. Blue boxes depict taxonomic groups selected for DNA based molecular gut analyses. Red boxes depict prey organism groups found through DNA based molecular gut analyses. Red directional arrows represent inferred energy pathways, from DNA based molecular gut analyses. Larger groupings such as Zooplankton, Crustaceans, and Phytoplankton are presented based on descriptions of trophic interactions from literature.

In Saguaro Lake, five trophic levels were also identified (Figure 28). The first tier of primary producers differs from Lake Pleasant as filamentous cyanobacteria are found in Saguaro Lake. The second tier is less diverse than Lake Pleasant, lacking the omnivorous calanoids and cladoceran grazer *Diaphanosoma*. The third tier differs as Tilapia were not present in Saguaro Lake (as of 2011, AZGFD indicates only “occasional” reports of Tilapia). The fourth tier of large fish differs as Striped Bass are not found in Saguaro Lake.

However, the cold-water species Rainbow Trout is heavily stocked throughout the winter. The Rainbow Trout is a piscivore and planktivore. Similar to Lake Pleasant, piscivore raptors (Bald Eagles and the Osprey) and humans are the top carnivores in the Saguaro Lake food web.

It should be noted that differences existed between the food webs for each reservoir. The pelagic community of Saguaro Lake was less diverse than the pelagic community of Lake Pleasant. The greatest difference was the occurrence of the large pelagic piscivore, the striped bass, in Lake Pleasant. This large piscivore biomass near the top level of the food web exerted pressure on lower trophic levels resulting in a trophic cascade that affected all other organism groups (see below). The occurrence of omnivorous calanoid copepods and the herbivorous cladoceran *Diaphanosoma* in Lake Pleasant represented new, third and forth, large crustacean grazer groups in the food web, when compared to Saguaro Lake. These additional populations of grazers also exerted pressure on lower trophic levels, further strengthening any associated trophic cascades.

4. Controls of Community Structure

Trophic cascades were described by Carpenter et al. (1985) as the following: Large stocks of piscivores place enough pressure on planktivores to reduce biomass of the planktivores. The decrease in planktivore biomass allows herbivore biomass to increase. The increase in herbivore biomass leads to a decrease in phytoplankton biomass.

Lake Pleasant has a large population of picivorous striped bass positioned near the top of the trophic levels. This large amount of biomass in the upper trophic levels is evidence for a top-down control scheme. The large

abundance of striped bass (piscivore) (AZGFD: Bryan, 2005; Stewart et al. 2008) reduces the abundance of threadfin shad (planktivore). The reduction in threadfin shad allows the *Daphnia*, *Diaphanosoma*, and Calanoid (all herbivores) to increase. The large amount of herbivore biomass reduces the amount of phytoplankton (primary producer).

Saguaro Lake has a large biomass of primary producers which is evidence for a bottom-up control scheme and little top-down control. The smaller numbers of largemouth and yellow bass (piscivore) allows a relatively greater threadfin shad (planktivore) abundance. The large amount of threadfin shad reduces the biomass of *Daphnia* and *Bosmina* (herbivores). With reduced herbivore biomass, there is a large amount of phytoplankton (primary producer) biomass. The high predation on *Daphnia* by the Threadfin Shad also explains the small size of the *Daphnia* in Saguaro Lake (compared to Lake Pleasant), and the appearance of large helmet, tail, and carapace spines as predator deterrent..

High turbidity in each reservoir was partly due to blooms of phytoplankton. Reservoirs such as Lake Pleasant, with abundant large piscivores and the resulting trophic cascade (described above), had lesser amounts of phytoplankton biomass than reservoirs with trophic cascades similar to Saguaro Lake. The smaller amount of phytoplankton biomass correlates with lesser turbidity than reservoirs that contain greater amounts of phytoplankton biomass.

5. Hypothesis Evaluation

1) *Top-down control varied between the two reservoirs. The presence of a piscivore in a reservoir determines the amount of grazer and primary producer biomass through trophic cascades.* The data support this hypothesis. According

to the principles outlined by Carpenter (1985), Lake Pleasant is a good example of a community that is controlled from the top-down. This was evident by the high abundance of piscivore fish. The resulting trophic cascade would indicate a large zooplankton population (Figure 13) and a small amount of biomass of primary producers, as was inferred by chlorophyll *a* values in Figure 12 (b, d). Conversely, Saguaro Lake was controlled from the bottom-up by the nutrients of the reservoir. With the large amount of biomass at the primary producer level (chlorophyll *a* values, Figure 12a, c), the resulting cascade indicated a small grazer population (Figure 15) and a small piscivore fish population (evident by intensive AZGFD stocking of Rainbow Trout, which is not decimated by piscivores). DNA based molecular data from omnivorous calanoid copepods in (Figure 23) indicated predation on other zooplankton, a possible result of competition with cladoceran grazers *Daphnia* and *Bosmina* over scarce phytoplankton (Figure 27). Instead, the cyclopoid copepods in Saguaro Lake were found to be omnivores, grazing on phytoplankton and preying on other zooplankton (Figures 28 and 19)

2) *Nutrient loads differ for each reservoir*. *Greater nutrient concentrations yield greater primary producer biomass.* My data lead me to reject this hypothesis. Saguaro Lake was not more eutrophic compared to Lake Pleasant as originally expected. Dissolved inorganic phosphorus concentrations in Lake Pleasant were an order of magnitude greater than those in Saguaro Lake. Additionally, high levels of dissolved inorganic nitrogen were found for three months after the winter/spring peak in Lake Pleasant, where there was only a winter/spring peak of N in Saguaro Lake (Figure 8). The unused stock of nutrients in Lake Pleasant provides further support for top-down control (see above). According to the

Redfield Ratio (16:1 N:P), Saguaro Lake was N limited for 8 months of the year, while Lake Pleasant was N limited for 5 months. According to the "Elser" ratio (30:1 N:P), Saguaro Lake was N limited 10 months out of the year while Lake Pleasant remained N limited for 5 months. The N limitation in Saguaro Lake allowed the filamentous cyanobacteria (as was seen in previous investigations, Figure 3) to gain an ecological edge over eukaryotic algae, and dominate the phytoplankton community. This was not seen in Lake Pleasant as N limitation does not benefit the dominant cyanobacteria, *Synechococcus*, as it cannot readily fix nitrogen. Particulate P data would (if the data were available) indicate the nutritional value of phytoplankton for *Daphnia*. The small size and biomass of *Daphnia* in Saguaro Lake could be an effect of bottom-up control due to low particulate P content in the phytoplankton. For the two individual months where data do exist for particulate P, P in Saguaro Lake was approximately seven times lower (N:P 55:1) than Lake Pleasant (N:P 8:1) (Table 3).

6. Future Work

Lake Pleasant and Saguaro Lake experience differential amounts of recreational usage. In the summer, Saguaro Lake access is commonly restricted due to the large number of recreational boaters using the reservoir. The high recreational use of Saguaro Lake may have some anthropogenic effect on the nutrient loads in the reservoir. A possible future study could examine the effect of urea and other anthropogenic nutrient influxes on the two reservoirs.

Although consistent zooplankton data were produced for the 5m depth, it would be worthwhile to investigate diel migration. In the future, consistent deep casts in addition to night casts would generate more data to better understand zooplankton population distributions.

With the recent Quagga Mussel (*Dreissena bugensis*) invasion in Lake Pleasant, possible shifts in zooplankton community structure might occur due to the planktonic larvae of the mussel. Additionally, adult forms have the capability to filter a liter of water per day feeding on phytoplankton (AZGFD, 2011a); this might represent a new form of competition for other zooplankton herbivores. It would be interesting to determine the spread of Quagga Mussels throughout Lake Pleasant. Additionally it would be interesting to determine how Quagga Mussels affect the local phytoplankton community, and how predation rates by Redear Sunfish (*Lepomis microlophus*) reduce mussel colonies, as they are the only known predator of the mussels.

References

Agostinho, A. et al. (1999) Patterns of Colonization in Neotropical Reservoirs, and Prognoses on Aging. *Theoretical Reservoir Ecology and its Applications*. Backhuys Publishers, Brazil. Pages 227-265.

Amundsen, P. et al. (2007) Intraspecific Competition and Density Dependence of Food Consumption and Growth in Arctic Charr. *Journal of Animal Ecology*, vol. 76. Pages 149-158.

Arizona Game and Fish Department. (2011a) *Quagga Mussels*. Retrieved May 5th, 2011 from www.azgfd.gov/h_f/zebra_mussels

Arizona Game and Fish Department. (2011b) Special Regulations, Central, Commission Order 40, Ruling 12-4-317. *2011-2012 Fishing Regulations*. Retrieved June 14th 2011 from www.azgfd.gov/h_f/hunting_fishing

Arizona Game and Fish Department. (2011c) *Where to Fish – Central Arizona*. Retrieved June 14th, 2011 from www.azgfd.gov/h_f/where_fish

Arizona Game and Fish Department. (2011d) *Feb. 2 Fishing Report – Saguaro Lake*. February, 2011. Retrieved June 15th, 2011 www.azgfd.net/artman/publish/FishingReport/

Bryan, S. (2005) Limnological and Fisheries Investigation of Lake Pleasant. *Final Report to the U.S. Bureau of Reclamation – February 2005*. Arizona Game and Fish Department. 145 Pages.

Bureau of Reclamation. (2009) *New Waddell Dam*. Retrieved March 10th, 2011 from www.usbr.gov

Carpenter, S. et al. (1985) Cascading Trophic Interactions and Lake Productivity. *Bioscience*, vol. 35. Pages 634-639.

Central Arizona Project. (2011) *Lake Pleasant Operations.* Retrieved March 10th, 2011 from www.cap-az.com

Chick, J. et al. (2010) Underestimation of Rotifer Abundance a Much Greater Problem Than Previously Appreciated. *Limnology and Oceanography: Methods*. Pages 79-87.

DeMott, W. (1982) Feeding selectivities and relative ingestion rates of *Daphnia* and *Bosmina*. *Limnology and Oceanography*, vol. 27. Pages 518-527.

DeMott, W. and Moxter, F. (1991) Foraging Cyanobacteria by Copepods: Responses to Chemical Defense and Resource Abundance. *Ecology*, vol. 72. Pages 1820-1834.

DeVries, D. et al. (1991) Stocking Threadfin Shad: Consequences for Young-of-Year Fishes. *Transactions of the American Fisheries Society*, vol. 120. Pages 368-381

Diez, B. et al. (2001) Study of Genetic Diversity of Eukaryotic Picoplankton in Different Oceanic Regions by Small Subunit rRNA Gene Cloning and Sequencing. *Applied Environmental Microbiology*, vol. 67. Pages 2932-2941.

Dumont, H. (1999) The Species Richness of Reservoir Plankton and the Effect of Reservoirs on Plankton Dispersal (with Particular Emphasis on Rotifers and Cladocerans). *Theoretical Reservoir Ecology and its Applications*. Backhuys Publishers, Brazil. Pages 477-491.

Dumont, H. et al. (1975) The Dry Weight Estimate of Biomass in a Selection of Cladocera, Copepoda and Rotifera from the Plankton, Periphyton and Benthos of Continental Waters. *Oecologia*, vol. 19. Pages 75-97.

Elser, J. et al. (1995) Effects of Food Web Compensation After Manipulation of Rainbow Trout in an Oligotrophic Lake. *Ecology*, vol.76. Pages 52-69.

Elser, J. et al. (2000) Nutritional Constraints in Terrestrial and Freshwater Foodwebs. *Nature*, vol. 408. Pages 570-580.

Franson, M. (1998) Persulfate Digestion Method and Ascorbic Acid Method for Phosphorus Determination. *Standard Methods for the Examination of Water and Wastewater*, 20th edition. Joint publication by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

Gannon, J. and Gannon, S. (1975) Observations on the Narcotization of Crustacean Zooplankton. *Crustaceana*, vol. 28. Pages 220-224.

Gido, K. (2001) Ecology of Three Omnivorous Fishes in Lake Texoma (Oklahoma-Texas). *The Southwestern Naturalist*, vol. 46. Pages 23-33.

Gu, B. et al. (1997) Intrapopulation Feeding Diversity in Blue Tilapia: Evidence from Stable- Isotope Analyses. *Ecology*, vol. 78. Pages 2263-2266.

Hach Company. (2006) *Digital Titrator, Model 16900*.

Haney, J. and Hall, D. (1973) Sugar-Coated *Daphnia*: A Preservation Technique for Cladocera. *Limnology and Oceanography*, vol. 18. Pages 331-333.

Hansen, A. and Hairston, N. (1998) Food Limitation in a Wild Cyclopoid Copepod Population: Direct and Indirect Life History Responses. *Oecologia*, vol. 115. Pages 320-330.

Haywood, D. and Ohmart, R. (1986) Utilization of Benthic-Feeding Fish by Inland Breeding Bald Eagles. *The Condor*, vol. 88. Pages 35-42.

Kagami, M. et al. (2002) Direct and Indirect Effects of Zooplankton on Algal Composition in in Situ Grazing Experiments. *Oecologia*, vol. 133. Pages 356-363.

Kerfoot, C. (1987) Translocation Experiments: Bosmina Responses to Copepod Predation. *Ecology*, vol. 68. Pages 596-610.

Koenings, J. and Edmundson, J. (1991) Secchi Disk and Photometer Estimates of Light Regimes in Alaskan Lakes: Effects of Yellow Color and Turbidity. *Limnology and Oceanography*, vol. 36. Pages 91-105.

Kormondy, E. (1996) *Concepts of Ecology*. Prentice Hall, New Jersey. Pages 112-114.

Lampert, W. and Sommer, U. (2007) *Limnoecology*. Oxford University Press, Oxford. Page 201.

Maly, E. and Maly, M. (1974) Dietary Differences between Two Co-Occurring Calanoid Copepod Species. *Oecologia*, vol. 17. Pages 325-333.

McNatt, R. (1977) *Zooplankton Species Composition, Abundance, and Distribution in a Desert, Pumped-Storage Reservoir*. PhD. Dissertation, Arizona State University. 280 Pages.

Medlin, L. et al. (1988) The Characterization of Enzymatically Amplified Eukaryotic 16S-Like rRNA-Coding Regions. *Gene*, vol. 71. Pages 491-499.

Michewicz, J. et al. (1972) The White Amur for Aquatic Weed Control. *Weed Science of America*, vol. 20. Pages 106-110.

National Weather Service. (2011) *2010 Monthly Observed Precipitation*. Retrieved April 21th, 2011 from www.water.weather.gov/precip

Neuer, S. and T.J. Cowles. (1994). Protist Herbivory in the Oregon Upwelling System. *Marine Ecology Progress Series*, vol. 113. Pages 147-162.

Pennak, R. (1989) *Fresh-Water Invertebrates of the United States*, 3rd edition. John Wiley & Sons Inc., New York. 656 Pages.

Primack, R. (2006) *Essentials of Conservation Biology*. Sinauer Associates Inc., Massachusetts. Page 44.

Prophet, Carl. (1988) Changes in Seasonal Population Structures of Two Species of *Diaptomus* (Calanoida, Copepoda) Subsequent to Introductions of Threadfin and Gizzard Shad. *The Southwestern Naturalist*, vol. 33. Pages 41-53.

Qiagen. (2006) DNeasy *Blood and Tissue Handbook*.

Redfield, A. C. (1958) The Biological Control of Chemical Factors in the Environment. *American Scientist*, 46, 205-221.

Remmel, E. et al. (2011) An Experimental Analysis of Harmful Algae–Zooplankton Interactions and the Ultimate Defense. *Limnology and Oceanography*, vol. 56. Pages461-470.

Salt River Project. (2011) *Stewart Mountain Dam.* Retrieved March 10th, 2011 from www.srpnet.com

Steel, A. and Neuhausser, S. (2002) Comparison of Methods for Measuring Visual Clarity. *Journal of North American Benthological Society*, vol. 21. Pages 326-355.

Sterner, R. and Elser, J. (2002) *Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere*. Princeton University Press, Princeton. 584 Pages.

Stewart, B. et al. (2008) Lake Pleasant Striped Bass. *Technical Guidance Bulletin No. 11 – February 2008*. Arizona Game and Fish Department. 42 Pages.

Stocker, J. and Shortreed, K. (1988) Response of Anabaena and Synechococcus to Manipulation of Nitrogen: Phosphorus Ratios in a Lake Fertilization Experiment. *Limnology and Oceanography*, vol. 33. Pages 1348-1361.

Tarrant, P. et al. (2009) Feasibility Study for Early Warning Systems for Algae-induced Tastes and Odors – *Final Report to AWWA T&O Subcommittee*. 25 Pages.

Tarrant, P. et al. (2010) Assessing the Potential of Medium-Resolution Imaging Spectrometer (MERIS) and Moderate-Resolution Imaging Spectroradiometer (MODIS) Data for Monitoring Total Suspended Matter in Small and Intermediate Sized Lakes and Reservoirs. *Water Resources Research*, vol. 46.

Thorp, J. and Covich, A. (1991) *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press Inc., San Diego. 936 Pages.

UCSB MSI Analytical Lab. (2011) *Seawater Nutrients by FIA*. Retrieved June 1st, 2011 from www.msi.ucsb.edu/services/analytical-lab

U.S. Geological Survey. (2010) *Free-living and Parasitic Copepods (Including Branchiurans) of the Laurentian Great Lakes: Keys and Details on Individual Species*. Retrieved May 15th, 2010 from www.glsc.usgs.gov/greatlakescopepods

Von Elert, E. et al. (2003) Absence of Sterols Constrains Carbon Transfer between Cyanobacteria and a Freshwater Herbivore (*Daphnia galeata*). *Proceedings: Biological Sciences*, vol. 270. Pages 1209-1214.

Westerhoff, P. and Sommerfeld, M. (2005) Reducing 2-Methylisoborneol (MIB) and Geosmin in the Metropolitan-Phoenix Area Water Supply. Cooperative research between ASU, City of Phoenix, SRP, CAP, City of Tempe, and City of Peoria. Retrieved June 10th, 2011 from www.enpub.fulton.asu.edu/pwest/tasteandodor

Westerhoff, P. et al. (2010) *Regional Water Quality Issues: Algae and Associated Drinking Water Challenges- Workshop 2010.* Retrieved June 7th, 2011 from www.enpub.fulton.asu.edu/pwest

Wiedner, C. et al. (2007) Climate Change Affects Timing and Size of Populations of an Invasive Cyanobacterium in Temperate Regions. *Oecologia*, vol. 152. Pages 473-484.

W.M. Keck Foundation Laboratory for Environmental Biogeochemistry (2007) *13C and 15N by Elemental Analysis (EA)*. Retrieved March 10th, 2011 from kfelb.asu.edu

Yodzis, P. (2001) Trophic Levels. *Encyclopedia of Biodiversity*, vol. 5. Academic Press, California. Pages 695-700.

YSI, Incorporated. (2009) *Conductivity*.

YSI, Incorporated. (2011) *YSI 85 System Specifications*. Retrieved June 6th, 2011 from www.ysi.com

APPENDIX

DNA BASED MOLECULAR PREY PREFERANCE RESULTS

BLAST Results of Gut and Water Column Data from Saguaro Lake and Lake Pleasant during 2010

Sequence Number	Taxa	Acession Number	Closest Match	Max ID	Sample Origin
1	Rotifera	GQ402486.1	Rotifera environmental sample 18S ribosomal RNA gene	98	Saguaro Lake, January, Water Column
2	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	100	Lake Pleasant, January, Water Column
3	Fungi	GQ844461.1	Uncultured fungus 18S ribosomal RNA gene	99	Saguaro Lake, January, Water Column
5	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	99	Lake Pleasant, January, Water Column
5	Rotifera	DQ079916.1	Asplanchnopus dahlgreni 18S ribosomal RNA gene	99	Lake Pleasant, January, Water Column
7	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	99	Lake Pleasant, February, Water Column
7	Cladocera	EU370423.1	Daphnia cf. magna 18S ribosomal RNA gene	92	Lake Pleasant, February, Water Column
9	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	99	Lake Pleasant, March, Water Column
9	Apicomplexa	EU162644.1	Uncultured stramenopile 18S ribosomal RNA gene	88	Lake Pleasant, March, Water Column
11	Coccidia, Protist	EF024452.1	Eimeriidae environmental sample 18S ribosomal RNA gene	74	Lake Pleasant, March, Water Column

13	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	99	Lake Pleasant, March, Water Column
11	Fungi	FJ827659.1	Triparticalcar sp. 18S ribosomal RNA gene	69	Lake Pleasant, March, Water Column
13	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	99	Lake Pleasant, March, Water Column
13	Ciliophora	FJ939037.1	Uncultured ciliate 18S ribosomal RNA gene	95	Lake Pleasant, March, Water Column
15	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	99	Lake Pleasant, March, Water Column
15	Chlorophyta	HQ219399.1	Uncultured Chlorophyta 18S ribosomal RNA gene	89	Lake Pleasant, March, Water Column
17	Ciliophora	AY642698.1	Uncultured eukaryotic picoplankton 18S ribosomal RNA gene	97	Saguaro Lake, April, Water Column
19	Ciliophora	HQ219369.1	Uncultured ciliate 18S ribosomal RNA gene	77	Saguaro Lake, April, Water Column
21	Ciliophora	EU143873.1	Uncultured ciliate 18S ribosomal RNA gene	92	Saguaro Lake, April, Water Column
22	Rotifera	DQ297714.1	Ploesoma hudsoni 18S ribosomal RNA gene	98	Saguaro Lake, April, Water Column
23	Chlorophyta	AB511837.1	Chlamydomonas reinhardtii gene for 18S rRNA	84	Saguaro Lake, April, Water Column
25	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	98	Lake Pleasant, April, Water Column

27	Chlorophyta	HQ219399.1	Uncultured Chlorophyta 18S ribosomal RNA gene	92	Lake Pleasant, April, Water Column
25	Ciliophora	FN690047.1	Uncultured alveolate 18S rRNA gene	92	Lake Pleasant, April, Water Column
27	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	99	Lake Pleasant, April, Water Column
29	Chlorophyta	AJ431370.2	Tetraselmis kochiensis	87	Saguaro Lake, May, Cyclopoid
27	Dinophyceae	EU350918.1	Uncultured eukaryote 18S ribosomal RNA gene	87	Lake Pleasant, April, Water Column
29	Ciliophora	AY331781.2	Uncultured marine eukaryote 18S ribosomal RNA gene	96	Saguaro Lake, May, Cyclopoid
31	Ciliophora	FJ939051.1	Uncultured alveolate 18S ribosomal RNA gene	97	Saguaro Lake, May, Cyclopoid
35	Ciliophora	AY642698.1	Uncultured eukaryotic picoplankton 18S ribosomal RNA gene	97	Saguaro Lake, May, Daphnia
37	Ciliophora	FN690357.1	Uncultured alveolate partial 18S rRNA gene	97	Saguaro Lake, May, Nauplii
39	Ciliophora	HM138167.1	Uncultured freshwater eukaryote 18S ribosomal RNA gene	97	Saguaro Lake, May, Nauplii
43	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	99	Lake Pleasant, June, Calanoid
45	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	100	Lake Pleasant, June, Calanoid

47	Ciliophora	EF417834.1	Opisthonecta minima 18S ribosomal RNA gene	84	Lake Pleasant, June, Cyclopoid
49	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	83	Lake Pleasant, June, Cyclopoid
51	Dinophyceae	FJ410727.1	Uncultured alveolate 18S ribosomal RNA gene	84	Saguaro Lake, June, Cyclopoid
53	Dinophyceae	FJ410727.1	Uncultured alveolate 18S ribosomal RNA gene	94	Saguaro Lake, June, Nauplii
55	Apicomplexa	EU091855.1	Uncultured Banisveld eukaryote 18S ribosomal RNA gene	78	Lake Pleasant, July, Water Column
57	Kinetoplastida	DQ674768.1	Uncultured eukaryote 18S ribosomal RNA gene	91	Lake Pleasant, July, Water Column
59	Spizellomycetales	DQ409110.1	Uncultured eukaryotic picoplankton 18S ribosomal RNA gene	70	Lake Pleasant, July, Water Column
61	Spermatophyta	DQ674768.1	Uncultured eukaryote 18S ribosomal RNA gene	93	Lake Pleasant, July, Water Column
63	Fungi	AJ864649.1	Orpinomyces sp.	80	Lake Pleasant, July, Water Column
65	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	99	Lake Pleasant, July, Calanoid
67	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	99	Lake Pleasant, July, Calanoid
69	Proporata	AF167423.1	Scleraulophorus cephalatus 18S ribosomal RNA gene	71	Lake Pleasant, July, Nauplii

71	Rhizidiomycetaceae	EF196772.1	Uncultured eukaryotic picoplankton 18S ribosomal RNA gene	95	Lake Pleasant, August, Water Column
73	Bicosoecidae	DQ248192.1	Uncultured marine eukaryote 18S ribosomal RNA	83	Lake Pleasant, August, Water Column
76	Fungi	FJ804149.1	Mesochytrium penetrans	92	Lake Pleasant, August, Water Column
78	Bosmina	AM490275.1	Bosmina longirostris	84	Lake Pleasant, August, Water Column
75	Rotifera	AY218113.1	Testudinella sp. 18S ribosomal RNA gene	89	Lake Pleasant, August, Water Column
77	Dinophyceae	EU144003.1	Uncultured eukaryote 18S ribosomal RNA gene	87	Lake Pleasant, August, Water Column
79	Ciliophora	GQ872429.1	Vorticella gracilis 18S ribosomal RNA gene	89	Lake Pleasant, August, Water Column
81	Dinophyceae	AY460574.1	Dinoflagellate 18S ribosomal RNA gene	96	Lake Pleasant, August, Water Column
81	Rotifera	DQ297705.1	Macrochaetus collinsi 18S ribosomal RNA gene	90	Lake Pleasant, August, Water Column
83	Codonosigidae	GU290101.1	Uncultured eukaryote 18S ribosomal RNA gene	96	Lake Pleasant, August, Water Column
85	Dinophyceae	AJ415514.1	Heterocapsa triquetra	80	Lake Pleasant, August, Cyclopoid
85	Rotifera	DQ079914.1	Filinia longiseta 18S ribosomal RNA gene	78	Lake Pleasant, August, Cyclopoid

87	Rotifera	AY218113.1	Testudinella sp. 18S ribosomal RNA gene	97	Lake Pleasant, August, Cyclopoid
89	Cyanidiales	AB275016.1	Uncultured eukaryote gene for SSU rRNA	69	Lake Pleasant, August, Daphnia
91	Daphnia	EU370423.1	Daphnia cf. magna BMR-2008	99	Lake Pleasant, August, Daphnia
91	Rotifera	DQ297707.1	Monommata maculata 18S ribosomal RNA gene	99	Lake Pleasant, August, Nauplii
95	Ciliophora	U51554.1	Anophyroides haemophila 18S ribosomal RNA gene	72	Saguaro Lake, August, Water Column
99	Ichthyosporea	HM227512.1	Uncultured eukaryote 18S ribosomal RNA gene	97	Saguaro Lake, August, Water Column
101	Ciliophora	DQ297721.1	Trichocerca elongata 18S ribosomal RNA gene	67	Saguaro Lake, August, Water Column
103	Ciliophora	FJ939037.1	Uncultured ciliate 18S ribosomal RNA gene	99	Saguaro Lake, August, Water Column
98	Ciliophora	GQ844427.1	Uncultured alveolate 18S ribosomal RNA gene	91	Saguaro Lake, August, Water Column
100	Ciliophora	FN690042.1	Uncultured alveolate partial 18S rRNA gene	97	Saguaro Lake, August, Water Column
104	Rotifera	AM179818.1	Uncultured monogonontan partial 18S rRNA gene	96	Saguaro Lake, August, Water Column
100	Ciliophora	FJ765378.1	Uncultured ciliate 18S ribosomal RNA gene	94	Saguaro Lake, August, Water Column

106	Ciliophora	DQ297689.1	Ptygura libera 18S ribosomal RNA gene	79	Saguaro Lake, August, Nauplii
102	Acanthocystidae	AY749599.1	Pterocystis foliacea 18S ribosomal RNA gene	78	Saguaro Lake, August, Water Column
104	Ciliophora	HQ219432.1	Uncultured ciliate 18S ribosomal RNA gene	98	Saguaro Lake, August, Water Column
106	Ciliophora	DQ297722.1	Trichocerca rattus 18S ribosomal RNA gene	96%	Saguaro Lake, August, Nauplii
104	Rotifera	DQ297720.1	Scaridium longicaudum 18S ribosomal RNA gene	90	Saguaro Lake, August, Water Column
106	Ciliophora	FN690046.1	Uncultured alveolate 18S rRNA gene	97	Saguaro Lake, August, Nauplii
108	Rotifera	AM179818.1	Uncultured monogonontan 18S rRNA gene	94	Saguaro Lake, August, Nauplii
106	Ciliophora	AF060454.1	Platyophrya vorax 18S ribosomal RNA gene	90	Saguaro Lake, August, Nauplii
108	Ciliophora	EU860496.1	Uncultured eukaryote 18S ribosomal RNA gene	88	Saguaro Lake, August, Nauplii
110	Rotifera	DQ297711.1	Notommata cordonella	99	Saguaro Lake, August, Nauplii
108	Ciliophora	AF060454.1	Platyophrya vorax 18S ribosomal RNA gene	90	Saguaro Lake, August, Nauplii
110	Ciliophora	GQ872429.1	Vorticella gracilis 18S ribosomal RNA gene	99	Saguaro Lake, August, Nauplii

110	Rotifera	DQ297716.1	Polyarthra remata 18S ribosomal RNA gene	99	Saguaro Lake, August, Nauplii
116	Rotifera	DQ297716.1	Polyarthra remata	99	Lake Pleasant, September, Water Column
114	Fungus	GU067982.1	Uncultured fungus 18S ribosomal RNA gene	97	Lake Pleasant, September, Water Column
116	Ciliophora	GU067975.1	Uncultured ciliate 18S ribosomal RNA gene	85	Lake Pleasant, September, Water Column
116	Ciliophora	FJ410586.1	Uncultured ciliate 18S ribosomal RNA gene	98	Lake Pleasant, September, Water Column
118	Ciliophora	FN690357.1	Uncultured alveolate 18S rRNA gene	96	Lake Pleasant, September, Water Column
118	Ciliophora	EU143858.1	Uncultured ciliate 18S ribosomal RNA gene	87	Lake Pleasant, September, Water Column
120	Ciliophora	GU067819.1	Uncultured Rimostrombidium 18S ribosomal RNA gene	80	Lake Pleasant, September, Water Column
120	Ciliophora	FJ765408.1	Uncultured freshwater eukaryote 18S ribosomal RNA gene	97	Lake Pleasant, September, Water Column
122	Dinophyceae	HQ191324.1	Uncultured dinoflagellate 18S ribosomal RNA gene	92	Lake Pleasant, September, Water Column
124	Diaphanosoma	AF144210.1	Diaphanosoma sp. TS-1999 18S ribosomal RNA gene	92	Lake Pleasant, September, Diaphanosoma
126	Diaphanosoma	AF144210.1	Diaphanosoma sp. TS-1999 18S ribosomal RNA gene	92	Lake Pleasant, September, Diaphanosoma

128	Ciliophora	FJ480419.1	Strombidium cf. basimorphum	94	Lake Pleasant, September, Calanoid
128	Calanoida	AY339154.1	Leptodiaptomus moorei 18S ribsomal RNA gene	100	Lake Pleasant, September, Calanoid
130	Calanoida	AY339161.1	Skistodiaptomus pygmaeus 18S ribsomal RNA gene	100	Lake Pleasant, September, Calanoid
132	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	91	Lake Pleasant, September, Bosmina
132	Bosmina	GU474406.1	Uncultured eukaryote 18S ribosomal RNA gene	72	Lake Pleasant, September, Bosmina
134	Ciliophora	EU399529.1	Meseres corlissi strain CHI	96	Saguaro Lake, September, Water Column
134	Ciliophora	FJ858215.1	Nolandia sp. WYG07050702	83	Saguaro Lake, September, Water Column
136	Ciliophora	AF399124.1	Strobilidium sp. clone Strob00ssu_1	72	Saguaro Lake, September, Water Column
136	Ciliophora	AB486009.1	Pelagothrix alveolata	89	Saguaro Lake, September, Water Column
138	Ciliophora	AM412525.1	Ciliate sp. NCMS060	90	Saguaro Lake, September, Water Column
138	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	77	Saguaro Lake, September, Water Column
140	Ciliophora	FJ858215.1	Nolandia sp. WYG07050702	75	Saguaro Lake, September, Water Column

140	Ciliophora	AF100313.1	Paramecium polycaryum	98	Saguaro Lake, September, Water Column
142	Ciliophora	EF535730.1	Stylonychia mytilus	73	Saguaro Lake, September, Water Column
142	Ciliophora	FN429124.1	Oxytricha sp. Ox_L1	100	Saguaro Lake, September, Water Column
144	Ciliophora	DQ910904.2	Pseudouroleptus caudatus	73	Saguaro Lake, September, Water Column
144	Ciliophora	DQ986131.1	Rimostrombidium lacustris	75	Saguaro Lake, September, Water Column
146	Ciliophora	DQ986131.1	Rimostrombidium lacustris	87	Saguaro Lake, September, Water Column
146	Ciliophora	EU024986.1	Rimostrombidium sp. FU44-33	75	Saguaro Lake, September, Water Column
148	Ciliophora	GU987024.1	Vorticella sp. 2 PPS-2010	97	Saguaro Lake, September, Water Column
148	Coccidian	AY642591.1	Cryptosporidium muris strain Kawatabi	87	Saguaro Lake, September, Water Column
150	Ciliophora	AY547545.1	Plagiotoma lumbrici	79	Saguaro Lake, September, Water Column
150	Rotifera	GQ402486.1	Rotifera environmental sample clone 24_BSA6S5Euk	99	Saguaro Lake, September, Water Column
152	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	92	Saguaro Lake, September, Water Column

152	Rotifera	DQ297714.1	Ploesoma hudsoni	97	Saguaro Lake, September, Water Column
154	Ciliophora	DQ393786.1	Parastrombidinopsis minima	89	Saguaro Lake, September, Water Column
154	Rotifera	DQ079916.1	Asplanchnopus dahlgreni	99	Saguaro Lake, September, Water Column
156	Ciliophora	FJ422988.1	Novistrombidium orientale	95	Saguaro Lake, September, Nauplii
158	Rotifera	DQ297717.1	Proales doliaris	98	Saguaro Lake, September, Nauplii
160	Rotifera	GQ402486.1	Rotifera environmental sample clone 24_BSA6S5Euk	99	Saguaro Lake, September, Nauplii
162	Rotifera	DQ297710.1	Notommata allantois	98	Saguaro Lake, September, Nauplii
166	Diatom	EF219381.1	Stramenopile sp. MAST-12 KKTS_D3	89	Lake Pleasant, October, Water Column
168	Fungi	AB521052.1	Mortierella sp. CO-21	73	Lake Pleasant, October, Water Column
170	Fungi	AY635821.1	Rhizophydium sp. JEL317 isolate AFTOL-ID 35	77	Lake Pleasant, October, Water Column
172	Fungi	AF164245.2	Powellomyces sp. JEL95	80%	Lake Pleasant, October, Water Column
174	Ciliophora	EU024994.1	Strombidiidae sp. LO128-19	98%	Lake Pleasant, October, Water Column

176	Prymnesiaceae	AM491019.1	Chrysochromulina parva	72%	Lake Pleasant, October, Water Column
178	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	93%	Lake Pleasant, October, Water Column
180	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	100%	Lake Pleasant, October, Water Column
182	Calanoida	AY339154.1	Leptodiaptomus moorei	100%	Lake Pleasant, October, Nauplii
184	Ciliophora	FJ858215.1	Nolandia sp. WYG07050702	84%	Saguaro Lake, October, Water Column
186	Ciliophora	FJ858215.1	Nolandia sp. WYG07050702	88%	Saguaro Lake, October, Water Column
188	Ciliophora	DQ393786.1	Parastrombidinopsis minima	90%	Saguaro Lake, October, Water Column
190	Prymnesiaceae	AM491019.1	Chrysochromulina parva	74%	Saguaro Lake, October, Water Column
192	Rotifera	DQ297697.1	Keratella quadrata	99%	Saguaro Lake, October, Nauplii
194	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	91	Lake Pleasant, November, Water Column
195	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	98	Lake Pleasant, November, Water Column
196	Protist	GU810144.1	Ichthyosporea sp. ATCC PRA-279	83	Lake Pleasant, November, Water Column

197	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	99	Lake Pleasant, November, Water Column
198	stramenopiles	AY520444.1	Bicosoeca petiolata strain ATCC 50639	87	Lake Pleasant, November, Water Column
199	Rhizaria	EF024163.1	Cercomonadida environmental sample	85	Lake Pleasant, November, Water Column
200	Fungus	Z27393.1	N.vitellina	94	Lake Pleasant, November, Water Column
202	stramenopiles	FJ794911.1	Saprolegnia sp. SAP4	86	Lake Pleasant, November, Water Column
201	Fungus	AB013543.1	Candida kruisii	73	Lake Pleasant, November, Water Column
202	Ciliophora	AF305625.1	Aspidisca steini	83	Lake Pleasant, November, Water Column
204	Trematoda, fluke	AY749614.1	Sphaerastrum fockii 18S ribosomal RNA genE	82	Lake Pleasant, November, Water Column
203	Ciliophora	AF300281.1	Chilodonella uncinata clone 1	87	Lake Pleasant, November, Water Column
204	Ciliophora	GU187050.1	Vorticella sp. SP-2009-3	76	Lake Pleasant, November, Water Column
205	Ciliophora	AF335518.1	Vorticella campanula	96	Lake Pleasant, November, Water Column
206	Calanoida	AY339154.1	Leptodiaptomus moorei	99	Lake Pleasant, November, Water Column

207	Protist	GU810145.1	Ichthyosporea sp. ATCC PRA-280	94	Lake Pleasant, November, Cyclopoid
208	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	98	Lake Pleasant, November, Cyclopoid
209	Calanoida	AY339154.1	Leptodiaptomus moorei	100	Lake Pleasant, November, Cyclopoid
210	Fungi	AF157144.1	Mortierella multidivaricata	77	Saguaro Lake, November, Water Column
211	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	68	Saguaro Lake, November, Water Column
212	Ciliophora	DQ411862.1	Spathidium stammeri	98	Saguaro Lake, November, Water Column
213	Ciliophora	DQ411862.1	Spathidium stammeri	98	Saguaro Lake, November, Water Column
214	Ciliophora	FJ824122.1	Protaspis obliqua isolate 2	72	Saguaro Lake, November, Water Column
215	Ciliophora	DQ393786.1	Parastrombidinopsis minima	88	Saguaro Lake, November, Water Column
217	Dinophyceae	AM503929.1	Thecate dinoflagellate UDTSW0701	82	Saguaro Lake, November, Water Column
219	Protist	GU810145.1	Ichthyosporea sp. ATCC PRA-280	90	Saguaro Lake, November, Cyclopoid
221	Rotifera	DQ297686.1	Collotheca campanulata	99	Saguaro Lake, November, Nauplii

222	Rotifera	DQ297686.1	Collotheca campanulata	79	Saguaro Lake, November, Nauplii
223	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	95	Lake Pleasant, December, Water Column
224	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	90	Lake Pleasant, December, Water Column
225	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	90	Lake Pleasant, December, Water Column
226	Ciliophora	AF508763.1	Oxytricha longa	95	Lake Pleasant, December, Water Column
227	Choanoflagellida	EF024012.1	Codonosigidae environmental sample	80	Lake Pleasant, December, Water Column
228	Ciliophora	DQ986131.1	Rimostrombidium lacustris	92	Lake Pleasant, December, Water Column
229	Alveolata	EF675616.1	Rana sphenocephala pathogen MJY-2007	92	Lake Pleasant, December, Water Column
230	Protist	GU810145.1	Ichthyosporea sp. ATCC PRA-280	94	Lake Pleasant, December, Calanoid
231	Calanoida	AY339161.1	Skistodiaptomus pygmaeus	100	Lake Pleasant, December, Calanoid
232	Calanoida	AY339154.1	Leptodiaptomus moorei	98	Lake Pleasant, December, Nauplii
233	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	90	Saguaro Lake, December, Water Column

234	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	94	Saguaro Lake, December, Water Column
235	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	93	Saguaro Lake, December, Water Column
236	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	93	Saguaro Lake, December, Water Column
237	Ciliophora	AM412525.1	Ciliate sp. NCMS0601	93	Saguaro Lake, December, Cyclopoid
239	Rotifera	DQ297710.1	Notommata allantois 18S	98	Saguaro Lake, December, Nauplii
241	Centroheliozoa	AY749532.1	Uncultured eukaryote 18S ribosomal RNA gene	76	Saguaro Lake, December, Nauplii
240	Rotifera	DQ297714.1	Ploesoma hudsoni	99	Saguaro Lake, December, Nauplii