Inventory of aquatic invasive species and water quality in lakes in the Lower Truckee River Region: 2013

by

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INTRODUCTION

The introduction of invasive species to aquatic ecosystems can be detrimental to the natural ecology of lakes and be responsible for regional and widespread economic loss. For example, the Laurentian Great Lakes have suffered plant invasions by Eurasian water milfoil (*Myriophyllum spicatum*) and zooplankton such as the Spiny waterflea (*Bythotrephes longimanus)*, both have altered natural ecosystem function, and displaced native species (Mills et al. 1994; Riccardi and MacIsaac 2000). More recently, zebra (*Dreissena polymorpha*) and quagga (*Dreissena bugensis*) mussels have entered the Great Lakes (Riccardi and MacIsaac 2000), and have continued to spread throughout the United States (Ludyanski et al 1993; Stockstad 2007) causing ecosystem wide consequences (Hecky et al. 1994; Ludyanski et al. 1993), and economic loss (Leung et al. 2002; Pimentel et al. 2000).

The introduction and establishment of aquatic invasive species throughout the Truckee River region of California and Nevada is of growing concern to resource managers and threatens the regions ecological integrity. Recent research from the region, conducted largely within Lake Tahoe, suggests that invasives cause both ecological and economic impacts (Kamerath et al. 2008; Vander Zanden et al. 2003). For example, the recent introduction of Asian clam (*Corbicula fluminea*) is thought to facilitate increases in algal blooms in the southeastern part of Lake Tahoe and have a variety of negative effects (Sousa et al., 2008). While, invasive plants such as water milfoil (*Myriophyllum spicatum*) can alter nearshore habitats and facilitate the invasion of other species such as warmwater fishes which have drastic impacts on lake ecology (Kamerath et al. 2008). The invasion of species which is facilitated by previous non-natives has been described as “invasional meltdown” and can cause catastrophic shifts in ecosystems (O.Dowd et al. 2003)

The majority of the lakes in the Truckee River Watershed have resisted invasion by many of the exotic species (Rammer and Chandra 2010). However, as aquatic nuisances continue to spread to the western United States (e.g. dreissenid mussels in Lake Mead; Stockstad 2007) they are a risk to lakes and a concern to resource managers in the Truckee River watershed. Dreissenids have been known to significantly impact water quality, resulting in large scale economic damage by clogging water intake pipes and reducing recreational activity when they establish. Given the ability of dreissenids to spread between systems and the extensive boat traffic (a common vector for aquatic invasions) in the Truckee River watershed, the potential for the establishment of invasive mussels could be significant (Wittmann et al. 2009; Umek et al. 2009).

Researchers have attempted to predict the potential of dreissenid invasion using varying parameters such as ecosystem depth, substrate size and other physiochemical factors (Bossenboeck et al. 2001; Drake and Bossenboeck 2004, Whittier et al. 2008). For example, Jones and Riccardi (2005) used depth, substrate size, and calcium concentration to model the distribution of dreissenids in the St. Lawrence River, and suggest that all 3 variables play a role in zebra mussel colonization, while only depth and sediment size are important for quagga mussel establishment, indicating that zebra mussels are more dependent on water calcium levels. The concentration of calcium in the waters of the Truckee River region is low (Rammer and Chandra 2010) and suggests that mussels may not be as likely to invade these ecosystems (Whittier et al. 2008). However, with the recent invasion of Asian clams to the ultra-oligotrophic and low calcium waters of Lake Tahoe and Donner Lake (Rammer and Chandra 2010), mussels may be able to survive if transported to the Truckee River watershed (Chandra et al. 2009).

Currently, boat inspection stations have been put in place along the Truckee River and lakes in the region to minimize the risk of transporting species. To date, these inspections have been effective. However, in the event of a species invasion, it is important to document them as soon as possible to notify managers and the public and reduce the risk of transporting to other water bodies.

The objective of this project is to identify water bodies within the Truckee River region (Donner Lake, Stampede Reservoir, Boca Reservoir, Prosser Reservoir) that have already established invasive invertebrate and plant communities, and to identify and document recent or new invasions. This is year three of the project and builds upon data collected in 2010 (Rammer and Chandra 2010), 2011 (Caldwell and Chandra 2011) and 2012 (Caldwell and Chandra 2012). Specifically, our goals were to

1. Use the method developed by Rammer and Chandra (2010) to continue shoreline surveys for invasive invertebrates (Dreissenid mussels, New Zealand mudsnail, Asian clam, and crayfish) and invasive plant (Hydrilla, Curly leaf pondweed and Eurasian water milfoil) species.
2. Sample lakes for the DNA of dreissenid mussel veligers to document invasions using zooplankton net hauls.
3. Quantify the concentration of calcium in the eplimentic waters of each lakes.

METHODS

Study Sites

During the summer of 2013four lakes that represent the major recreational water bodies in the Truckee River Watershed region were chosen for invasive species assessment (Table 1). All four lakes (Boca Reservoir, Stampede Reservoir, Prosser Reservoir, Donner Lake) are located in California (Figure 1). These lakes were chosen because of the high frequency of recreational use, and frequent movement of boats between these lakes.

Water quality and limnological profiles

An index sampling station at the deepest part of the lake was selected to determine the physical and chemical nature of each lake. Secchi depth was taken at this location using a standard 30cm multi-colored (black and white) secchi disk. The disk was lowered until it was unable to be seen by the naked eye, and raised till it could be seen again. The mid-point between these two depths was considered the secchi depth. This process was repeated twice by two different people. A handheld YSI-85 meter (YSI Incorporated, Yellow Springs, Ohio) was used to determine a quantitative profile for temperature, dissolved oxygen, and specific conductivity twice from July to October in.

Epilimnetic water samples were collected from each lake to analyze for calcium (Ca) twice during the year (early summer, late summer). All calcium samples were placed on ice and transported back to the University of Nevada. Each sample was filtered through a 0.7µm Glass Fiber Filter (GFF), then through a 0.45 µm magna-nylon filter. Samples were frozen and shipped overnight to the University of California–Davis plasma mass spectrometry center for analysis.

Adult invasive invertebrate and plant surveys

A protocol was developed to survey lake shoreline area for adult invasive species and invasive plants (Rammer and Chandra 2010). Shoreline area sight surveys were conducted via boat or on foot, depending on feasibility, along the entire lake shoreline. When boating was required, a 14 ft rowboat was driven at a slow and constant speed around the shore. Fifteen transects were chosen in each lake for a detailed evaluation. Transect locations were chosen based on areas where invasive mussel and clam species were likely to be found (i.e., boat launches, public docks, and other hard substrates). Because lake habitat is heterogeneous, our secondary consideration was to choose transects that would be representative of habitat variability in each system. GPS coordinates were recorded for each transect and the location described.

At each transect, a 5 m^2 section was closely examined for the presence of invasive species and evaluated for substrate composition. Within each section, rocks were uprooted and examined for mollusk species and sand was dug up by hand and examined for New Zealand mud snails. Unknown plants and invertebrates were collected and taken back to the laboratory for identification. At each transect, the location, substrate composition, and percent of area where invasive species were present (when applicable) was recorded. Wentworth's substrate guide (1922) was modified and used to qualitatively define general substrate types present at each transect.

Quagga and zebra mussel veliger detection

Plankton tows were used to detect the presence of zebra and quagga mussel veligers during 2013. During the season each lake was sampled twice following a standard protocol developed by California Fish and Game (CFG 2008). Samples were sent to the California Fish and Game (CFG) laboratory for analysis within the time allotted in the CFG protocol. A 64 micron, 30 cm diameter plankton tow net was used to sample for dreissenid veligers at various locations (high use areas such as boat launches) within each lake. Combinations of vertical and horizontal tows were used depending on water depth and sampling location. Each sample was composed of 2-3 tows from the same location and stored in a 25% by volume 95% reagent grade (non-denatured) ethanol (ETOH) solution. To prevent possible contamination between lakes, all sampling equipment was soaked in vinegar, rinsed, and dried between samplings (California Fish and Game, 2008).

Crayfish population dynamics

To collect the introduced crayfish (*Pacifastacus leniusculus*), baited minnow traps were set twice (July and Sept/Oct) along depth transects (1m, 5m, 10m) overnight during summer of 2013. Catch per unit effort (CPUE) was calculated by dividing total catch by the effort (hours) fished. To determine the size class distribution of crayfish, carapace length was measured using digital calipers to the nearest 0.00mm. Crayfish populations were compared among lakes using one-way Analysis of Variance (ANOVA) and statistical groups were formed using Tukeys Honest Significant Difference (HSD). All statistics were carried out using R (version 3.0.2).

RESULTS

Water quality and limnological profiles

The majority of the lakes surveyed were thermally stratified by the late June/early July sampling event (Figure 2). This trend is different from the first year of study in this project (2010) when lakes were not stratified until July (Appendix A), but similar to the previous 2 years (2011,2012) this is likely related to the minimal snow pack and early onset of high temperatures early in the season during 2013. Dissolved oxygen levels were typically 6-8 mg/L in the epilimentic waters of the lakes and generally declined with depth, especially in Stampede where levels were approximately 2 mg/L below 15m. Conductivity was low (<60 µS) in the all of the lakes sampled, and varied slightly over time (Figure 2).

Secchi disk readings are presented in Table 2 and were comparable to readings which were taken in 2010 and 2012 (Table 2), suggesting that productivity levels have been consistent in recent years.

Adult invasive invertebrate and plant surveys

Invasive species were detected in 1 of the 4 lakes which were surveyed during 2013 (Table 2). Asian clams were detected in several parts of Donner Lake and appeared to have spread from the initial clam patch described in 2010 (Rammer and Chandra 2010). This has been confirmed by other surveys done by other agencies (Dan Shaw, personal correspondence, California State Parks). Patches of clams were detected along the state park beach, and near the outlet at the east end of the lake. Zebra mussels (*Dreissena polymorpha*), quagga mussels (*Dreissena rostriformis*), New Zealand mudsnails (*Potamopyrgus antipodarum*) and hydrilla (*Hydrilla verticillata*) were not detected in any of the study lakes (Table 3). However, New Zealand mudsnails were detected in the lower Truckee River (Chris Crookshanks, personal correspondence, Nevada Deparment of Wildlife) during Summer of 2013. Shoreline invasive species survey data can be found in Appendix A. A variety of substrates and high use areas were surveyed over the course of the year (Appendix A).

Quagga and zebra mussel veliger detection

Veliger DNA or veligers (via microscopy) were not detected in any of the lakes sampled (Donner, Stampede, Boca, Prosser, Marlette, Martis Creek Lake, Spooner, and Independence) during 2012 (Table 3), or since this monitoring program began in 2010.

Calcium levels and dreissenid mussel invasion potential

Epilimentic calcium concentrations were low (< 10ppm) in the lakes surveyed during 2013 (Table 4). The concentration of calcium increased in Boca, Donner and Prosser between the earlier (late June/early July) and the latter (late Sept/early Oct) sampling periods (Table 4). This is in contrast to data collected during 2011 (Caldwell and Chandra 2011), when calcium concentrations were similar during the entire period of study. The trend observed this year was similar to the data collected during 2010 and 2012, which showed a decrease in calcium concentration inter-annually (Rammer and Chandra 2010, Caldwell and Chandra 2012). The inter-annual increase in calcium concentration during 2010, 2012 and 2013 is likely caused by lower water levels typically observed at the end of the season. Because snowpack was high, water level remained high throughout the year during 2011 and is a potential explanation of why this pattern was not observed during that year.

Calcium data has been collected since 2010 in the majority of these lakes. This data suggests that the concentration of calcium in some of these waters has been decreasing since 2010. However concentrations increased again this during this sampling period (Figure 3). For example in Boca reservoir the concentration has decreased from 8.04 ± 1.73 ppm in 2010 to 4.85

± 0.98 ppm in 2012, but has increased this year to 6.47 ± 0.73 ppm, this trend was similar among all lakes that were surveyed during 2013 (Figure 3). The intra-annual dynamics of calcium concentrations in lakes are difficult to understand but are likely related to weather patterns of each year, lake levels, and geology of the lake, these relationships deserver further investigation.

Crayfish population dynamics

The lowest catch per unit effort (CPUE averaged across depths) recorded for crayfish was at Boca Reservoir, (0.16±0.09 CPUE; Figure 4), which corresponded with the highest mean carapace length (Figure 5). Catch per unit effort was highest at Stampede Reservoir (1.33±0.33 CPUE; Figure 4) and was significantly higher than both Boca and Prosser Reservoirs. CPUE generally increased in all lakes from 2012 to 2013 (Figure 6). Crayfish carapace length ranged from 37.3 ± 0.63mm (Donner Lake) to 54.8 ± 1.07 mm (Boca Reservoir; Figure 5). The average carapace length was significantly different between each lake studied during this survey period.

DISCUSSION

Status of invasive species

The results of the invasive species shoreline surveys suggest that no new invasive species have arrived since 2010. Additionally, veliger DNA has yet to be detected in any of the lakes indicating that dreissenid mussels have not yet established in the lakes surveyed. Although we have not detected any new species in these lakes, non-native species invasions are still occurring globally at an increasing frequency (Chandra and Gerhardt 2008; Lodge et al. 2006; Mills et al. 1994, Vanderploeg et al. 2002). Thus, the risk of an invasion by known aquatic nuisance species (e.g. *Bythotrephes*; Yan et al. 2002) and un-known species in these lakes is still present and the consequences of these introductions could be significant. For example, the introduction of a predatory cladoceran (*Bythotrephes*) could cause havoc in the food web and have serious impacts on the recreational fisheries (Yan et al. 2002). The use of voluntary boat inspections and public outreach by the TRCD has likely been pivotal in preventing any new invasions in these lakes, and both are highly recommended to continue.

This project provides baseline data on the status of invasive species in the lakes of the Truckee River Watershed, and is important to continue this monitoring to document any new invasions. Knowledge of the time of invasions can give researchers and managers the opportunity to document changes in lake processes caused by the invasion of exotic species, allowing for better management and control.

Certain lakes with limited access (e.g. Marlette Lake, Independence Lake) are at a reduced risk of an invasion of by aquatic nuisance species, thus we eliminated them from this year’s surveys and only sampled and surveyed Donner Lake, Boca Reservoir, Stampede Reservoir, and Prosser Reservoir.

Calcium levels and dreissenid mussel invasion potential

Invasive dreissenids, zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis*) mussels, have altered the ecology of lakes and rivers by coupling pelagic and benthic energy pathways, increasing offshore clarity, stimulating benthic production and altering biodiversity (Makarewicz et al. 1999, Bially and MacIssac 2000, Nalepa and Schloesser 2013, Ricciardi et al. 1998). In recent years there has been a western range expansion in North America of mussels and it first appeared in western U.S. in Lake Mead, AZ-NV in early 2007 (Stokstad et al. 2007) and has subsequently been found in other major western impoundments including Lakes Powell and Mohave. The costs of the invasion are already apparent, as the Southern Nevada Water Authority has spent approximately $32 million (US dollars until 2009) to manage quagga biomass impacts on the water intake infrastructure of Lake Mead, a recently invaded reservoir in the Western U.S. (Peggy Roefer, Southern Nevada Water Authority, pers. communication). These recent invasions have spurred efforts to determine invasion risk posed by zebra and quagga mussels in western waters.

Risk assessment models have been used to determine the potential for dreissenid mussel establishment in bodies of water. However, these approaches have been based on European and Eastern North American invasions that may or may not be appropriate for evaluations of western water ways. Risk assessment for the western U.S. can be based on these approaches, but must be interpreted with caution and careful consideration given the differences between eastern and western waters. Water column calcium concentration is often used as an index for determining the potential for dreissenid establishment, growth, and reproduction with variable requirements depending on the species (Ramcharan et al. 1992, Sousa et al. 2008, Whittier et al. 2008). However, in western waters such as Lake Mead determining what drives quagga populations has been difficult (Wittmann et al. 2011, Caldwell et al. *in review*). Food availability is also an important variable for mollusk establishment, and is often the cause for massive dreissenid mussel population crashes after initial population explosions (Strayer et al. 1996). Since the recent establishments in Lakes Mead, Powell and Mohave, numerous studies are underway to determine zebra and quagga mussel invasion risk to Western waterways. Based on empirical information gathered from water quality databases and modeled systems, Whittier et al. (2008) created a watershed-scale risk model for dreissenid species. This model is based on calcium requirements, primarily derived from zebra mussel data due to limited experimental data on quagga mussel survival. Managers have used this model to determine the risk-potential of quagga mussel establishment from invaded water bodies such as Lake Mead. Because quagga mussels appear to have different environmental tolerances than zebra mussels, (Jones and Riccardi 2005, Baldwin et al. 2002, Nalepa and Schloesser 2013, Spidle et al. 1994, Stoeckmann 2003, Roe and MacIssac 1997, Zhulidov 2004), and possibly in other parts of their range (Domm et al. 1993, Antonov and Shkorbatov 1990), the potential risk of invasion to western water bodies may be underestimated by using zebra mussel-based risk assessments.

We measured calcium levels and used existing literature to determine the invasion risk of each ecosystem based on these levels using Whittier's (2008) model to suggest the risk of invasion and comparing to an adult survival study using Lake Tahoe water by Chandra et al. (2009). Whittier et al. (2008) used literature-based calcium thresholds in create a broad scale, landscape-level approach to determine survival probability for dreissenid mussels in Western watersheds. Thresholds were established based on calcium limitations of zebra mussel, since little calcium-based survival information existed for quagga mussel. Thus, these authors assumed that zebra and quagga mussel requirements were similar because of the genetic proximity of these two closely related taxa. Their findings are still useful however for a 1st order estimate of the invasion potential by dreissenids but should still be interpreted with caution when applying them to lakes in the Truckee Watershed. They defined risk based on calcium concentrations as: very low (< 12 mg L^{-1}), low (12–20 mg L^{-1}), moderate (20–28 mg L^{-1}), and high (> 28 mg L^{-1}). According to their risk categories, the water bodies with "very low" risk during 2013 include Stampede, Boca, Prosser, and Donner. Although in 2010 Stampede was marginal in concentration and could be placed in the low category (Rammer and Chandra 2010), this was not the case in 2011 (Caldwell and Chandra 2011), and declined even further in 2012 (Caldwell and Chandra 2012). During this year all lakes surveyed increased in calcium concentration since 2012 and is likely and effect of low water levels in the basin during the last two years. In previous years Spooner Lake has had a relatively high (<25ppm) concentration of calcium when compared to other lakes in the basin. This is likely caused by its proximity to a major highway, run-off of various road way bi-products may be the driver of these high calcium concentrations.

In contrast to the Whittier and colleagues risk assessment however, we also utilized another study assessing adult survivability based on Lake Tahoe waters which contain approximately 13 ppm calcium. Chandra et al. (2009) suggests that after a 51 day exposure, quagga adults survive, exhibit positive growth, and may have the potential to release gametes. This study did not have the funding to follow the reproductive cycle of the mussels to determine if they could produce mature veligers. They suggest that the occurrence of veligers in the low calcium waters of Colorado Lake which are similar to the Truckee River Region suggest the potential for some viable production. A more comprehensive experiment is ongoing to determine the viability of quagga mussel adults and veligers in Tahoe water, which can then be applied to lakes in the Truckee Basin.

According to Whittier's (2008) risk assessment based on the concentration of calcium in the water column, the majority of systems surveyed in Truckee River Watershed were at relatively low risk for the invasion of dreissenids during 2013. Because this assessment was developed using a biased amount of data for the zebra mussel, it is likely that quagga mussels have different requirements (Jones and Riccardi 2005, Chandra et al. 2009). It is unclear, if adult quagga mussels can reproduce in calcium limited systems, making it difficult to accurately assess their potential to establish in the Truckee River Watershed Lakes. To develop more accurate assumptions research should be devoted to dreissenid reproduction in low calcium waters, and include parameters other than calcium (pH, substrate size, nutrient limitation, food quality, etc.), to lead to better preventative measures, and a decreased chance of dreissenid establishment.

Rammer and Chandra (2010) analyzed the concentration of calcium in sediment pore-water and found variability within each lake. In this study, we chose to examine the variability of concentration in sediment pore-water in Donner Lake because of the presence of Asian clams in the lake. We hypothesized that Asian clam distribution may be influenced by the concentration of calcium in sediment pore-water or in epilmentic waters. Results from the 2011 study suggest homogeneity of calcium in the sediment pore-water in Donner Lake and no clear pattern was observed between location of clams and density of calcium (Caldwell and Chandra 2012). In contrast to Rammer and Chandra (2010), the calcium concentration in the water column and in the sediment was similar in Donner Lake during 2011 (Caldwell and Chandra 2012), however this could be an artifact of a high water year in 2011. We replicated the study during 2012 and saw similar results to 2011. This suggests that there are other drivers influencing the distribution of Asian clams in Donner Lake besides the concentration of calcium in the epilimnetic waters and the sediment pore-water. Given the similarity of the results during the last two years we did not replicate this study this year. However, Asian clam populations are expanding in Donner Lake (Dan Shaw, California State Parks, personal communication), and calcium content in and around clam beds in the lake should be monitoring in the future. Increased densities of Asian clams may result in nutrient and potentially calcium concentrations in regions where they are located, with the potential to facilitate other invasions.

Crayfish population dynamics

The variability in CPUE between years is likely influence by lake productivity levels, along with year-specific water levels. However some trends have been observed, for example, Boca reservoir had the highest average size but lowest CPUE during 2013, and was also the case in 2012 (Caldwell and Chandra 2012). While in Stampede reservoir and Donner Lake CPUE was higher but size was lower. The significance of these patterns is not yet understood, but could indicate because of a smaller population in Boca, there is more food available for higher growth, while the opposite may be the case in Stampede Reservoir and Donner Lake.

Crayfish were likely introduced to these systems to increase fish production sometime during the late 1800's and early 1900's, about the same time they were introduced into Lake Tahoe, CA (Abrammason and Goldman 1970). Crayfish have the potential to play a role in the flow of energy and nutrients throughout the system often having positive and negative impacts on both algal production and benthic invertebrate production and diversity (Flint and Goldman 1975). At low densities (0.16 ind/m^2), Flint (1975) showed that crayfish can stimulate periphyton production by removing old senescent cells, while at higher densities (1.05 ind/m^2) they reduce periphyton potentially reducing food for benthic invertebrates. Additionally, crayfish excretion experiments by Flint (1975) indicate that they are a source of nitrogen to the lake, and can result in increased periphyton production. Given the variety of effects grazing can have on periphyton production, along with their impact on the flow nutrients (Flint 1975; Lodge et al. 1994), the overall role of crayfish in benthic primary production is still not well understood. Thus, their role in primary production in these lakes may be significant and could impact a variety of lake variables, including clarity, and producitvity.

Table 1. Basic morphological characteristics of the 2013 Truckee River region study lakes.

Lakes	Max Depth (m)	Surface Area (ha)	Shoreline (km)
Donner	70.0	390.0	12.07
Stampede	52.0	1351.7	40.2
Boca	24.0	396.6	24.14
Prosser	24.0	303.5	17.7

Table 2. Secchi depth measurements from the Truckee River region lakes during 2010, 2012, and 2013.

LAKE	DATE	SECCHI (m)
Donner	7/6/2010	9.0
	8/16/2010	12.2
	9/15/2010	12.2
	8/23/2012	12.9
	10/2/2012	12.5
	6/27/2013	6.4
	10/1/2013	NA[1]
Stampede	7/7/2010	6.5
	9/13/2010	5.3
	6/13/2012	6.2
	8/17/2012	3.1
	9/26/2012	4.8
	7/1/2013	6.0
	10/1/2013	2.0
Boca	7/14/2010	5.8
	9/13/2010	4.5
	6/13/2012	3.1
	8/8/2012	NA[1]
	9/24/2012	2.5
	6/26/2013	6.5
	9/4/2013	4.0
Prosser	7/17/2010	5.2
	9/13/2010	4.2
	6/13/2012	6.1
	8/7/2012	4.2
	9/27/2012	4.1
	7/2/2013	3.9
	10/1/2013	2.0

Table 3. Invasive plants and adult invertebrates present in Truckee River region lakes in 2010,2011, 2012, and 2013 as determined from UNR shoreline surveys and CFG visual surveys. Species presence is denoted by “X.” A blank space indicates no species were found during the surveys.

	Adult Invertebrates				**Plants**	
Lakes	**Quagga**	**Zebra**	**NZMS**	**Corbicula**	**EWM**	**Hydrilla**
Donner				X		
Stampede						
Boca						
Prosser						

Table 4. Concentration of calcium (ppm) in the epilimnetic waters of lakes in the Truckee River region during 2013.

Lake	**Date**	**Mean(ppm)**	**SE**
Boca	6/28/2013	4.79	1.43
Boca	9/4/2013	6.02	0.46
Donner	6/27/2013	2.25	0.54
Donner	9/30/2013	5.32	0.63
Prosser	7/2/2013	4.64	0.46
Prosser	9/30/2013	5.24	0.52
Stampede	7/1/2013	5.85	0.35
Stampede	9/4/2013	5.69	0.54

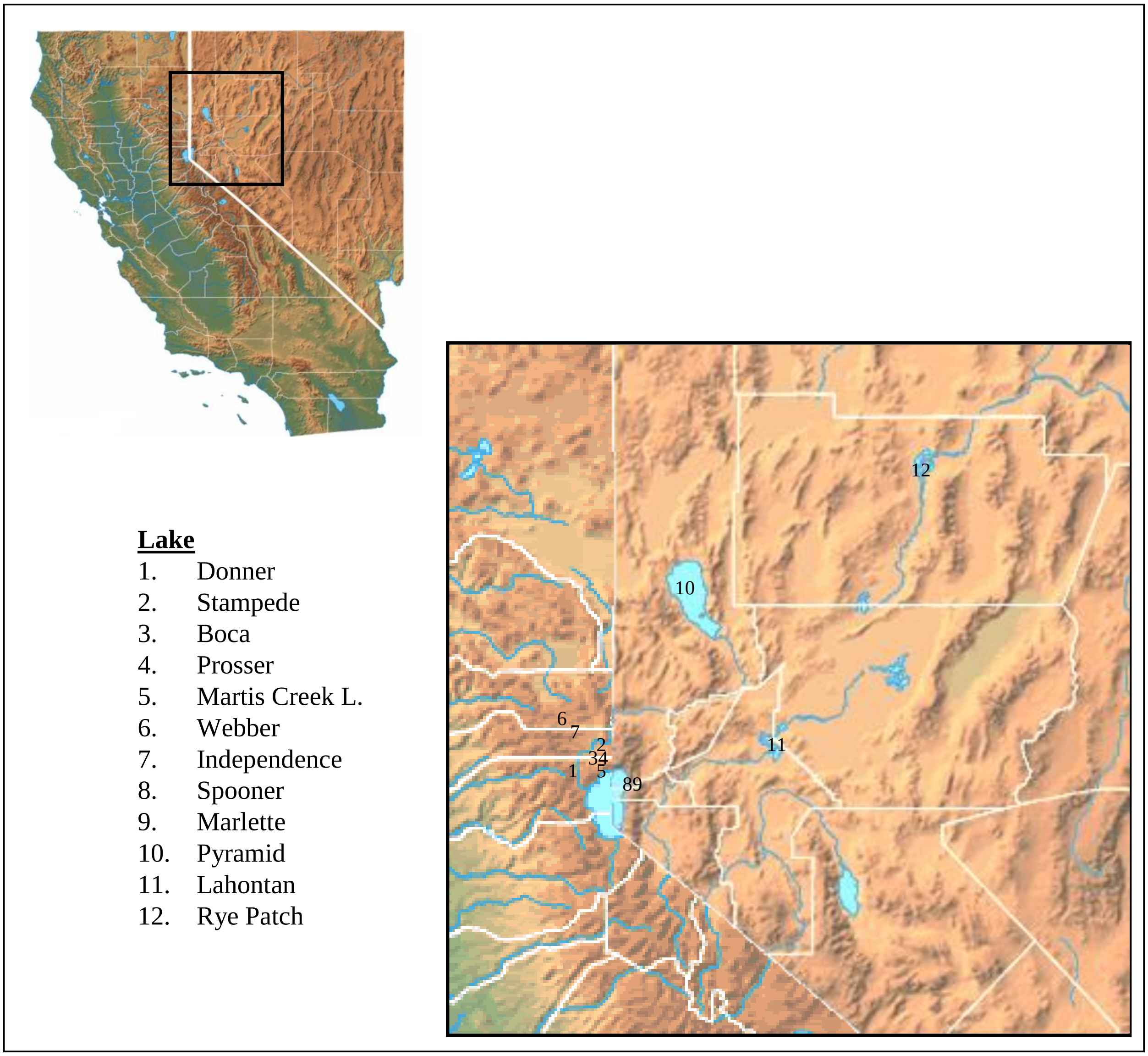
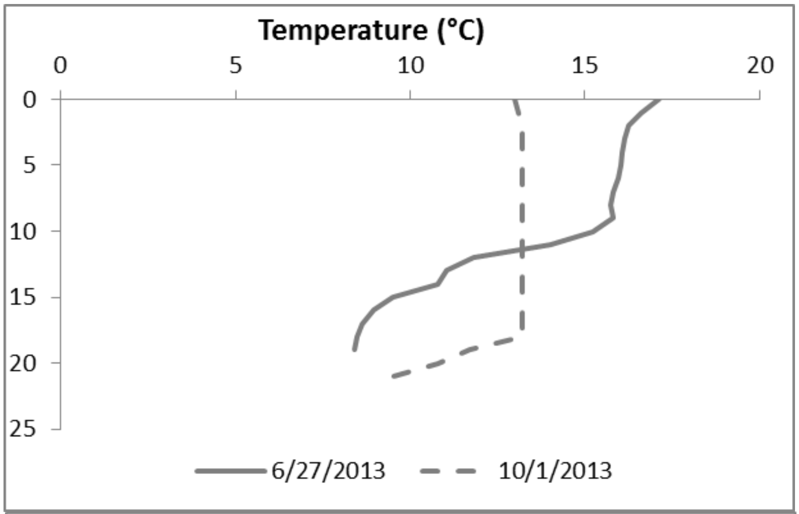
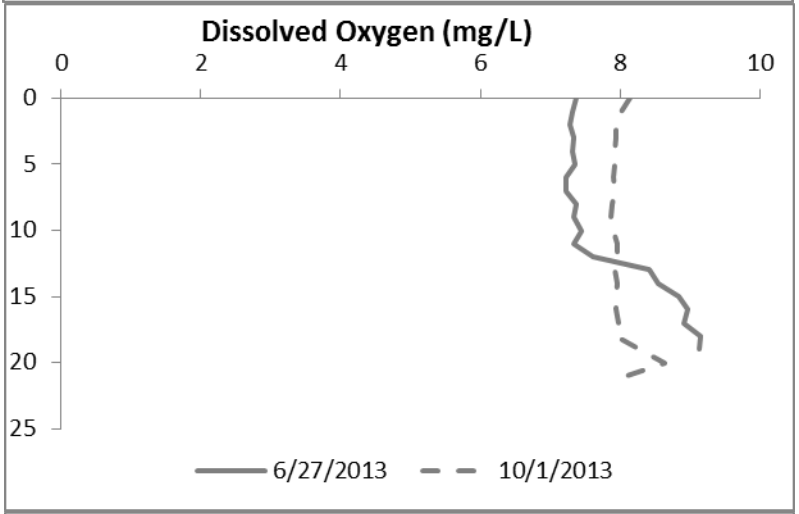
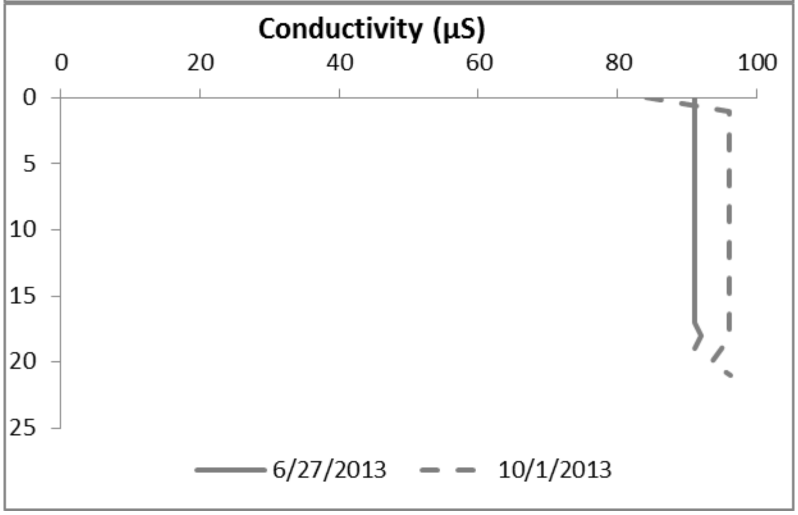


Figure 1. Truckee River Watershed and location of study lakes within the watershed.

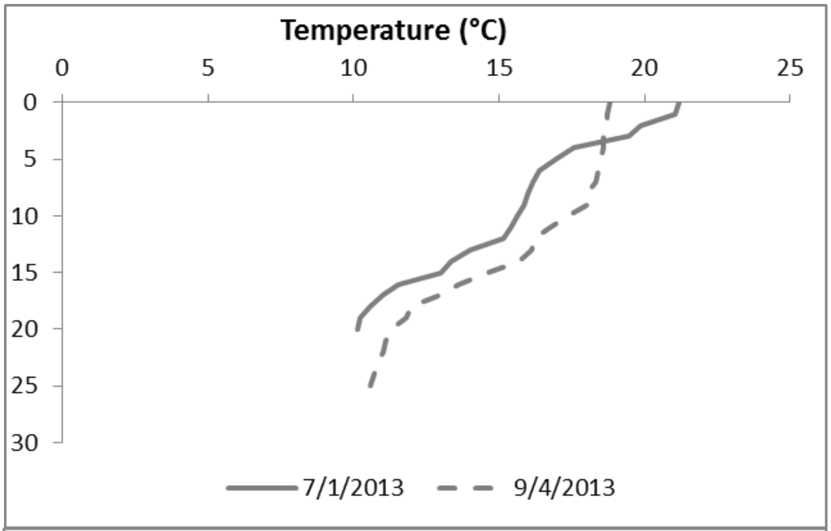
A. Donner Lake

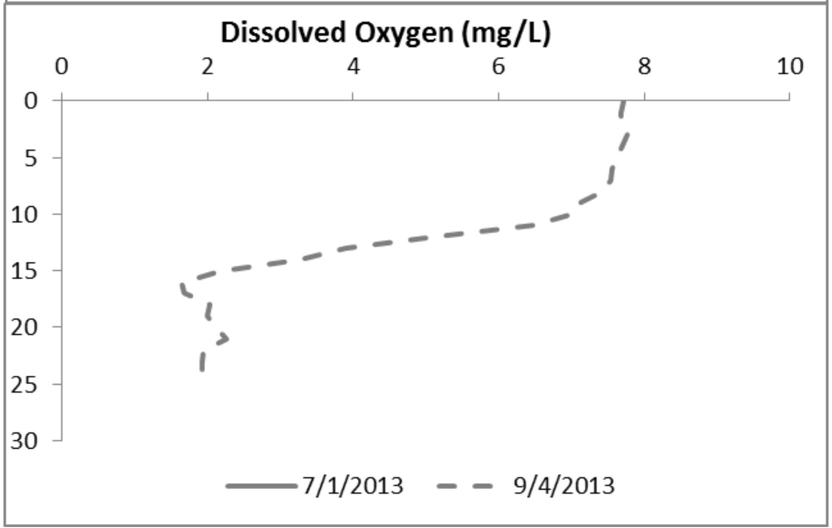


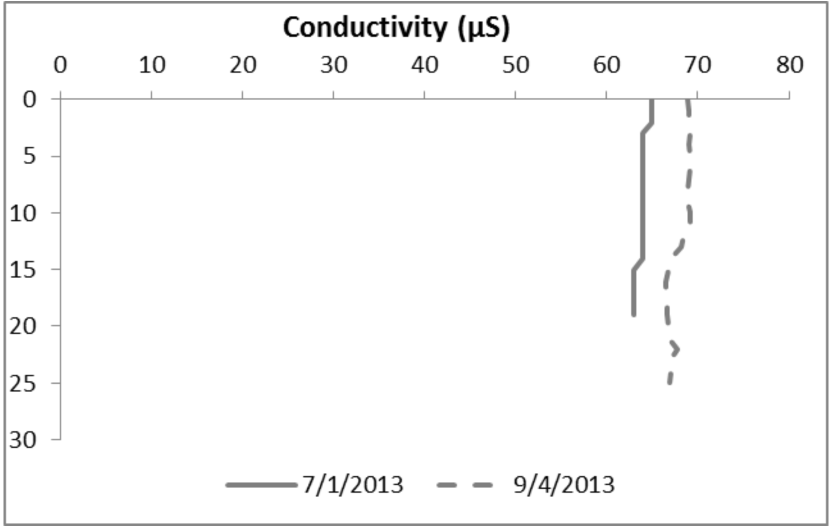




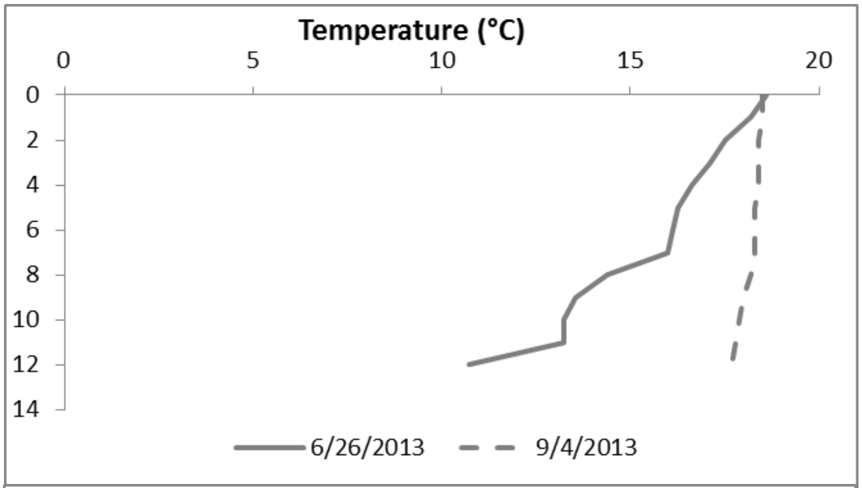
B. Stampede Reservoir

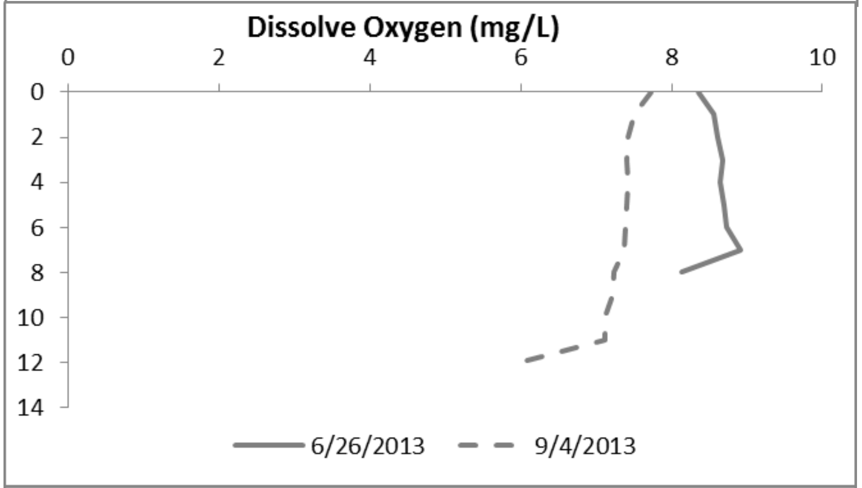


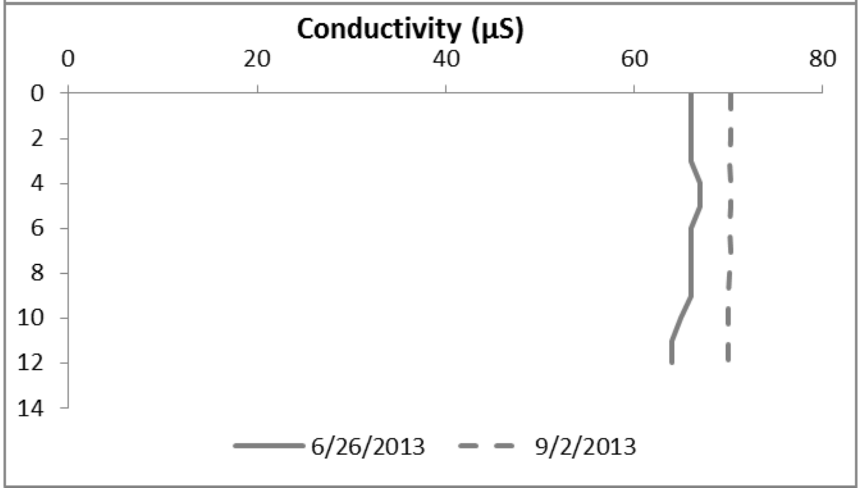




C. Boca Reservoir







D. Prosser Reservoir

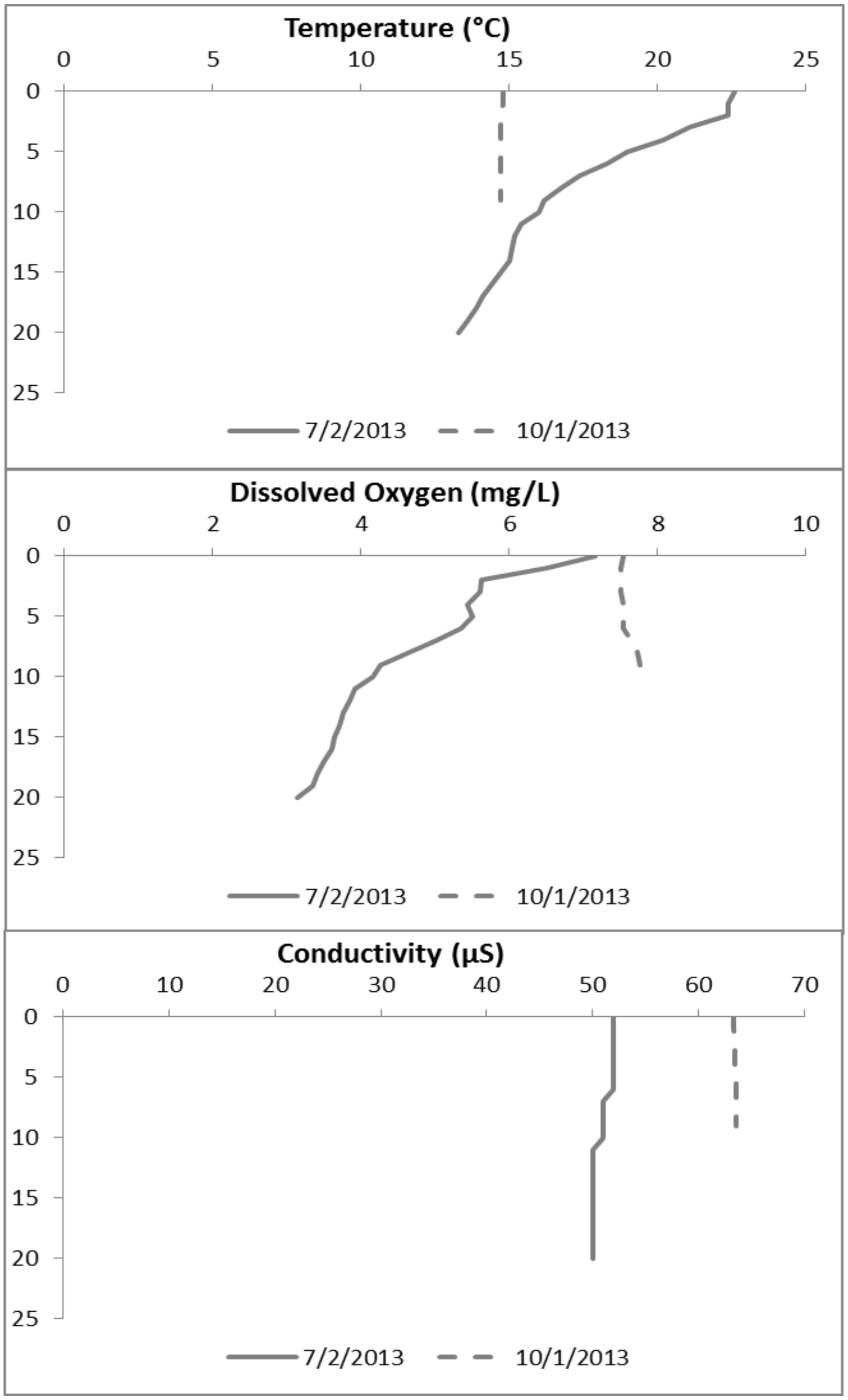


Figure 2. Temperature, dissolved oxygen and conductivity profiles for lakes in the Truckee River region during 2013, A. Donner Lake, B. Stampede Reservoir, C. Boca Reservoir, and D Prosser Reservoir. Dissolved oxygen was unavailable for Stampede during September due to probe malfunction.

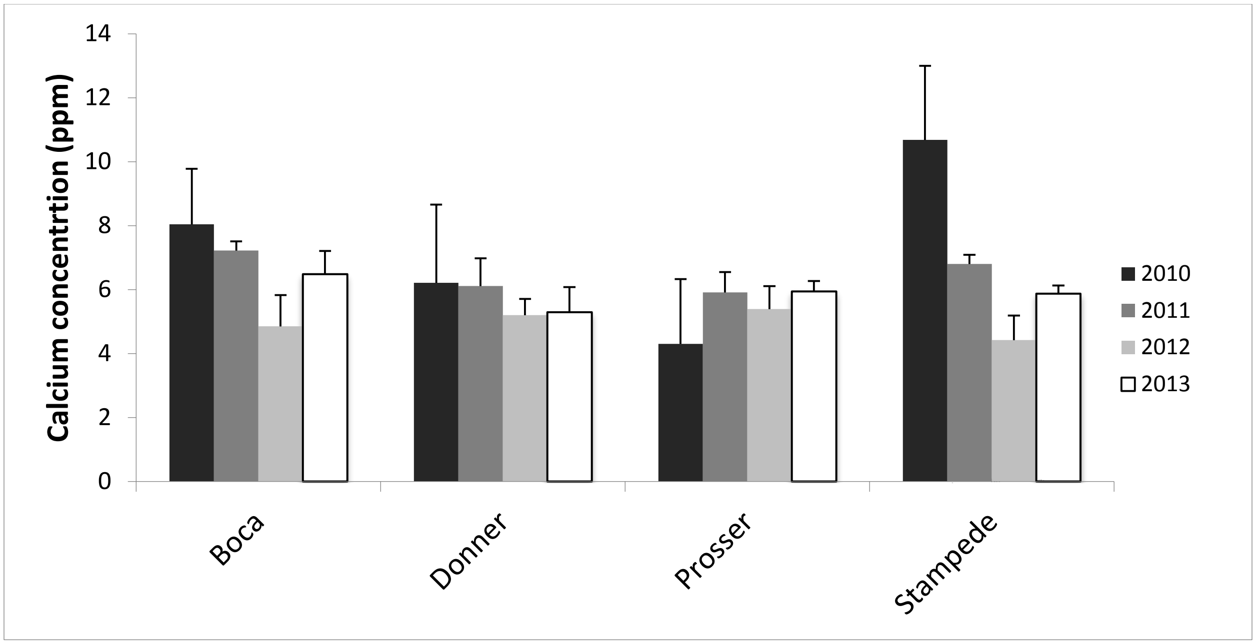


Figure 3. Mean concentration of calcium in the epilimnetic waters of the Truckee River Watershed lakes, from 2010, 2011, 2012, and 2013.

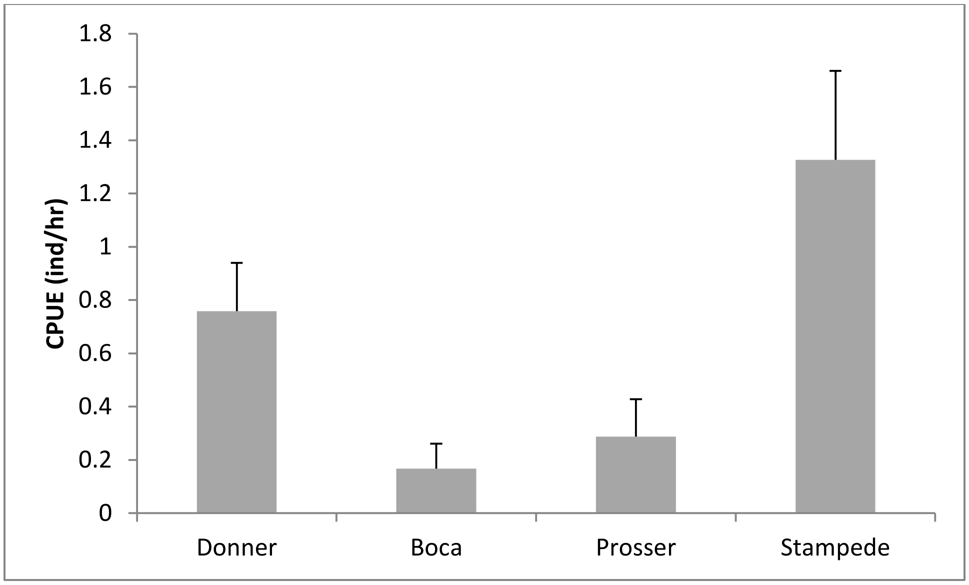


Figure 4. Catch per unit effort (CPUE) for crayfish in the lakes in the Truckee River lakes region. Stampede was significantly higher than Boca or Prosser (Tukeys HSD, p<.05).

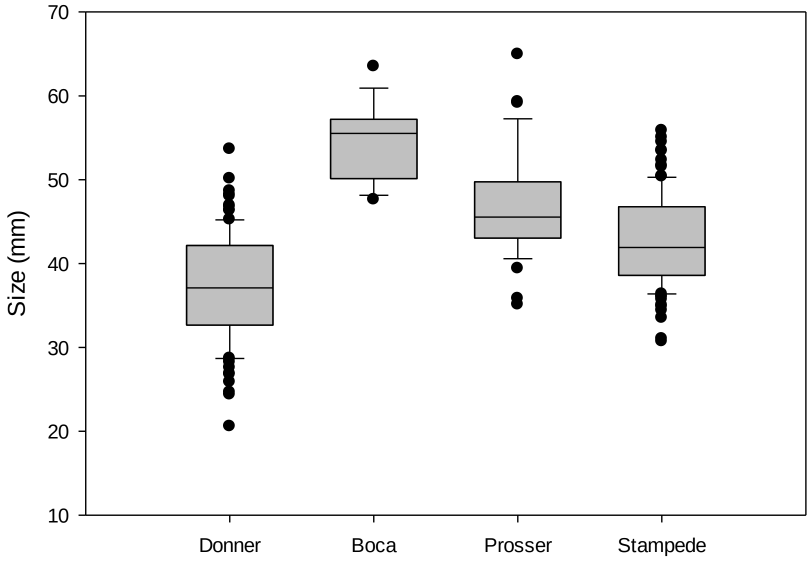


Figure 5. Size distribution of crayfish carapace size (mm) in lakes in the Truckee River region, all lakes were statistically different from each other (Tukeys HSD p<.05).

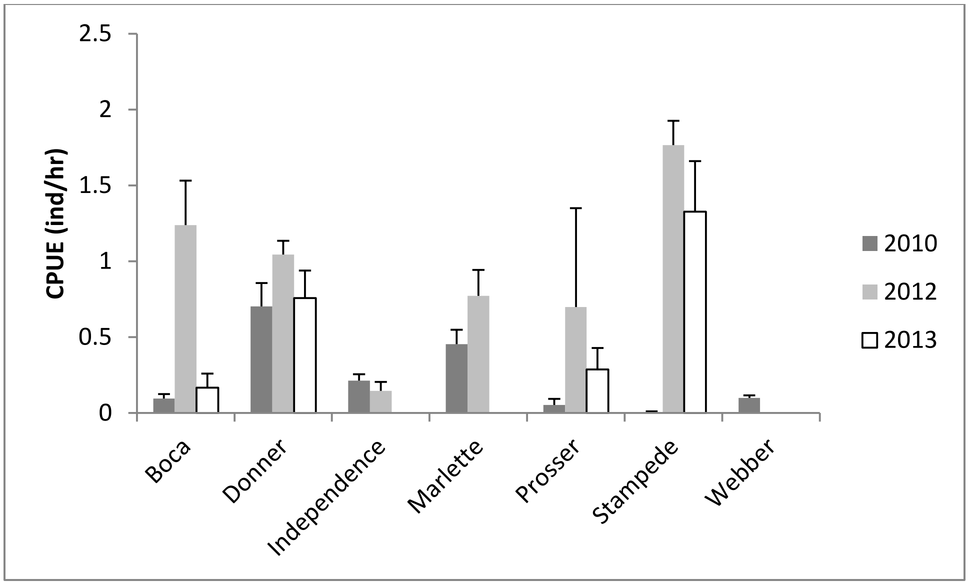


Figure 6. Comparison of crayfish CPUE from 2010 to 2012 in lakes in the Truckee River region.

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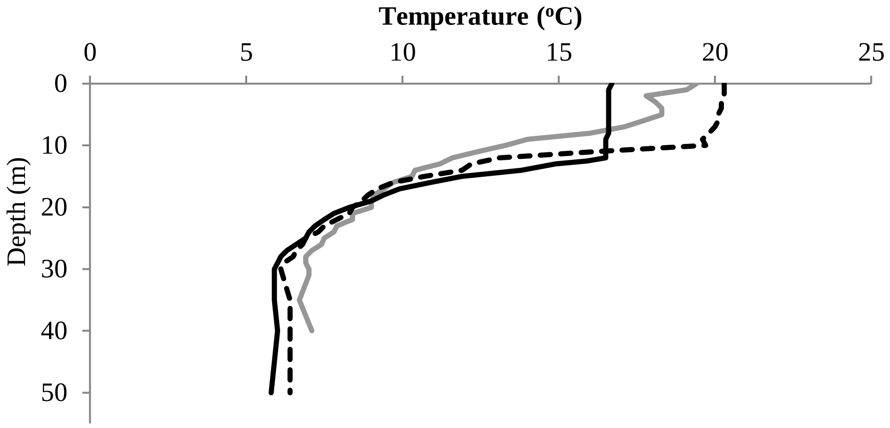
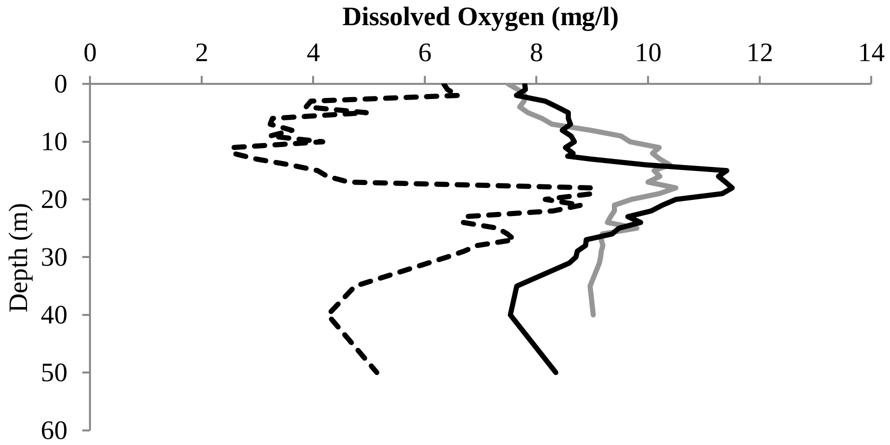
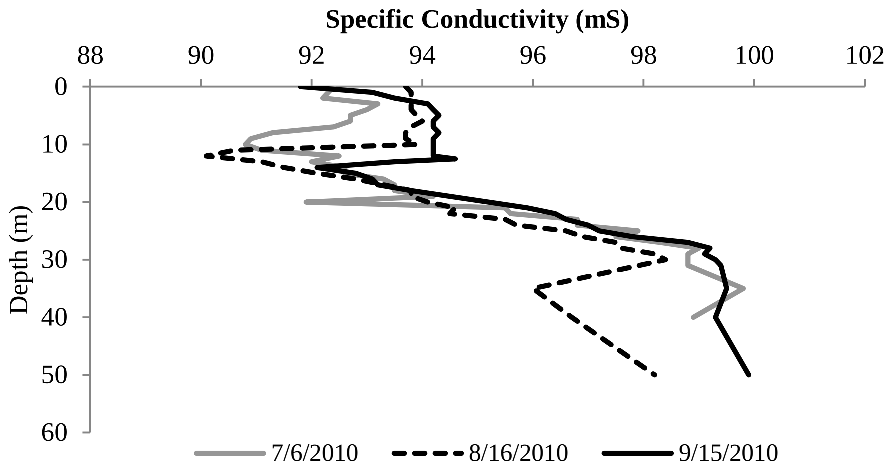
Appendix A. Water quality profiles (temperature, dissolved oxygen, and specific conductivity) for each of the Truckee River region study lakes in 2010.
a. Donner, b. Spooner, c. Martis Creek L., d. Independence, e. Marlette, f. Webber, g. Prosser, h. Boca, i. Stampede, j. Lahontan, k. Rye Patch, and l. Pyramid.

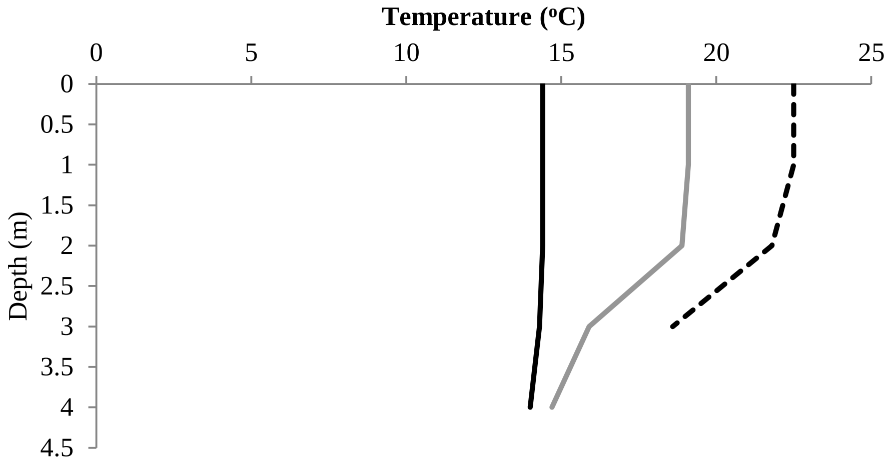
a. Donner Lake

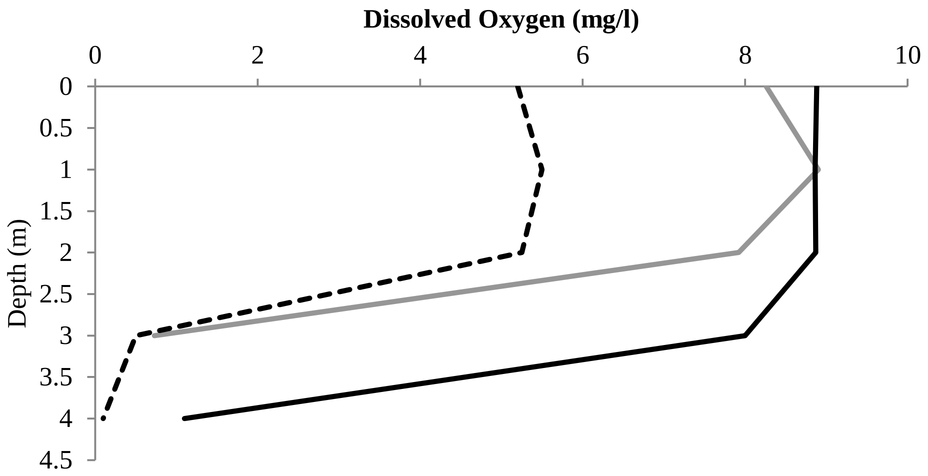


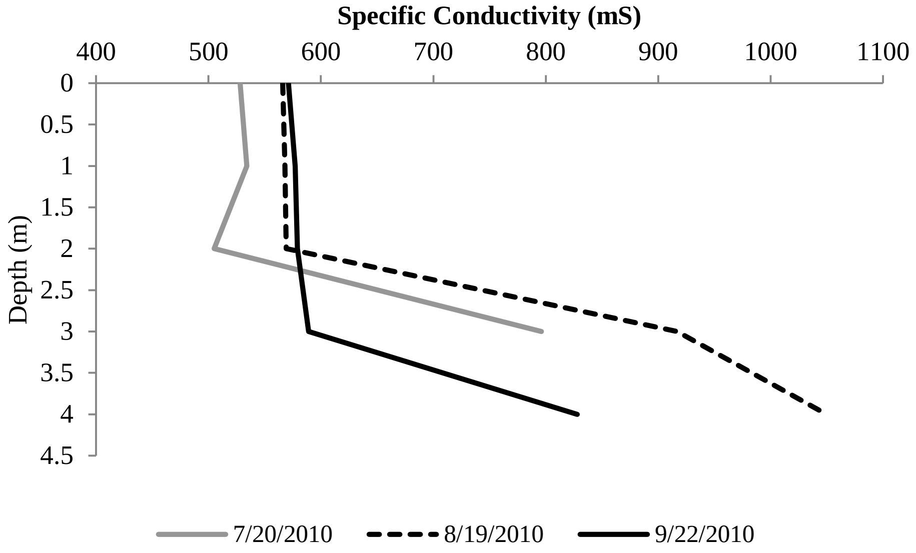




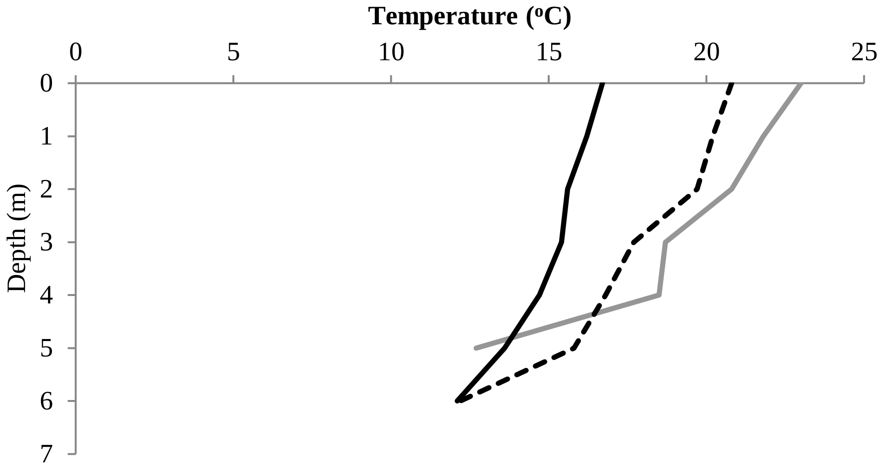
b. Spooner Lake

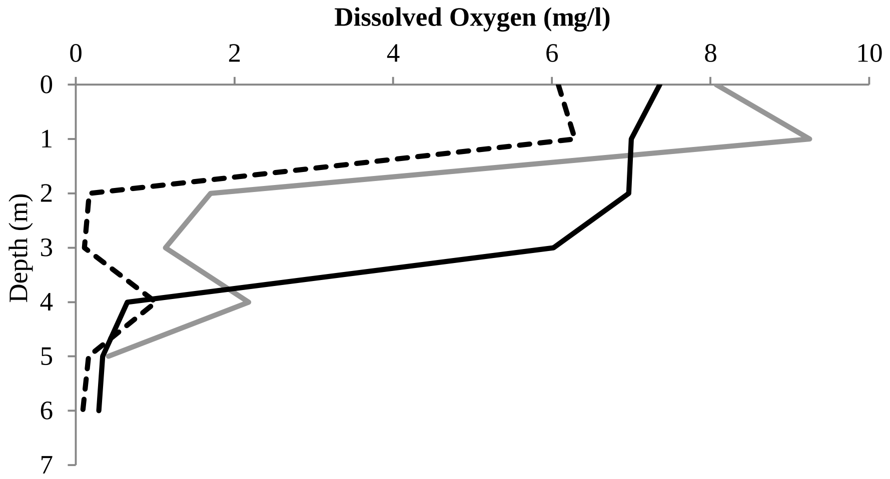


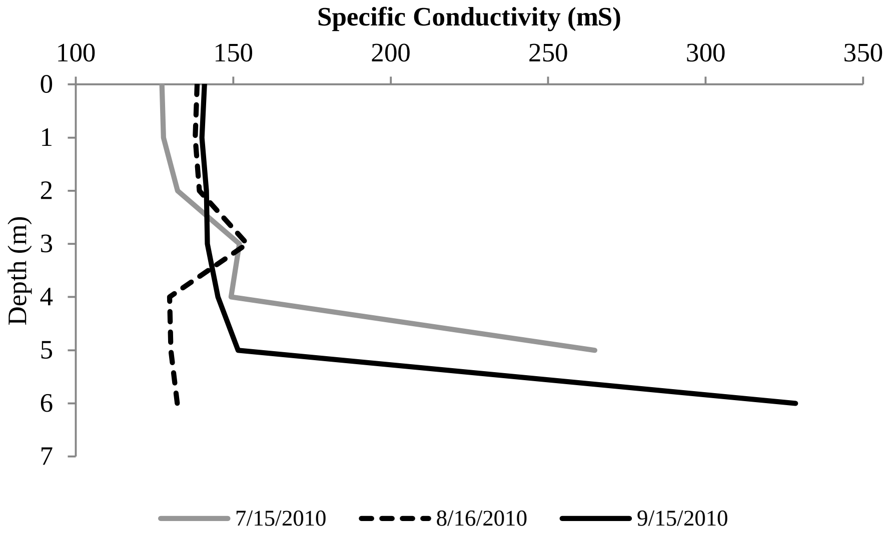




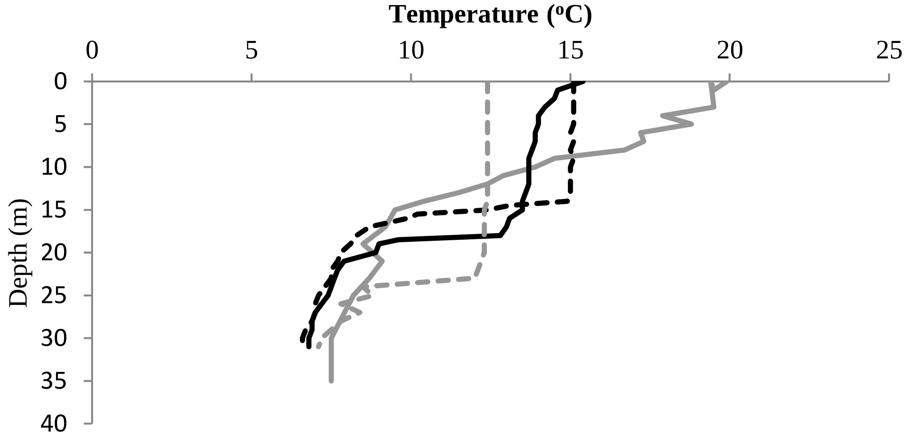
c. Martis Creek L.

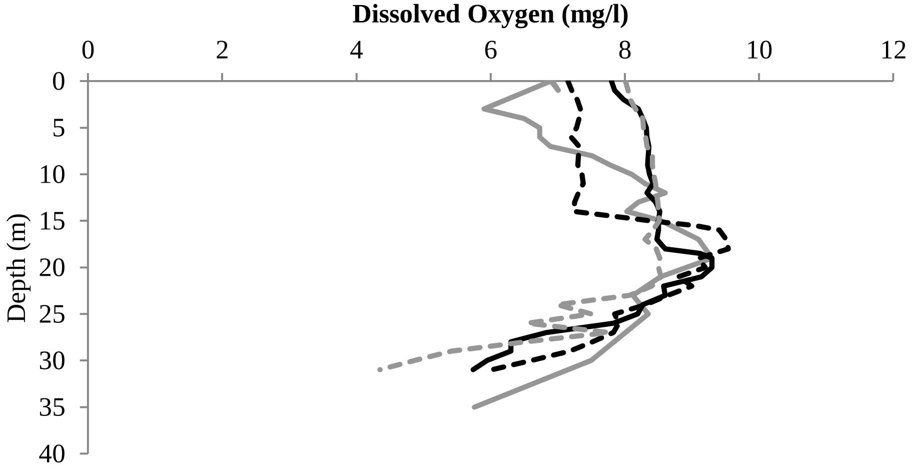


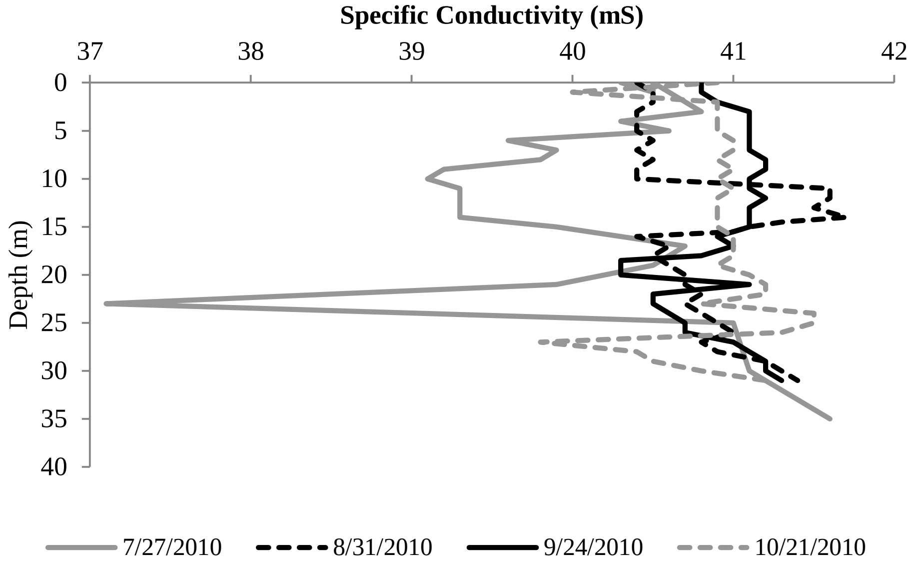




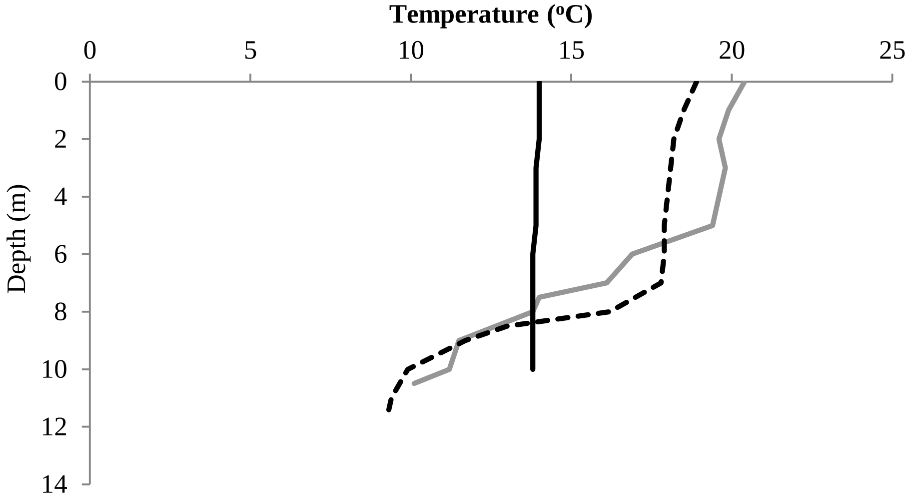
d. Independence Lake

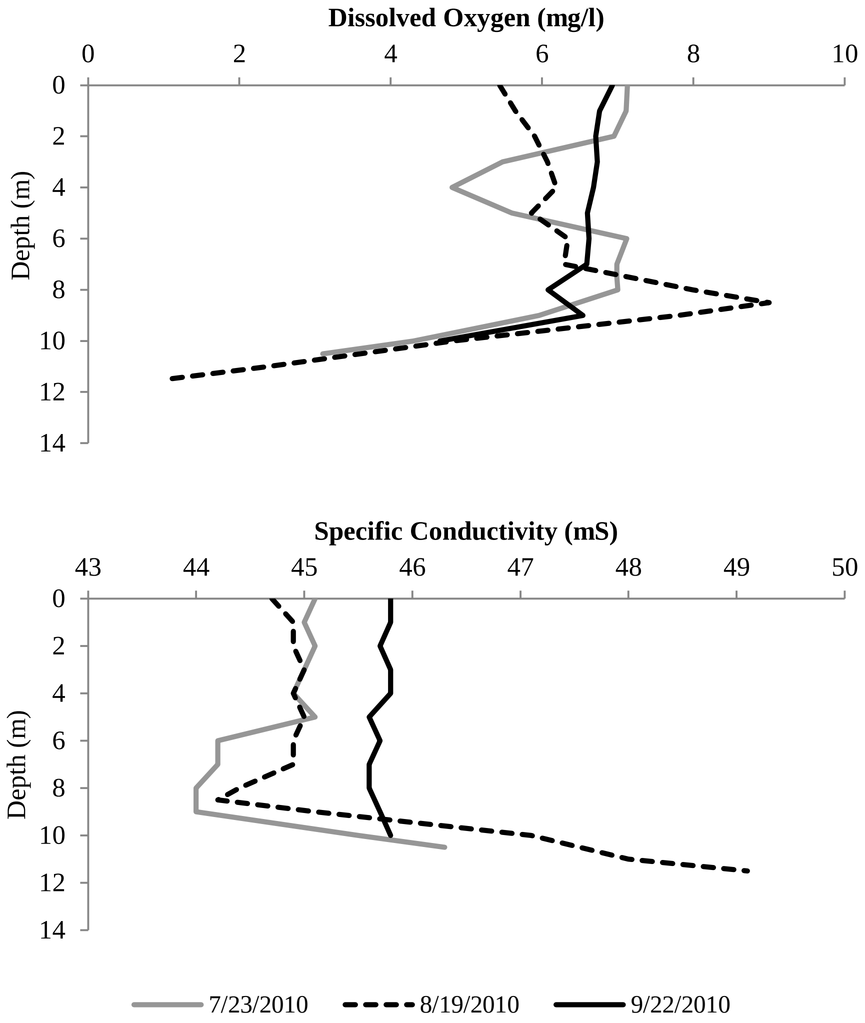




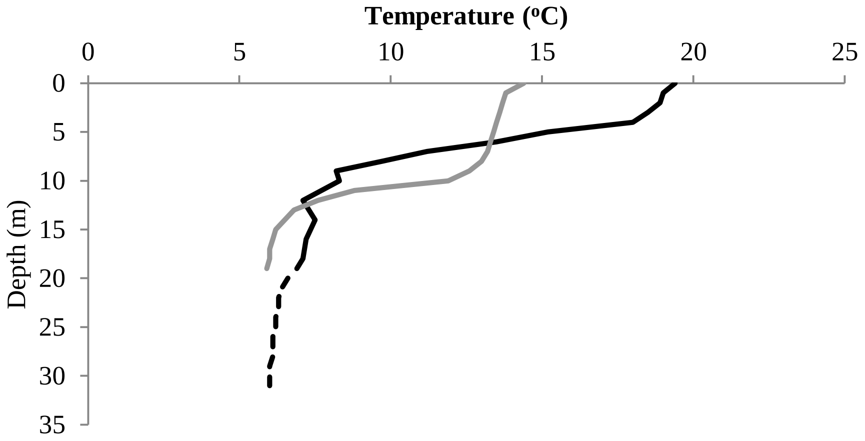


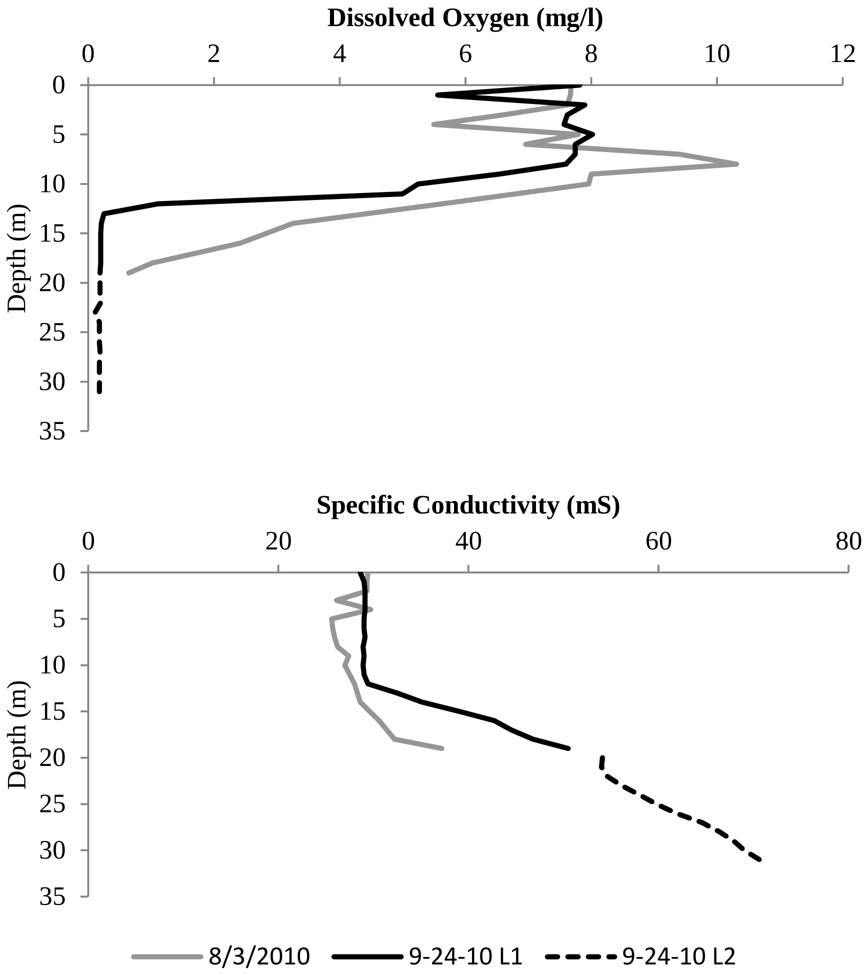
e. Marlette Lake





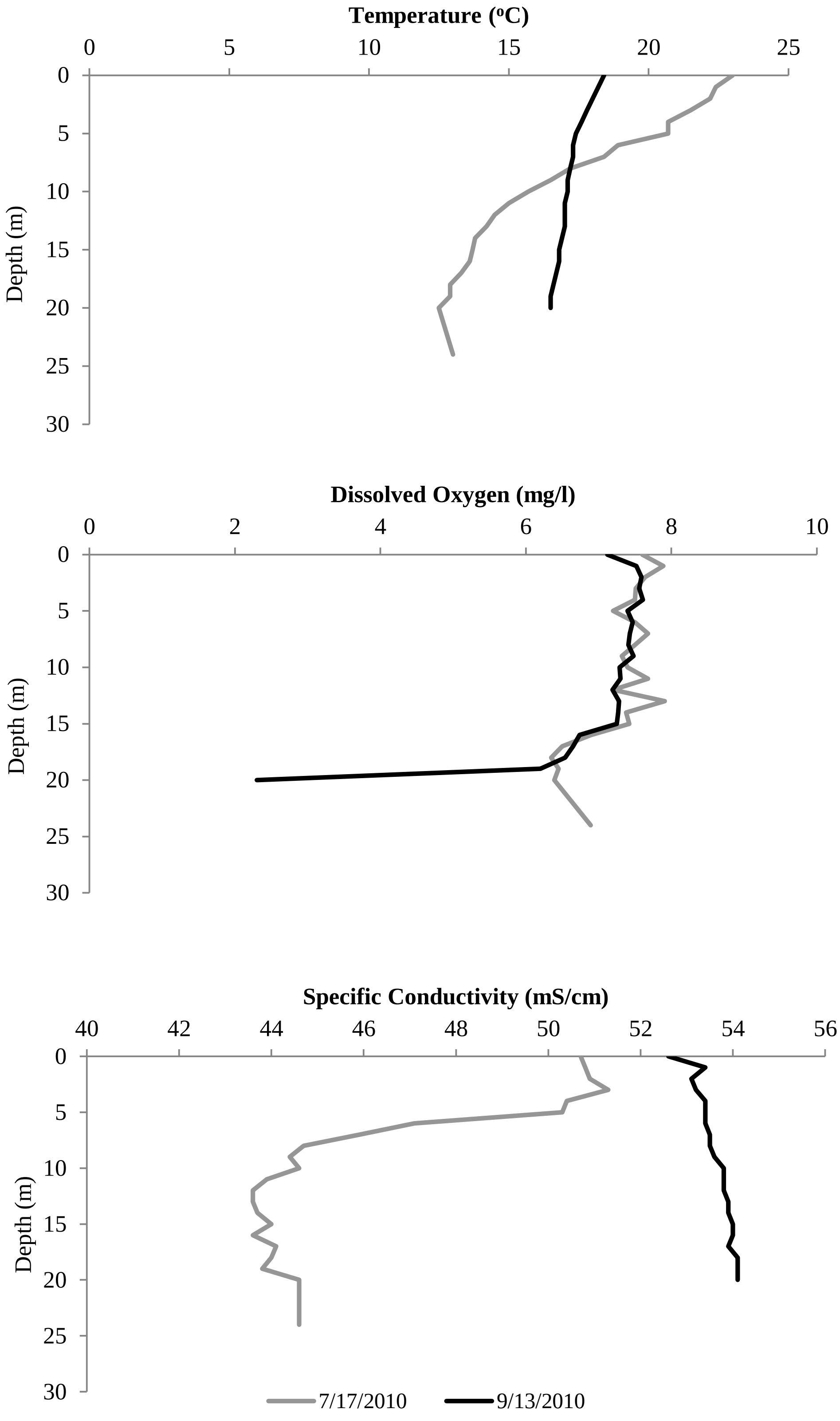
f. Webber Lake



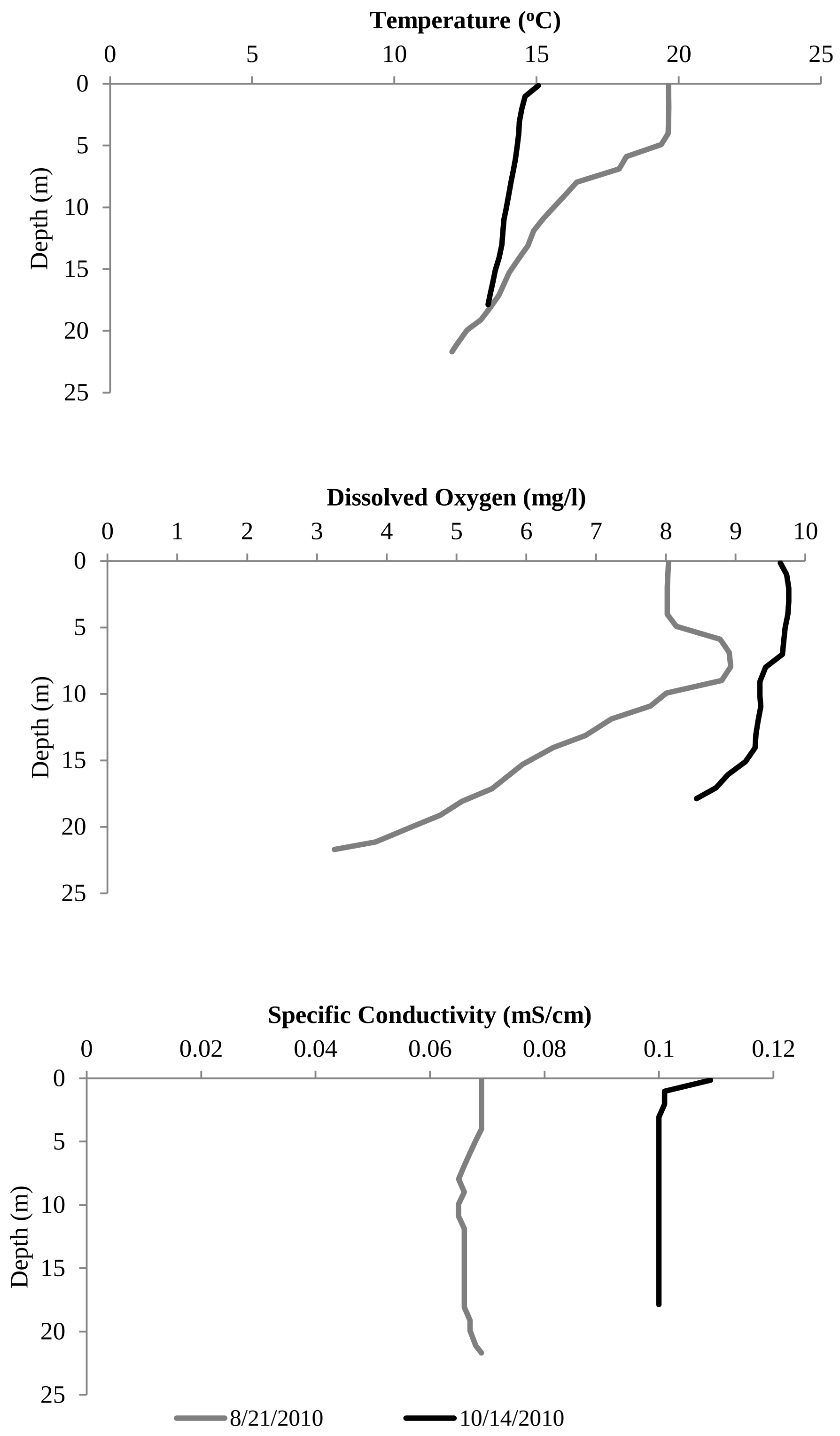


*L1 and L2 represent two different sampling locations on 9-24. The second location had an increased depth of fine sediments from 20 to 31 m.

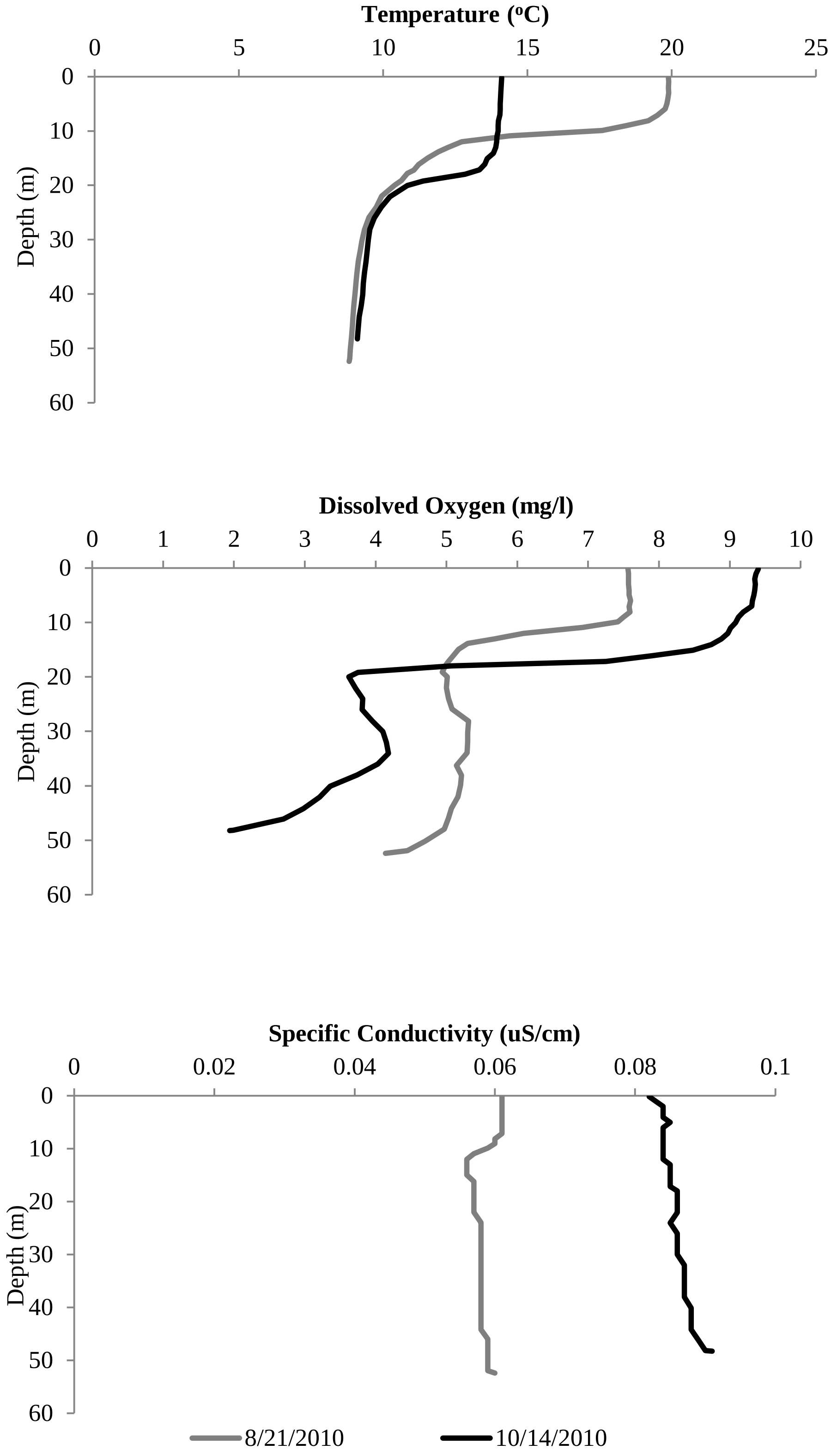
g. Prosser Reservoir



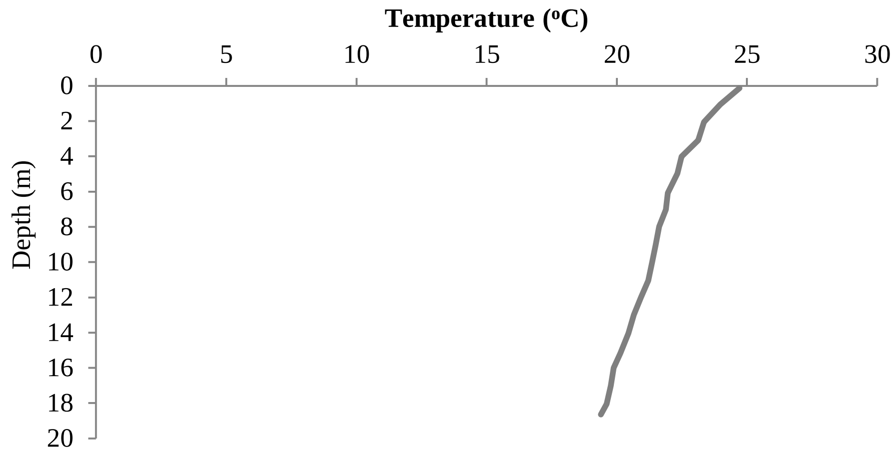
h. Boca Reservoir

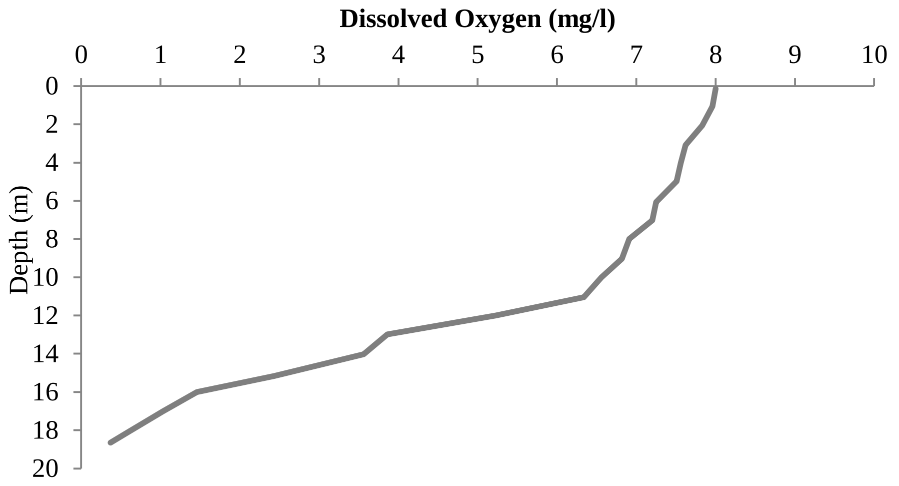


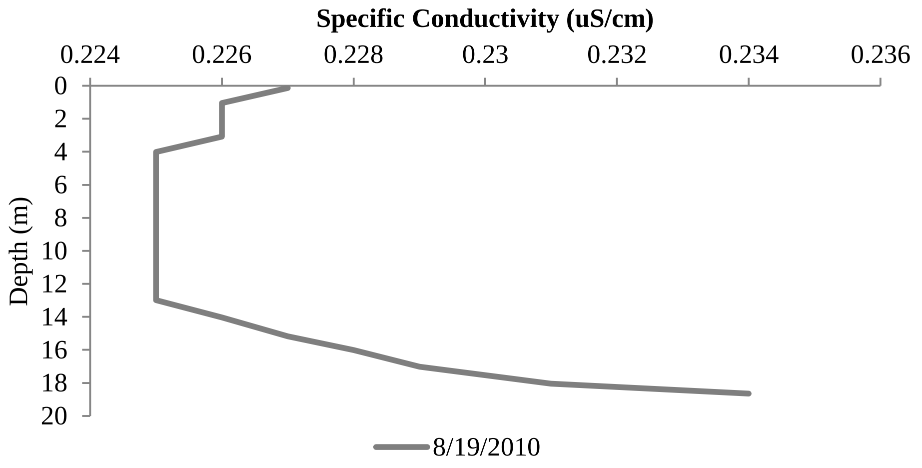
i. Stampede Reservoir



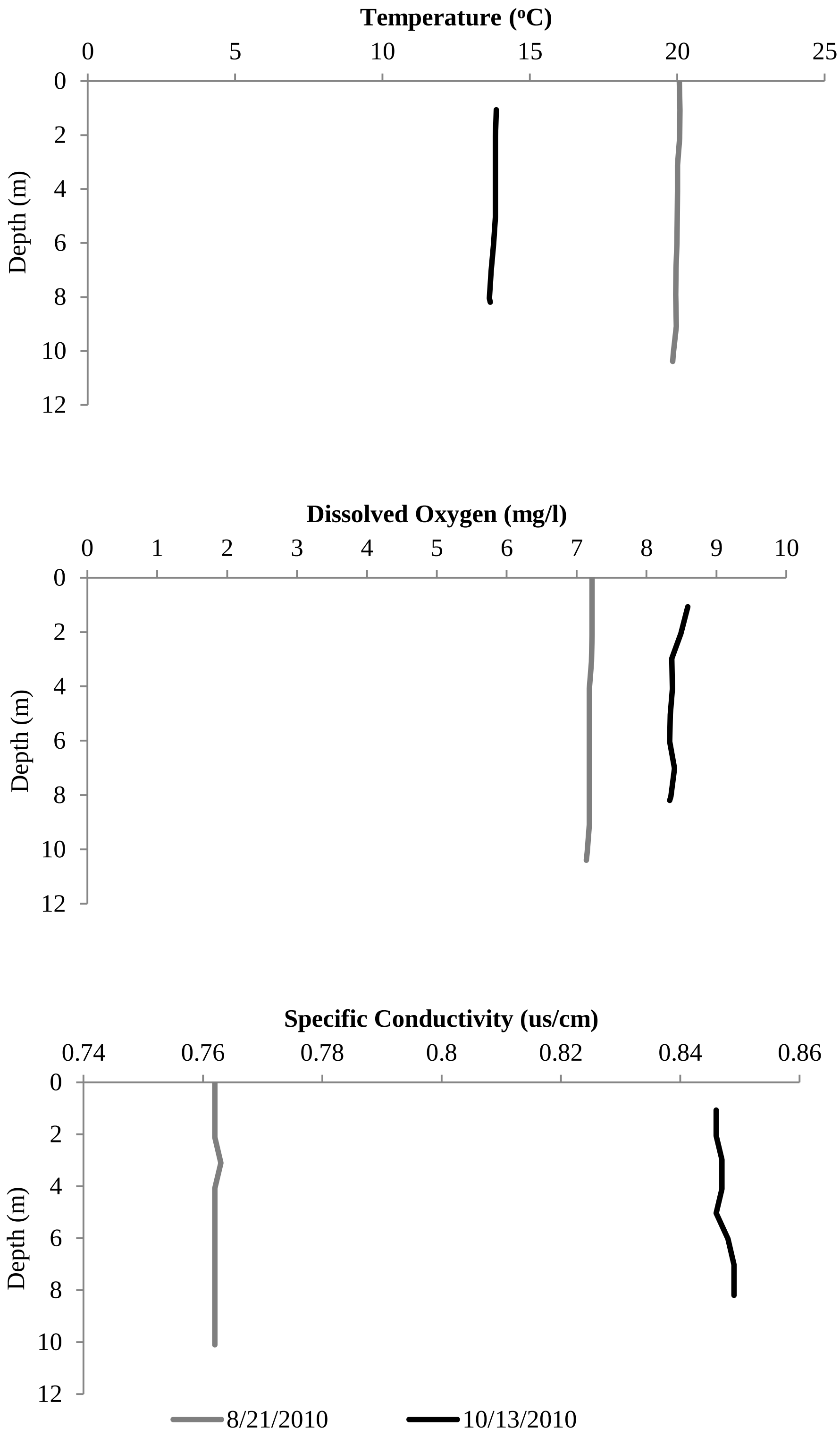
j. Lahontan Reservoir



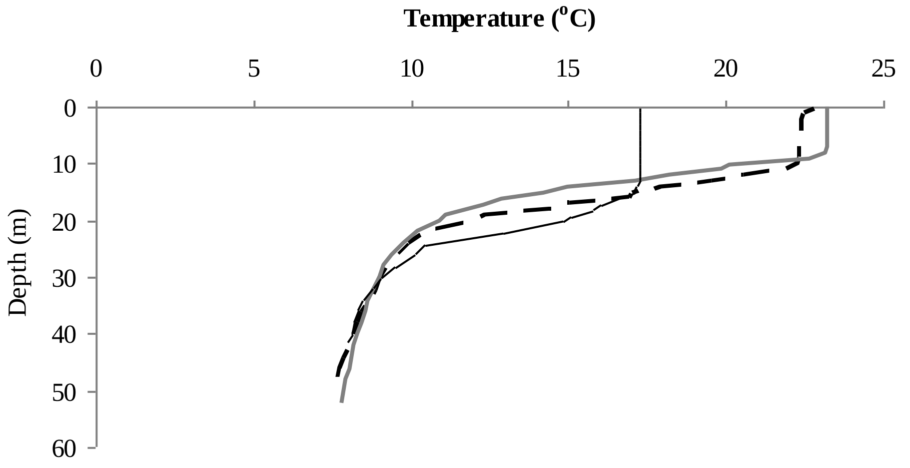


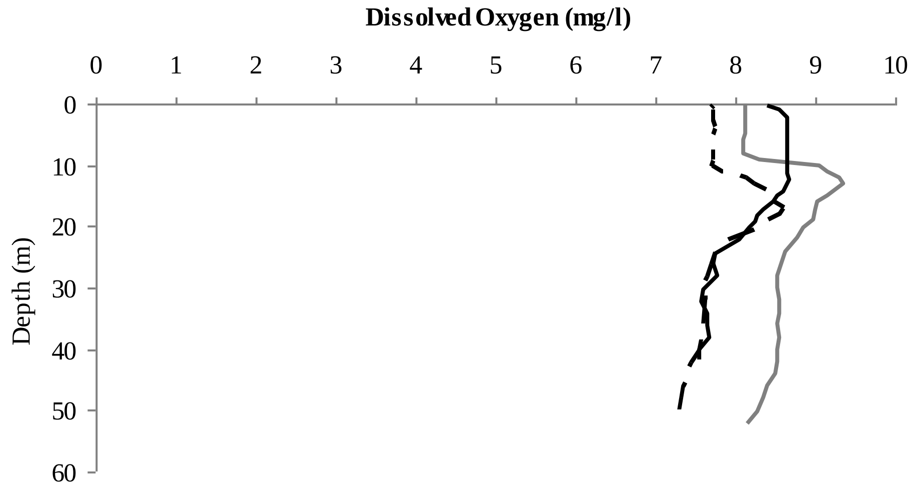


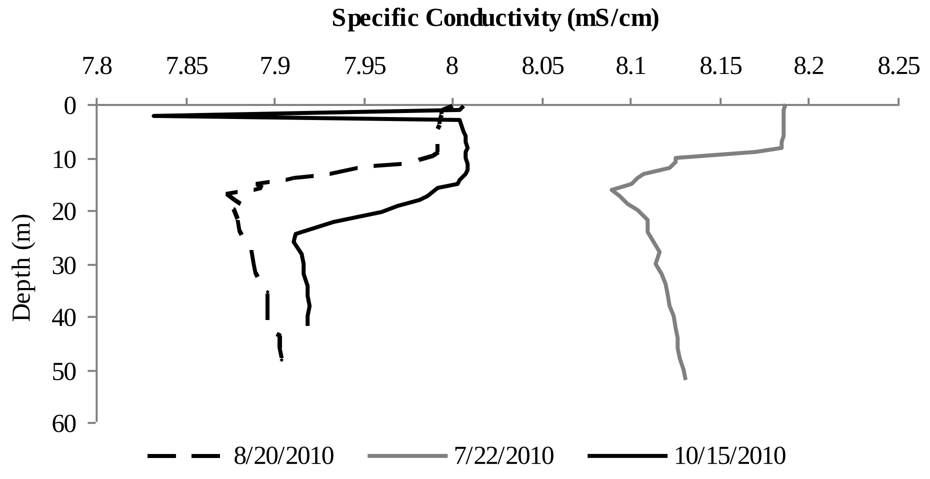
k. Rye Patch Reservoir



l. Pyramid Lake

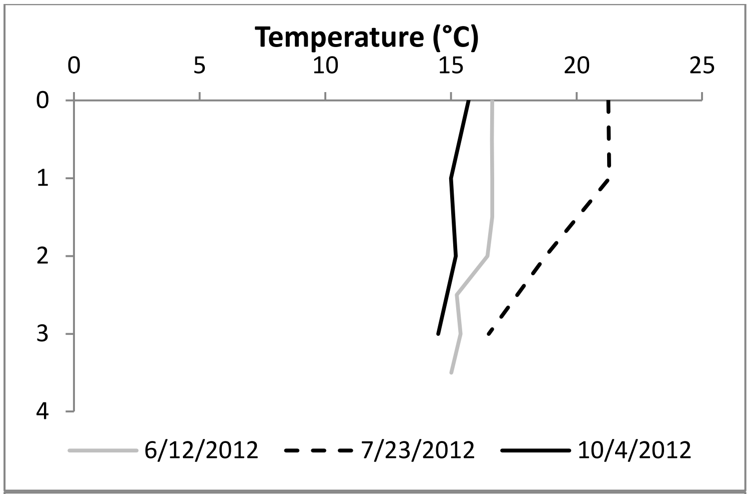

Temperature (^oC)

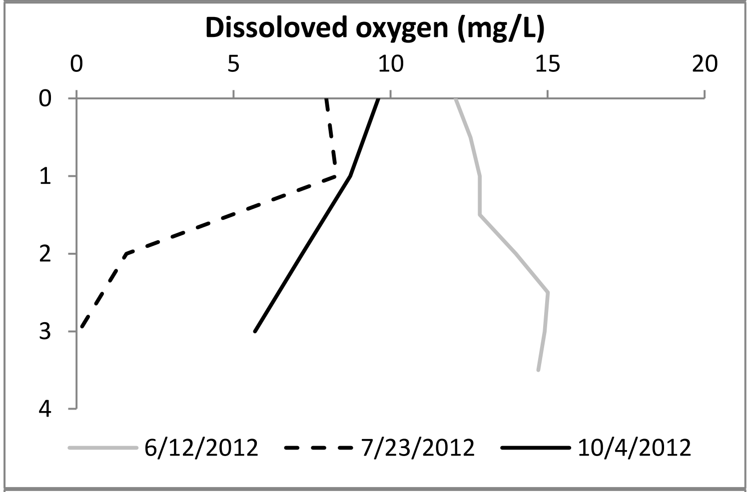

Dissolved Oxygen (mg/l)

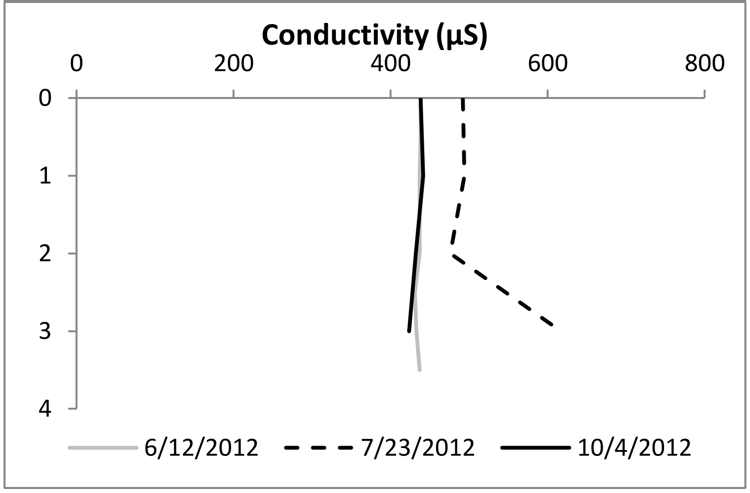

Specific Conductivity (mS/cm)

Appendix B. Water quality profiles (temperature, dissolved oxygen, and specific conductivity) for each of the Truckee River region study lakes in 2012.
a. Spooner, b.Marlette, c. Boca, d. Stampede, e. Prosser, f. Independence, g.Martis Creek, h. Donner.

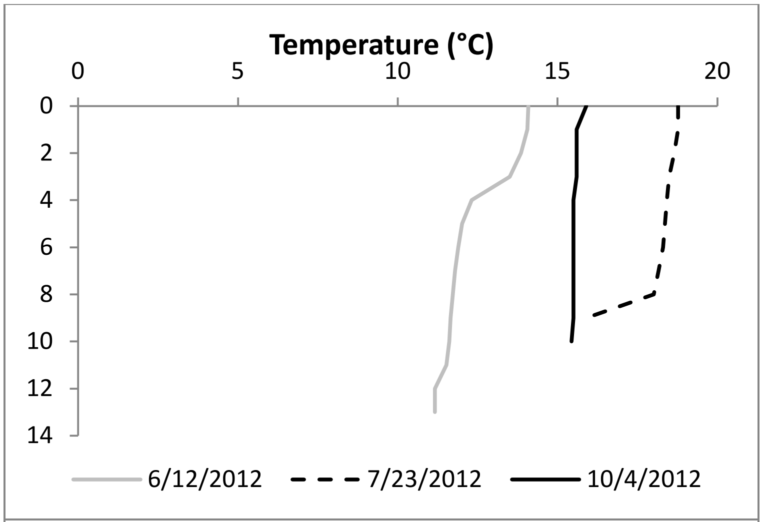
A. Spooner Lake

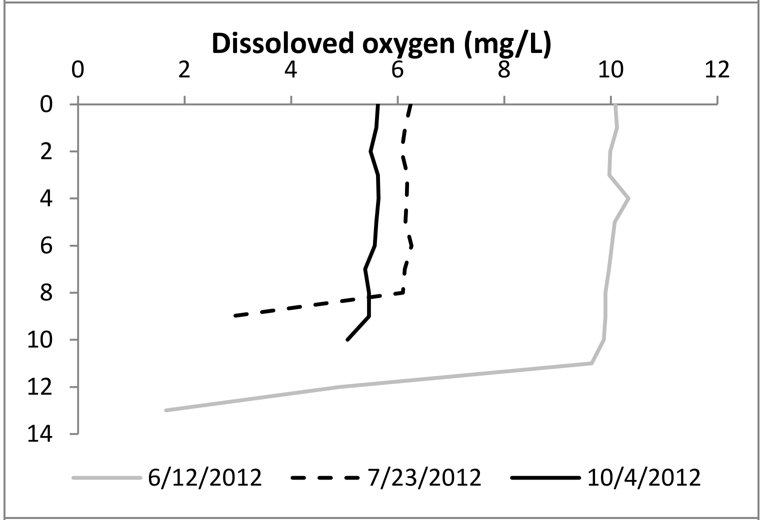


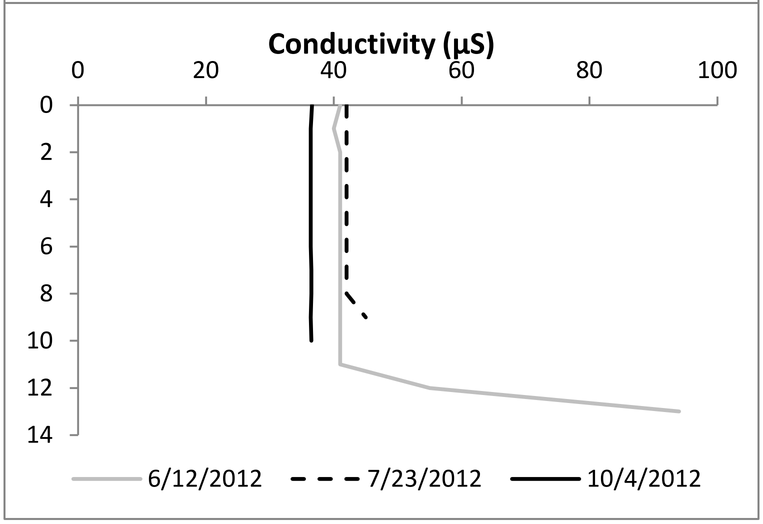




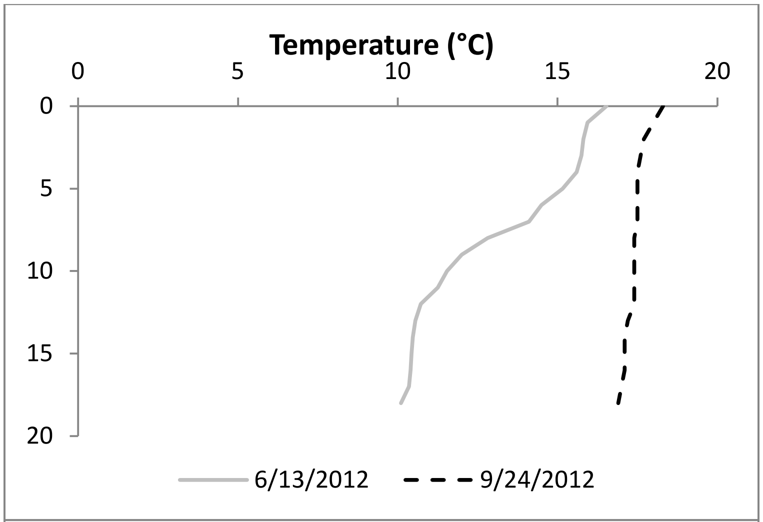
B. Marlette Lake

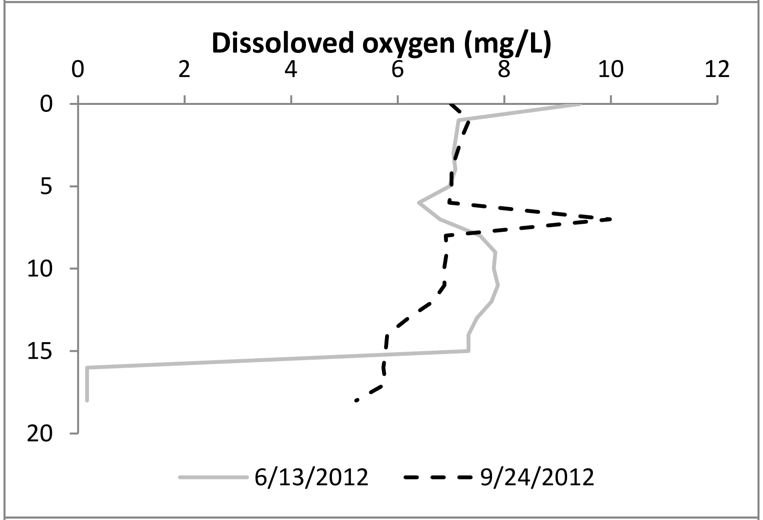


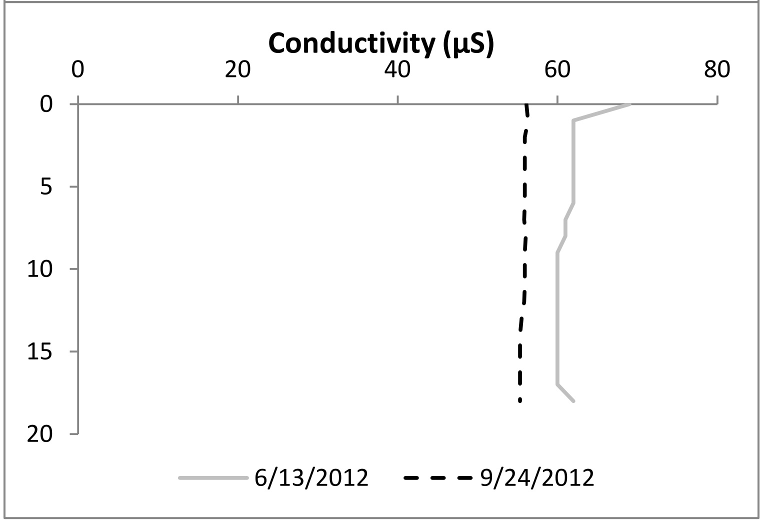




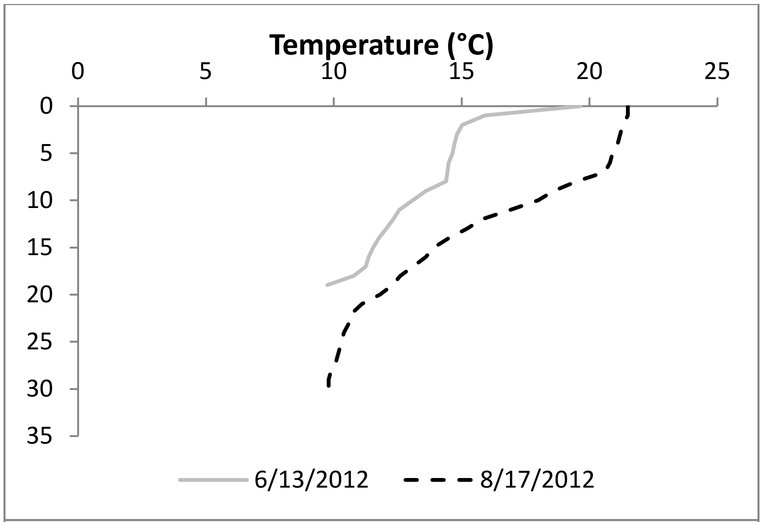
C. Boca Reservoir

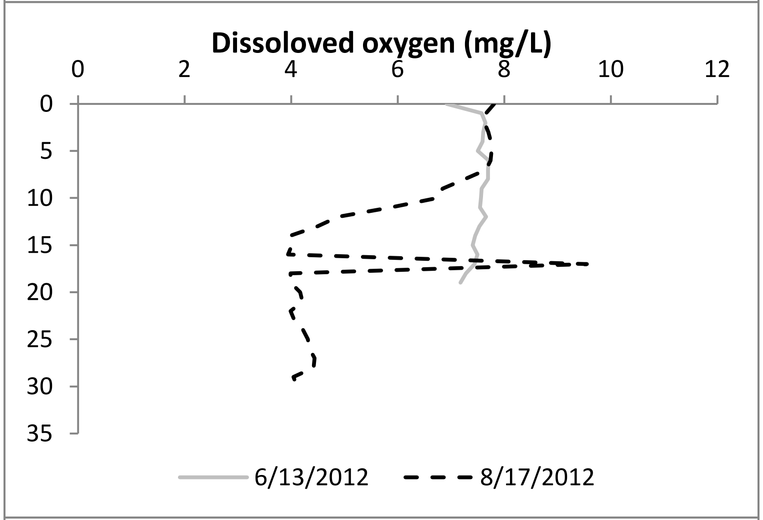


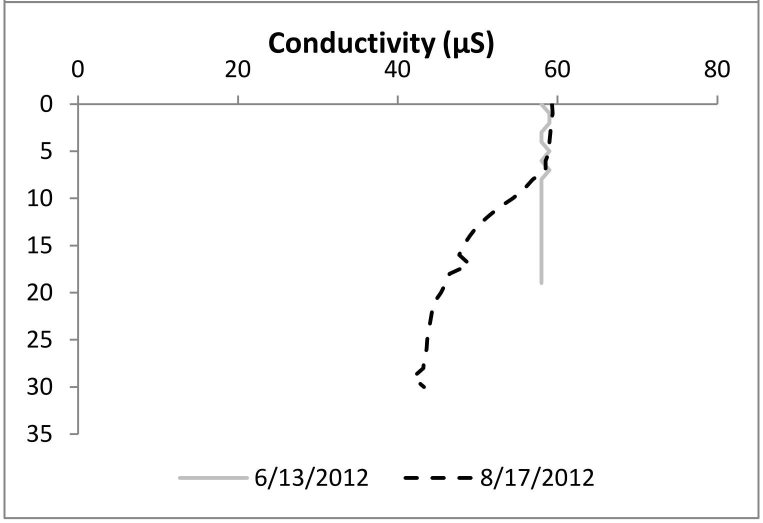




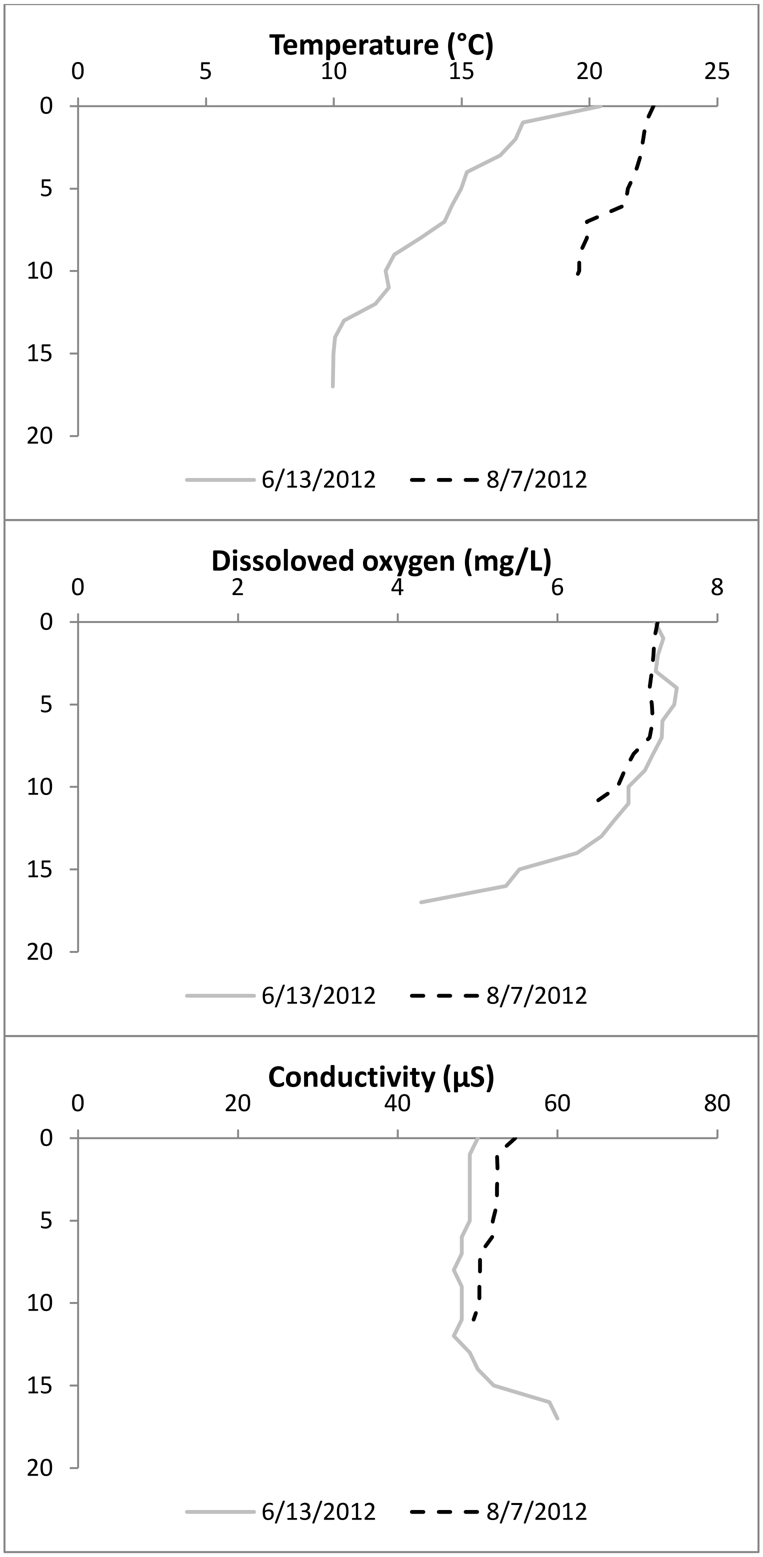
D. Stampede Reservoir



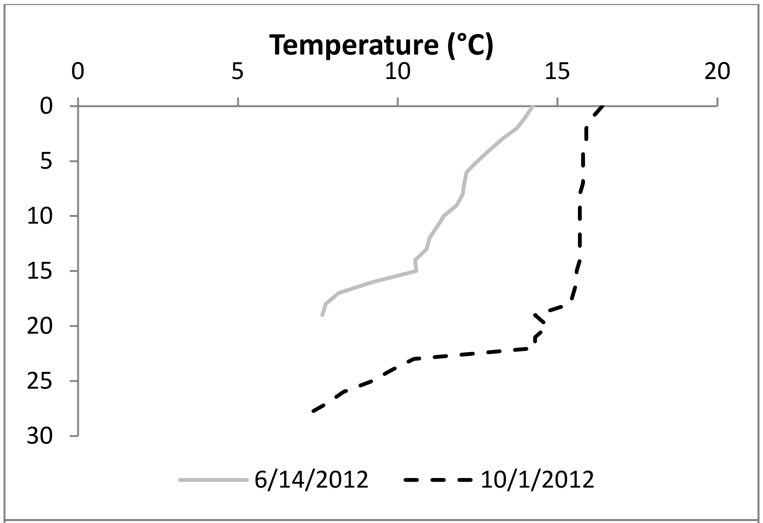


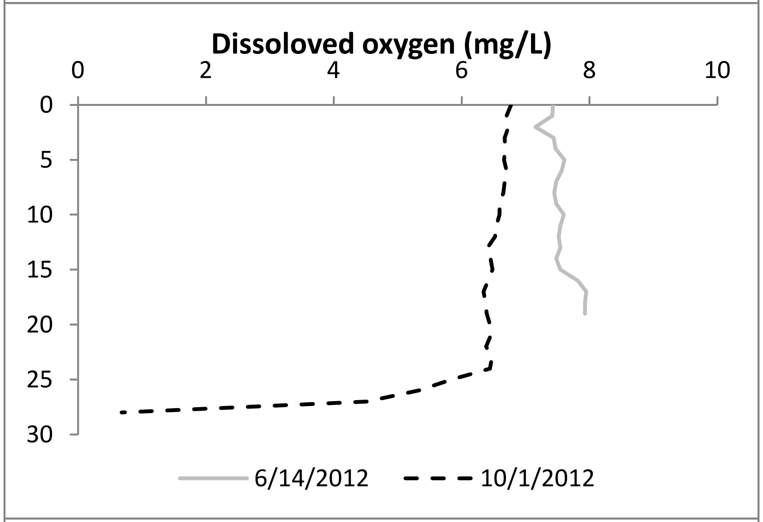


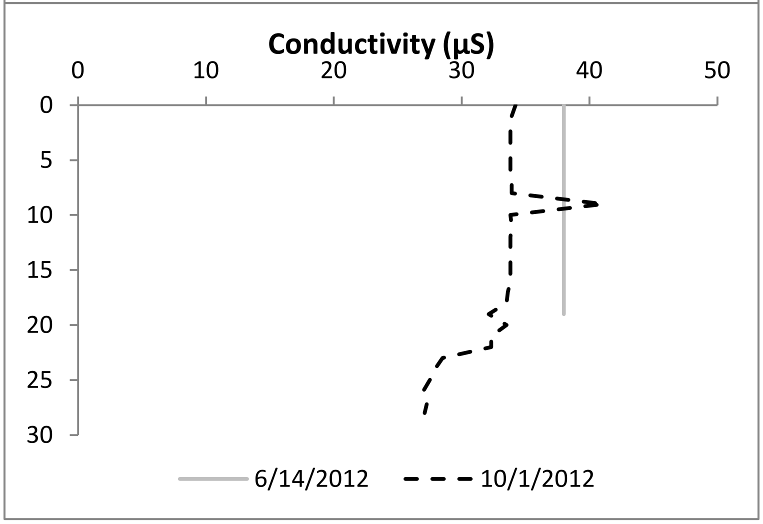
E. Prosser Reservoir



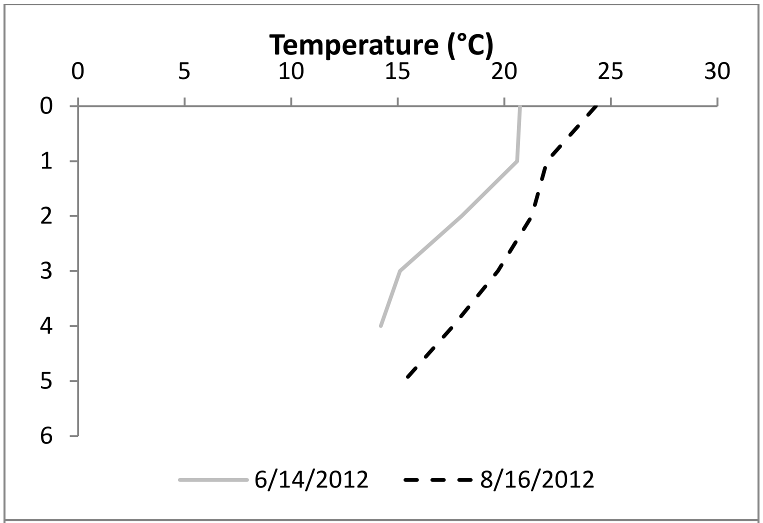
F. Independence Lake

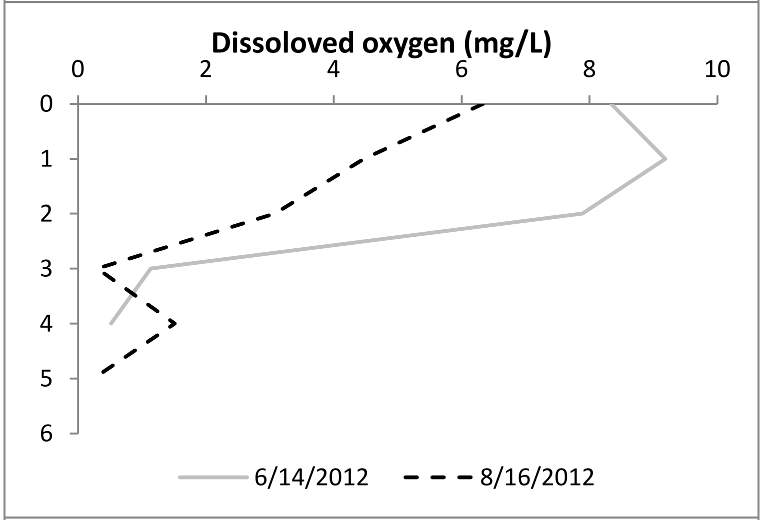


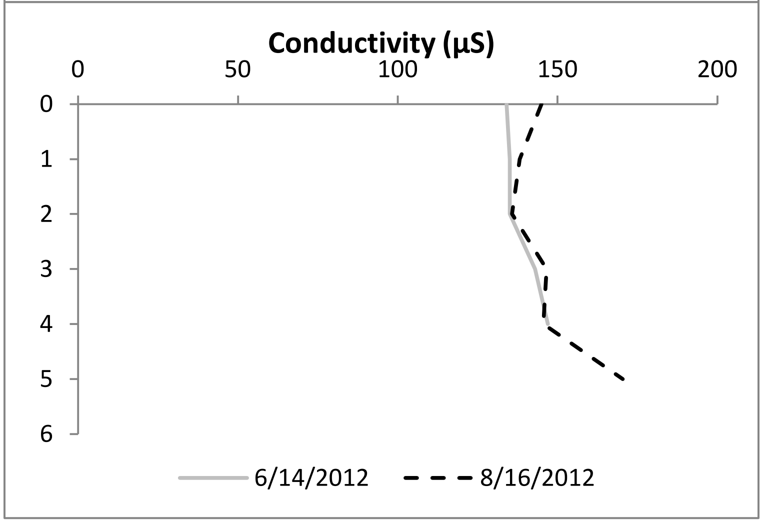




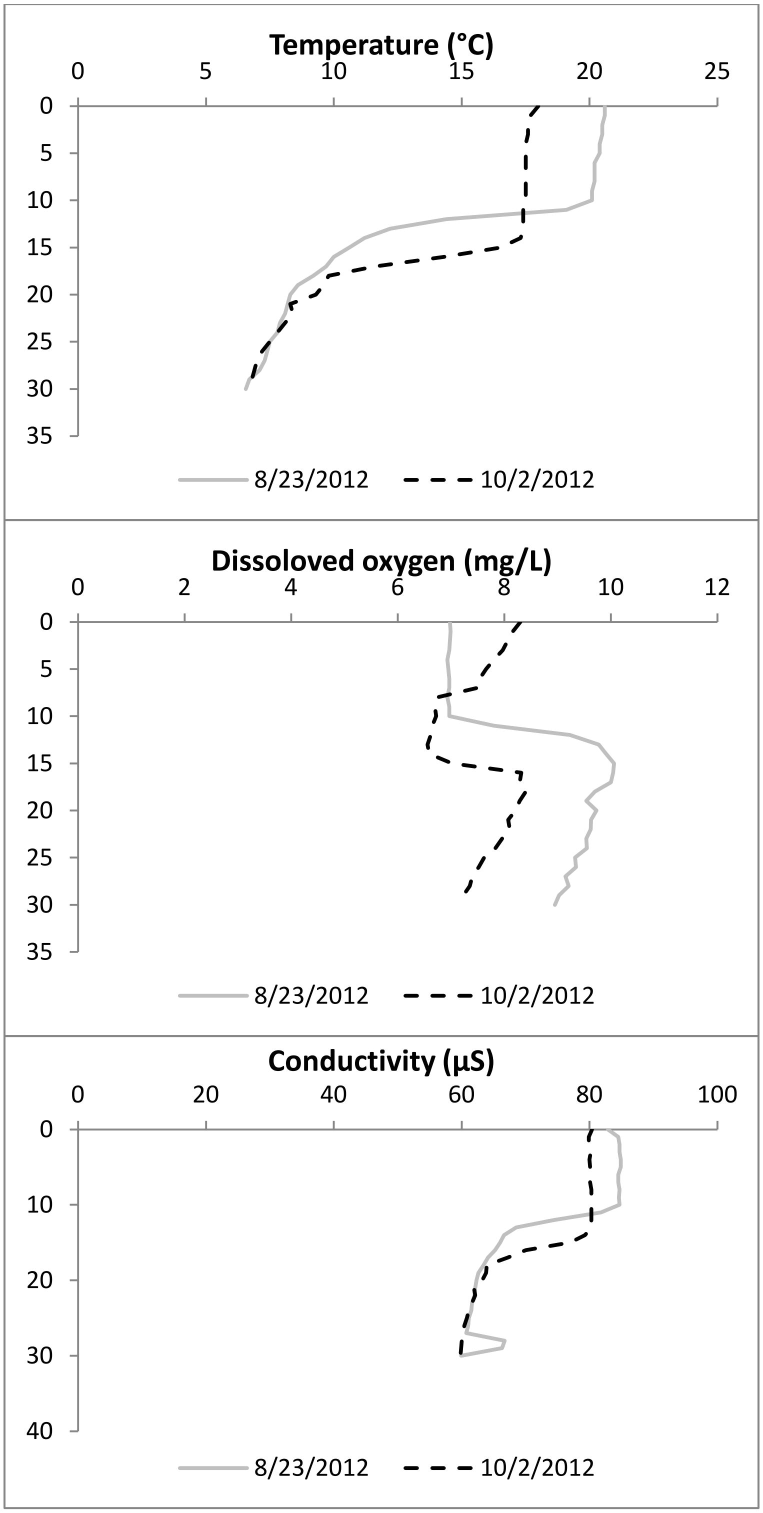
G. Martis Creek Lake







H. Donner Lake



Appendix C. Invasive species visual shoreline survey data from 2013. For previous years see reports from2010, 2011, and 2012.

Boca Reservoir

	LOCATION			SUB	INVASIVES					
Date	**T**	**N**	**W**	**% Type**	**EWM**	**Hydrilla**	**Zebra**	**Quagga**	**NZMS**	**Corbicula**
18-Jul-13	1	39 23 54.38	120 6 29.12	60F 40C	0	0	0	0	0	0
	2	39 23 57.82	120 6 15.12	70C 30F	0	0	0	0	0	0
	3	39 23 50.61	120 6 20.13	90F 10C	0	0	0	0	0	0
	4	39 23 46.16	120 6 10.57	100C	0	0	0	0	0	0
	5	39 23 36.39	120 5 59.87	90F 10C	0	0	0	0	0	0
	6	39 23 22.49	120 5 50.56	70F 20R 10C	0	0	0	0	0	0
	7	39 23 28.24	120 5 34.52	90C 10R	0	0	0	0	0	0
	8	39 23 58.66	120 5 17.36	100C	0	0	0	0	0	0
	9	39 24 6.22	120 5 25.05	100C	0	0	0	0	0	0
	10	39 24 19.15	120 5 29.40	100C	0	0	0	0	0	0
	11	39 24 28.37	120 5 29.81	100C	0	0	0	0	0	0
	12	39 24 35.61	120 5 28.33	90C 10W	0	0	0	0	0	0
	13	39 25 0.83	120 5 16.98	90C 10W	0	0	0	0	0	0
	14	39 25 12.45	120 5 16.73	60C 40R	0	0	0	0	0	0
	15	39 25 35.86	120 5 6.99	95F 5R	0	0	0	0	0	0
3-Sep-13	1	39 23 46.8	120 5 26.4	90C 10S	0	0	0	0	0	0
	2	39 24 7.8	120 5 25.7	90C 10S	0	0	0	0	0	0
	3	39 24 15.3	120 5 28.4	70C 30S	0	0	0	0	0	0
	4	39 24 23.7	120 5 28.8	90C 10S	0	0	0	0	0	0
	5	39 24 32.6	120 5 28.1	70C 30S	0	0	0	0	0	0
	6	39 25 0.5	120 5 16.7	100C	0	0	0	0	0	0
	7	39 25 7.7	120 5 15.1	75C 15R 10S	0	0	0	0	0	0
	8	39 23 30.9	120 5 33.9	5R 70C 25S	0	0	0	0	0	0
	9	39 23 31.0	120 6 0.01	20C 30S 50F	0	0	0	0	0	0
	10	39 23 47.9	120 6 10.3	25C 75S	0	0	0	0	0	0
	11	39 23 54.4	120 6 30.3	80F 5C 15P	0	0	0	0	0	0
	12	39 23 56.7	120 6 25.9	90F 10C	0	0	0	0	0	0
	13	39 23 54.2	120 6 27.6	5R 10S 85F	0	0	0	0	0	0
	14	39 23 52.6	120 6 25.6	100F	0	0	0	0	0	0
	15	39 23 22.5	120 5 50.1	25R 25C 50S	0	0	0	0	0	0

Stampede Reservoir

	LOCATION			SUB	INVASIVES					
Date	**T**	**N**	**W**	**% Type**	**EWM**	**Hydrilla**	**Zebra**	**Quagga**	**NZMS**	**Corbicula**
16-Jul-13	1	39 28 10.13	120 6 10.13	R	0	0	0	0	0	0
	2	39 28 16.40	120 8 9.13	80F 20C	0	0	0	0	0	0
	3	39 28 15.94	120 8 1.82	80F 20B	0	0	0	0	0	0
	4	39 28 14.45	120 7 57.84	90F 10C	0	0	0	0	0	0
	5	39 28 0.15	120 8 14.74	95F 5B	0	0	0	0	0	0
	6	39 28 11.56	120 7 47.12	90F 10C	0	0	0	0	0	0
	7	39 28 12.06	120 7 39.67	100C	0	0	0	0	0	0
	8	39 28 5.69	120 7 52.15	90F 10C	0	0	0	0	0	0
	9	39 28 23.25	120 7 0.28	10C 5W 85F	0	0	0	0	0	0
	10	39 28 22.45	120 6 50.57	65F 30C 5B	0	0	0	0	0	0
	11	39 28 20.81	120 6 28.19	80F 20C	0	0	0	0	0	0
	12	39 28 23.79	120 6 22.66	80F 15C 5S	0	0	0	0	0	0
	13	39 28 24.42	120 6 17.86	80F 15C 5S	0	0	0	0	0	0
	14	39 28 36.07	120 6 14.38	100B	0	0	0	0	0	0
	15	39 29 43.56	120 5 49.05	40C 20S 20B	0	0	0	0	0	0
3-Sep-13	1	39 28 36.4	120 6 14.5	100S	0	0	0	0	0	0
	2	39 28 35.7	120 6 14.6	100B	0	0	0	0	0	0
	3	39 28 22.6	120 6 24.8	75S25C	0	0	0	0	0	0
	4	39 28 20.3	120 6 48.6	75C25S	0	0	0	0	0	0
	5	39 28 14.2	120 6 53.8	5R 95S	0	0	0	0	0	0
	6	39 28 20.0	120 6 54.7	5R 95S	0	0	0	0	0	0
	7	39 20 24.5	120 8 16.6	80S 20C	0	0	0	0	0	0
	8	39 28 0.1	120 5 16.6	98S 2R	0	0	0	0	0	0
	9	39 20 4.0	120 8 21.8	50S 50C	0	0	0	0	0	0
	10	39 28 16.1	120 8 6.2	100S	0	0	0	0	0	0
	11	39 28 15.8	120 8 01.5	50R 50S (DOCK)	0	0	0	0	0	0
	12	39 28 14.5	120 78 57.8	90S 10S	0	0	0	0	0	0
	13	39 28 13.3	120 7 52.3	50C 50S	0	0	0	0	0	0
	14	39 28 11.4	120 7 47.0	80S 20C	0	0	0	0	0	0
	15	39 28 12.8	120 7 43.7	100C	0	0	0	0	0	0

Prosser Reservoir										
	LOCATION			SUB	INVASIVES					
Date	T	N	W	% Type	EWM	Hydrilla	Zebra	Quagga	NZMS	Corbicula
18-Jul-31	1	39 22 30.01	120 9 15.18	90F 10C	0	0	0	0	0	0
	2	39 22 37.55	120 9 12.00	95F 5C	0	0	0	0	0	0
	3	39 22 25.42	120 9 16.79	100C	0	0	0	0	0	0
	4	39 22 19.30	120 9 24.88	90F 10B	0	0	0	0	0	0
	5	39 22 40.47	120 8 38.82	80F 20C	0	0	0	0	0	0
	6	39 22 38.91	120 8 72.35	70F 20C 10B	0	0	0	0	0	0
	7	39 22 39.75	120 8 27.52	90F 10C	0	0	0	0	0	0
	8	39 22 48.82	120 8 15.73	80F 10C 10W	0	0	0	0	0	0
	9	39 22 52.12	120 8 19.77	80C 20F	0	0	0	0	0	0
	10	39 23 7.46	120 8 41.87	90F 5B 5W	0	0	0	0	0	0
	11	39 22 58.37	120 8 40.83	90F 10C	0	0	0	0	0	0
	12	39 22 59.53	120 9 2.24	70F 25C 5B	0	0	0	0	0	0
	13	39 22 50.57	120 9 24.89	90C 10F	0	0	0	0	0	0
	14	39 22 59.10	120 10 1.97	100F	0	0	0	0	0	0
	15	39 22 54.35	120 9 53.82	90F 5W 5C	0	0	0	0	0	0
1-Oct-13	1	39 22 47.84	120 8 17.24	100R	0	0	0	0	0	0
	2	39 22 45.52	120 8 20.33	100R	0	0	0	0	0	0
	3	39 22 54.21	120 8 23.23	98F 2C	0	0	0	0	0	0
	4	39 23 7.19	120 8 4.40	100F	0	0	0	0	0	0
	5	39 22 57.64	120 8 39329	10S 90F	0	0	0	0	0	0
	6	39 22 59.74	120 8 38.77	100F	0	0	0	0	0	0
	7	39 22 58.99	120 9 4.31	50S 50F	0	0	0	0	0	0
	8	39 23 0.95	120 9 18.98	75S 25R	0	0	0	0	0	0
	9	39 22 40.11	120 8 12.26	100R	0	0	0	0	0	0
	10	39 22 39.94	39 22 39.94	80R 20S	0	0	0	0	0	0
	11	39 22 40.94	120 8 26.26	50R 50S	0	0	0	0	0	0
	12	39 22 31.63	120 9 15.18	80C 20S	0	0	0	0	0	0
	13	39 22 28.41	120 9 16.94	50S 50C	0	0	0	0	0	0

Donner Lake

	LOCATION			SUB	INVASIVES					
Date	**T**	**N**	**W**	**% Type**	**EWM**	**Hydrilla**	**Zebra**	**Quagga**	**NZMS**	**Corbicula**
17-Jul-13	1	39 19 24.31	120 17 1.08	100C	0	0	0	0	0	0
	2	39 19 29.12	120 16 56.82	100B	0	0	0	0	0	0
	3	39 19 18.81	120 17 22.37	100S	0	0	0	0	0	0
	4	39 19 28.39	120 19 49.39	60B 40C	0	0	0	0	0	0
	5	39 19 29.11	120 16 28.81	70C 30B	0	0	0	0	0	0
	6	39 19 30.68	120 16 13.77	80S 20B	0	0	0	0	0	0
	7	39 19 35.28	120 15 56.47	80S	0	0	0	0	0	0
	8	39 19 41.33	120 15 34.54	60S 30C 10B	0	0	0	0	0	0
	9	39 19 37.38	120 14 30.45	70S 30C	0	0	0	0	0	0
	10	39 19 22.76	120 14 15.27	95S 5B	0	0	0	0	0	0
	11	39 19 22.82	120 14 37.79	60C 40S	0	0	0	0	0	0
	12	39 19 22.60	120 14 51.88	50C 30S 20B	0	0	0	0	0	0
	13	39 19 20.83	120 14 58.23	40C 35S 10B 5W	0	0	0	0	0	0
	14	39 19 12.83	120 15 7.7	100C	0	0	0	0	0	0
	15	39 19 11.36	120 115 8.26	95C 5B	0	0	0	0	0	0
1-Oct-13	1	39 19 41.87	120 14 27.17	10R 90C	0	0	0	0	0	0
	2	39 19 38.03	120 14 37.02	60R 30C 10S	0	0	0	0	0	0
	3	39 19 43.30	120 15 25.89	50R 50C	0	0	0	0	0	0
	4	39 19 41.22	120 15 34.68	73R 20C 10S	0	0	0	0	0	0
	5	39 19 38.87	120 15 43.91	20R 40C 40S	0	0	0	0	0	0
	6	39 19 35.27	120 15 55.02	90S 10R	0	0	0	0	0	0
	7	39 19 33.25	120 16 0.82	10F 10R 80S	0	0	0	0	0	0
	8	39 19 31.52	120 16 11.65	30R 30C 10S	0	0	0	0	0	0
	9	39 19 28.16	120 16 44.54	50S 30C	0	0	0	0	0	0
	10	39 19 28.73	120 16 57.27	20R 40C 40S	0	0	0	0	0	0
	11	39 19 29.04	12017 1.21	DOCK	0	0	0	0	0	0