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Physical, Chemical and Biological Assessment of Yoncalla Log Ponds

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On the cover: Fall colors at Yoncalla Log Pond. Photo by Rich Miller, November 26, 2013.

1 EXECUTIVE SUMMARY

The Yoncalla Log Ponds are a series of four ponds located in within the city limits of the town in Yoncalla in northern Douglas County, Oregon. The ponds were created in stages between the late 1930s and the 1950s and used for log storage through the 1970s (North Douglas Betterment 2014). North Douglas Betterment purchased the land surrounding the ponds and contracted with the Center for Lakes and Reservoirs at Portland State University to assess the current morphometry, vegetation and water quality status of the ponds and provide recommendations for management of the aquatic vegetation. The scope of this document covers the current status assessment of the ponds using data collected from June 2013 through May 2014.

Bathymetric maps were generated from a hydroacoustic survey data conducted in the large pond, manual depth-sounding data in the three smaller ponds, collection of geographic information, and surface interpolation techniques. The new maps indicate that the shoreline of the largest pond drops off quickly to over a meter deep throughout the pond. A general trend of deeper water to the north of the pond is evident. The deepest point of 3.9 m is located in the northwest third of the pond. At full pool, the average depth of the pond is 1.9 m. the surface area is 15.1 ha and the volume 0.29 hm^3. Ponds 2, 3, and 4 are much shallower and smaller with average depths of 0.5, 0.4, and 0.8 m and surface areas of 1.1, 0.1, and 0.2 ha respectively. The water level in Pond 1 ranged by 0.4 m during the survey period. Ponds 3 and 4 dropped by over 0.6 m during the summer of 2013 and nearly became completely dry. Pond 2 dropped by 0.55 m during the survey period due to a leak in the dike containing the pond.

Aquatic vegetation in Ponds 1 and 2 was surveyed on two dates while Ponds 3 and 4 were surveyed on a single date. Aquatic vegetation in Pond 1 was dominated the native floating leaf plant species *Brasenia schreberi* (watershield). *B. schreberi* was present and very dense at 96% of the sites surveyed in Pond 1 and was only absent from the deepest parts of the pond. The dense coverage by *B. schreberi* persisted throughout the survey period with the exception of during the late winter. *B. schreberi* was also present in Pond 2, but at fewer locations and mixed in with a broad diversity of dense submerged aquatic vegetation. Most species were native to the area, however, the invasive species *Myriophyllum spicatum* (Eurasian watermilfoil) was fairly common. The other invasive plant observed was the non-native or non-native x native hybrid cattail (*Typha* sp.) found along the shoreline. Ponds 3 and 4 were dominated by native submerged plants including *Ceratophyllum dermersum* (coontail).

Water quality in the ponds were greatly affected by the density and types of aquatic vegetation in the ponds. The dense floating leaves of *B. schreberi* that covered Pond 1 blocked light from reaching into the water and restricted oxygen and carbon dioxide exchange between the water and air creating low dissolved oxygen concentrations and low pH values in the pond during much of the year. Dissolved oxygen concentrations were well below Oregon Department of Environmental Quality criteria designed to protect warm water fish species most of the year. Oxygen and pH measured over daily cycles in Pond 1 did not show and clear patterns indicating that decomposition was dominating the metabolism in the water column. Oxygen concentrations and pH values in the other ponds were much different because the plant communities were dominated by submerged aquatic vegetation. During the summer, oxygen concentrations in the three ponds reached almost 200% of atmospheric saturation and pH values reached to near pH 10.

Total nutrient concentrations, water clarity, and phytoplankton species composition in all ponds indicate that the ponds are nutrient rich, or mesotrophic to eutrophic. Low concentrations of bioavailable forms of N and P in Pond 1 indicate that algal growth was limited by N and/or P. Higher concentrations of bioavailable P in the other ponds indicate that P does not limit algal growth in these ponds. Low concentrations of bioavailable N in Ponds 2-4, on the other hand, indicate that these system may be N limited during the spring through early fall. Phytoplankton species include several cyanobacteria species, but at extremely low concentrations.

A diverse assemblage of zooplankton species was encountered in the ponds and densities varied considerably over the course of the survey period. Many of the species were typical of littoral areas. Two invasive animal species were detected during benthic surveys: *Corbicula fluminea* (Asian clam) and *Gambusia affinis* (mosquitofish). Several other snail, clam, and other invertebrate species were present.

2 BATHYMETRIC MAPPING

2.1 INTRODUCTION

Accurate estimates of the morphometric characteristics of a waterbody are essential for assessing hydrologic budgets, nutrient budgets, and vegetation management strategies such as dredging and herbicide application. Bathymetric maps also provide recreational users with information to help them better enjoy a waterbody. Survey data were collected from the four Yoncalla Ponds and data was processed to produce bathymetric maps and estimates of volume and surface area.

2.2 METHODS

Two methods were used to collect bathymetric data at the Yoncalla Ponds: a hydroacoustic data survey of the largest pond, and manual depth sounding at points within three smaller ponds. The hydroacoustic survey was conducted on March 18, 2014 during full pool conditions. Data was collected using a Biosonics Inc. DE4000 Scientific Digital Echosounder equipped with a 420 kHz narrow beam (8°) transducer paired with a differentially corrected Trimble Pathfinder Pro GPS receiver. The acoustic data were collected at a pulse width of 0.4 milliseconds and a rate of five to ten acoustic pings per second. GPS location data were recorded once per second at boat speed of less than 2.5 m/s resulting in acoustic data at a maximum distance of 0.9 m between data points. Since acoustic data were recorded more frequently than location data, unknown locations were interpolated between known locations along transects. Data was collected along concentric paths parallel to the pond shoreline spaced approximately 20 m apart (Figure 1). Additional data was collected in the deeper areas of the pond with more complex topography.

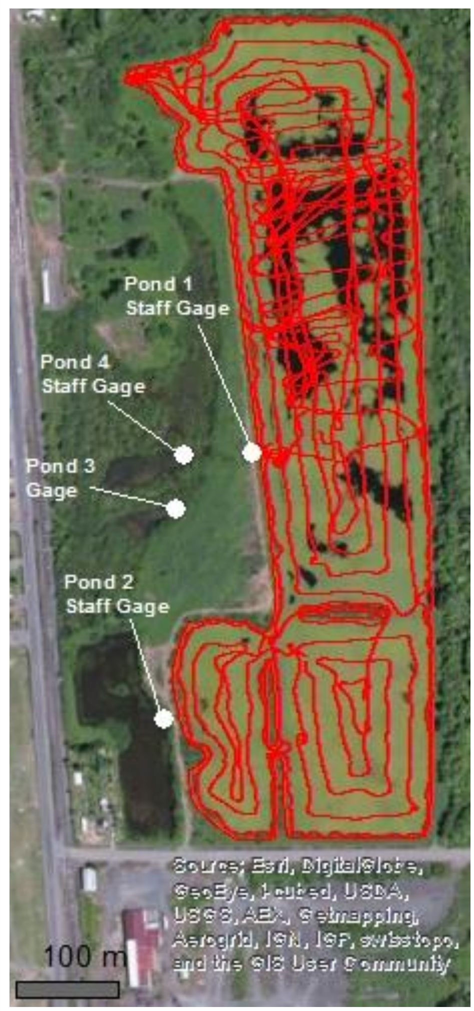


Figure 1. Yoncalla Pond hydroacoustic survey data collection pathlines and temporary staff gage locations.

Depth at the three smaller ponds was measured by lowering a pole marked at 10 cm increments to the sediment surface at sites evenly distributed across each pond. Depth was measured at 58 sites in Pond 2, 26 sites in Pond 3, and 26 sites in Pond 4. Site locations were recorded with a differentially corrected Trimble Pathfinder Pro GPS receiver. Distances between measurement sites were less than 15 m in Pond 2, 9 m in Pond 3, and 11 m in Pond 4.

Since reference elevations points relative to sea level were not available near the ponds, water levels on survey dates were referenced to the top of temporary galvanized pipes driven vertically into each of the ponds (Figure 1). As Lidar data becomes available for the area, the relative elevation data can be referenced to a vertical datum relative to sea level.

Shapefiles of each pond's shoreline was downloaded from the National Hydrographic Database (http://nhd.usgs.gov/data.html, accessed July 2014) and edited in ArcMap to match a 0.3 m resolution digital color image (Microsoft UC-G image). Vertices of the polygons were densified to one meter spacing, converted to a point shapefile, and assigned a depth of 0 m.

Hydroacoustic data collected from Pond Number One was processed using Biosonics Visual Analyzer software to produce water depth, latitude, and longitude at each sample point. All hydroacoustic point data from Pond Number One; manually measured point data from Ponds Two, Three, and Four; and shoreline points for all ponds were imported into a Microsoft Access database.

Bathymetric surfaces of the ponds were interpolated from the point data using the spline with tension algorithm in ESRI ArcGIS 10 software. Volume and surface area below contours on the interpolated surfaces were calculated using the ArGIS Surface Volume tool.

2.3 Results

The measured water level in Yoncalla Pond 1 during the March 18, 2014 bathymetric survey date was within 1 cm of the maximum level observed in the pond during the survey period (Figure 2). Water levels in Ponds 3 and 4 during June 26, 2013 bathymetric surveys were 0.3 m below the maximum observed during the survey period, while the level in Pond Number Two was the highest observed during the project period. Water levels in Pond 2 would have been higher with fall and winter rains, however, the dike containing the pond developed a leak during the project period (Kent Smith, North Douglas Betterment, personal communication).

The morphometry of Pond 1 is characterized by a steep shoreline that drops quickly to a relatively flat, shallow surface across most of the pond (Figure 3). There is a general trend of increasing depth from the south to the north. Much of the southern portion is less than 2 m deep while the northern basin ranges up to 3.9 m deep with considerable portions deeper than 2 m. Notable features include the remnants of an old dike running from east to west near the north end of the pond and several relatively deep submerged channels in the northern half of the pond. The submerged dike along with islands in the southern part of the pond result in four distinct basins in Pond 1.

The volume of Pond 1 at full pool is 292,643 m^3 (0.29 hm^3; 237.25 acre-feet), the surface

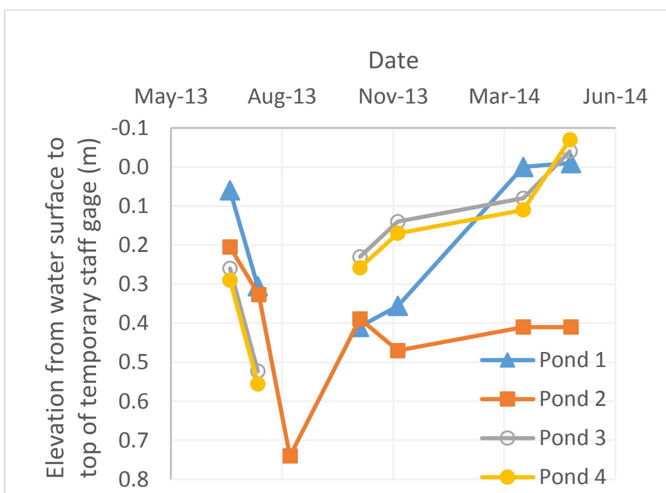


Figure 2. Water surface elevations below the top of temporary staff gages at the four Yoncalla Ponds.

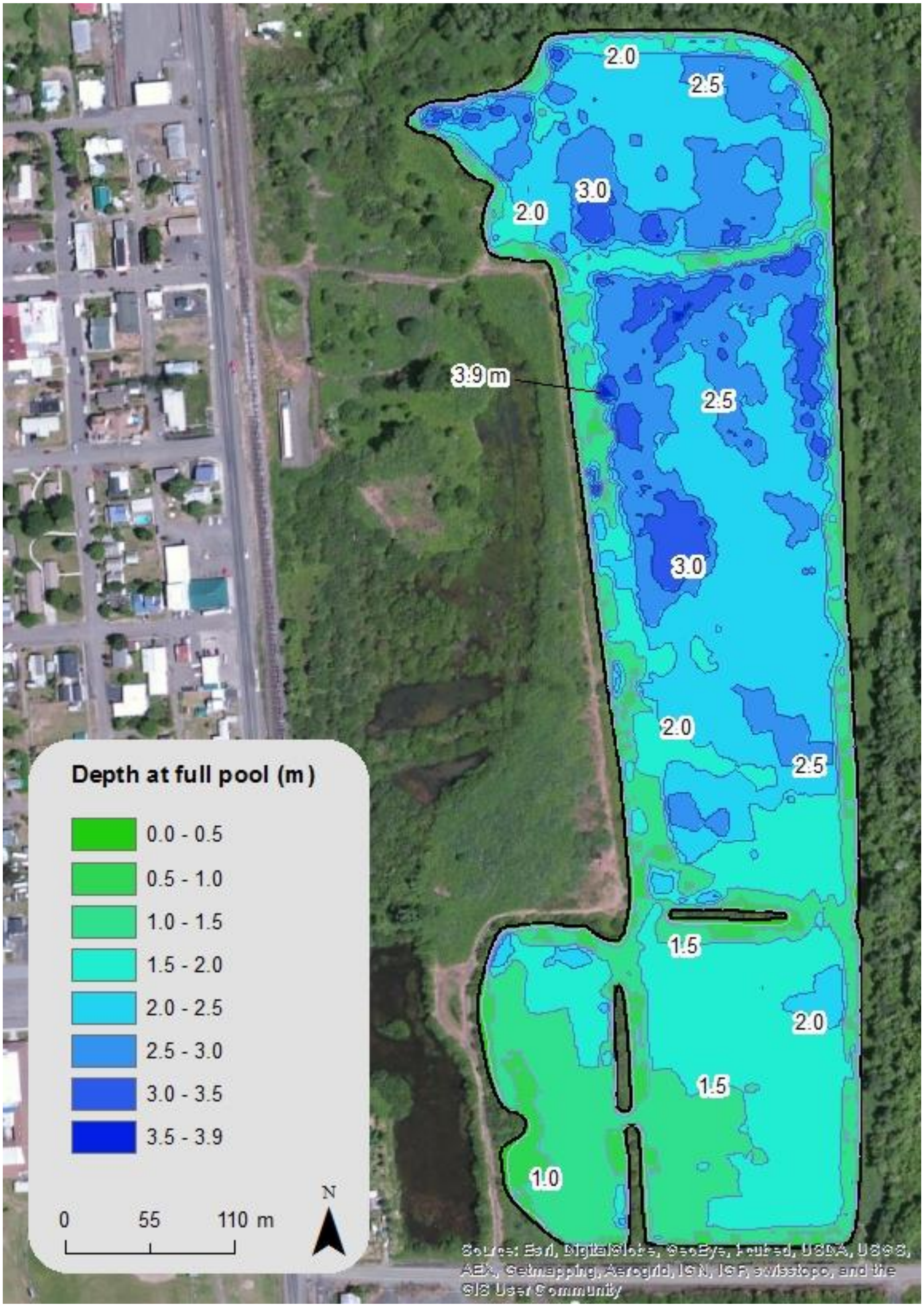
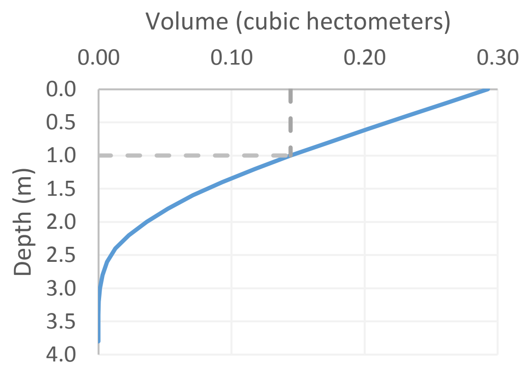
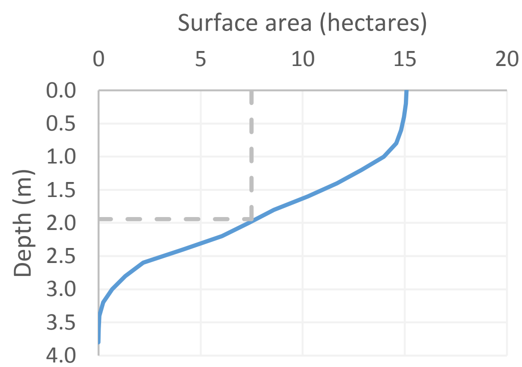


Figure 3. Bathymetric contours of Yoncalla Pond Number 1. Depth contours in 0.5 m intervals are relative to full pool elevation measured on March 18, 2014.

Table 1. Morphometric statistics (left) and hypsographic curves (right) for Yoncalla Pond Number One. Values are calculated from a surface interpolated from hydroacoustic data collected on March 18, 2014. Depths are relative to full pool elevation measured on the survey date. Dashed lines represent depths with 50% of total volume and surface area at full pool.

Depth (m)	Surface area at depth (hectares)	Volume below depth (m^3)
0	15.08	292,643
0.2	15.05	262,334
0.4	14.95	232,270
0.6	14.82	202,529
0.8	14.59	173,137
1.0	13.97	144,428
1.2	12.89	117,489
1.4	11.68	92,998
1.6	10.25	70,979
1.8	8.59	52,128
2.0	7.35	36,324
2.2	6.05	22,773
2.4	4.13	12,623
2.6	2.19	6,449
2.8	1.32	3,052
3.0	0.68	1,110
3.2	0.23	243
3.4	0.03	24
3.6	0.002	2
3.8	0.0003	0.1





area is 15.08 ha (37.27 acres), and the mean depth is 1.9 m. The deepest measured point in the pond (3.9 m, 12.8 ft) is located in the northwestern portion of the middle basin. Fifty percent of the pond's volume lies below 1 m depth. Morphometric statistics at different water levels and hypsographic curves based on the statistics are presented in Table 1.

Ponds 2-4 are much smaller and shallower than Pond 1 with surface areas of 1.13 ha, 0.11 ha, and 0.24 ha (Table 2, Figure 4). The maximum depths of ponds 2-4 are 1.0, 0.6, and 1.3 m; and mean depths are 0.5, 0.4, and 0.8 m respectively.

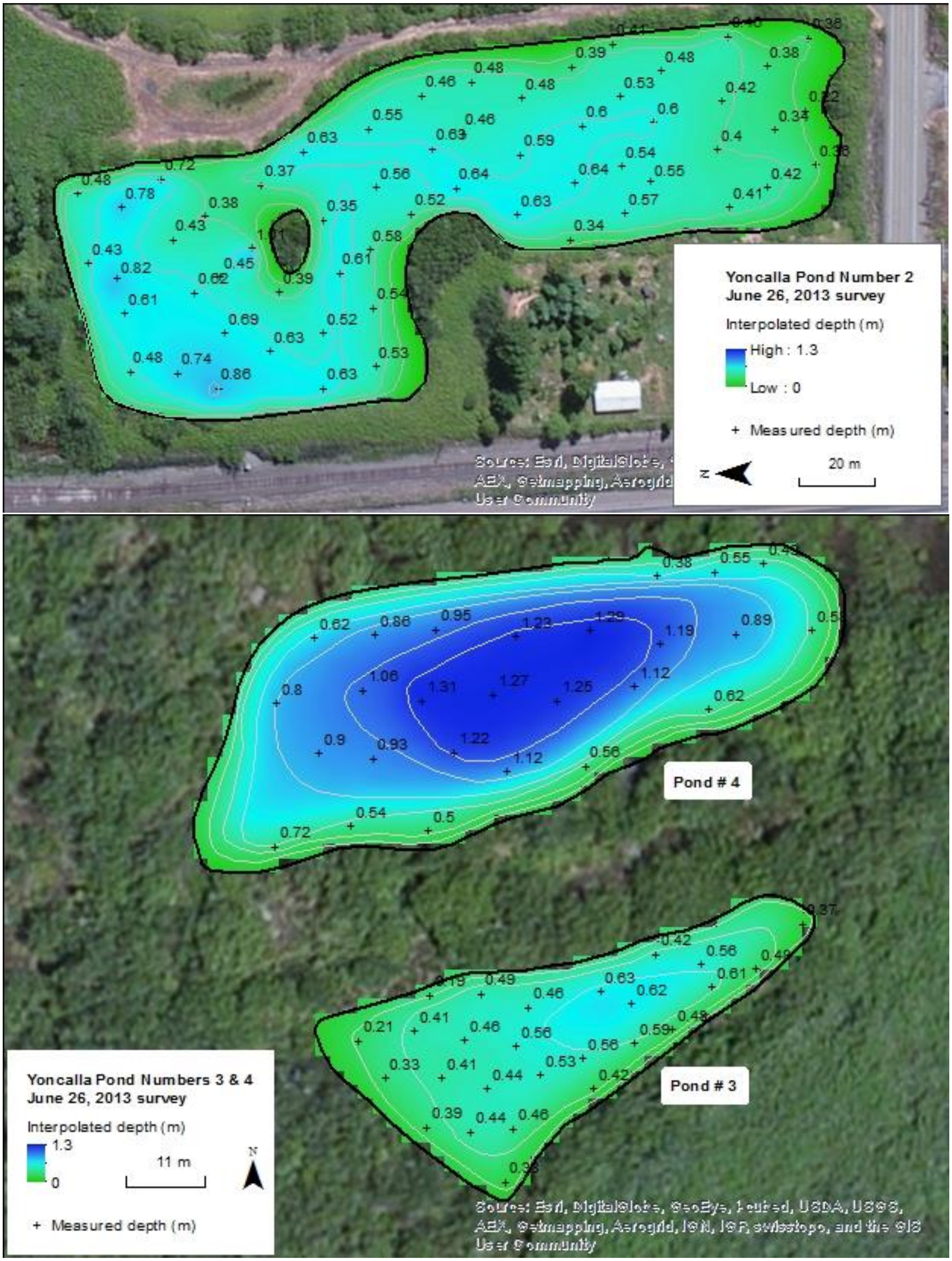
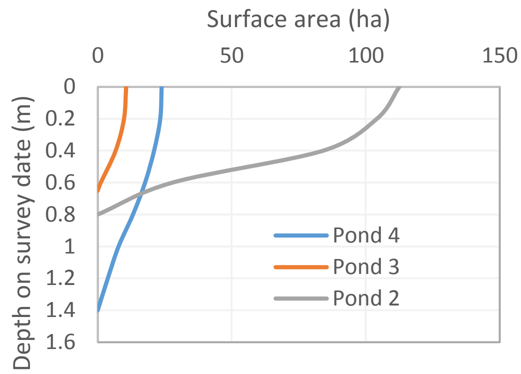
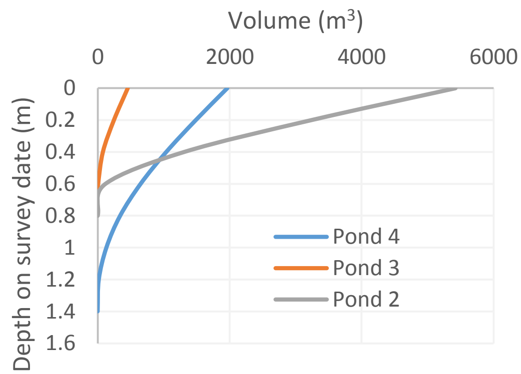


Figure 4. Yoncalla Pond 2 (top) and Ponds 3 and 4 (bottom) bathymetric maps. Measured depth points and 0.2 m contours are relative to the water surface elevation on June 26, 2013.

Table 2. Morphometric statistics (left) and hypsographic curves (right) for Yoncalla Ponds 2-4. Values are calculated from surfaces interpolated from sounding data collected on June 26, 2013. Depths are relative to the water surface elevation on the survey date.

Pond	Depth (m)	Surface area at depth (m^2)	Volume below depth (m^3)
2	0	11257	5423
	0.2	10423	3238
	0.4	8428	1309
	0.6	2804	117
	0.8	7	0
3	0	1056	453
	0.2	978	244
	0.4	667	76
	0.6	114	4
4	0	2388	1965
	0.2	2337	1488
	0.4	2106	1041
	0.6	1770	651
	0.8	1317	341
	1	780	133
	1.2	378	18





3 AQUATIC VEGETATION COVERAGE AND SPECIES COMPOSITION

3.1 INTRODUCTION

Aquatic vegetation can be beneficial to ponds and lakes though preventing shoreline erosion and sediment re-suspension, and providing food and habitat for fish and other aquatic organisms. Some aquatic plants such as arrowhead (*Sagittaria latifolia*) can also been used as a human food source. Excessive growth of aquatic plants, however, can harm the ecology and economy of a waterbody. For example, growth of non-native plant species such as Eurasian watermilfoil (*Myriophyllum spicatum*) or native plant species such as watershield (*Brasenia schreberi*) can aggressively crowd out other native plants, degrade water quality, interfere with boating and fishing, decrease property values, and incur management costs.

We assessed the species composition and relative density of submerged and floating leaf aquatic plants in the Yoncalla Ponds during the summer of 2013. Plant samples were collected throughout each of the ponds, species were identified, and specimens were pressed and archived.

3.2 METHODS

Submerged and floating leaf aquatic plant samples were collected from the pond on two dates in 2013. All ponds were sampled on 6/26/13. Ponds 1 and 2 were resampled on 8/21/13 to assess seasonal differences. Ponds 3 and 4 were not resampled because they went dry later in the summer. Sites were evenly distributed across each pond ranging from approximately 7 m apart in Pond 3 to 30 m apart in Pond 1 (Figure 5, Table 3). The number of sites in each waterbody ranged from 202 in Pond 1 to 26 in Ponds 3 and 4. Samples were collected at the sites by inserting a double-sided thatch rake attached to a graduated aluminum pole to the sediment surface, noting the depth, twisting the rake 360 degrees, and retrieving all attached vegetation for identification. Species composition, relative abundance, and sample depths were recorded on field datasheets. Identifications were verified according to Crow and Hellquist (2006),

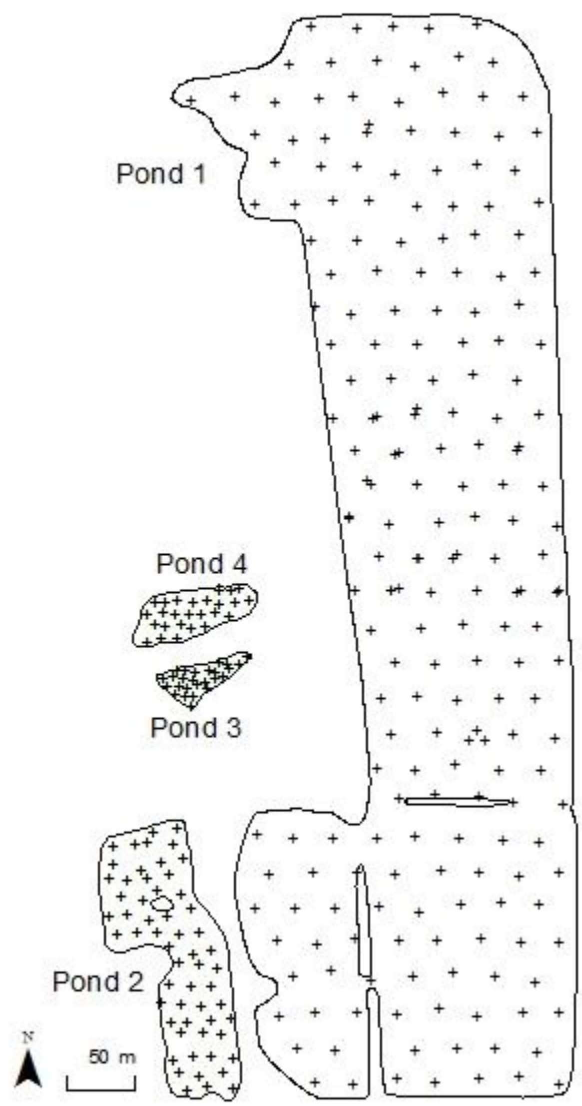


Figure 5. Aquatic plant sampling locations (+).

Table 3. Distance between aquatic plant sample sites and number of sites per waterbody

Pond	Distance between sites (m)	Number of sites sampled on date 6/26/13	8/21/13
1	30	202	10
2	15	58	57
3	7	26	dry
4	10	26	dry

Crow et al. (2006), Brayshaw (2000), Jepson eFlora (2014) and Flora of North America North of Mexico (1993). Voucher specimens were pressed and archived at Portland State University. All data are stored in a Microsoft Access Database.

3.3 Results

3.3.1 Pond 1

The extent of the aquatic plant coverage of Pond 1 is indicated on a June 2012 satellite image where 94% of the pond surface appears to be covered with plants (Figure 6) (USDA-FSA 2012). Our survey on June 26, 2013 indicates that the plant species community was dominated by the native floating leaf species *Brasenia schreberi* (watershield) which was present at 96% of the 202 sites surveyed (Figure 7). The sites where *B. schreberi* was not detected were restricted to the deepest parts of the pond and ranged in depth from 2.3 to 2.9 m. The sites with *B. schreberi* present ranged up to 3.1 m.

The only submersed species detected in pond, *Potamogeton pusillus* (small pondweed), was found at two shallow water sites. Small patches of water purslane (*Ludwigia palustris*), an emergent plant species, were encountered at several locations around the shoreline but not at any of the sampling sites. Both species are native and common in Oregon. An invasive *Typha* sp. (cattail), either *T. angustifolia* or a hybrid between *T. angustifolia* and the native *T. latifolia*, was present at several locations along the shoreline. *B. schreberi* was the only plant collected from 10 sites sampled during August 2013.

3.3.2 Pond 2

Brasensia schreberi was also found in Pond 2; however, it did not dominate the aquatic plant community as it did in Pond 1. *B. schreberi* was present at 3% of the 58 sites sampled on June 26 and 60% of the 57 sites sampled on August 21, 2013. A total of seventeen aquatic plant species were found in the pond (Table 4) and at least one plant species was observed at each site. The most common species encountered were *Najas guadalupensis* (common water nymph) and *Elodea canadensis* (Canadian waterweed).

Figure 6. *B. schreberi* coverage of Pond 1 on 7/7/2012 (USDA-FSA 2012).

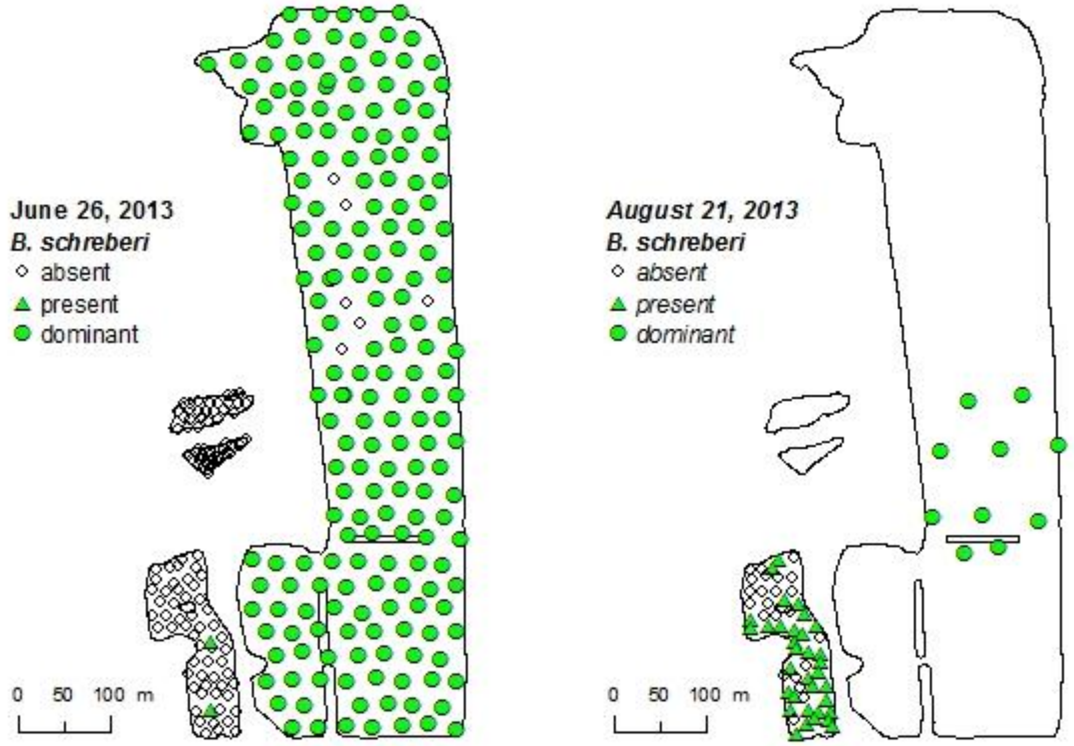


Figure 7. Presence, absence and dominance of *Brasensia schreberi* in Yoncalla Ponds during June (left) and August (right) 2013. Points presented for the August sampling of Pond 1 represent sites that were checked to verify that no other species were present. *B. shreberi* covered nearly the entire pond during the August sampling event.

Two non-native species were present in the pond: *Myriophyllum spicatum* (Eurasian watermilfoil) and *Potamogeton crispus* (curly-leaf pondweed) (Figure 8). Since morphological characteristics can be unreliable in distinguishing between *Myriophyllum spicatum* and hybrids of *M. spicatum* and the native *M. sibiricum* (northern watermilfoil), identification of *M. spicatum* was verified by Grand Valley State University using genetic markers. *M. spicatum* is a B Listed Weed on Oregon's Noxious Weed List (ODA 2014) which is defined as "a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties". ODA's recommended action for a B Listed Weed is for limited to intensive control on a site specific, case-by-case basis. *M. spicatum* was present at 22% of the sites during June and 63% of the sites during August. *P. crispus* was present at 9% of the sites during each sampling event. Although *P. crispus* is a non-native species that can cause some of the same problems as *M. spicatum*, it is not included on Oregon's Noxious Weed List.

3.3.3 Pond 3

Aquatic plants were present at 25 of the 26 Pond 3 sample sites during June 2013 at depths ranging up to 0.63 m. Six aquatic plant species were present, all of which were native species (Table 5). *Ceratophyllum demersum* (coontail), a non-rooted aquatic plant that acquires nutrients from the water column rather than the sediment, was the most commonly encountered species. *Callitriche heterophylla* (water starwort) and the macro-alga species *Nitella* sp. (brittlewort) were also very common. The overall submerged plant density in the pond was very high. Since the pond was dry during August 2013, a second plant sampling event was not conducted.

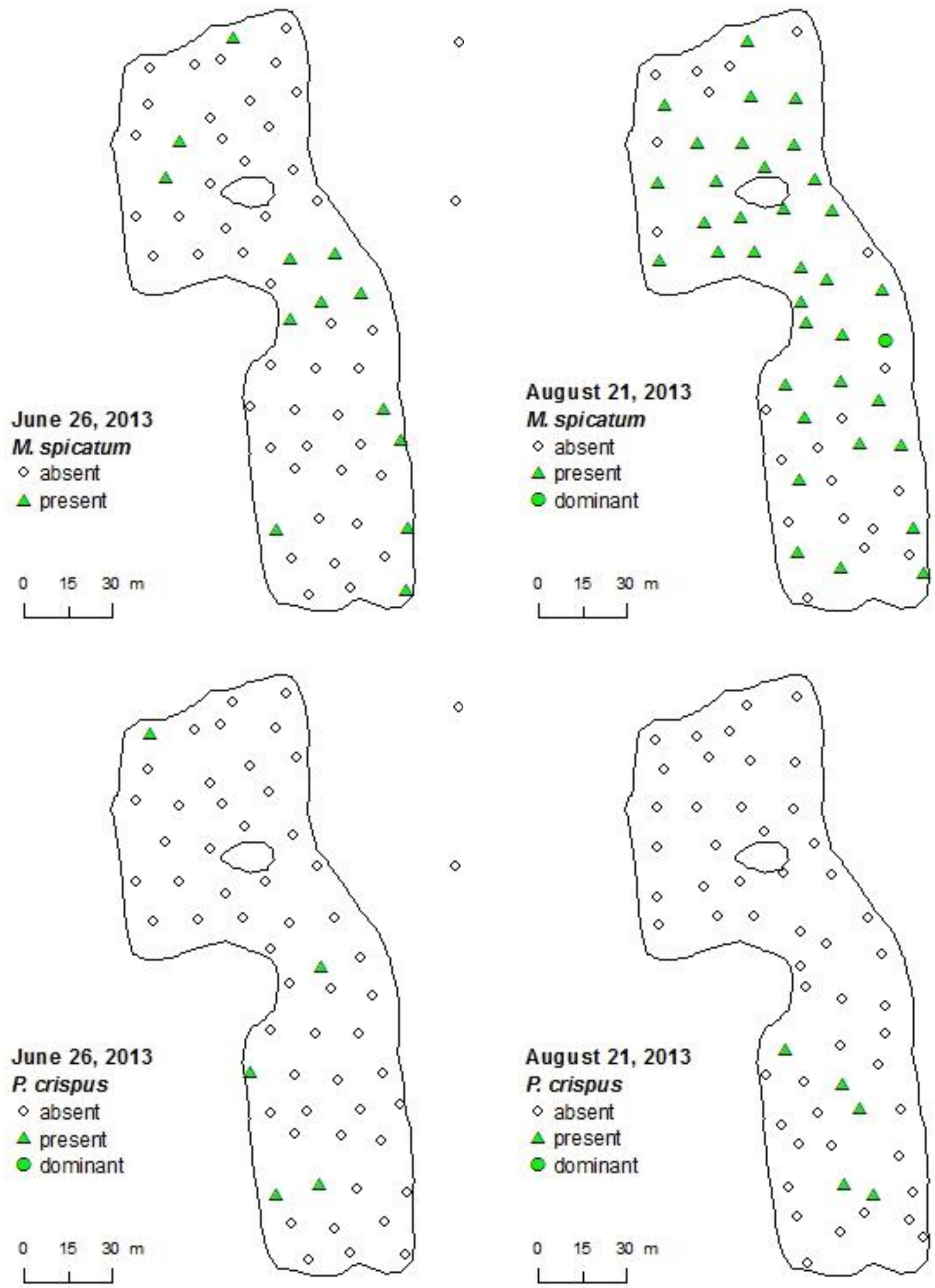


Figure 8. Presence, absence, and dominance of *Myriophyllum spicatum* (top) and *Potamogeton crispus* (bottom) in Pond 2 during June (left) and August (right) 2013.

3.3.4 Pond 4

At least one aquatic plant species was present at each of the 26 sites sampled in Pond 4 during June 2013. Seven native aquatic plant species were detected in Pond 4, all of which were native (Table 5). *C. demersum* was present at 100% of the sites and was densely distributed through the pond. Three native *Potamogeton* sp. (pondweed) were found that were not found upstream in Pond 3. Like Pond 3, Pond 4 was not resampled in August because the pond was nearly dry.

Table 4. Occurrence of aquatic plant species in Yoncalla Pond 2.

Species	Common name	Status	% of sites with species 6/26/13	8/21/13
Myriophyllum spicatum	Eurasian watermilfoil	non-native, ODA Class B	22	63
Potamogeton crispus	curlyleaf pondweed	non-native	9	9
Typha sp.	narrow leaf cattail	non-native	*	*
Najas guadalupensis	common water nymph	native	86	89
Elodea canadensis	Canadian waterweed	native	81	98
Potamogeton pusillus	small pondweed	native	38	46
Eleocharis acicularis	needle-leaf spikerush	native	31	2
Potamogeton amplifolius	big-leaf pondweed	native	24	67
Schoenoplectus subterminalis	water bulrush	native	12	51
Brasenia schreberi	watershield	native	3	60
Eleocharis sp.	spikerush	native	3	16
Carex sp.	sedge	native	3	-
Potamogeton epihydrus	ribbon-leaf pondweed	native	2	4
Sparganium sp.	bur-reed	native	2	4
Potamogeton natans	floating-leaved pondweed	native	-	9
Juncus sp.	rush	native	-	7
Callitriche heterophylla	water starwort	native	-	4
Ludwigia palustris	water purslane	native	-	2

* Present along shoreline, but not at any sampling sites

Table 5. Occurrence of submersed and emergent aquatic plant species in Ponds 3 and 4 on 6/26/13.

Species	Common name	Status	% of sites with species Pond 3	Pond 4
Ceratophyllum demersum	coontail	native	81	100
Nitella sp.	brittlewort	native	38	8
Callitriche heterophylla	water starwort	native	31	4
Persicaria lapathifolia	common knotweed	native	19	8
Elodea canadensis	Canadian waterweed	native	4	-
Chara sp.	muskwort	native	4	-
Potamogeton pusillus	small pondweed	native	-	12
Potamogeton epihydrus	ribbon-leaf pondweed	native	-	4
Potamogeton amplifolius	big-leaf pondweed	native	-	4

4 Water Quality Assessment

4.1 Introduction

The water quality of a waterbody consists of the physical, chemical and biological condition of the waterbody. These characteristics determine the suitability of the waterbody for different aquatic organisms as well as the utility of the waterbody for human needs such as drinking water and recreation. Water quality is affected by many factors including the land use within watersheds, management practices within waterbodies, proliferation of invasive species, and changes in weather and climate.

This water quality assessment is intended to determine the water quality status of the four Yoncalla Ponds and provide a baseline for assessing change. The assessment covers the topics of nutrient concentrations, thermal stratification, dissolved oxygen and pH dynamics, biological communities, and a summary of the trophic status of the ponds.

4.2 Methods

Measurements and samples were collected from the four Yoncalla Ponds during seven sampling events during the period from June 2013 to May 2014 (Table 6). The timing of the sampling events was intended to characterize conditions during the summer growing season when aquatic plant biomass was at a maximum, the start of the rainy season in early and late fall, late winter when the aquatic plant biomass was low, and early spring as aquatic plant biomass was on the increase. Sampling was conducted in the deepest section of each pond (Figure 9).

Figure 9. Water quality sampling sites.

In situ measurements were collected from the deepest part of each pond using a Eureka Manta™ or Manta2™ multiprobe. Vertical profiles of temperature, pH, dissolved oxygen (DO), and specific conductance were measured at 0.5 m intervals from the surface to the bottom of Pond 1, while surface water measurements (0.5 m) were collected from the three shallower ponds. Specific conductance and pH were calibrated prior to sampling on each date using NIST certified standards. Dissolved oxygen was calibrated to 100% saturation at the measured barometric pressure in air saturated water. Multiprobe sensors were allowed to equilibrate with conditions in each pond for a minimum of five minutes or until readings were stable before recording measurements. At least 90 s was allowed for equilibration between measurements at different depths.

A calibrated Manta™ or Manta2™ multiprobe was also deployed in Pond 1 over the course of each sampling event: a time period of between one and three days. The multiprobe was suspended at

Table 6. Samples and measurements collected from Yoncalla Ponds.

Pond	Sample dates	Secchi	*In situ* Meas.	Chemistry samples	Phyto-plankton	Chl-a	Zoo-plankton	Benthos
1	June 25-28, 2013	X	X	X	X	-[4]	X	X
	July 23-24, 2013	-[3]	X	X	X	-[4]	X	X
	Aug 21-22, 2013	X	X	X	-	-[4]	X	X
	Oct 22-23, 2013	X	X	X	X	-[4]	X	X
	11/26/2013	X	X	X	-	-[4]	X	X
	Mar 18-19, 2013	X	X	X	X	-[4]	X	X
	Apr 30- May 1, 2014	X	X	X	X	-[4]	X	X
2	June 27, 2013	-[1]	X	X	X	-[4]	-	X
	July 24, 2013	-[1]	X	X	X	-[4]	-	X
	Aug 21,2013	-[1]	X	X	-	-[4]	-	X
	Oct 23, 2013	-[1]	X	X	X	-[4]	X	X
	Nov 26, 2013	-[1]	X	X	-	-[4]	-	X
	Mar 19, 2014	-[1]	X	X	X	-[4]	X	X
	May 1, 2014	-[1]	X	X	X	-[4]	X	X
3	June 27, 2013	X	X	X	X	-[4]	-	X
	July 23, 2013	-[1]	X	X	X	-[4]	-	X
	Aug 21,2013	-[1]	-[2]	-[2]	-	-[4]	-	-
	Oct 23, 2013	X	X	X	X	-[4]	X	X
	Nov 26, 2013	-[1]	X	X	-	-[4]	-	X
	Mar 19, 2014	-[1]	X	X	X	-[4]	X	X
	Apr 30, 2014	-[1]	X	X	X	-[4]	X	X
4	June 28, 2013	X	X	X	X	-[4]	-	X
	July 23, 2013	X	X	X	X	-[4]	-	X
	Aug 21,2013	-[1]	X	-[2]	-	-[4]	-	-
	Oct 23, 2013	X	X	X	X	-[4]	X	X
	Nov 26, 2013	X	X	X	-	-[4]	-	X
	Mar 19, 2014	X	X	X	X	-[4]	X	X
	Apr 30, 2014	X	X	X	X	-[4]	X	X

[1] Secchi visible on bottom. [2] Not measured due to low water. [3] Not recorded. . [4] Analytical error.

approximately 1 m from a surface buoy depth located at the deepest part of the pond and set to record data at a maximum interval of once every 15 min.

Grab samples were collected for analysis of nutrients, acid neutralizing capacity, and chlorophyll-a concentration using a horizontal 4.2 L Van Dorn sampler at the deepest location in each pond. Surface samples (0.5 m) were collected from the three shallower ponds. Samples collected from Pond 1 consisted of vertical composites of subsamples collected from 0.5, 1, and 2 m. Unfiltered subsamples were submitted to the Cooperative Chemical Analytical Laboratory (CCAL)[1] for analysis of total phosphorus (TP) and total nitrogen (TN) concentrations. Subsamples were also filtered through Whatman GFF glass fiber filters (nominal pore size of 0.7 µm) and submitted to CCAL for the analysis of orthophosphate (PO_4-P), ammonia nitrogen (NH_3-N), and nitrate plus nitrite nitrogen (NO_3+NO_2-N). All nutrient samples were stored in acid washed HDPE bottles on ice or refrigerated. One field replicate nutrient sample was submitted for each sampling event. Subsamples were decanted into opaque HDPE bottle for the analysis of acid neutralizing capacity by Gran titration (Wetzel and Likens 2000) and chlorophyll-a by fluorometry (Arar and Collins 1997) at the Portland State University Center for Lakes

[1] Analytical data were provided by the Cooperative Chemical Analytical Laboratory established by memorandum of understanding no. PNW-82-187 between the U.S. Forest Service Pacific Northwest Research Station and the College of Forestry, Department of Forest Ecosystems and Society, Oregon State University.

and Reservoirs Laboratory. Subsamples collected on five of the seven dates were preserved with Lugol's solution (Wetzel and Likens 2000) and submitted to Aquatic Analysts Inc. in Friday Harbor, Washington for phytoplankton enumeration and biovolume estimation.

Zooplankton were collected using a 20 cm diameter opening, 64 µm mesh plankton net, rinsed into HDPE bottles, and preserved with ethanol to 30% final concentration. Multiple vertical net tows were collected from the deepest spot in Pond 1 on each date and composited into a single sample. The number of tows per sampling event was dependent on the amount of material collected with each tow. Because the remaining three ponds were shallow, tows were collected by tossing and retrieving the net horizontally for several meters. Zooplankton samples were not collected from the three shallow ponds when the ponds were dry or aquatic plants were growing throughout the water column. Samples were submitted to ZPs Taxonomic Service in Olympia, Washington for identification and enumeration.

Benthic samples were collected from five sites within each pond during each of the four summer and fall sampling events. Sediment samples were collected using a petit ponar dredge, placed on a course sieve (approximately 300 µm mesh size), and rinsed to remove small material. The remaining material was inspected for snails, clams and any other organisms suspected to be non-native. Representative specimens were preserved in 95% ethanol and identified at the Center for Lakes and Reservoirs Laboratory according to Martinson et al. (2009), Merritt et al. (2009), Thorp and Covich (2009), and Kipp et al. (2014).

4.3 Results

4.3.1 Nutrient concentrations

The plant nutrients phosphorus (P) and nitrogen (N) are the primary chemical constituents that are in short enough supply in relation to other chemical requirement for growth to limit algal growth. Unless algal growth is limited by other factors such as light availability, excess amounts of nutrients can lead to vigorous growth of plants and algae and associated water quality problems such as high pH or toxin producing algal species. Decomposition of all of this plant and algal growth can lead to other problems such as low dissolved oxygen concentrations.

Phosphorus and nitrogen are present in a water body in many forms including phosphate, nitrate, nitrite, and ammonia. These bio-available forms of dissolved N and P are ready for algae to take up and use for growth, and thus are generally present at low concentrations - unless algal nutrient uptake cannot outpace dissolved nutrient supply. The sum of N and P locked up algal biomass, N and P complexed with organic and inorganic compounds in the water, and the dissolved forms noted above constitute total phosphorus (TP) and total nitrogen (TN). The concentration of TP in the surface waters can be used as a measure of the trophic status of a water body (Carlson 1977). The relative concentrations of TN to TP can influence the species of algae that are likely to thrive in a water body. For example, cyanobacteria are less likely to dominate an algal assemblage with high TN:TP ratios (Smith 1983, Nõges et al. 2008).

Ortho-phosphorus concentrations in Pond 1 were below or at the method detection limit during all sampling events except for the March 2014 event (Figure 10). The low concentrations indicate that P was in high demand relative to supply in Pond 1 during the survey period. Concentrations in Ponds 2-4 were considerably higher than in Pond 1. Ammonia concentrations in Pond 1 were at or below method detection limits throughout the survey period. Concentrations were also low in the other three ponds for most of the time period, but substantially higher during the late fall and winter sampling events. Nitrate plus nitrite concentrations follow a similar pattern in the other ponds. Unlike ammonia concentrations, nitrate plus nitrite concentrations in Pond 1 were very high during the March 2014 event. Altogether, low concentrations of bioavailable forms of N and P in Pond 1 indicate that algal growth is limited by N and/or P. Higher concentrations of bioavailable P in the other ponds indicate that P does not limit algal growth in these ponds. Low concentrations of bioavailable N in Ponds 2-4, on the

Figure 10. Seasonal variation of total and dissolved nutrient concentrations in Yoncalla Ponds 1-4. Dashed lines indicate method detection limits.

other hand, indicate that these system were N limited during the spring through early fall.

Table 7. Summary of chemical conditions in Yoncalla Ponds 1-4.

Parameter (units)	Site	Mean ± s.d.	Range	# samples
Total nitrogen (mg/l)	Pond 1	0.38 ± 0.10	0.24 - 0.49	7
	Pond 2	0.50 ± 0.08	0.40 - 0.61	7
	Pond 3	0.85 ± 0.41	0.48 - 1.51	6
	Pond 4	0.80 ± 0.45	0.48 - 1.71	6
Total phosphorus (mg/l)	Pond 1	0.034 ± 0.015	0.016 - 0.058	7
	Pond 2	0.035 ± 0.011	0.020 - 0.049	7
	Pond 3	0.046 ± 0.026	0.019 - 0.077	6
	Pond 4	0.038 ± 0.012	0.026 - 0.060	6
Soluble reactive phosphorus (mg/l)	Pond 1	0.001 ± 0.001	0.000 - 0.003	7
	Pond 2	0.006 ± 0.004	0.001 - 0.012	7
	Pond 3	0.004 ± 0.002	0.002 - 0.007	6
	Pond 4	0.003 ± 0.001	0.001 - 0.004	6
Ammonia-nitrogen (mg/l)	Pond 1	0.008 ± 0.003	0.004 - 0.012	7
	Pond 2	0.032 ± 0.048	0.002 - 0.138	7
	Pond 3	0.042 ± 0.069	0.007 - 0.181	6
	Pond 4	0.045 ± 0.055	0.006 - 0.135	6
Nitrate plus nitrite-nitrogen (mg/l)	Pond 1	0.189 ± 0.498	0.000 - 1.319	7
	Pond 2	0.190 ± 0.498	0.001 - 1.320	7
	Pond 3	0.441 ± 0.680	0.001 - 1.321	6
	Pond 4	0.441 ± 0.681	0.000 - 1.322	6
Acid neutralizing capacity (mg/l as $CaCO_3$)	Pond 1	19.2 ± 2.5	16.7 - 22.4	5
	Pond 2	34.9 ± 8.0	25.8 - 47.6	5
	Pond 3	82.6 ± 27.3	55.8 - 112.4	4
	Pond 4	72.4 ± 16.7	51.0 - 88.2	4
Surface water conductivity (µS/cm)	Pond 1	42 ± 4	38 - 47	7
	Pond 2	77 ± 11	65 - 96	7
	Pond 3	167 ± 54	101 - 250	6
	Pond 4	159 ± 22	125 - 189	7

Average TP concentrations in the ponds ranged from 0.034 mg/L in Pond 1 to 0.046 mg/L to Pond 3 (Table 7) and were generally higher during the summer than winter (Figure 10). Waterbodies with TP concentrations between 0.024 and 0.027 mg/L are classified as eutrophic (Carlson 1977). Nitrogen to phosphorus ratios in all ponds during the spring through fall were less than 30:1 (Figure 10), which suggests that cyanobacteria may dominate the algal assemblage.

4.3.2 Stratification, dissolved oxygen, and pH dynamics

Thermal stratification is a physical property of a water body in which warmer, less dense water floats on top of colder, denser water. A water body with a 1° C decrease in temperature over a 1 m change in depth is considered stratified (Kalff 2001). During stratification, the mixing of dissolved oxygen and other chemicals between the layers is restricted. If the processes that consume oxygen (respiration) outpace the processes that produce oxygen (photosynthesis), oxygen concentrations in the bottom layer will decrease. If stratification is persistent, anoxic conditions can result leading to phosphorus release from bottom sediments and loss of habitat for aquatic organisms.

Thermal stratification was evident in Pond 1 during all sampling events except for the October 2013 and March 2014 event (Figure 11). Stratification was particularly strong with as much as a 3° C difference in temperature over a 0.5 m depth increment. Two factors contributed to the strong stratification in Pond

1. First, coverage of much of the pond surface by the floating leaf plant *Brasenia schreberi* restricted wind induced mixing of the water column. Second, the pond's brown water in open water along with the plant coverage prevented solar heat from penetrating into the water very far. The marked increase in specific conductance below 1.5 m indicates that stratification in the pond was persistent through the spring and summer. The increase in specific conductance in the bottom of the pond was likely due to

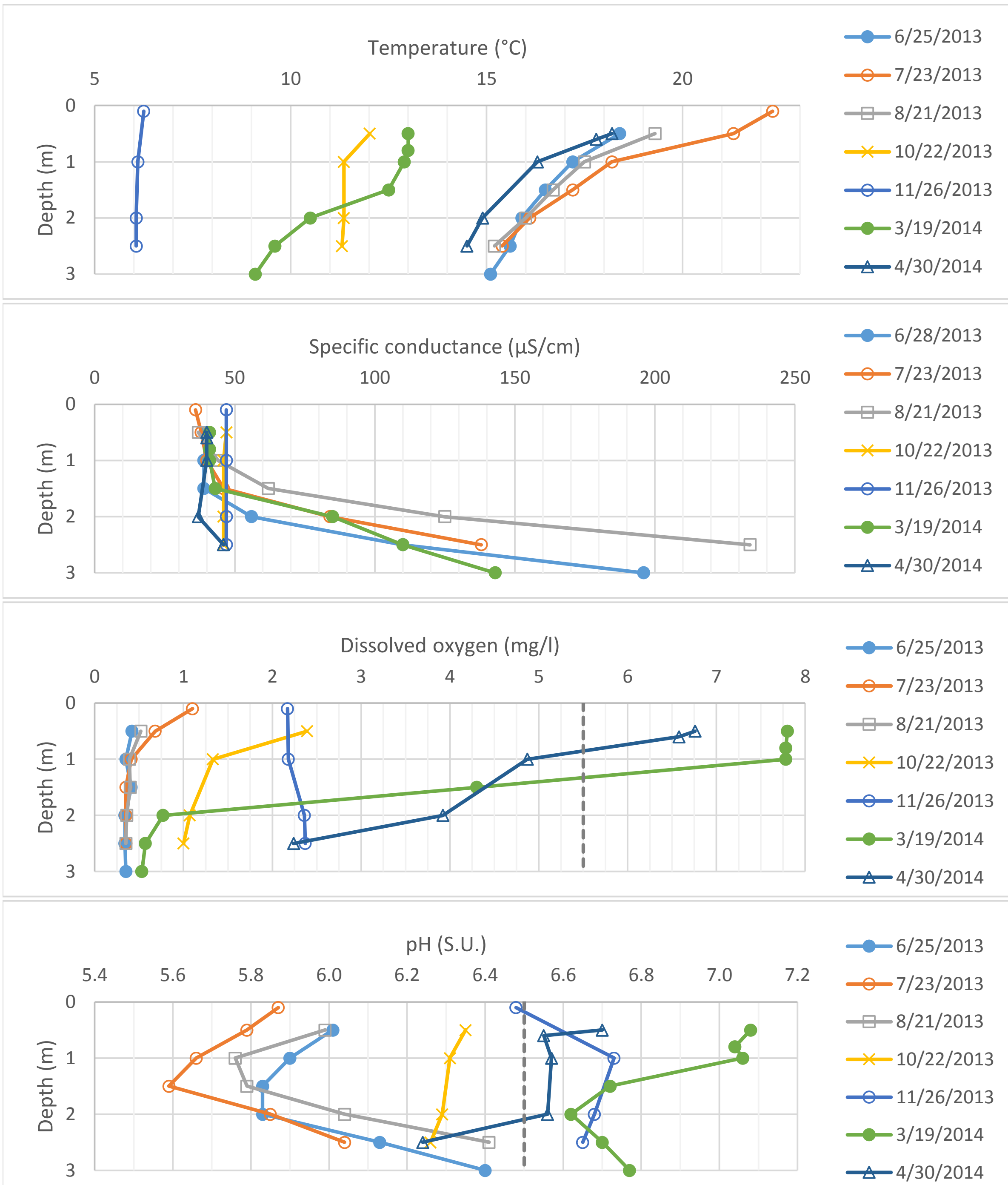


Figure 11. *In situ* water quality profiles measured in Yoncalla Pond 1. The dashed vertical lines represents the Oregon DEQ minimum criteria of 5.5 mg DO/L and pH 6.6.

ionic loading from the sediment and redox reactions under anoxic conditions that generate alkalinity (Talling 2009).

Dissolved oxygen (DO) concentrations were extremely low throughout the water column of Pond 1 during the summer sampling events and low in the lower portion of the water column the entire survey period (Figure 11). Surface water concentrations were below than the Oregon Department of Environmental Quality's criterion of 5.5 mg/L as an absolute minimum (Oregon Administrative Rules 2007) during all but two of the sampling events. The pH values in Pond 1 were slightly acidic during the summer and fall to circumneutral during the winter and spring. Highest values were observed during the March 2014 sampling event when floating leaf plant biomass was at its lowest point. Values during the summer and fall were below the DEQ criteria of pH 6.5 (Oregon Administrative Rules 2003). The most acidic values were observed during the summer sampling events when floating leaf plants covered nearly the entire pond.

As was the case with temperature profiles in Pond 1, the coverage of the pond by *B. schreberi* had a large effect on DO concentrations and pH values. Dense coverage of floating leaves restricts the exchange of oxygen and carbon dioxide between the water column and the atmosphere. In addition, the plant coverage blocks light from reaching into the water column. The effect of these factors on the water column is low photosynthesis using pCO_2 and producing DO due to a lack of light; continued respiration producing pCO_2 and consuming dissolved oxygen; and limited exchange of DO and pCO_2 with the atmosphere. The net effect is a decline in dissolved oxygen and a build-up of pCO_2, with the increase in pCO_2 causing a decrease in pH.

In productive ponds, the daily light-dark cycle can result in a measureable daily pattern in DO and pH due to a change in the balance between photosynthesis and respiration. However, because floating leaf plants exchange CO_2 and O_2 directly with the atmosphere rather than through the water column, the daily cycle of DO and pH in the water may not be measurable. No daily patterns were evident in the pH and DO data logged at set intervals over each one to three-day sampling event (Figure 12). Since vertical stratification of DO and pH in the pond is so pronounced, the small magnitude variations in pH and DO shown in the plots may be due to increases in wind causing slight mixing of the water column. Instrument drift was present during several of the sampling events.

Since the aquatic vegetation of Ponds 2, 3, and 4 was dominated by submerged vegetation (SAV) rather than floating leaf vegetation, DO concentrations and pH values behaved in a completely different manner than in Pond 1 (Figure 13). While photosynthesizing, SAV obtains pCO_2 from, and releases DO to the water column rather than directly to the atmosphere through floating leaves. This resulted in much higher DO concentrations in the SAV dominated ponds. DO concentrations during the summer reached almost 250% of what would be expected when at equilibrium with the atmosphere. The consumption of pCO_2 from the water column raised the pH of the ponds to near pH 10 during the summer sampling events.

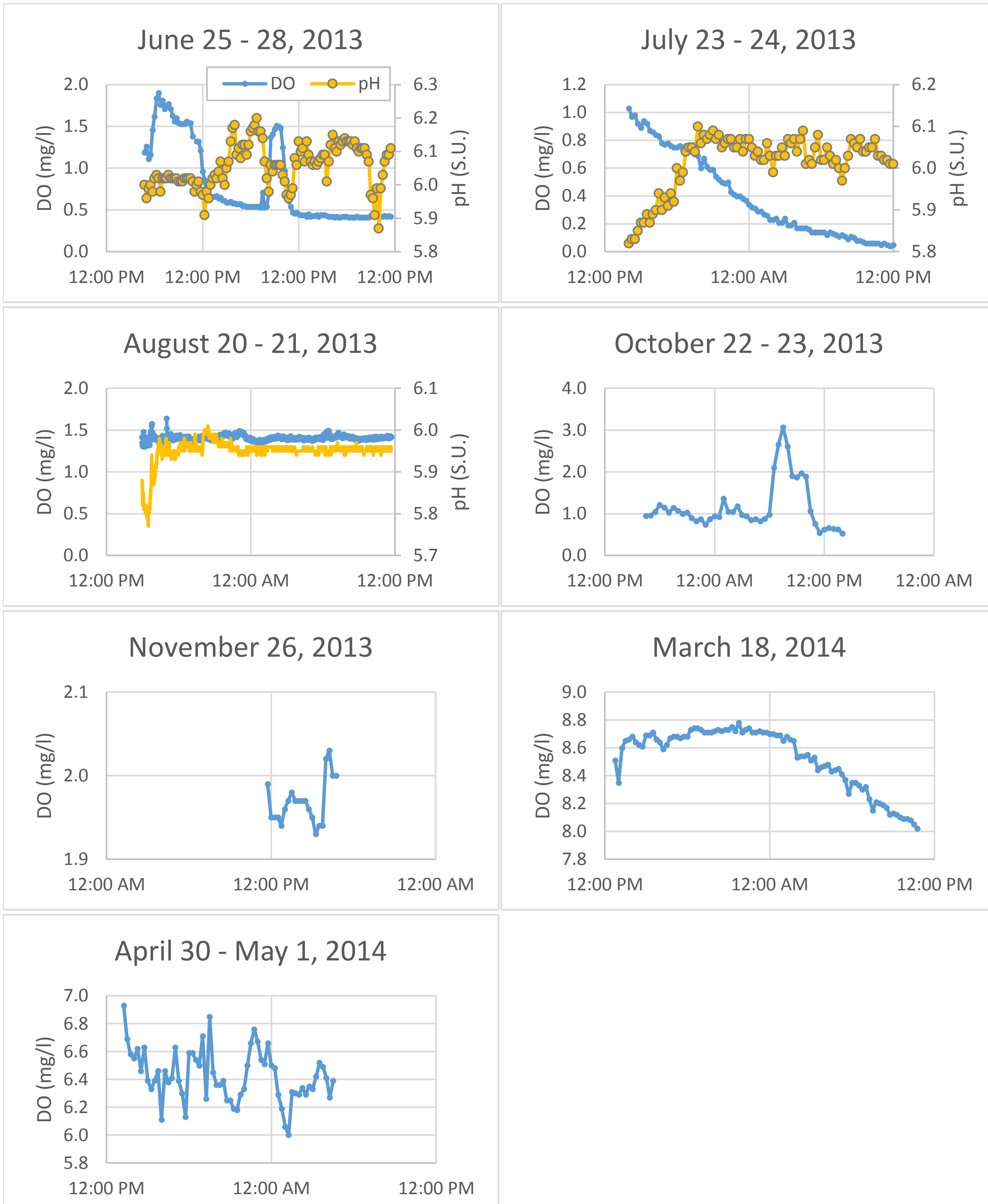


Figure 12. Variation in dissolved oxygen and pH at Yoncalla Pond 1 within each one- to three-day sampling event. pH values for the last four sampling events were not presented since their accuracy did not meet quality assurance targets.

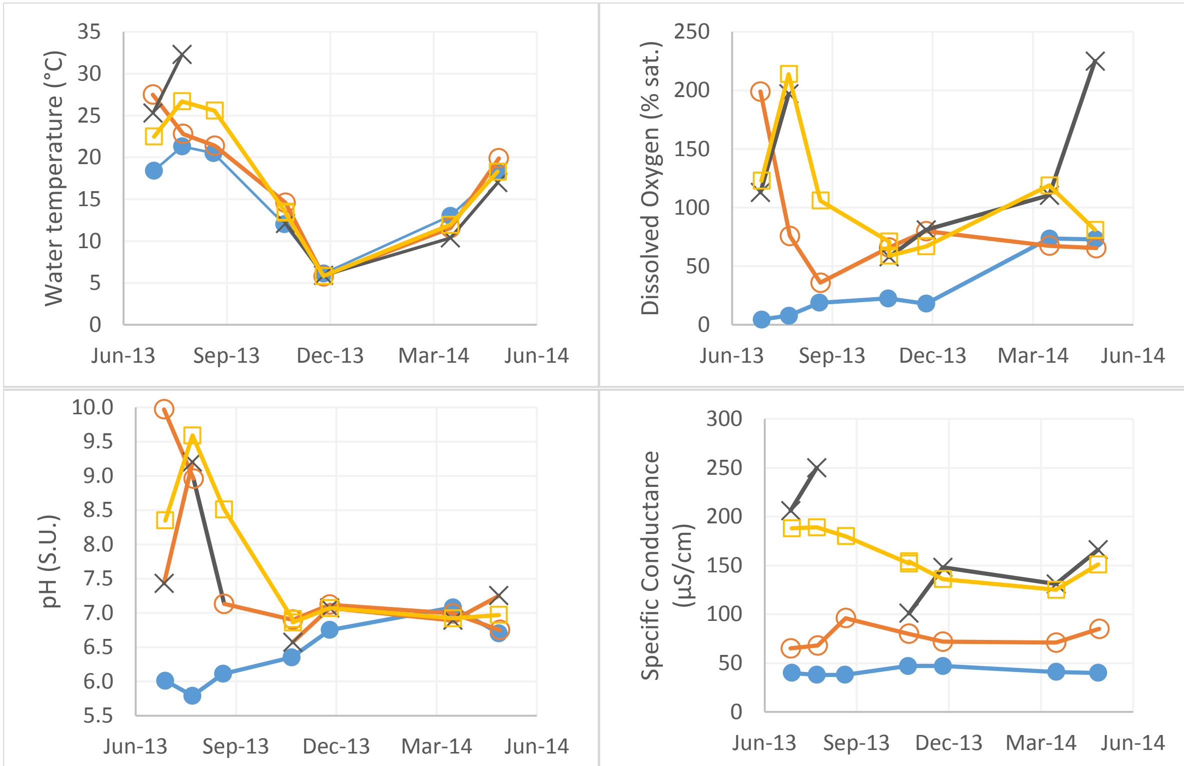


Figure 13. Surface water measurements in Pond 1 (solid circles) Pond 2 (open circles), Pond 3 (X's) and Pond 4 (squares).

4.3.3 Phytoplankton and trophic state

Phytoplankton are the photosynthetic organisms present within the water column of a waterbody. The diversity of phytoplankton species is very high and consist of several groups of eukaryotic algae as well as photosynthetic bacteria, also known as cyanobacteria or blue-green algae. The amount and types of phytoplankton in a water body are fundamentally important components of water quality. Surrogate measures for the amount of phytoplankton in a water body, e.g. Secchi transparency and chlorophyll-a (Carlson 1977) as well as direct measures of phytoplankton biovolume (Sweet 1986) are used as a measure of the trophic status or productivity of a water body. Some species of cyanobacteria are capable of producing toxins that can harm human and animal health. Since some phytoplankton species tend to be more prevalent in certain environmental niches, the phytoplankton community composition can tell us about the environment they are growing in. For example, some cyanobacteria species prefer warmer, nutrient rich water.

Phytoplankton biovolume in Ponds 1 and 2 tended to be much lower than in Ponds 3 and 4 (Figure 14). A similar pattern is present in the Secchi transparency measurements with Pond 1 showing better clarity than Ponds 3 and 4. Secchi transparency was not measured in Pond 2 because the Secchi disk was visible to the bottom of the pond on all sampling dates. The results for the other measure of algal biomass, chlorophyll-a, are not presented due to analytical problems in the CLR laboratory.

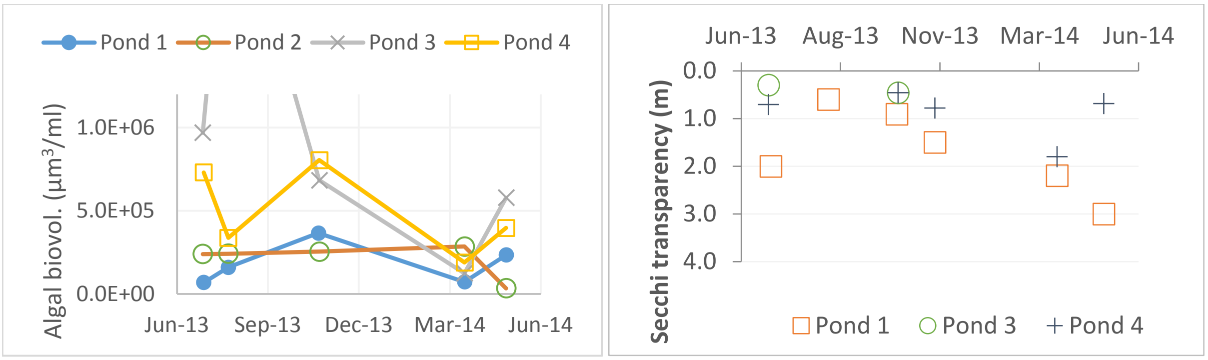


Figure 14. Algal biovolume (left) and Secchi transparency (right) in the Yoncalla Ponds. Biovolume of Pond 3 on July 23, 2013 was off scale at 2.6E+6 $\mu m^3/ml$.

Comparisons of trophic status estimates calculated from phytoplankton biovolume and total phosphorus concentrations indicate that biovolume in all ponds was lower than would be expected from the phosphorus concentrations (Figure 15). Biovolume trophic state indices (TSI's) suggest that all ponds are oligotrophic, while total phosphorus and Secchi transparency TSI's suggest meso- to eutrophic conditions. In Ponds 3 and 4 this discrepancy can be explained by two factors: 1) light limitation of algal growth due to high inorganic turbidity in the ponds, or 2) unavailability of a portion of the phosphorus due to the binding with inorganic turbidity particles. In Pond 1, algal growth may be light limited due to the brown humic color, phosphorus bound to humic materials, or nitrogen availability.

Phytoplankton species diversity over the entire survey period was much higher in Ponds 2-4 than in Pond 1 (Table 8). The difference in diversity is due to the higher numbers of Bacillariophyta (diatoms) and Chlorophyta (green algae) species in Ponds 2-4. Algal biovolume in Pond 1 was dominated by two species: the cryptomonad species *Cryptomonas erosa* and the euglenoid species *Trachelomonas volvocina* (Table 9). Cryptomonads are typical of small, nutrient enriched lakes and can handle low light condition like is found in Pond 1 (Reynolds 2006). Euglenoid species such as the benthic species *T. volvocina* are typical of small organic rich ponds and can tolerate low dissolved oxygen (Reynolds 2006).

Cryptomonads and euglenoids were also important in Ponds 2-4; however, other species such diatoms and green algae contributed substantially to total algal biovolume. Many of these species were benthic species entrained into the water column, including the filamentous green algae *Spriogyra sp*. and many benthic diatoms. During the July 2013 sampling event total biovolume in Pond 3 was dominated by two nitrogen fixing benthic diatoms: *Rhopalodia gibba* and *Epithemia turgida* (Prechtl 2004) which suggests that available nitrogen was in low supply. Very low biovolumes of two cyanobacteria genera were detected in Ponds 1-3. *Anabaena flos-aquae* and *Anabaena* sp. were detected in Pond 3. *Anabaena* sp. are capable of producing the cyanotoxins anatoxin-a, microcystin, and saxtoxin (Chorus and Bartram 1999). *Oscillatoria limosa*, *O. limnetica*, and *O.* sp. which are capable of producing anatoxin-a and microcystin were detected in Pond 1.

Table 8. Number of algal species detected in Ponds 1-4 by taxonomic group.

	Pond			
Group	1	2	3	4
Bacillariophyta	3	17	45	27
Chlorophyta	3	15	7	5
Chyrsophyta	4	5	6	3
Cryptophyta	2	3	2	2
Cyanophyta	2	2	2	0
Euglenophyta	2	3	2	3
Total # spp.	*17*	*47*	*67*	*44*

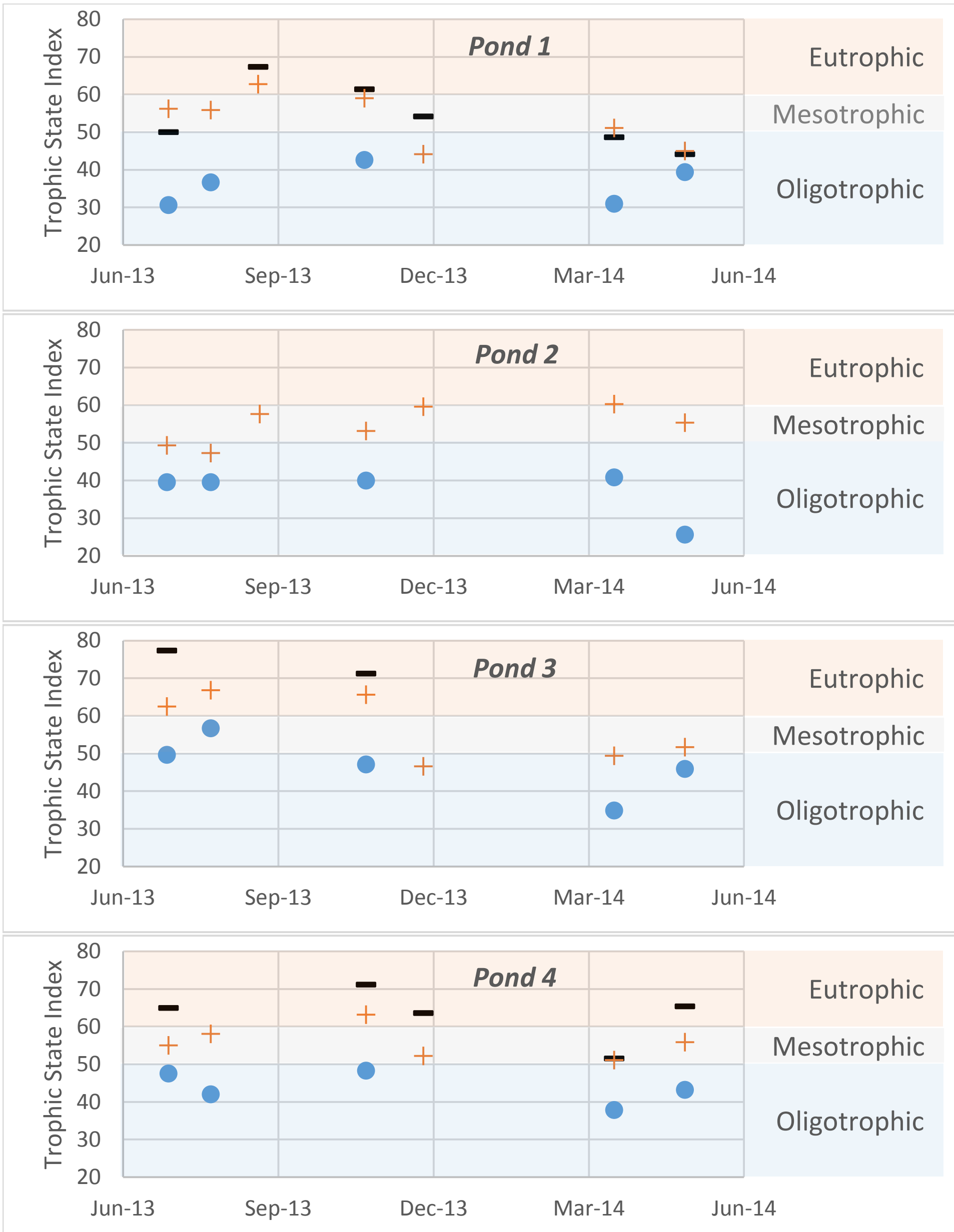


Figure 15. Trophic state indices of Ponds 1-4 calculated from algal biovolume (circles), Secchi (dashes) and TP (crosses).

Table 9. Dominant algal species (> 10% of total sample biovolume) in Yoncalla Ponds 1-4.

Site	Sample Date	Species name	Division	% of total biovolume
Pond 1	6/28/2013	*Cryptomonas erosa*	Cryptophyta	51
		Chlamydomonas sp.	Chlorophyta	30
		Trachelomonas volvocina	Euglenophyta	19
	7/23/2013	*Cryptomonas erosa*	Cryptophyta	63
		Trachelomonas volvocina	Euglenophyta	16
	10/22/2013	*Trachelomonas volvocina*	Euglenophyta	68
		Cryptomonas erosa	Cryptophyta	26
	3/19/2014	*Cryptomonas erosa*	Cryptophyta	59
		Trachelomonas volvocina	Euglenophyta	19
	4/30/2014	*Dinobryon sertularia*	Chrysophyta	66
		Trachelomonas volvocina	Euglenophyta	10
Pond 2	6/27/2013	*Cryptomonas erosa*	Cryptophyta	65
		Chlamydomonas sp.	Chlorophyta	13
	7/23/2013	*Spirogyra* sp.	Chlorophyta	34
		Glenodinium sp.	Pyrrophyta	24
		Staurastrum gracile	Chlorophyta	12
		Oscillatoria limosa	Cyanophyta	11
	10/23/2013	*Trachelomonas volvocina*	Euglenophyta	40
		Trachelomonas hispida	Euglenophyta	18
		Cryptomonas erosa	Cryptophyta	10
	3/19/2014	*Cryptomonas erosa*	Cryptophyta	78
	4/30/2014	*Trachelomonas robusta*	Euglenophyta	24
		Chlamydomonas sp.	Chlorophyta	18
		Fragilaria construens venter	Bacillariophyta	17
		Gomphonema subclavatum	Bacillariophyta	14
Pond 3	6/27/2013	*Euglena* sp.	Euglenophyta	25
		Cryptomonas erosa	Cryptophyta	17
	7/23/2013	*Rhopalodia gibba*	Bacillariophyta	57
		Epithemia turgida	Bacillariophyta	14
	10/23/2013	*Cryptomonas erosa*	Cryptophyta	39
		Euglena sp.	Euglenophyta	14
		Mallomonas sp.	Chrysophyta	12
	3/19/2014	*Cryptomonas erosa*	Cryptophyta	29
		Synedra radians	Bacillariophyta	22
	4/30/2014	*Spirogyra* sp.	Chlorophyta	94
Pond 4	6/28/2013	*Ceratium hirundinella*	Pyrrophyta	52
		Cryptomonas erosa	Cryptophyta	27
	7/23/2013	*Chlamydomonas* sp.	Chlorophyta	40
		Cosmarium sp.	Chlorophyta	20
		Trachelomonas volvocina	Euglenophyta	18
	10/23/2013	*Dinobryon sertularia*	Chrysophyta	55
		Chlamydomonas sp.	Chlorophyta	24
		Cryptomonas erosa	Cryptophyta	11
	3/19/2014	*Cryptomonas erosa*	Cryptophyta	76
	4/30/2014	*Cryptomonas erosa*	Cryptophyta	64

4.3.4 Zooplankton community

Zooplankton are important components of the food chain in lakes and ponds. Feeding by zooplankton on algae can structure the algal community. Some species are especially efficient algal grazers which can lead to increased water clarity. Zooplankton are also an important components of fish diets, particularly the diets of young fish.

Zooplankton densities in Pond 1 decreased over the course of the summer and increased through the spring (Figure 16). Zooplankton densities in Pond 3 were lower than the other ponds. Eleven cladoceran zooplankton species were found in the ponds (Table 10). Six of the species were found in all four ponds. *Bosmina longirostris*, a species common in open water and in littoral areas, was, on average, the most abundant species in Ponds 1, 2, and 4. *Daphnia rosea* was the most abundant species in Pond 3. Four copepod species were detected in the ponds. The most commonly encountered species, *Diacyclops thomasi*, is a common copepod species throughout the United States (Hudson and Lesko 2003). Numerous rotifer species were found in the ponds, particularly Pond 1. Rotifers are smaller zooplankton that consume algae and bacteria are a food source for larger zooplankton. Other zooplankton or zoobenthos found in the ponds included midge larvae (*Chaoborus* sp. and Chironomidae), ostracods (*Cypridopsis vidua*), worms (Oligochaeta) and freshwater polyps (*Hydra* sp.). Most of the zooplankton species encountered are associated with littoral habitats.

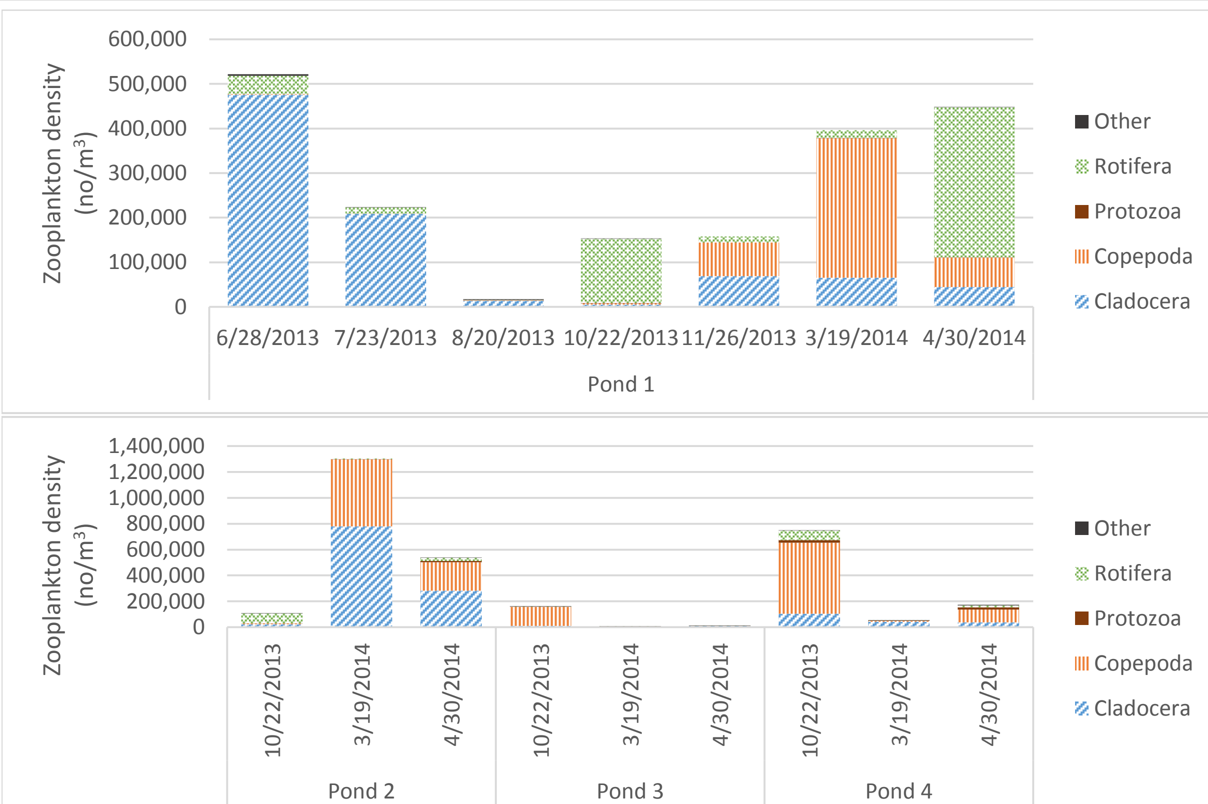


Figure 16. Zooplankton density by major taxonomic group

Table 10. Zooplankton species detected in Yoncalla Ponds. Densities are average values across all sampling dates for each pond.

		Average zooplankton density (no/m^3)			
Group	Species	Pond 1	Pond 2	Pond 3	Pond 4
Copepoda	*Diacyclops thomasi*	1623	11137	3850	12046
	Microcyclops varicans	1844	1070	204	
	Skistodiaptomus oregonensis	170	4380		340
	Macrocyclops albidus			16	2716
	Harpacticoids			6	
Cladocera	*Bosmina longirostris*	54877	100750	187	18286
	Ceriodaphnia dubia	9708	59588	70	255
	Daphnia rosea	866	54291	1536	10092
	Daphnia mendotae	1222	9167	366	1641
	Chydorus sphaericus	233	917	1210	788
	Alona costata	407	509	35	113
	Simocephalus serrulatus	170	68	48	
	Pleuroxus aduncus	11		48	
	Diaphanosoma brachyurum		509		
	Eurycercus lamellatus			99	170
	Macrothrix laticornis			16	
Rotifera	*Polyarthra vulgaris*	27639	4516	225	4312
	Conochilus unicornis	23428	509.3		
	Polyarthra major	11453	2547	12.7	
	Kellicottia bostonensis	9086	2037		
	Synchaeta sp.	4584	10390	226	747
	Platyias patulus	1324	204	6	
	bdelloid rotifer	1192		11	
	Keratella cochlearis	582			
	Collotheca pelagica	509			
	Ploesoma truncatum	509			
	Trichocerca cylindrica	509			
	Trichocerca elongata	407		6	
	Monostyla closterocerca	407			
	Filinia terminalis	170		6	
	Hexarthra mira	21			
	Keratella irregularis		23733	204	14696
	Asplanchna priodonta		102		
	Trichotria tetractis			143	
	Platyias quadricornis			6	
	Monostyla bulla				736
Other	*Difflugia* sp.1	350	3871	430	12291
	Difflugia sp.2				679
	Difflugia sp.3	413	306	19	57
	Chaoborus sp.	376			
	Chironomidae	69	34	27	815
	Cypridopsis vidua	501	289	731	905
	Hydra sp.			215	113
	Nematoda			16	
	Oligochaeta			48	169.8
	Hydrachnidae		34	16	340

4.3.5 Invasive animals

Like invasive aquatic plant species, invasive aquatic animal species can cause environmental and economic harm, and can pose a threat to human health (Pimentel et al. 2005). Zebra and quagga mussels (*Dreissena polymorpha* and *D. rostiformis bugensis*) are particularly notable examples of impactful invasive animal.

Two non-native aquatic animals were found during the benthic surveys (Table 11). A single Asian clam (*Corbicula fluminea*) shell was found in Pond 4. Asian clams can displace native freshwater clams and can compete for benthic food resources with other species (Sousa et al. 2008). The other non-native species detected, mosquitofish (*Gambusia affinis*), was common in Pond 4. Mosquitofish are often used introduced into ponds since they are thought to control mosquito larvae populations, but can have a negative impact on other native invertebrates (Pyke 2008).

One other clam species and at least five snail species were found in the ponds. The snail species were identified to genus and the clam was identified to the family level. Although we cannot be certain that these species are native, we did rule out the possibility that the species are known high impact non-native species. Several other types of animal species were collected during the benthic surveys including water beetles, leeches, and worms: none of which are known to be invasive species.

Table 11. Animal species detected in benthic sieve samples collected from Yoncalla Ponds.

Group	Common name	Species or lowest taxonomic group	Status	Pond 1	Pond 2	Pond 3	Pond 4
Molluscs	Asian clam	*Corbicula fluminea*	Non-native				X
	bladder snails	*Physella* sp.			X	X	X
	fingernail calms	Sphaeriidae family		X	X	X	X
	pond snails	*Lymnaea* sp.		X	X		
	ramshorn snails	*Gyraulus* sp.				X	
	ramshorn snails	*Menetus* sp.			X	X	X
	ramshorn snails	*Planorbella* sp.			X	X	
Fish	mosquitofish	*Gambusia affinis*	Non-native				X
Other	crane flies	Tipulidae family			X		
	leaf beetles	Chrysomelidae family		X			
	predatory diving beetles	Dytiscidae family		X			
	riffle beetles	*Stenelmis* sp.		X			
	water boatmen	Corixidae family				X	
	water mites	*Hydrachna* sp.			X		
	leeches	subclass Hirudinea		X			
	worms	subclass Oligochaeta		X		X	

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