Section 4

Mono Basin Waterfowl
Habitat and Population Monitoring
RY 2013-14

APPENDIX 1

Limnology

2013 Annual Report

Mono Lake Limnology Monitoring

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INTRODUCTION

Limnological monitoring was conducted in 2013 at Mono Lake as required under the State Water Resources Control Board Order No. 98-05. The limnological monitoring program at Mono Lake is one component of the Mono Basin Waterfowl Habitat Restoration Plan (LADWP 1996). The purpose of the limnological monitoring program as it relates to waterfowl is to assess limnological and biological factors that may influence waterfowl use of lake habitat (LADWP 1996). The limnological monitoring program consists of four components: meteorological, physical/chemical, phytoplankton, and brine shrimp population data.

An intensive limnological monitoring of Mono Lake has been funded by Los Angeles Department of Water and Power (LADWP) since 1982. The Marine Science Institute (MSI), University of California, Santa Barbara served as the principle investigator, and Sierra Nevada Aquatic Research Laboratory (SNARL) provided field sampling and laboratory analysis technicians up to July 2012. After receiving training in limnological sampling and laboratory analysis methods from the scientists and staff at MSI and SNARL, LADWP Watershed Resources staff assumed responsibility for the program, and has been conducting limnological monitoring of Mono Lake since July of 2012.

This report summarizes monthly field sampling for the year of 2013. Laboratory support including the analysis of ammonium and chlorophyll *a* in 2013 was provided by Environmental Science Associates, Davis, California.

METHODS

Methodologies for both field sampling and laboratory analysis followed those specified in *Field and Laboratory Protocols for Mono Lake Limnological Monitoring (Field and Laboratory Protocols)* (Jellison, 2011). The methods described in *Field and Laboratory Protocols* are specific to the chemical and physical properties of Mono Lake and therefore may vary from standard limnological methods (e.g. Strickland and Parsons 1972). The methods and equipment used by LADWP to conduct limnological monitoring was consistent and followed those identified in *Field and Laboratory Protocols* except where noted below.

Meteorology

Two meteorological stations provided weather data in 2013 - Paoha Island and Cain Ranch. The Paoha Island measuring station is located approximately 30 m from shore on the southern tip of the island. The base of the station is at 1948 m above sea level, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten minute averages or hourly values in a Campbell Scientific CR 1000 datalogger. Data are downloaded to a storage module which is collected periodically during field sampling visits.

At the Paoha Island station, wind speed and direction (RM Young wind monitor) are measured by sensors at a height of 3 m above the surface of the island and are averaged over a 10-minute interval. During the ten minute interval, maximum wind speed is also recorded. Using wind speed and direction measurements, the 10-minute wind vector magnitude and wind vector direction are calculated. Hourly measurements of photosynthetically available radiation (PAR, 400 to 700 nm, Li-Cor 192-s), ten minute averages of relative humidity and air temperature (Vaisalia HMP35C), and total rainfall (Campbell Scientific TE525MM-L tipping bucket) are also stored. The minimum detection limit for the tipping bucket gage is 1 mm of water. The tipping bucket is not heated therefore the instrument is less accurate during periods of freezing due to sublimation of ice and snow. Paoha Island station precipitation data for 2013 will not be reported due to the inaccuracy of measurements recorded (<6 mm total rainfall recorded).

The Cain Ranch meteorological station is located approximately 7 km southwest of the lake at an elevation of 2088 m. This is an automated weather station managed by LADWP that records daily minimum and maximum air temperature and precipitation. Precipitation data was recorded in inches and is reported in millimeters for consistency with previous reports.

The daily mean wind speed, maximum mean wind speed, and relative humidity were calculated from 10-minute averaged data from the Paoha Island site.

Field Sampling

Sampling of the physical, chemical and biological properties of the water including the *Artemia* community was conducted at 12 buoyed stations at Mono Lake (Figure 1). The water depth at each station at a lake elevation of 1,946 meters is indicated on Figure 1. Stations 1-6 are considered western sector stations, and stations 7-12 are eastern sector stations. Surveys were generally conducted around the 15th of each month.

Physical and Chemical

Sampling of the physical and chemical properties included lake transparency, water temperature, conductivity, dissolved oxygen, and nutrients (ammonium). Lake elevation data was obtained directly from the Mono Lake Committee website (http://www.monobasinresearch.org/data/levelmonthly.php). Lake transparency was measured at all 12 stations using a Secchi disk. A high-precision conductivity temperature-depth (CTD) profiler (Idronaut,Model 316 Plus) was used to record water temperature and conductivity at nine stations (2, 3, 4, 5, 6, 7, 8, 10 and 12). The CTD is programmed to collect data at 200 millisecond intervals. The CTD was lowered to the bottom at a rate of ~0.2 meters/second, therefore data collection occurred at approximately 4 cm depth intervals.

Dissolved oxygen was measured at one centrally located station (Station 6). Dissolved oxygen concentration was measured with a Yellow Springs Instruments Rapid Pulse Dissolved Oxygen Sensor (YSI model 6562). Readings were taken at one-meter intervals throughout most of the water column, and at 0.5 meter intervals in the vicinity of the oxycline or other regions of rapid change. Data are reported for one-meter intervals only.

Monitoring of ammonium in the epilimnion was conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. An ammonium profile was developed by sampling at station 6 from eight discrete depths (2, 8, 12, 16, 20, 24, 28, and 35 meters) using a vertical Van Dorn sampler. Samples for ammonium analyses were filtered through Gelman A/E glass-fiber filters and following collection, immediately placed onto dry ice and frozen in order to stabilize the ammonium content (Marvin and Proctor 1965). Ammonium samples were transported on dry ice back to the laboratory transfer station. The ammonium samples were stored frozen until delivered frozen to the University of California Davis Analytical Laboratory (UCDAL) located in Davis, California. Samples were stored frozen until analysis.

Phytoplankton

Chlorophyll a sampling

Monitoring of chlorophyll a in the epilimnion was conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. A chlorophyll profile was developed by sampling at station 6 from seven discrete depths (2, 8, 12, 16, 20, 24, and 28 meters) using a vertical Van Dorn sampler. Water samples were filtered into opaque bottles through a 120 µm sieve to remove all stages of *Artemia*. Chlorophyll *a* samples were kept cold and transported on ice back to the laboratory transfer station located in Sacramento, CA.

Brine Shrimp

<u>*Artemia* sampling</u>

The *Artemia* population was sampled by one vertical net tow from each of twelve stations (Figure 1). Samples were taken with a plankton net (0.91 m x 0.30 m diameter, 118 µm Nitex mesh) towed vertically through the water column. Samples were preserved with 5% formalin in Mono Lake water. When adults were present, an additional net tow was taken from four western sector stations (1, 2, 5 and 6) and three eastern sector stations (7, 8 and 11) to collect adult females for fecundity analysis including body length and brood size. Live females collected for fecundity analysis were kept cool and in low densities during transport to LADWP laboratory in Bishop.

Laboratory Analysis

Ammonium

Nitrogen is the primary limiting macronutrient in Mono Lake as phosphate is super-abundant throughout the year (Jellison et al 1994 in Jellison 2011). External inputs are low, and vertical mixing controls much of the annual internal recycling of nitrogen.

Starting in August 2012, the methodology used by UCDAL for ammonium was flow injection analysis. In July 2012, this method was tested on high salinity Mono Lake water and was found to give results comparable to previous years. This method has detection limits of approximately 2.8 µM. Immediately prior to analysis, frozen samples were allowed to thaw and equilibrate to room temperature, and were shaken briefly to homogenize. Samples were heated with salicylate and hypochlorite in an alkaline phosphate buffer (APHA 1998a, APHA 199b, Hofer 2003, Knepel 2003). EDTA (Ethylenediaminetetraacetic acid) was added in order to prevent precipitation of calcium and magnesium, and sodium nitroprusside was added in order to enhance sensitivity. Absorbance of the reaction product was measured at 660 nm using a Lachat Flow Injection Analyzer (FIA), QuikChem 8000, equipped with a heater module. Absorbance at 660 nm is directly proportional to the original concentration of ammonium, and ammonium concentrations were calculated based on absorbance in relation to a standard solution.

Chlorophyll a

Chlorophyll *a* is the most abundant form of chlorophyll found bound within the cells of the algae comprising the phytoplankton community at Mono Lake. Chlorophyll *a* is therefore monitored as an indicator of phytoplankton activity and abundance.

In 2013 the determination of chlorophyll *a* was done by fluorometric analysis following acetone extraction. Fluorometry was chosen, as opposed to spectrophotometry, due to higher sensitivity of the fluorometric analysis, and because data on chlorophyll *b* and other chlorophyll pigments were not needed.

At the laboratory transfer station in Sacramento, water samples (200 mL) were filtered onto Whatman GF/F glass fiber filters (nominal pore size of 0.7 µm) under vacuum. Filter pads were then stored frozen until they could be overnight mailed, on dry ice, to the University of Maryland Center for Environmental Science Chesapeake Biological Laboratory (CBL), located in Solomons, Maryland. Sample filter pads were extracted in 90% acetone and then refrigerated in the dark for 2 to 24 hours. Following refrigeration, the samples were allowed to warm to room temperature, and then centrifuged to separate the sample material from the extract. The extract for each sample was then analyzed on a fluorometer. Chlorophyll *a* concentrations were calculated based on output from the fluorometer. Throughout the process, exposure of the samples to light and heat was avoided.

The fluorometer used in support of this analysis was a Turner Designs TD700 fluorometer equipped with a daylight white lamp, 340-500 nm excitation filter and >665 nm emission filter, and a Turner Designs Trilogy fluorometer equipped with either the non-acid or the acid optical module.

<u>Artemia</u> Population Analysis and Biomass

An 8x to 32x stereo microscope was used for all *Artemia* analyses. Depending on the density of shrimp, counts were made of the entire sample or of a subsample made with a Folsom plankton splitter. When shrimp densities in the net tows were high, samples were split so that approximately 100-200 individuals were subsampled. Shrimp were classified as nauplii (instars 1-7), juveniles (instars 8-11), or adults (instars >12), according to Heath's classification (Heath 1924). Adults were sexed and the reproductive status of adult females was determined. Non-reproductive (non-ovigerous) females were classified as empty. Ovigerous females were classified as undifferentiated (eggs in early stage of development), oviparous (carrying cysts) or ovoviviparous (naupliar eggs present).

An instar analysis was conducted at seven of the twelve stations (Stations 1,2,5,6,7,8, and 11). Nauplii at these seven stations were further classified as to specific instar stage (1-7). Biomass was determined from the dried weight of the shrimp tows at each station. After counting, samples were rinsed with tap water and dried in aluminum tins at 50°C for at least 48 hours. Samples are weighed on an analytical balance immediately upon removal from the oven.

Artemia Fecundity

Immediately upon return to the laboratory, ten females from each sampled station were randomly selected, isolated into individual vials, and preserved with 5% formalin. Female length was measured at 8X from the tip of the head to the end of the caudal furca (setae not included). Egg type was noted as undifferentiated, cyst, or naupliar. Undifferentiated egg mass samples were discarded. Brood size was determined by counting the number of eggs in the ovisac and any eggs dropped in the vial. Egg shape was noted as round or indented.

Artemia Population Statistics

Calculation of long-term *Artemia* population statistics followed Jellison and Rose (2011). Daily values of adult *Artemia* between sampling dates were linearly interpolated in Microsoft Excel. The mean, median, peak and centroid day (calculated center of abundance of adults) were then calculated for the time period May 1 through November 30. Long-term values were determined by calculating the mean, minimum and maximum values for these parameters for the time period 1979-2013.

RESULTS

Meteorology

Wind Speed, relative humidity, air temperature and precipitation data from the weather station at Paoha Island are summarized monthly for 2013. Precipitation data from the weather station at Cain Ranch is summarized monthly.

Wind Speed and Direction

Mean daily wind-speed varied from 0.85 to 9.54 m/sec with an overall mean for this time period of 3.2 m/sec (Figure 2). The daily maximum 10-min averaged wind speed on Paoha Island averaged 1.5 times the mean daily wind speed. The maximum recorded 10-min reading of 13.4 m/sec occurred on the afternoon of March 6th. As has been case in previous years, winds were predominantly from the south (mean 187 degrees).

Air Temperature

Daily air temperatures as recorded at Paoha Island ranged from a low of -11.4°C on January 13, 2013 to a high of 24.4°C on July 20 (Figure 3). Winter temperature (January through February) ranged from -8.5°C to 3.4°C with an average maximum daily temperature of 3.4°C. The average maximum daily summer temperature (June through August) was 26.8°C.

Relative Humidity and Precipitation

The mean relative humidity for the period January 1st – December 31st, 2013 was 54% (Figure 4). Mean relative humidity was negatively correlated with both daily mean wind speed ($r = -0.482$, $p<0.001$, $n=365$), and maximum 10-minute mean wind speed ($r = -0.470$, $p<0.001$, $n=365$). The total precipitation measured at Cain Ranch was 87.9 mm. Winter month precipitation was modest but increased in spring with April rainfall of 13 mm and 11.2 mm in May (Figure 5). The largest rain event produced 12.4 mm of rain on September 22ndth. Both total amount of rain (15 mm) and frequency of rain events (6) were greatest in July. The end of the 2013 was dryer producing less than 6 mm of rainfall in November and about 1.8 mm in December.

Physical and Chemical

Surface Elevation

The surface elevation of Mono Lake in January 2013 was 6382.0 feet. A slight increase in elevation to 6382.2 feet was observed in April. Starting in May lake elevation declined and continued through December. From the 2013 high of 6382.2 feet in April, the lake dropped a total of 1.8 feet to a low of 6380.4 feet by December 11th. Figure 6 shows lake elevation 1979 through 2013 and the mixing regime observed each year. As will be discussed below, Mono Lake continued to exhibit a monomictic mixing regime in 2013. For 2013 the greatest change is surface elevation (0.4 feet) occurred in late summer from August to September and early fall from September to October.

Transparency

The lowest spring secchi (average) depth was 0.38 m +/- 0.02 mm in April (Table 1, Figure 7). Secchi depth increased through mid-May when transparency was 1.15 m +/- 0.12 m. As *Artemia* grazing reduced midsummer phytoplankton, lakewide transparency increased to a maximum of 5.08 m +/- 0.2 m in July. Secchi depths began to decrease through the fall, and remained between 0.57 m and 0.66 m from October through December.

Water Temperature

The water temperature data from Station 6 indicate that Mono Lake remained meromictic in 2013 as the lake was thermally stratified from late spring to early fall with turnover occurring once later in the fall (Table 2, Figure 8). In April the thermocline began to form at 9-10 m (as indicated by the greater than 1°C change per meter depth) and fluctuated between 9 and 11 m through August before deepening to 15 m by September. In October temperatures began to cool and stratification weakened as temperatures throughout the water column differed by less than 1˚C. By the late November survey temperatures were fairly isothermic from 1 m to 40 m indicating the onset of holomixis (Table 2, Figure 8). Holomixis persisted throughout December as temperature data indicate little change with water temperatures at 6.3°C from 2 meters gradually declining to 5.2°C at 39 m.

Dissolved Oxygen

Dissolved oxygen (DO) levels at Station 6 were indicative of historical limnological mixing patterns observed at Mono Lake. In 2013 Mono Lake had one period of fall turnover marking the 2nd continuous year of monomictic conditions. DO concentration in winter/spring months within the first 15 m of the water column ranged as low as 5.8 mg/l in April to as high as 13.6 mg/l in May (Table 4, Figure 10*).* In May DO levels in the first 6 m of the water column were about twice as high (12.9 mg/l) as 2012 levels (6.1 mg/l). Dissolved oxygen levels at Mono Lake are typically higher in spring months as phytoplankton blooms follow increased sunlight and temperature levels. DO levels near the lake substrate (39m) decreased from February to May (7.1 to 1.8 mg/l) prior to the onset of meromixis. In June, Mono Lake began to thermally stratify with meromictic conditions persisting through August. In September the thermocline began to slowly breakdown prior to holomixis. In the fall epilimnetic DO concentrations were highest in September (9.3 mg/l) followed by October (3.1 mg/l) and were lowest in November (1.0 mg/l) as monomolimnetic hypoxic waters fully mixed with epilimnetic waters (Table 4, Figure 10). Mono Lake remained monomictic in December.

Conductivity

Conductivity data was collected from the CTD field sampling device on a monthly basis. In situ conductivity measurements were corrected for temperature (25˚C) and reported at one meter intervals beginning at one meter in depth down to the lake bottom. Conductivity data is used to evaluate the salinity profile of the lake and are reported in Table 3. Data from February and March are not reported due to malfunction of the CTD probe. The winter of 2013 marked the second consecutive year of monomixis at Mono Lake. Mono Lake surface elevation slowly increased in the beginning of 2013 and reached its peak in April as freshwater inputs from snowmelt likely contributed to vertical salinity stratification. Specific conductivities for April ranged from 83.6 to 85.9 mS/cm in the epilimnion and from 88.1 to 89.5 mS/cm below 14 meters (Table 3).

As thermal and chemical stratification became more prominent in the summer months the greatest difference between epilimnetic and hypolimnetic specific conductivities were reported in July and August (Table 3, Figure 9). For August specific conductivity averaged 78.8 mS/cm in the epilimnion and 87.7 mS/cm in the hypolimnion. By October as the thermocline became less defined (<1˚C temp difference per meter) average specific conductivity was only 0.8 mS/cm different between the epilimnion (85.4 mS/cm) and hypolimnion (86.2 mS/cm). By late November as Mono lake became holomictic specific conductivity varied the least throughout the water column (0.4 mS/cm, Table 3, Figure 9).

Ammonium

Ammonium levels were uniform throughout the water column in early 2013 (Table 5, Figure 11) due to holomixis that occurred in late 2012. Ammonium levels in February and March of 2013 (24 m and below) as measured at Station 6 ranged from 5.5 to 7.2 µM. Commensurate with increased algal growth, ammonium levels declined throughout the water column into April and were below the detection limit in May (<2.8 µM). Epilimnetic ammonium levels increased in June and July as *Artemia* abundance increased and excretion of fecal pellets raised the ammonium levels in the water column. The July through October period had large increases in the level of ammonium in the hypolimnion below approximately 20 m (12.2 to 25 µM). Increases in the ammonium concentration in the hypolimnion during these months is associated with increases in algal debris and *Artemia* fecal pellets as these waste products sink to the bottom and decompose (Jellison 2011). Under anoxic conditions during summer thermal stratification ammonium concentrations tend to be higher at the sediment-water interface as bacterial nitrification ceases and the adsorptive capacity of the sediments is greatly reduced due to loss of the oxidized microzone (Wetzel, 2001). Ammonium was below the detection limit (<2.8 µM) and well-mixed throughout the water column by November and mixing remained complete through mid-December. This reduction in ammonium levels throughout the water column coincides with holomixis and increased uptake by phytoplankton as predation pressure from *Artemia* decreases in winter months.

Phytoplankton

Seasonal changes were noted in the phytoplankton community, as measured by chlorophyll *a* concentration (Tables 7 and 8, Figure 12). On the February survey, epilimnetic chlorophyll levels averaged 47.4 µg/L (Table 8). Within the epilimnion, lakewide mean chlorophyll values decreased through the spring and reached their lowest point in the middle of summer (1.6 µg/L, Table 8). As the lake began to stratify in late spring and zooplankton grazing increased, chlorophyll levels reduced from 38.3 µg/L in May, to 3.6 µg/L in June at 8 meters in depth (Table 7). In August chlorophyll concentrations varied from 3.5 µg/L at 2 meters to 53.5 µg/L at 28 meters in the hypolimnion. By October as the water column began to fully mix the lakewide epilimnionic average had increased to 42.6 µg/l and reached its peak in December at 55.5 µg/L (Table 8). Overall both the lakewide trends (Table 8) and discrete sampling at Station 6 (Table 7) indicate changes in chlorophyll concentrations closely follow turnover conditions and fluctuations in grazing pressure from population changes of brine shrimp.

Brine Shrimp

Artemia Population Analysis and Biomass

Artemia population data is presented in Tables 9a through 9c as lakewide means, sector means associated standard errors and percentage of population by age class. As discussed in previous reports (Jellison and Rose 2011), zooplankton populations can exhibit a high degree of spatial and temporal variability. In addition, when sampling, local convergences of water masses may concentrate shrimp above overall means. For these reasons, Jellison and Rose have cautioned that the use of a single level of significant figures in presenting data is inappropriate, and that the reader should always consider the standard error associated with *Artemia* counts when making inferences from the data.

Artemia Population

Hatching of overwintering cysts had already initiated by February as the mid-February sampling detected an instar lakewide mean abundance of 1,481 +/- 312/m^2. The overwhelming majority (96.9%) of the instars in mid-February were instar 1. Instar abundance increased through mid-April to a peak of 81,757 +/- 13,273/m^2 which was twice the density of April 2012 counts. Similar to 2012 in early spring adults continued to be essentially absent. The 2013 peak *Artemia* lakewide abundance of 90,302 +/-18,865/m^2 was recorded on the May 14 survey. By May, adults comprised approximately 34% of the *Artemia* population. The instar analysis indicated a diverse age structure of instars 1-7 and juveniles (instars 8-11) in May. In June, females with cysts were first recorded. By July females with cyst abundance peaked at 16,385 +/- 2,509/m^2 and by August reproduction decreased significantly, with instars and juveniles comprising only 4.2% of the population. The greatest summer adult *Artemia* abundance occurred in July (54,347+/-8,198/m^2). The adult population declined in August (45,152 +/- 8,509/m^2) with a much greater reduction by September (12,449 +/- 1,257/m^2). In mid-October, adult shrimp numbered 2,349 +/- 338/m^2, dropping to a low of 35 +/- 9/m^2 in November and 44 +/- 16/m^2 in December.

Instar Analysis

The instar analysis, conducted at seven stations, showed patterns similar to those shown by the lakewide and sector analysis, but provide more insight into *Artemia* reproductive cycles occurring at the lake (Table 10). Instars 1 and 2 were most abundant in February and March as overwintering cysts were hatching. In April various age classes of instars 1-7 and juveniles were present and comprised approximately 99.5% of the *Artemia* population. In May a diverse age structure of instars was present, while adults comprised 34.8% of all *Artemia*. The number of instar 1 increased again in June indicating a second generation of reproduction. By June juvenile and instar abundance represented about 50% of the age structure population. The presence of late stage instars and juveniles indicate survival and recruitment into the population. Instar and juvenile abundance decreased to 21.6% in July and reached a low of 4.2% of the *Artemia* population. Adult abundance decreased from 90% in September to 4.7% in December while instar and juvenile age classes increased from 10% to near 95% over the same period. While proportions of *Artemia* age classes changed over the year, adult, juvenile and instar abundances declined considerably in November and December as anticipated (Table 9a).

Biomass

Mean *Artemia* biomass values were low in February and March, ranging from 0.14 gm/m^2 in February to 1.80 gm/m^2 in March (Table 11). Mean lakewide *Artemia* biomass peaked at 28.58 gm/m^2 in mid-July, and remained fairly level through August, at 23.85 gm/m^2 before declining in September to14.98 gm/m^2. By October, mean lakewide biomass had declined to 3.64 gm/m^2, and was minimal in November and December. Biomass values differed between western and eastern sectors seasonally as early spring (March and April) biomass was higher in the east, and early fall values (August-Sept) were slightly higher in the west. In July during peak shrimp abundance biomass values were higher in the east at 22.39 gm/m^2 compared to 14.37 gm/m^2 in the west.

Reproductive Parameters and Fecundity Analysis

Table 12 and Figure 13 show the result of the fecundity analysis and lakewide reproductive parameters. In May, no ovigery was detected. In June approximately 84% of females were ovigerous, with 69% oviparous (cyst-bearing), 7.2% ovoviviparous (naupliar eggs) and 7.6% undifferentiated eggs (Table 9c). From July through October, over 90% of females were ovigerous with the majority (72-86%) oviparous. Ovovivipary was over 10% in both October (11%) and December (14%).

The lakewide mean fecundity showed pronounced seasonal variation. The lakewide mean fecundity was initially 24.2 +/- 0.9 eggs per brood in mid-June, decreasing slightly to 17.6 +/- 0.6 eggs per brood in July (Table 12). Lakewide fecundity was 69.1 +/- 2.9 eggs per brood in September and reached a high of 93.7 +/- 4.3 eggs per brood in October. The majority of fecund females (91-100%) were oviparous, while ovoviviparous females with naupliar eggs constituted the remainder. Little difference was observed in fecundity between the western and eastern sectors. The minimum mean female length was 8.9 mm in July which corresponded with the smallest mean brood sizes for the year. The largest females (mean 10.9 mm) were recorded in October when mean brood size was also at its highest for the year (93.7). The number of indented cysts remained relatively constant near 50% with a high of 66% in July (Table 12).

Artemia Population Statistics

The calculated seasonal peak in adult *Artemia* of 54,347/m^2 was above the long-term average of 45,694/m^2 (Table 13). The mean and median were also above average (26,033 vs. 19,775/m^2

and 31,275 vs 18,574/m^2). The centroid is the calculated center of abundance of adults. The centroid day of 196 in 2013 corresponds to July 15th. The long-term mean centroid day for the time period 1979-2013 is 211 (July 29). Figure 14 shows daily lakewide mean adult *Artemia* values for 1982-2013. Adult *Artemia* numbers were the second highest ever recorded for July in 2013 and moderate through fall. In contrast, 2012 adult numbers peaked in May and were the second lowest ever recorded in July (Figure 14). In 2013, mean adult abundance was the 6th highest ever recorded. Interestingly 2013 was the first year since the most recent episode of meromixis in 2011 that ammonium previously contained in the hypolimnion was fully available for phytoplankton. The year 2012 marked the 4th time that Mono Lake shifted from meromixis to monomixis during the period of record. There is data to suggest that years following the onset of monomixis have coincided with high adult *Artemia* abundance at Mono Lake (Figure 15). The long term data show 1989 and 2004 as the 2nd and 3rd highest adult density recorded from 1979-2013 (Table 12, Figure 14). The longest periods of meromixis, 1983-1987 and 1995-2002 ended just previous to these years (see Figure 6).

DISCUSSION

Thermal and Chemical Stratification

In 2013, Mono Lake experienced a net reduction in elevation of 1.6 feet and holomixis or complete autumn mixing for the second year in a row. Following winter holomixis, thermal stratification became evident as early as April and strong thermal stratification was present by June. Thermal stratification was observed as late as September. By November an isothermal water column was present indicating full mixing of the water column.

Conductivity data indicated the establishment of a salinity gradient beginning in April with the greatest difference in specific conductivity in the epilimnion and hypolimnion occurring in July and August. In November conductivity measurements were most consistent throughout the water column during holomixis and were greatest on average in December likely attributable to decreased lake volume.

Dissolved Oxygen

The dissolved oxygen values followed the seasonal pattern generally observed at Mono Lake. DO values were highest in spring during algal blooms, but decreased noticeably in the summer throughout the water column. Increasing water temperatures lead to decreases in dissolved oxygen as the concentration of oxygen in solution is inversely proportional to temperature.

Increases in *Artemia* populations also decrease algal populations, thereby decreasing oxygen production. As algal populations likely recovered in the fall due to decreasing shrimp numbers, dissolved oxygen values in the epilimnion increased. Stratification of the lake through the summer results in a depletion of oxygen beneath the thermocline. When mixing occurs, further depletion of oxygen in the water column may occur as water in the oxic epilimnion is mixed with the anoxic hypolimnetic water, and consumed by biological oxygen demand in the monimolimnion (Jellison and Rose 2011). This was evident during November and December sampling when oxygen values were low throughout the water column as deep mixing was occurring.

Ammonium and Chlorophyll

Ammonium sampling further supports the presence of a monomictic lake regime in 2013. Prior to summer stratification ammonium concentrations were similar throughout the water column. The June through October period showed large increases in the level of ammonium in the hypolimnion below approximately 20 m, as algal debris and *Artemia* fecal pellets accumulated and decomposed in the hypolimnion. In addition, in the anoxic hypolimnion internal loading occurs as ammonium released from the sediments further increases ammonium levels. Ammonium concentrations were low (below detection limit) throughout the water column by mid-November and mixing remained complete through mid-December. Low levels of ammonium in winter months coincided with the greatest concentration of mean chlorophyll in the epilimnion across all stations sampled and throughout the water column at station 6.

Epilimnetic chlorophyll levels were initially moderate from February through April and decreased almost 50% in May coincident with the increase in shrimp numbers and subsequent decreases in the algal population. Mean epilimnetic chlorophyll levels were lowest in July coinciding with peak adult *Artemia* abundance. As shrimp numbers declined in early fall, by mid-October, chlorophyll levels were nearly recovered to February 2013 levels.

Brine Shrimp

Mean adult *Artemia* abundance was almost 60% higher in 2013 compared to 2012, although peak adult abundance was only slightly higher (Table 13). Total brine shrimp numbers (adults and instars) peaked in May and were fairly evenly represented by early and late stage instars and adult *Artemia* (Table 9a). Adult abundance peaked in July which was more representative of the long term trend as compared to the previous sampling year (Figure 14). The centroid peak in abundance occurred on July 15th which was 15 days earlier than the long term mean. Peak early instar abundance occurred in April representing more than 50% of early stage instars for the year (Table 9a). Recruitment of early instars to the population was evident by increasing late stage instars in May and June and peak adult numbers in July. Mean biomass was greatest in summer months reaching its peak in July (Table 11). Shrimp numbers remained steady through fall and were moderate into October as compared to long-term data. A high rate of ovigery and high brood numbers were observed in early fall. Long-term parameters indicate an above average seasonal peak in adult *Artemia* with mean abundance 32% greater than the long term mean (Table 13).

Recent Period of Monomixis and Importance to Biota

The health of *Artemia* populations are linked to primary food sources such as phytoplankton. The main nutrients required by phytoplankton are nitrogen and phosphorous. In Mono Lake nitrogen and its external inputs are limited but phosphorous is abundant. The majority of nitrogen biologically available for direct uptake by phytoplankton is in the form of ammonium. In Mono Lake ammonium is the limiting nutrient for primary productivity and relative contributions from internal nutrient cycling and brine shrimp have been documented (Jellison and Melack 1986, 1988). Ammonium bound in the sediments is made available by internal nutrient recycling driven by changes in thermal and chemical density stratification of Mono Lake. Historically, Mono Lake has shifted between meromictic and monomictic conditions dependent on a multitude of factors including climatic conditions such as temperature, evaporation, wind, freshwater inputs from precipitation and runoff and diversions. All of these influences affect stratification and mixing dynamics of Mono Lake. Mono Lake exhibited a monomictic mixing regime from 2008-2010, was meromictic in 2011, returned to monomixis in 2012 and remained so in 2013. Monomixis, or annual mixing once a year, is important to the nutrient cycle at Mono Lake as it returns nutrients, most importantly, ammonium back to the epilimnion for use by phytoplankton.

Historic Shifting from Meromictic to Monomictic Conditions

Analysis of long term mixing regimes at Mono Lake is important as water column mixing and internal nutrient cycling affect biota including *Artemia* population dynamics. As stated previously the most recent episode of monomixis (2012-2013) marks the 4th time since 1982 that Mono Lake has shifted from a meromictic to a monomictic state. Although vertical mixing does not provide the sole source of ammonium in Mono Lake, it is especially important for primary producers in the spring and fall as contributions from *Artemia* excretions are greatly reduced (Melack, 1988, Jellison and Melack, 1993). *Artemia* populations have greatly fluctuated since LADWP began monitoring Mono Lake in 1982 (see Table 13, Figure 14). Historically *Artemia* abundance has been high in years following the onset of monomixis including 1989, 2004, 2009 and 2013 (Figure 15). Ammonium liberated from anoxic sediments is made biologically available to plankton the fall and winter (1st year of monomixis) previous to years when annual *Artemia* abundance peaks have occurred. Perhaps an abundance of primary production in the year following breakdown of meromixis allow brine shrimp populations to peak the subsequent spring and summer as evidenced by high abundance in those years. Jellison and Rose report high values for primary production in those years following the breakdown of meromixis (2011), although there are occurrences when primary production was high during the calendar year of meromixis (Jellison and Rose, 2011). Studies have shown that spring generation brine shrimp raised at high food densities develop more quickly, begin reproducing earlier and that abundance of algae may likely affect year to year changes in shrimp abundance (Jellison and Melack, 1993).

While availability of food sources and nutrients are important they do not fully determine year to year abundance of *Artemia* (subsequent to meromixis). The unique life history of female brine shrimp allow for dormant cysts to stay viable for years. It is known that diapausing cysts require oxygen for hatching (Lenz, 1984). Under meromictic conditions when much of sediment has been anoxic for multiple years a large percentage of cysts likely fail to hatch. When sediments finally become reoxygenated during monomixis dormant cysts may begin to hatch (Jellison et al. 1989). The combination of reoxygenated dormant cyst hatching and mixing of ammonium rich water may likely explain peak years in adult brine shrimp abundance following long periods of meromixis.

Mono Lake Volume and Changes from Fluctuation in Freshwater Inputs

When evaluating the mean surface elevation from 1979 to 2013 a pattern may be emerging between declining lake elevation and annual brine shrimp abundance. The greatest mean adult shrimp density documented since 1979 occurred in 1982 when mean annual surface elevation was at the lowest recorded level in the past 34 years (Figure 15, Figure 16). During the preceding years water exports were high resulting in minimal release to Mono Lake (Figure 17). This year (1982) was subsequent to a period of several years of monomixis and was followed by a large release of freshwater in 1983 which set up conditions for a 5 year period of meromixis. The 2nd and 3rd highest mean adult *Artemia* densities occurred in 1989 and 2004 which are years subsequent to the breakdown of meromixis. These were years following below normal runoff years resulting in declining lake levels due to decreased freshwater input. The reduced lake volume combined with reduced fresh water input lessens the thermal and chemical gradient between the upper and lower water column and Mono Lake begins to mix. There may be a long term pattern of population booms during periods of transition from low to high lake levels or more importantly periods following the breakdown of meromixis (Figure 15, Figure 16). Despite the benefits from the release and circulation of ammonium rich water during initial years post meromixis, adult brine shrimp populations greatly reduce the following years during both monomictic and meromictic periods (Figure 15).

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Table 1. Secchi Depths (m); February – December 2013.

STATION	SAMPLING DATE 13-Feb	13-Mar	22-Apr	14-May	20-Jun	16-Jul	14-Aug	18-Sep	21-Oct	25-Nov	11-Dec
Western Sector											
1	0.40	0.60	0.40	0.70	2.80	6.10	4.80	2.10	0.60	0.45	0.7
2	0.60	0.60	0.40	0.65	3.50	5.50	5.50	1.80	0.70	0.55	0.8
3	0.50	0.55	0.30	0.95	2.80	5.30	4.40	1.70	0.60	0.65	0.7
4	0.50	0.55	0.40	1.00	2.20	4.90	4.00	1.30	0.60	0.6	0.7
5	0.60	0.55	0.45	1.00	2.50	4.50	5.50	1.50	0.60	0.6	0.75
6	0.45	0.70	0.40	0.90	2.40	4.30	4.10	1.40	0.50	0.5	0.7
AVG	0.51	0.59	0.39	0.87	2.70	5.10	4.72	1.63	0.60	0.56	0.73
SE	0.03	0.02	0.02	0.06	0.19	0.27	0.27	0.12	0.03	0.03	0.02
n	6	6	6	6	6	6	6	6	6	6	6
Eastern Sector											
7	0.40	0.50	0.50	1.70	2.60	4.60	4.10	1.40	0.70	0.6	0.6
8	0.60	0.60	0.30	1.00	2.40	4.90	4.90	1.60	0.70	0.6	0.7
9	0.40	0.60	0.35	0.95	2.75	4.90	5.10	1.80	0.80	0.6	0.6
10	0.50	0.50	0.40	1.50	2.30	4.60	4.20	1.40	0.70	0.55	0.6
11	0.65	0.50	0.35	1.80	2.00	6.60	4.70	1.30	0.60	0.5	0.5
12	0.55	0.55	0.35	1.70	2.50	4.80	4.60	1.60	0.70	0.6	0.6
AVG	0.52	0.54	0.38	1.44	2.43	5.07	4.60	1.52	0.70	0.58	0.60
SE	0.04	0.02	0.03	0.15	0.11	0.31	0.16	0.07	0.03	0.02	0.03
n	6	6	6	6	6	6	6	6	6	6	6
Total Lakewide											
AVG	0.51	0.57	0.38	1.15	2.56	5.08	4.66	1.58	0.65	0.57	0.66
SE	0.03	0.02	0.02	0.12	0.11	0.20	0.15	0.07	0.02	0.02	0.02
n	12	12	12	12	12	12	12	12	12	12	12

Table 2. Temperature (°C) at Station 6, February – December 2013.

Temperature (°C) at Station 6, February - December, 2013

Depth (m)	13- Feb	13- Mar	22- Apr	14- May	20- Jun	16- Jul	14- Aug	18- Sep	21- Oct	25- Nov	11- Dec
0	4.7	8.7	15.0	16.4	19.2	20.4	21.5	17.8	13.2	9.2	6.9
1	2.3	5.4	11.2	15.3	18.5	20.4	20.2	17.8	11.6	8.7	6.6
2	1.9	5.2	10.4	14.3	17.9	20.1	20.0	17.4	11.5	8.7	6.3
3	1.9	5.2	9.3	13.9	17.8	20.3	19.9	17.4	11.4	8.6	6.3
4	1.8	4.3	9.0	12.4	17.7	20.3	19.8	17.4	11.5	8.7	6.3
5	1.8	3.8	8.9	11.7	17.7	20.2	19.8	17.4	11.6	8.7	6.3
6	1.8	3.6	8.0	11.2	17.7	20.1	19.8	17.4	11.7	8.7	6.3
7	1.8	3.6	8.0	10.6	17.6	20.0	19.8	17.4	11.7	8.7	6.3
8	1.8	3.3	7.5	9.6	17.6	19.3	19.8	17.4	11.8	8.7	6.3
9	1.8	3.2	7.0	8.2	17.6	16.9	19.8	17.3	11.8	8.7	6.2
10	1.8	3.0	5.8	7.2	17.0	15.4	19.7	17.3	11.8	8.7	6.2
11	1.8	2.8	5.5	6.9	13.0	11.9	18.3	17.2	11.8	8.7	6.2
12	1.8	2.6	4.6	6.4	10.1	9.8	12.8	17.2	11.7	8.7	6.2
13	1.8	2.5	3.7	5.7	8.7	8.1	11.5	17.3	11.7	8.7	6.2
14	1.8	2.4	3.4	4.9	7.8	6.0	8.9	17.3	11.7	8.7	6.2
15	1.8	2.4	3.3	4.3	6.4	5.4	6.9	9.7	11.8	8.7	6.2
16	1.8	2.3	3.1	4.2	5.6	5.0	6.3	6.9	11.7	8.7	6.1
17	1.8	2.3	3.0	3.7	5.1	4.9	6.0	6.9	11.7	8.7	6.1
18	1.8	2.3	3.0	3.5	4.6	4.6	5.6	6.9	11.3	8.7	6.0
19	1.8	2.2	2.8	3.4	4.4	4.4	5.3	6.9	10.7	8.7	6.0
20	1.8	2.2	2.8	3.3	4.1	4.3	5.1	6.9	9.8	8.7	6.0
21	1.8	2.2	2.7	3.3	3.9	4.2	4.7	6.9	9.3	8.7	5.9
22	1.8	2.2	2.6	3.3	3.7	4.2	4.5	6.8	9.4	8.7	5.9
23	1.8	2.2	2.6	3.2	3.7	-	4.4	6.3	9.6	8.7	5.9
24	1.8	2.2	2.6	3.1	3.6	-	4.2	6.3	9.6	8.7	5.9
25	1.8	2.1	2.6	3.1	3.6	-	4.1	6.3	9.3	8.6	5.9
26	1.8	2.1	2.6	3.0	3.6	-	4.0	6.3	9.3	8.6	5.9
27	1.8	2.1	2.5	2.8	3.4	-	4.0	6.3	9.6	8.6	5.8
28	1.8	2.0	2.5	2.8	3.4	-	3.9	6.0	9.7	8.6	5.8
29	1.7	2.0	2.4	2.7	3.4	-	3.9	5.7	9.6	8.5	5.7
30	1.7	2.0	2.4	2.7	3.3	-	3.9	5.7	9.5	8.5	5.7
31	1.7	2.0	2.4	2.7	3.3	-	3.8	5.5	9.3	8.4	5.6
32	1.8	2.0	2.4	2.6	3.2	-	3.8	5.5	9.2	8.4	5.5
33	1.8	2.0	2.4	2.6	3.1	-	3.7	5.4	8.9	8.3	5.5
34	1.8	2.0	2.4	2.6	3.1	-	3.7	-	8.6	8.3	5.5
35	1.7	2.0	2.4	2.6	3.1	-	3.7	-	8.6	8.3	5.4
36	1.7	2.0	2.4	2.6	3.1	-	3.7	-	-	8.2	5.3
37	1.7	2.0	2.4	2.6	3.0	-	3.6	-	-	8.3	5.3
38	1.7	2.0	2.4	2.6	3.0	-	3.6	-	-	8.2	5.2
39	1.8	2.0	2.4	2.6	3.0	-	3.6	-	-	8.1	5.2
40	1.9	2.0	-	-	3.1	-	3.6	-	-	8.1	5.5

Temperature data is from YSI temperature-oxygen meter.

Table 3. Conductivity (mS/cm^{-1}at 25°C) at Station 6, April – December 2013.

Depth (m)	**22-Apr**	**13-May**	**20-Jun**	**16-Jul**	**14-Aug**	**18-Sep**	**21-Oct**	**25-Nov**	**11-Dec**
1	83.6	82.7	82.0	78.1	77.6	83.0	85.1	86.7	88.0
2	84.0	82.6	82.9	78.5	78.7	83.7	85.3	86.8	88.1
3	84.1	81.9	83.0	78.0	78.9	83.8	85.4	86.8	88.1
4	85.0	83.4	83.1	78.2	79.0	83.8	85.4	86.8	88.2
5	85.1	83.8	83.2	78.3	79.0	83.8	85.4	86.7	88.2
6	85.0	84.5	83.3	78.4	79.0	83.8	85.4	86.8	88.2
7	85.3	84.0	83.2	78.5	79.0	83.8	85.4	86.7	88.2
8	85.5	84.5	83.1	79.7	79.0	83.9	85.4	86.7	88.2
9	85.9	84.5	83.2	80.3	79.0	83.9	85.4	86.7	88.2
10	86.1	85.6	84.0	82.7	79.4	84.0	85.4	86.7	88.2
11	86.4	86.0	84.9	83.3	81.2	84.0	85.5	86.8	88.2
12	86.2	86.5	85.1	84.6	84.3	84.1	85.4	86.8	88.2
13	88.1	86.5	85.4	85.6	84.5	84.1	85.5	86.8	88.2
14	88.5	87.4	86.2	86.4	85.4	80.1	85.5	86.8	88.3
15	88.6	87.9	86.8	86.8	86.6	87.1	85.5	86.8	88.3
16	89.0	88.2	87.4	87.3	86.6	86.7	85.5	86.8	88.4
17	89.0	88.5	87.6	87.7	86.6	86.7	85.6	86.8	88.4
18	89.0	88.5	87.9	87.7	87.1	86.7	85.8	86.8	88.4
19	89.1	88.5	88.2	88.1	87.3	86.7	86.3	86.8	88.4
20	89.1	88.6	88.2	87.8	87.5	86.7	86.1	86.8	88.4
21	89.2	88.6	88.3	87.9	87.7	86.9	86.1	86.8	88.5
22	89.2	88.7	88.3	88.0	87.8	86.9	86.0	86.8	88.5
23	89.2	88.8	88.4	88.1	87.9	86.9	85.9	86.8	88.5
24	89.2	88.9	88.4	88.2	88.0	87.1	86.1	86.9	88.5
25	89.3	88.9	88.5	88.3	88.2	86.9	86.2	86.9	88.5
26	89.4	89.0	88.6	88.4	88.1	86.7	86.1	86.9	88.6
27	89.4	89.0	88.6	88.5	88.1	87.2	86.1	86.9	88.6
28	89.4	89.1	88.6	88.4	88.2	87.3	86.1	86.9	88.6
29	89.4	89.1	88.7	88.4	88.2	87.3	86.2	86.9	88.7
30	89.4	89.1	88.7	88.4	88.3	87.3	86.2	87.0	88.7
31	89.4	89.2	88.8	88.5	88.4	87.5	86.2	87.0	88.8
32	89.4	89.2	88.8	88.5	88.3	87.4	86.2	87.0	88.8
33	89.5	89.2	88.8	88.5	88.3	87.5	86.5	87.1	88.9
34	89.5	89.2	88.8	88.6	88.4	87.5	86.7	87.1	88.9
35	89.4	89.2	88.8	88.6	88.4	87.5	86.7	87.1	89.0
36	-	89.2	-	-	-	87.7	86.9	87.1	89.0
37	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-

Table 4. Dissolved Oxygen (mg/l) at Station 6, February – December 2013.

Depth (m)	13-Feb	13-Mar	22-Apr	14-May	20-Jun	16-Jul	14-Aug	18-Sep	21-Oct	25-Nov	11-Dec
1	11.2	9.9	12.0	10.2	4.3	5.4	7.3	9.3	3.1	1.0	1.4
2	11.4	10.4	12.3	10.2	4.4	5.5	7.3	8.9	3.1	1.1	1.4
3	10.7	10.5	12.4	11.0	4.4	5.4	7.2	8.7	3.1	1.1	1.3
4	10.3	10.7	12.9	12.0	4.4	5.5	7.0	8.5	2.9	1.0	1.2
5	9.8	10.4	12.0	13.4	4.3	5.5	7.0	8.3	2.8	1.0	1.0
6	9.6	9.7	10.7	13.6	4.3	5.5	7.0	8.1	2.6	0.9	0.8
7	9.6	9.3	10.4	12.8	4.2	5.5	7.0	7.7	2.5	0.9	0.6
8	9.6	9.2	9.4	11.8	4.1	5.5	6.9	7.6	2.3	0.9	0.5
9	9.7	9.0	8.9	10.4	3.9	5.3	6.9	7.4	2.2	0.9	0.4
10	9.6	8.5	8.6	9.4	3.9	5.5	6.8	7.3	2.2	0.8	0.3
11	9.5	8.0	8.4	8.4	4.4	5.9	6.1	6.2	2.3	0.8	0.2
12	9.4	7.7	7.9	7.6	4.6	6.7	5.0	6.2	2.3	0.8	0.2
13	9.5	7.4	7.1	7.3	4.5	5.3	3.9	6.2	2.3	0.8	0.2
14	9.4	7.2	6.1	6.2	4.2	4.6	2.7	6.3	2.3	0.7	0.2
15	9.4	7.0	5.8	5.9	3.5	3.2	1.9	2.0	2.2	0.7	0.1
16	9.3	6.8	5.8	5.4	3.1	1.6	1.0	1.7	2.1	0.7	0.1
17	9.3	6.7	5.8	5.3	2.4	0.9	0.6	1.6	2.1	0.7	0.1
18	9.3	6.6	5.6	5.3	1.4	0.6	0.5	1.6	1.7	0.7	0.1
19	9.2	6.6	5.5	5.3	0.9	0.3	0.5	1.5	1.4	0.7	0.1
20	9.3	6.5	5.4	5.1	0.6	0.2	0.4	1.5	1.1	0.7	0.1
21	9.2	6.4	5.4	5.0	0.3	0.2	0.4	1.5	1.1	0.7	0.1
22	9.2	6.4	5.2	4.6	0.1	0.1	0.4	1.5	1.2	0.7	0.1
23	9.3	6.4	5.0	4.2	0.1	0.1	0.4	1.5	1.3	0.7	0.1
24	9.4	6.4	5.0	4.2	0.0	-	0.4	1.5	1.1	0.7	0.1
25	9.5	6.4	5.0	4.1	0.0	-	0.4	1.5	0.8	0.7	0.1
26	9.0	6.4	4.9	4.0	0.0	-	0.4	1.5	0.6	0.6	0.1
27	9.1	6.4	4.8	4.1	0.0	-	0.4	1.5	0.5	0.6	0.1
28	9.2	6.3	4.7	4.2	0.0	-	0.4	1.5	0.4	0.6	0.1
29	9.1	6.3	4.6	4.2	0.0	-	0.4	1.5	0.2	0.6	0.1
30	9.0	6.3	4.4	4.2	0.0	-	0.4	1.5	0.2	0.6	0.1
31	8.9	6.2	4.3	4.2	0.0	-	0.4	1.5	0.1	0.6	0.1
32	8.6	6.0	4.3	3.9	0.0	-	0.4	1.5	0.0	0.6	0.1
33	8.4	5.9	4.3	3.4	0.0	-	0.4	1.5	0.0	0.6	0.1
34	8.4	5.8	4.0	3.1	0.0	-	0.4	-	0.0	0.6	0.1
35	8.0	5.8	3.8	2.9	0.0	-	0.4	-	0.0	0.6	0.1
36	7.9	5.7	3.8	2.4	0.0	-	0.4	-	-	0.6	0.1
37	7.8	5.7	3.8	2.1	0.0	-	0.4	-	-	0.6	0.1
38	7.4	5.7	3.8	2.0	0.0	-	0.4	-	-	0.6	0.1
39	7.1	5.7	3.7	1.8	0.0	-	0.4	-	-	0.6	0.1
40	5.3	4.7	-	-	0.0	-	0.4	-	-	0.6	0.1

Table 5. Ammonium (µM) at Station 6, February through December 2013.

Depth (m)	13-Feb	13-Mar	22-Apr	14-May	20-Jun	16-Jul	14-Aug	18-Sep	21-Oct	25-Nov	11-Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	6.1	6.7	3.9	<2.8	6.7	6.7	<2.8	<2.8	<2.8	<2.8	<2.8
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	6.1	6.1	4.4	<2.8	7.2	6.7	3.3	<2.8	<2.8	<2.8	<2.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	6.7	6.7	4.4	<2.8	6.7	6.7	4.4	<2.8	<2.8	<2.8	<2.8
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	6.7	6.1	5.0	<2.8	6.7	10.5	8.9	21.1	<2.8	<2.8	<2.8
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	5.5	6.1	6.1	<2.8	12.2	16.6	12.8	21.6	12.2	<2.8	<2.8
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	5.5	6.1	7.2	<2.8	15.0	13.9	18.3	23.8	13.3	<2.8	<2.8
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	7.2	7.2	8.3	<2.8	16.1	18.3	22.7	25.0	12.8	<2.8	<2.8

Laboratory detection limit of 2.8µm.

Table 6. 9-meter integrated values for Ammonium (µm) – February to December 2013.

Station	**13-Feb**	**13-Mar**	**22-Apr**	**14-May**	**20-Jun**	**16-Jul**	**14-Aug**	**18-Sep**	**21-Oct**	**25-Nov**	**11-Dec**
1	6.1	6.7	5.5	<2.8	7.2	8.3	<2.8	<2.8	3.9	<2.8	<2.8
2	6.7	6.7	4.4	<2.8	7.2	7.2	<2.8	<2.8	<2.8	<2.8	<2.8
5	6.1	6.1	4.4	<2.8	6.1	-	<2.8	<2.8	<2.8	<2.8	<2.8
6	6.7	6.7	4.4	<2.8	6.1	6.7	<2.8	<2.8	<2.8	<2.8	<2.8
7	6.1	7.2	6.1	<2.8	6.7	6.7	<2.8	<2.8	<2.8	<2.8	<2.8
8	6.7	6.1	5.5	<2.8	6.7	6.7	<2.8	<2.8	<2.8	<2.8	<2.8
11	6.7	6.7	5.0	<2.8	7.2	9.4	<2.8	<2.8	<2.8	<2.8	<2.8
Mean	6.41	6.6	34.4	2.8	6.7	1.6	2.8	2.8	3.0	2.8	2.8
SE	0.15	0.99	0.26	0.00	0.19	0.22	0.00	0.00	0.15	0.00	0.00

Laboratory detection limit of 2.8µm.

Table 7. Chlorophyll *a* (µg /l) at Station 6 – February through December 2013.

Depth (m)	13-Feb	13-Mar	22-Apr	14-May	20-Jun	16-Jul	14-Aug	18-Sep	21-Oct	25-Nov	11-Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	47.5	37.2	39.0	7.3	2.8	1.8	3.5	17.5	42.0	53.4	54.9
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	45.2	44.3	37.0	38.3	3.6	1.8	4.3	18.6	37.7	47.6	49.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	48.9	40.6	38.1	43.7	13.5	14.7	21.3	18.6	42.9	52.4	59.3
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	46.7	35.2	35.6	41.7	31.8	32.6	44.8	42.5	40.3	49.4	48.5
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	52.2	41.8	35.8	25.7	41.5	42.9	47.3	43.2	42.2	52.6	57.2
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	43.2	39.9	36.7	44.1	49.2	45.8	47.9	47.2	46.4	49.9	62.3
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	48.4	40.9	42.6	34.1	49.2	47.7	53.5	46.2	43.9	50.4	60.3

Table 8. 9-meter integrated values for chlorophyll *a* (µg/l) – February to December 2013.

Station	13-Feb	13-Mar	22-Apr	14-May	20-Jun	16-Jul	14-Aug	18-Sep	21-Oct	25-Nov	11-Dec
1	49.7	33.5	38.2	24.9	2.4	1.0	2.6	10.9	41.0	44.0	57.3
2	46.5	37.0	37.8	18.1	3.0	1.6	3.2	13.4	39.9	49.0	52.2
5	48.4	36.8	38.2	15.5	3.1	-	1.8	15.9	40.7	48.7	55.9
6	48.7	35.8	33.9	19.1	3.0	2.0	3.6	17.1	41.3	53.8	57.7
7	47.0	32.2	45.3	15.4	3.7	2.2	4.7	13.3	40.1	50.4	58.8
8	45.3	36.7	41.1	19.5	3.9	1.7	3.0	14.2	47.9	52.7	57.6
11	45.9	31.3	40.3	14.2	4.1	0.9	3.0	15.9	47.5	59.4	49.1
Mean	47.4	34.8	34.4	18.1	3.3	1.6	3.1	14.4	42.6	51.1	55.5
SE	0.80	0.97	1.32	1.36	0.22	0.22	0.34	0.80	1.33	1.82	1.34

Table 9a. *Artemia* lake and sector means, 2013.

	Instars					Ad Female Ovigery Classification				
	1-7	8-11	Adult Total	Adult Males	Adult Female Total	empty	undif	cysts	naup	Total *Artemia*
Lakewide mean										
13-Feb	1,461	20	27	17	9	9	0	0	0	1,508
13-Mar	28,106	0	0	0	0	0	0	0	0	28,106
22-Apr	81,355	402	0	0	0	0	0	0	0	81,757
14-May	30,181	28,706	31,415	21,274	10,141	9,926	0	0	215	90,302
20-Jun	11,858	25,835	39,759	27,820	11,938	1,932	912	8,236	858	77,451
16-Jul	3,579	11,419	54,347	31,761	22,586	2,092	2,193	16,385	1,916	69,345
14-Aug	1,336	649	45,152	24,665	20,487	1,059	2,136	15,685	1,607	47,137
18-Sep	1,103	284	12,449	7,162	5,287	47	227	4,537	476	13,836
21-Oct	985	139	2,349	1,482	866	24	57	690	96	3,472
25-Nov	219	43	35	28	6	0	3	2	2	296
11-Dec	807	87	44	33	11	2	3	5	2	937
Western Sector mean										
13-Feb	8,955	0	0	0	0	0	0	0	0	8,955
13-Mar	907	0	16	9	6	6	0	0	0	923
22-Apr	68,062	376	0	0	0	0	0	0	0	68,437
14-May	31,925	25,003	34,608	21,945	12,663	12,233	0	0	429	91,536
20-Jun	16,579	23,125	40,027	29,242	10,785	698	1,180	7,941	966	79,732
16-Jul	5,495	10,990	56,918	34,836	22,081	2,823	2,017	15,528	1,714	73,403
14-Aug	1,664	1,084	48,801	26,896	21,905	1,210	2,168	17,015	1,512	51,549
18-Sep	1,286	265	12,377	6,856	5,520	88	277	4,663	492	13,927
21-Oct	558	82	1,950	1,144	807	16	76	646	69	2,590
25-Nov	113	13	22	16	6	0	3	0	3	148
11-Dec	85	0	6	3	3	0	0	0	3	91
Eastern Sector mean										
13-Feb	47,257	0	0	0	0	0	0	0	0	47,257
13-Mar	2,015	41	38	25	13	13	0	0	0	2,094
22-Apr	94,648	429	0	0	0	0	0	0	0	95,077
14-May	28,437	32,408	28,223	20,604	7,619	7,619	0	0	0	89,068
20-Jun	7,136	28,545	39,490	26,398	13,092	3,166	644	8,531	751	75,171
16-Jul	1,664	11,847	51,776	28,686	23,090	1,361	2,369	17,242	2,117	65,287
14-Aug	1,008	214	41,504	22,434	19,069	907	2,105	14,355	1,701	42,726
18-Sep	920	302	12,522	7,468	5,054	6	176	4,411	460	13,744
21-Oct	1,412	195	2,748	1,821	926	32	38	734	123	4,355
25-Nov	325	72	47	41	6	0	3	3	0	444
11-Dec	1,528	173	82	63	19	3	6	9	0	1,783

Table 9b. Standard errors of *Artemia* sector means (from Table 9a), 2013.

	Instars					Ad Female Ovigery Classification				
	1-7	8-11	Adult Total	Adult Males	Adult Female Total	empty	undif	cysts	naup	Total *Artemia*
SE of Lakewide mean										
13-Feb	303	9	11	8	4	4	0	0	0	316
13-Mar	9,196	0	0	0	0	0	0	0	0	9,196
22-Apr	13,216	228	0	0	0	0	0	0	0	13,273
14-May	4,446	5,970	9,329	5,623	3,801	3,589	0	0	215	18,865
20-Jun	2,041	2,292	3,348	2,521	1,126	539	185	826	199	5,464
16-Jul	831	1,634	8,198	4,812	3,534	452	562	2,509	433	9,491
14-Aug	199	162	8,509	4,417	4,113	216	633	3,124	280	8,617
18-Sep	172	60	1,257	689	644	19	51	583	57	1,298
21-Oct	205	34	338	230	150	9	13	126	21	478
25-Nov	40	12	9	9	3	0	2	2	2	55
11-Dec	372	43	16	14	4	2	2	2	2	427
SE of Western Sector mean										
13-Feb	3,203	0	0	0	0	0	0	0	0	3,203
13-Mar	338	0	8	6	6	6	0	0	0	343
22-Apr	23,062	211	0	0	0	0	0	0	0	23,229
14-May	8,088	10,917	19,414	11,706	7,797	7,369	0	0	429	38,207
20-Jun	2,654	2,138	5,665	4,324	1,410	268	339	1,169	235	7,704
16-Jul	1,224	2,804	12,906	7,850	5,086	723	1,020	3,135	760	14,727
14-Aug	217	193	15,602	8,024	7,580	375	1,167	5,763	442	15,690
18-Sep	261	87	1,384	613	895	30	80	777	99	1,189
21-Oct	144	21	427	204	225	10	21	198	21	510
25-Nov	35	4	8	6	4	0	3	0	3	37
11-Dec	35	0	4	3	3	0	0	0	3	34
SE Eastern Sector Mean										
13-Feb	14,668	0	0	0	0	0	0	0	0	14,668
13-Mar	407	13	20	14	6	6	0	0	0	431
22-Apr	12,885	429	0	0	0	0	0	0	0	12,832
14-May	4,508	5,669	1,405	1,381	482	482	0	0	0	10,269
20-Jun	1,538	3,950	4,148	2,908	1,749	773	83	1,265	339	8,364
16-Jul	268	1,953	11,246	6,040	5,385	404	581	4,193	481	13,146
14-Aug	291	49	8,358	4,413	4,020	234	632	3,004	382	8,529
18-Sep	220	89	2,244	1,294	1,000	6	64	941	65	2,448
21-Oct	302	57	508	381	215	14	13	173	34	660
25-Nov	36	16	16	15	4	0	3	3	0	56
11-Dec	631	72	24	22	5	3	4	4	0	718

Table 9c. Percentage in different classes for *Artemia* sector means (from Table 9a), 2013.

	Instars						Ad Female Ovigery Classification				
	1-7	8-11	Instar %	Adult Total	Adult Males	Adult Female Total	empty	undif	cysts	naup	Ovigerous Female%
Lakewide %											
13-Feb	96.9	1.4	98.2	1.8	1.1	0.6	0.0	0.0	0.0	0.0	0.0
13-Mar	100.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22-Apr	99.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-May	33.4	31.8	65.2	34.8	23.6	11.2	97.9	0.0	0.0	0.0	0.0
20-Jun	15.3	33.4	48.7	51.3	35.9	15.4	16.2	7.6	69.0	7.2	83.8
16-Jul	5.2	16.5	21.6	78.4	45.8	32.6	9.3	9.7	72.5	8.5	90.7
14-Aug	2.8	1.4	4.2	95.8	52.3	43.5	5.2	10.4	76.6	7.8	94.8
18-Sep	8.0	2.0	10.0	90.0	51.8	38.2	0.9	4.3	85.8	9.0	99.1
21-Oct	28.4	4.0	32.4	67.6	42.7	25.0	2.7	6.5	79.6	11.1	97.3
25-Nov	73.9	14.4	88.3	11.7	9.6	2.1	0.0	50.0	25.0	0.0	75.0
11-Dec	86.1	9.2	95.3	4.7	3.5	1.2	14.3	28.6	42.9	14.3	85.7
Western Sector %											
13-Feb	100.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-Mar	98.3	0.0	98.3	1.7	1.0	0.7	0.0	0.0	0.0	0.0	0.0
22-Apr	99.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-May	34.9	27.3	62.2	37.8	24.0	13.8	96.6	0.0	0.0	0.0	0.0
20-Jun	20.8	29.0	49.8	50.2	36.7	13.5	6.5	10.9	73.6	9.0	93.5
16-Jul	7.5	15.0	22.5	77.5	47.5	30.1	12.8	9.1	70.3	7.8	87.2
14-Aug	3.2	2.1	5.3	94.7	52.2	42.5	5.5	9.9	77.7	6.9	94.5
18-Sep	9.2	1.9	11.1	88.9	49.2	39.6	1.6	5.0	84.5	8.9	98.4
21-Oct	21.5	3.2	24.7	75.3	44.2	31.1	2.0	9.4	80.1	8.6	98.0
25-Nov	76.6	8.5	85.1	14.9	10.6	4.3	0.0	50.0	0.0	50.0	100.0
11-Dec	93.1	0.0	93.1	6.9	3.4	3.4	0.0	0.0	0.0	0.0	0.0
Eastern Sector %											
13-Feb	100.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-Mar	96.2	2.0	98.2	1.8	1.2	0.6	0.0	0.0	0.0	0.0	0.0
22-Apr	99.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-May	31.9	36.4	68.3	31.7	23.1	8.6	100.0	0.0	0.0	0.0	0.0
20-Jun	9.5	38.0	47.5	52.5	35.1	17.4	24.2	4.9	65.2	5.7	75.8
16-Jul	2.5	18.1	20.7	79.3	43.9	35.4	5.9	10.3	74.7	0.0	84.9
14-Aug	2.4	0.5	2.9	97.1	52.5	44.6	4.8	11.0	75.3	8.9	95.2
18-Sep	6.7	2.2	8.9	91.1	54.3	36.8	0.1	3.5	87.3	0.0	90.8
21-Oct	32.4	4.5	36.9	63.1	41.8	21.3	3.4	4.1	79.3	0.0	83.3
25-Nov	73.0	16.3	89.4	10.6	9.2	1.4	0.0	50.0	50.0	0.0	100.0
11-Dec	85.7	9.7	95.4	4.6	3.5	1.1	16.7	33.3	50.0	0.0	83.3

Table 10. Lakewide *Artemia* instar analysis, 2013.

					Instars					
	1	2	3	4	5	6	7	8-11	Adults	Total
Lakewide Mean:										
13-Feb	1159	308	46	14	5	14	0	14	24	1583
13-Mar	32795	329	86	11	0	0	0	0	0	33222
22-Apr	14510	22351	31503	17798	1748	368	230	644	0	89152
14-May	736	2621	4277	3587	2759	4277	11130	27686	37482	94556
20-Jun	5887	4691	1656	782	184	138	460	26490	37022	77310
16-Jul	2766	1469	86	0	0	0	0	13525	63825	81671
14-Aug	400	616	259	86	0	0	0	637	50223	52222
18-Sep	184	243	130	162	76	81	76	335	11057	12343
21-Oct	151	149	194	221	132	65	41	157	2447	3557
25-Nov	24	73	49	38	22	22	5	49	35	316
11-Dec	173	111	76	108	49	46	59	68	35	724
Standard error of the mean:										
13-Feb	13843	141	86	11	0	0	0	0	0	13977
13-Mar	367	94	11	5	3	9	0	9	16	490
22-Apr	3453	6049	7434	4865	501	130	182	372	0	21148
14-May	552	661	1364	626	561	980	4742	9298	15843	31630
20-Jun	2953	794	646	297	119	96	138	3596	4455	8781
16-Jul	1193	791	86	0	0	0	0	2368	13031	14623
14-Aug	139	169	139	86	0	0	0	195	14137	14323
18-Sep	66	77	43	60	23	48	44	72	1522	1500
21-Oct	52	46	72	92	50	23	17	50	1522	1500
25-Nov	8	22	15	15	9	10	3	18	14	82
11-Dec	62	72	49	72	29	26	39	50	18	392
Percentage in different age classes:										
13-Feb	98.7	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	100.0
13-Mar	73.2	19.5	2.9	0.9	0.3	0.9	0.0	0.9	1.5	100.0
22-Apr	16.3	25.1	35.3	20.0	2.0	0.4	0.3	0.7	0.0	100.0
14-May	0.8	2.8	4.5	3.8	2.9	4.5	11.8	29.3	39.6	100.0
20-Jun	7.6	6.1	2.1	1.0	0.2	0.2	0.6	34.3	47.9	100.0
16-Jul	3.4	1.8	0.1	0.0	0.0	0.0	0.0	16.6	78.1	100.0
14-Aug	0.8	1.2	0.5	0.2	0.0	0.0	0.0	1.2	96.2	100.0
18-Sep	1.5	2.0	1.1	1.3	0.6	0.7	0.6	2.7	89.6	100.0
21-Oct	4.3	4.2	5.5	6.2	3.7	1.8	1.1	4.4	68.8	100.0
25-Nov	7.7	23.1	15.4	12.0	6.8	6.8	1.7	15.4	11.1	100.0
11-Dec	23.9	15.3	10.4	14.9	6.7	6.3	8.2	9.3	4.9	100.0

Table 11. *Artemia* biomass summary, 2013.

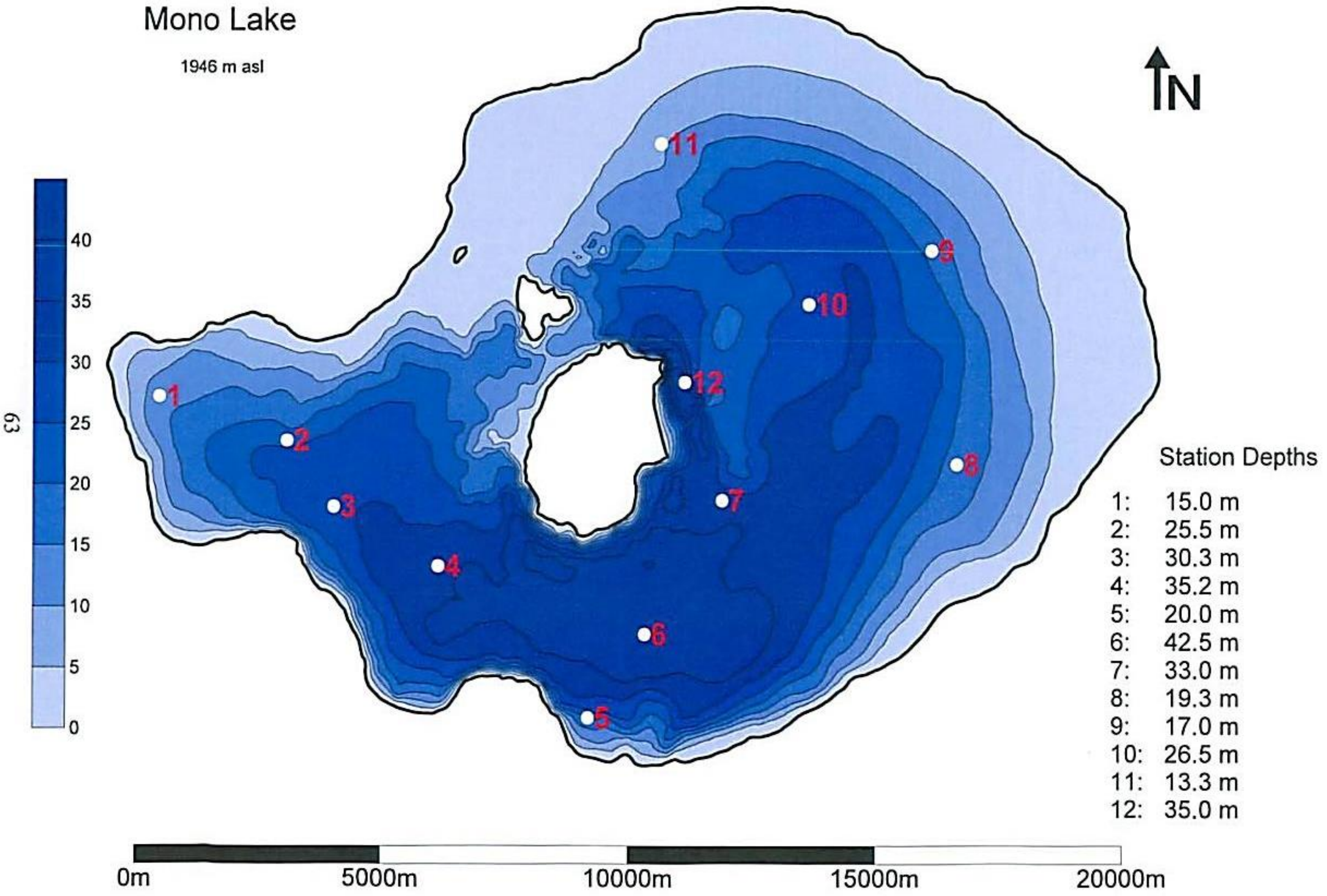
	Mean Biomass		
Date	Lakewide	Western Sector	Eastern Sector
13-Feb	0.14	0.15	0.14
13-Mar	1.80	0.35	3.25
22-Apr	17.18	15.05	19.30
14-May	13.77	14.18	13.36
20-Jun	23.23	20.96	25.49
16-Jul	28.58	14.37	22.39
14-Aug	23.85	26.03	21.67
18-Sep	14.98	15.13	14.83
21-Oct	3.64	3.29	3.99
25-Nov	0.23	0.21	0.24
11-Dec	0.21	0.14	0.27

Table 12. *Artemia* fecundity summary, 2013.

	#eggs/brood		%cysts	%indented	Female Length	
	mean	SE			Mean	SE
Lakewide Mean:						
20-Jun	24.2	0.9	99%	51%	9.4	0.1
16-Jul	17.6	0.6	100%	66%	8.9	0.1
14-Aug	22.1	1.0	100%	54%	9.3	0.1
18-Sep	69.1	2.9	99%	51%	10.7	0.1
21-Oct	93.7	4.3	91%	52%	10.9	0.2
Western Sector Mean:						
20-Jun	24.1	1.3	57%	26%	9.5	0.1
16-Jul	18.5	0.6	57%	37%	8.9	0.1
14-Aug	20.2	1.0	57%	29%	9.4	0.1
18-Sep	66.0	4.1	56%	39%	10.6	0.2
21-Oct	86.7	5.3	53%	34%	11.0	0.2
Eastern Sector Mean:						
20-Jun	24.4	1.3	41%	26%	9.2	0.1
16-Jul	16.5	1.0	43%	29%	8.9	0.1
14-Aug	24.6	1.7	43%	26%	9.2	0.2
18-Sep	73.2	4.0	43%	13%	10.9	0.2
21-Oct	103.9	6.7	36%	18%	10.8	0.3

Table 13. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979-2013.

Year	**Mean**	**Median**	**Peak**	**Centroid**
1979	14,118	12,286	31,700	216
1980	14,643	10,202	40,420	236
1981	32,010	21,103	101,670	238
1982	36,643	31,457	105,245	252
1983	17,812	16,314	39,917	247
1984	17,001	19,261	40,204	212
1985	18,514	20,231	33,089	218
1986	14,667	17,305	32,977	190
1987	23,952	22,621	54,278	226
1988	27,639	25,505	71,630	207
1989	36,359	28,962	92,491	249
1990	20,005	16,775	34,930	230
1991	18,129	19,319	34,565	226
1992	19,019	19,595	34,648	215
1993	15,025	16,684	26,906	217
1994	16,602	18,816	29,408	212
1995	15,584	17,215	24,402	210
1996	17,734	17,842	34,616	216
1997	14,389	16,372	27,312	204
1998	19,429	21,235	33,968	226
1999	20,221	21,547	38,439	225
2000	10,550	9,080	22,384	210
2001	20,031	20,037	38,035	209
2002	11,569	9,955	25,533	200
2003	13,778	12,313	29,142	203
2004	32,044	36,909	75,466	180
2005	17,888	15,824	45,419	192
2006	21,518	20,316	55,748	186
2007	18,826	17,652	41,751	186
2008	11,823	12,524	27,606	189
2009	25,970	17,919	72,086	181
2010	14,921	7,447	46,237	191
2011	21,343	16,893	48,918	194
2012	16,324	11,302	53,813	179
2013	26,033	31,275	54,347	196
Mean	19,775	18,574	45,694	211
Min	10,550	7,447	22,384	179
Max	36,643	36,909	105,245	252



1:	15.0 m
2:	25.5 m
3:	30.3 m
4:	35.2 m
5:	20.0 m
6:	42.5 m
7:	33.0 m
8:	19.3 m
9:	17.0 m
10:	26.5 m
11:	13.3 m
12:	35.0 m

Figure 1. Sampling Stations at Mono Lake and Associated Station Depths.

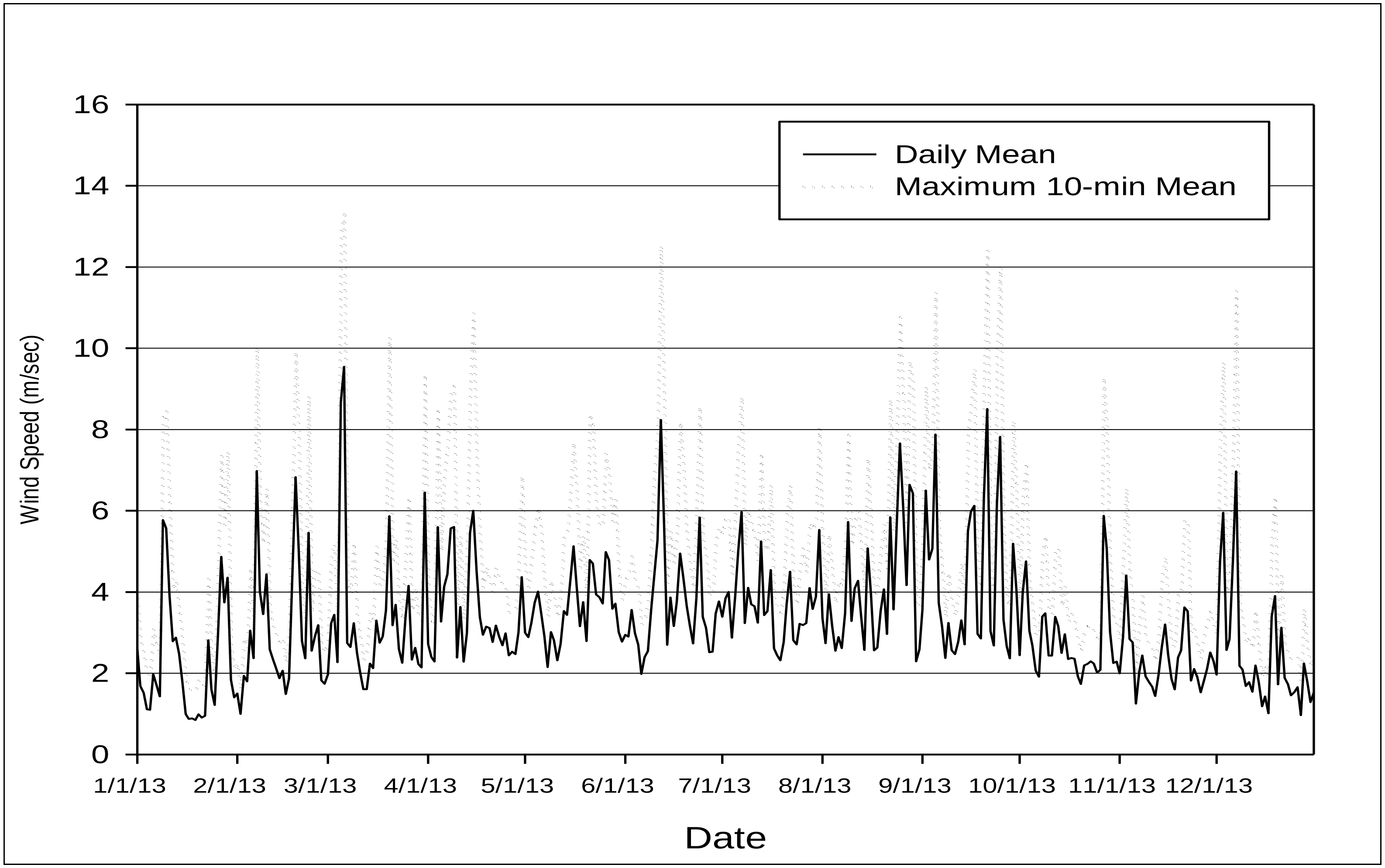


Figure 2. Mean daily wind speed and mean maximum 10-minute wind speed Paoha Island, January 1st- December 31st, 2013.

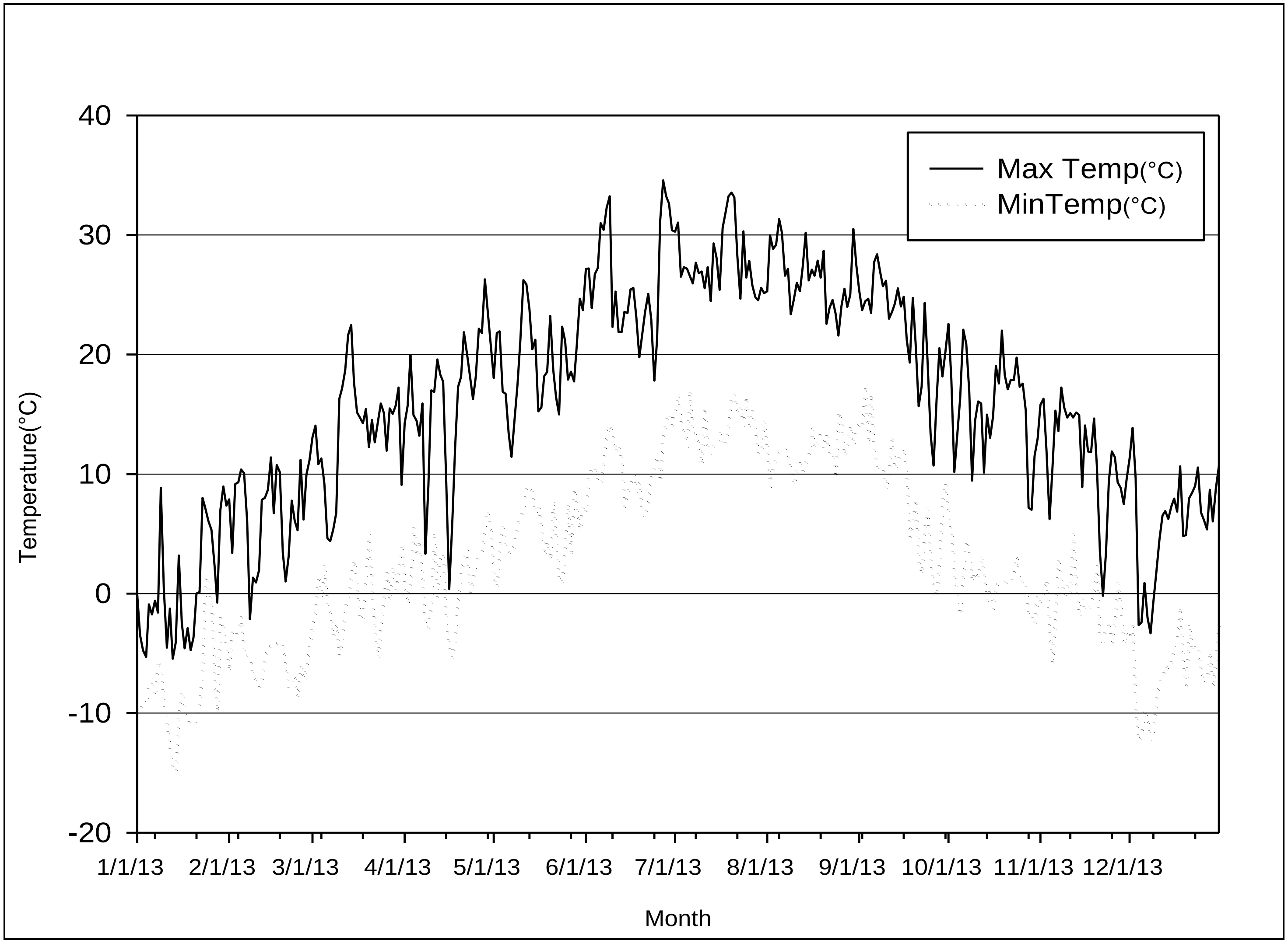


Figure 3. Minimum and maximum daily temperature (°C) as recorded at Paoha Island, January 1st- December 31st, 2013.

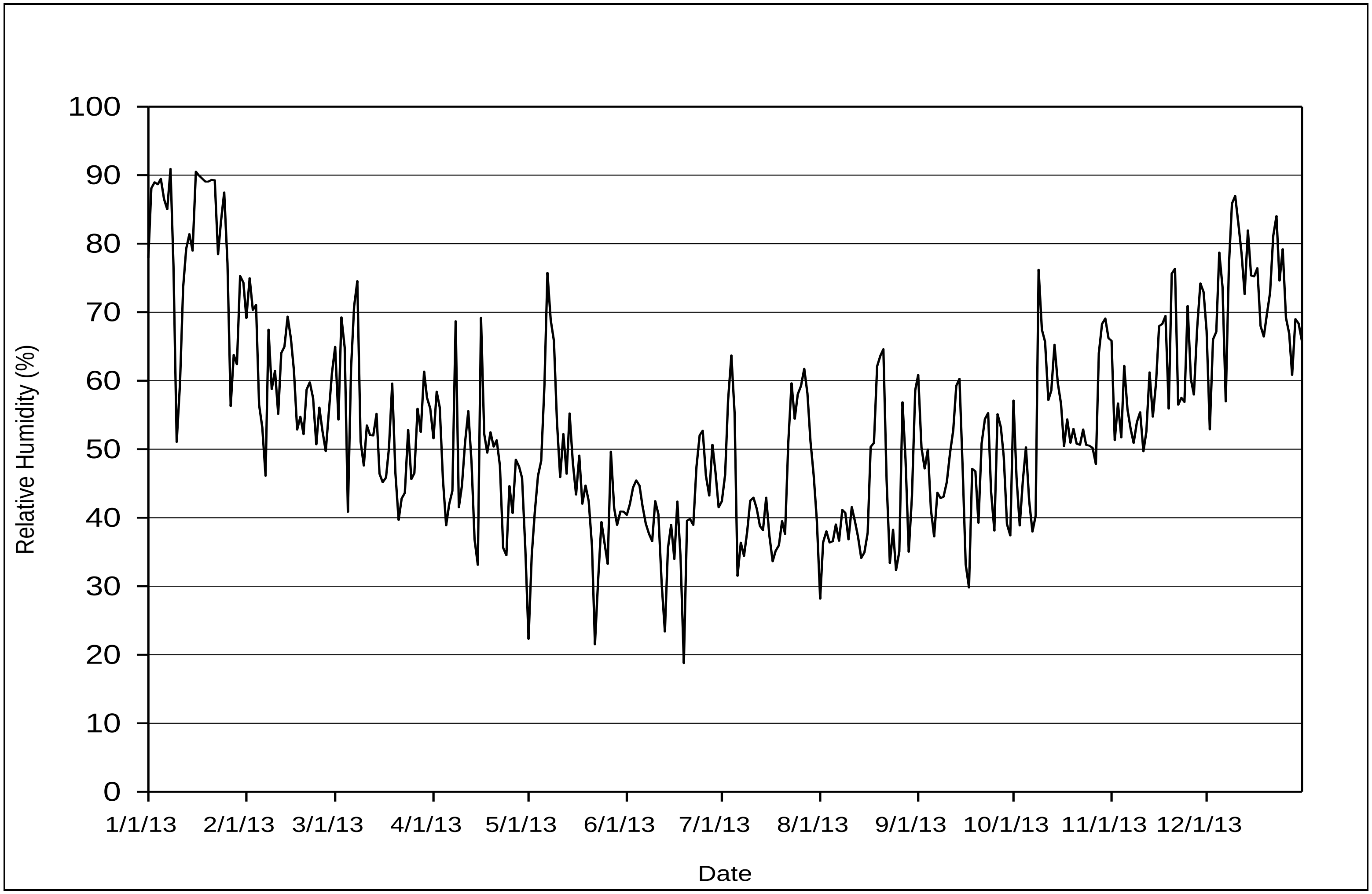


Figure 4. Mean relative humidity (%) – Paoha Island, January 1st- December 31st, 2013.

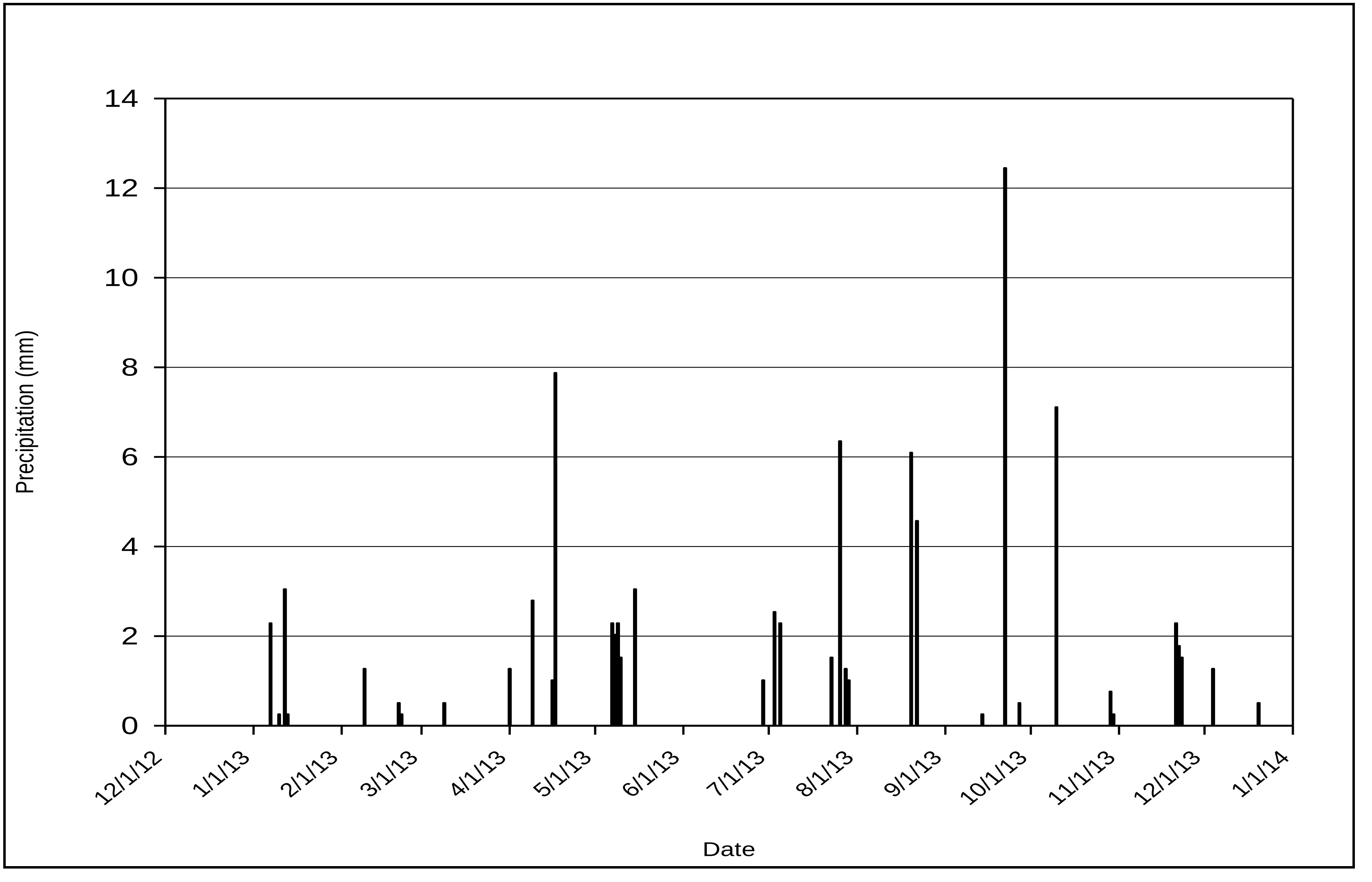


Figure 5. Precipitation (mm) at Cain Ranch , 2013.

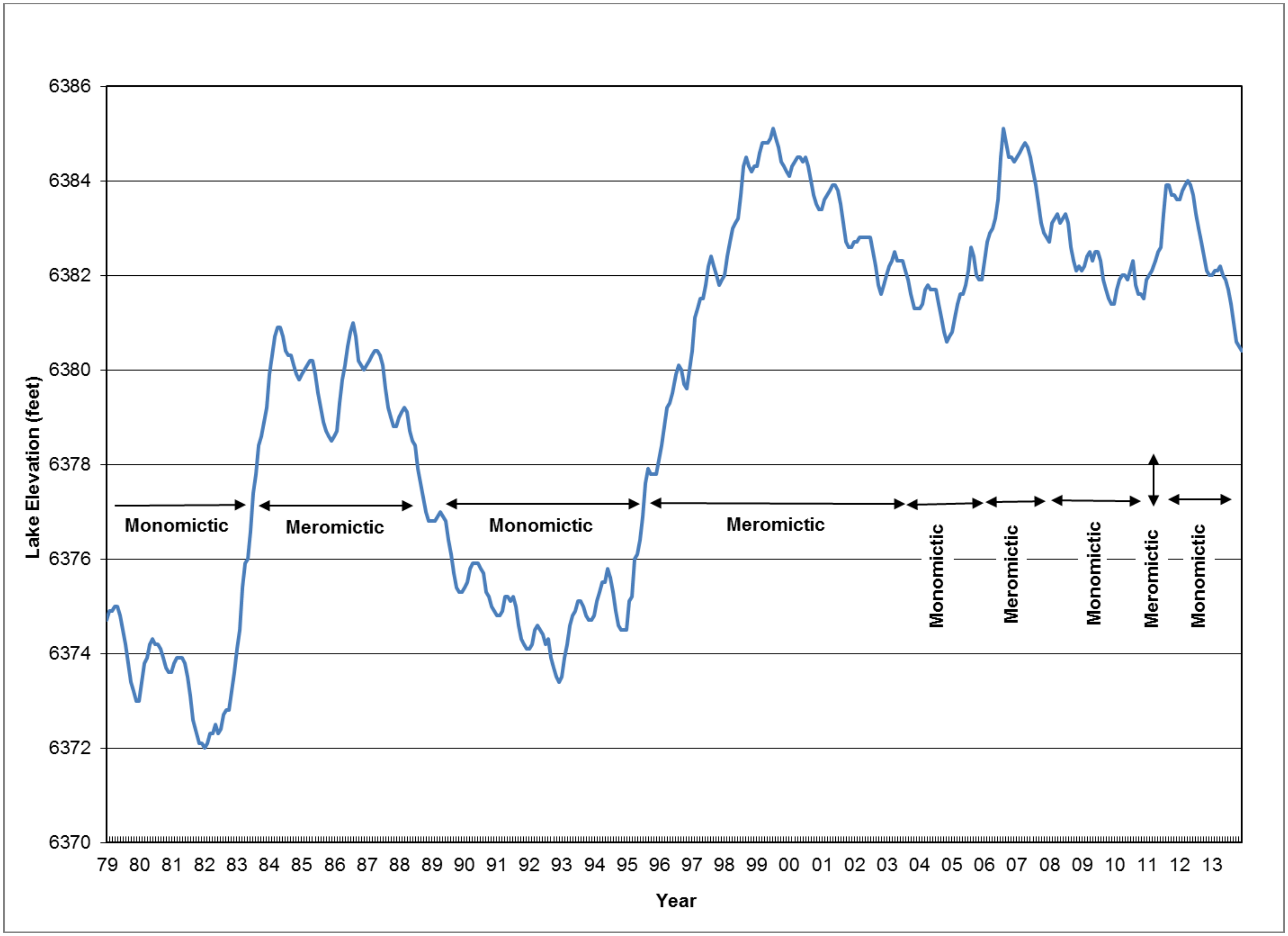


Figure 6. Surface elevation of Mono Lake and mixing regime, 1979-2013.

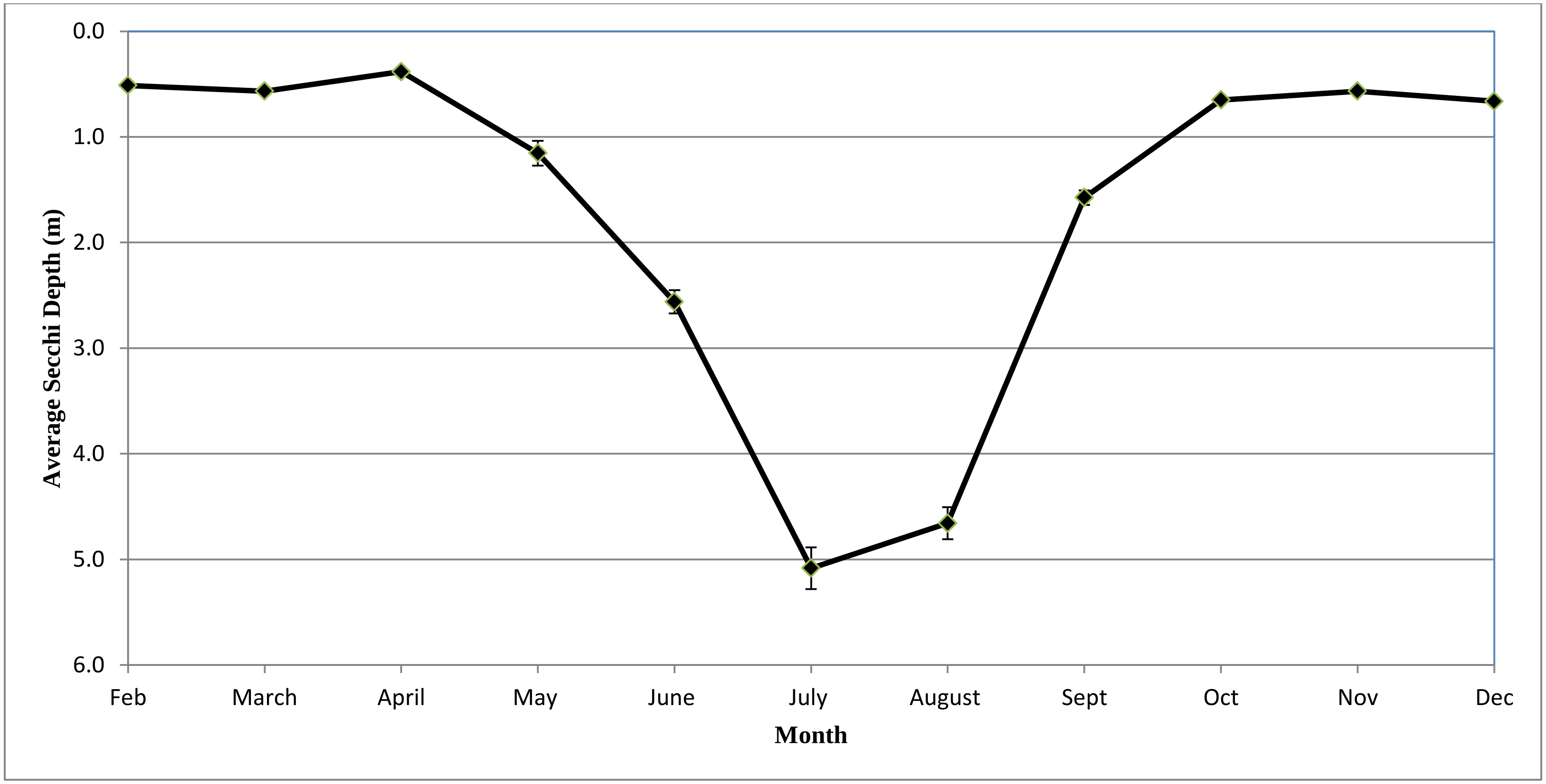


Figure 7. Secchi depths (meters) and standard error, 2013.

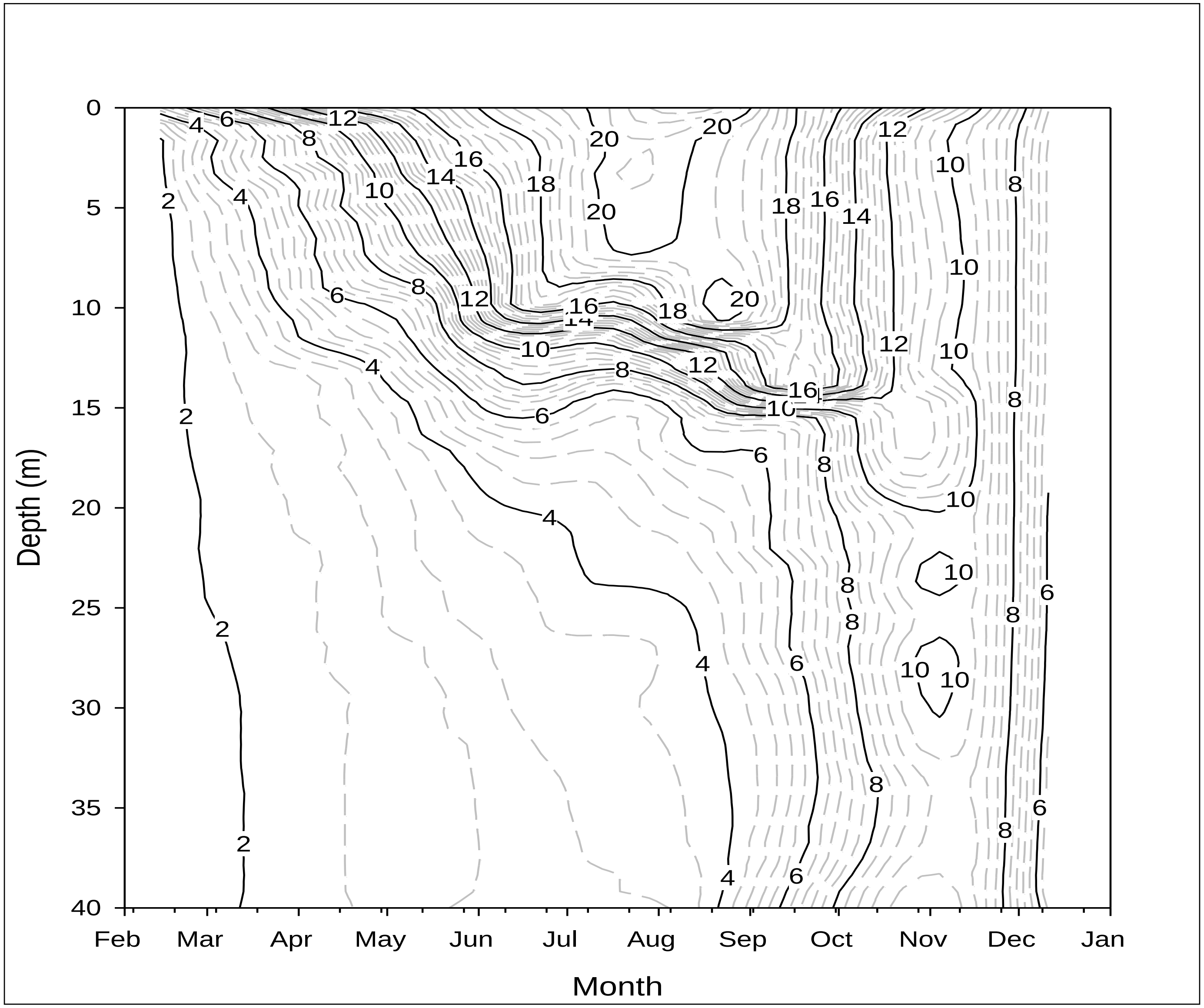


Figure 8. Temperature profiles at Station 6, February to December 2013.

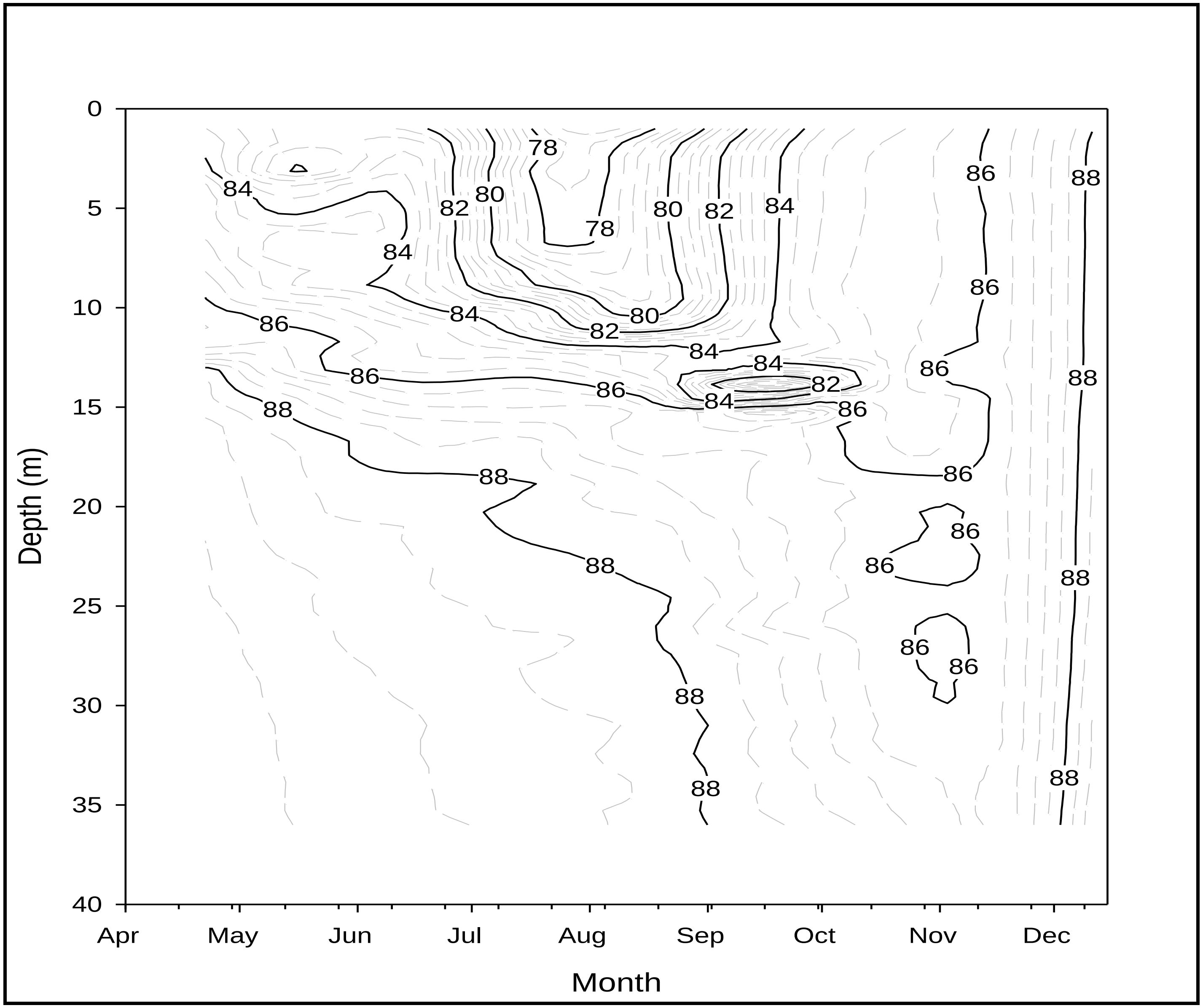


Figure 9. Conductivity (mS/cm) profiles at Station 6, April-December, 2013.

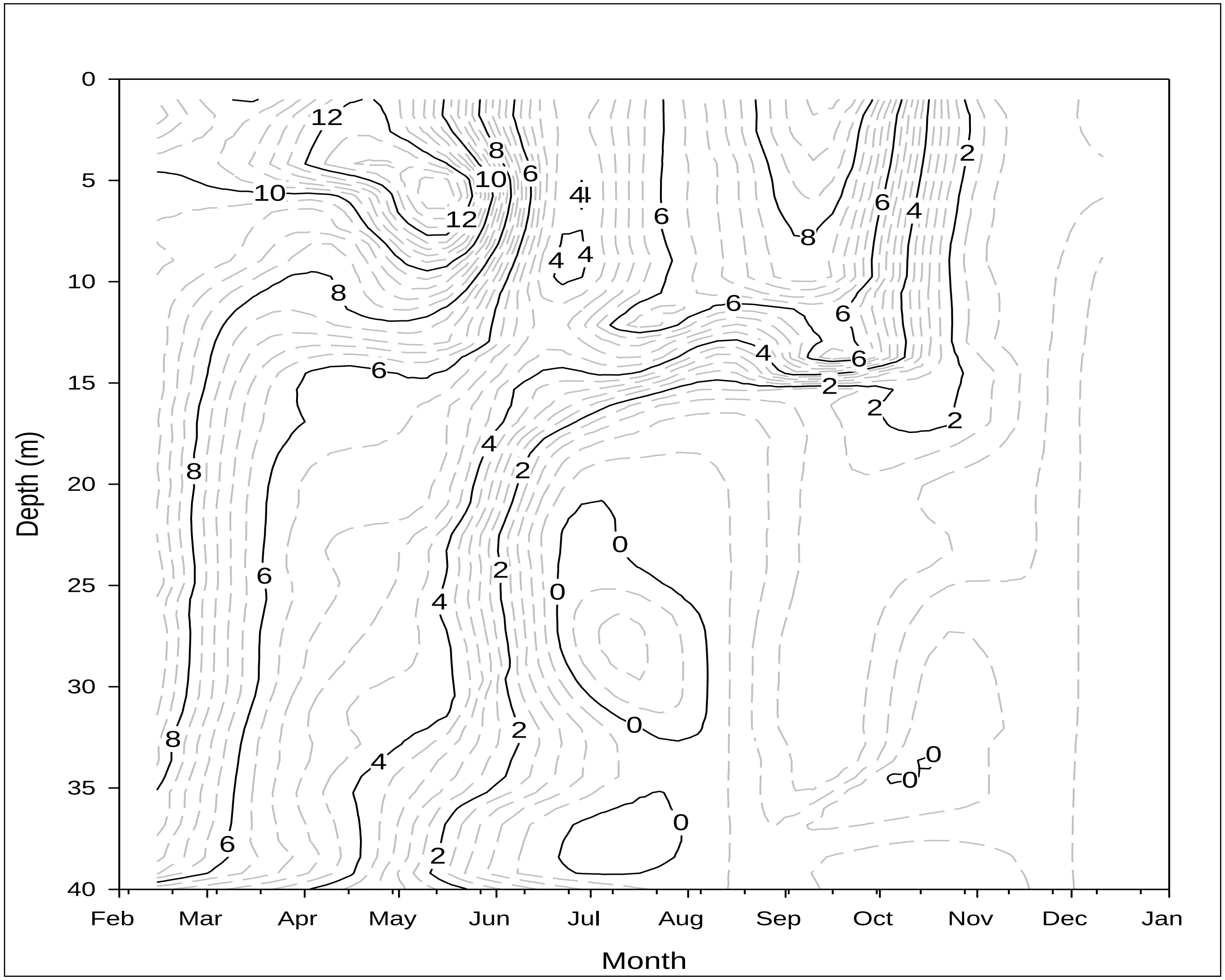


Figure 10. Dissolved oxygen profiles at Station 6, February – December 2013.

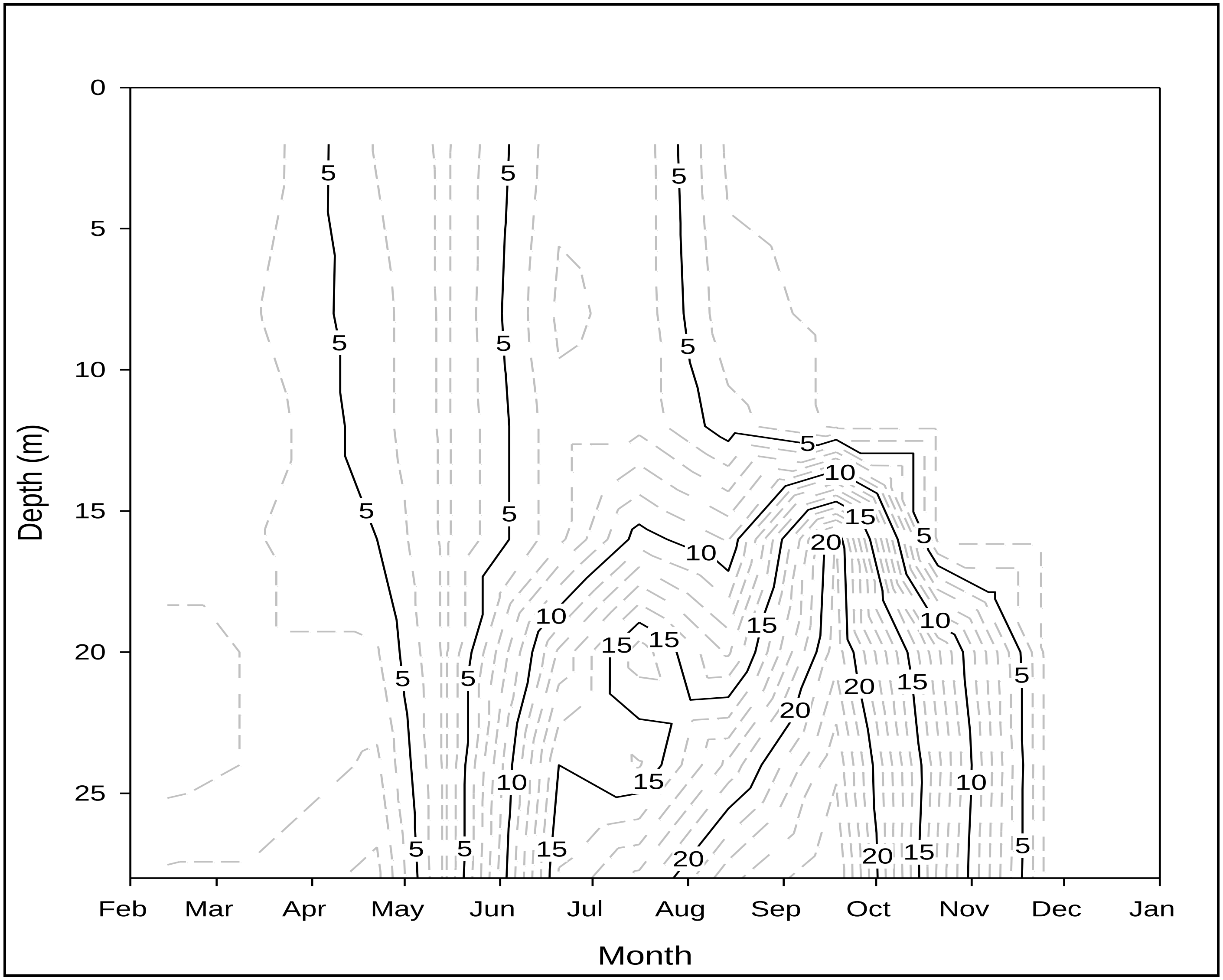


Figure 11. Ammonium profiles Station 6, February – December 2013.

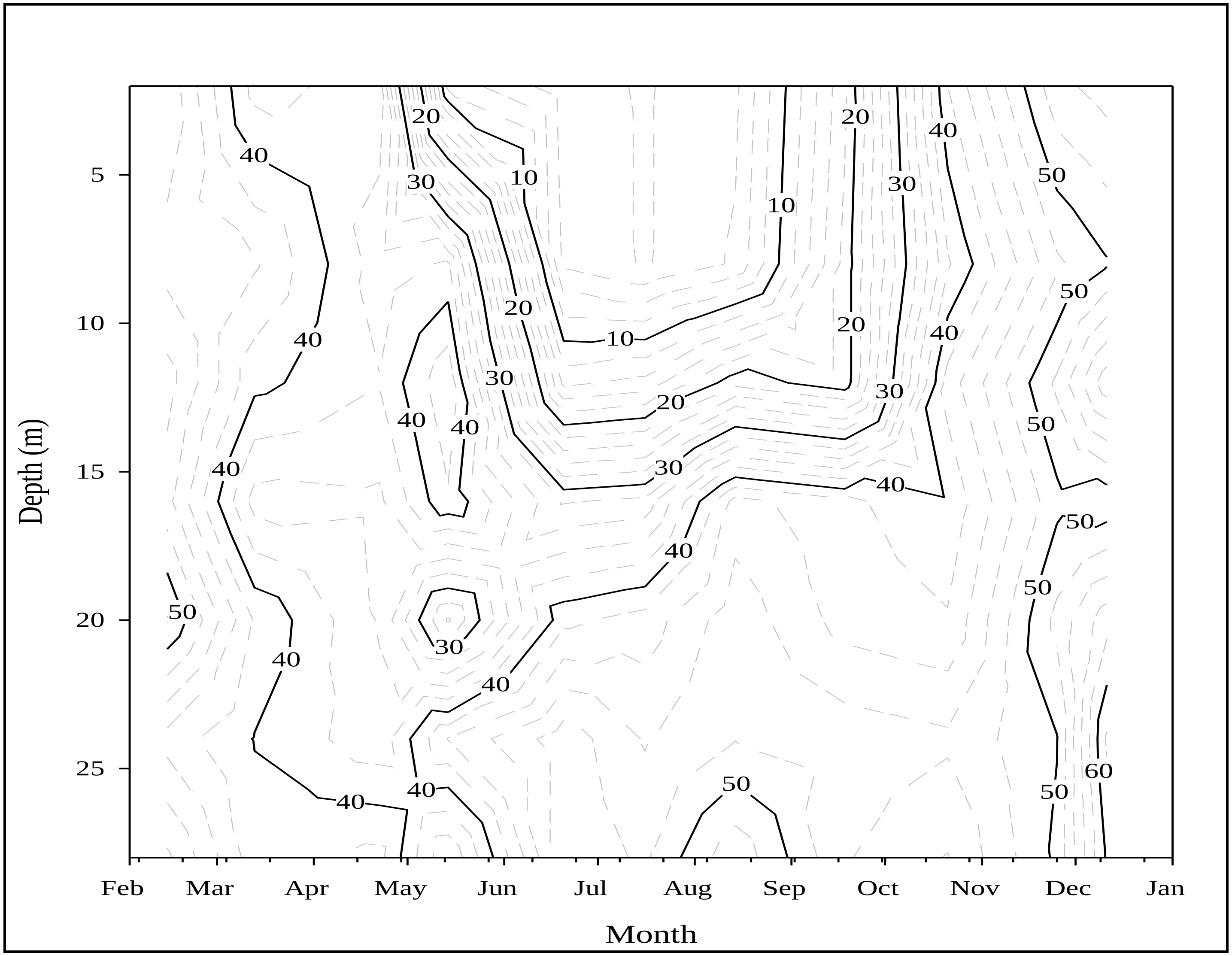


Figure 12. Chlorophyll *a* profiles at Station 6, February – December 2013.

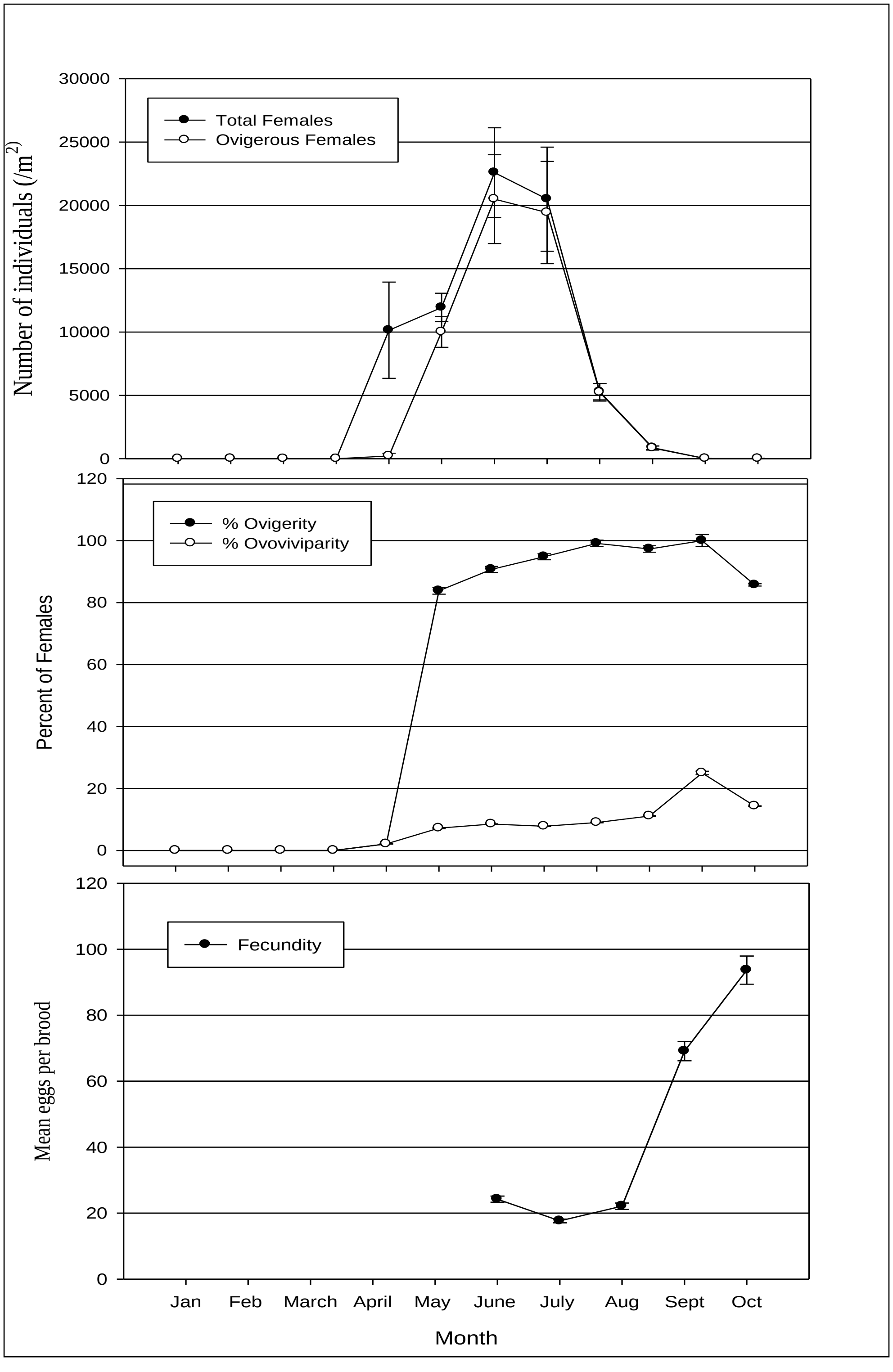


Figure 13. *Artemia* reproductive parameter and fecundity, 2013.

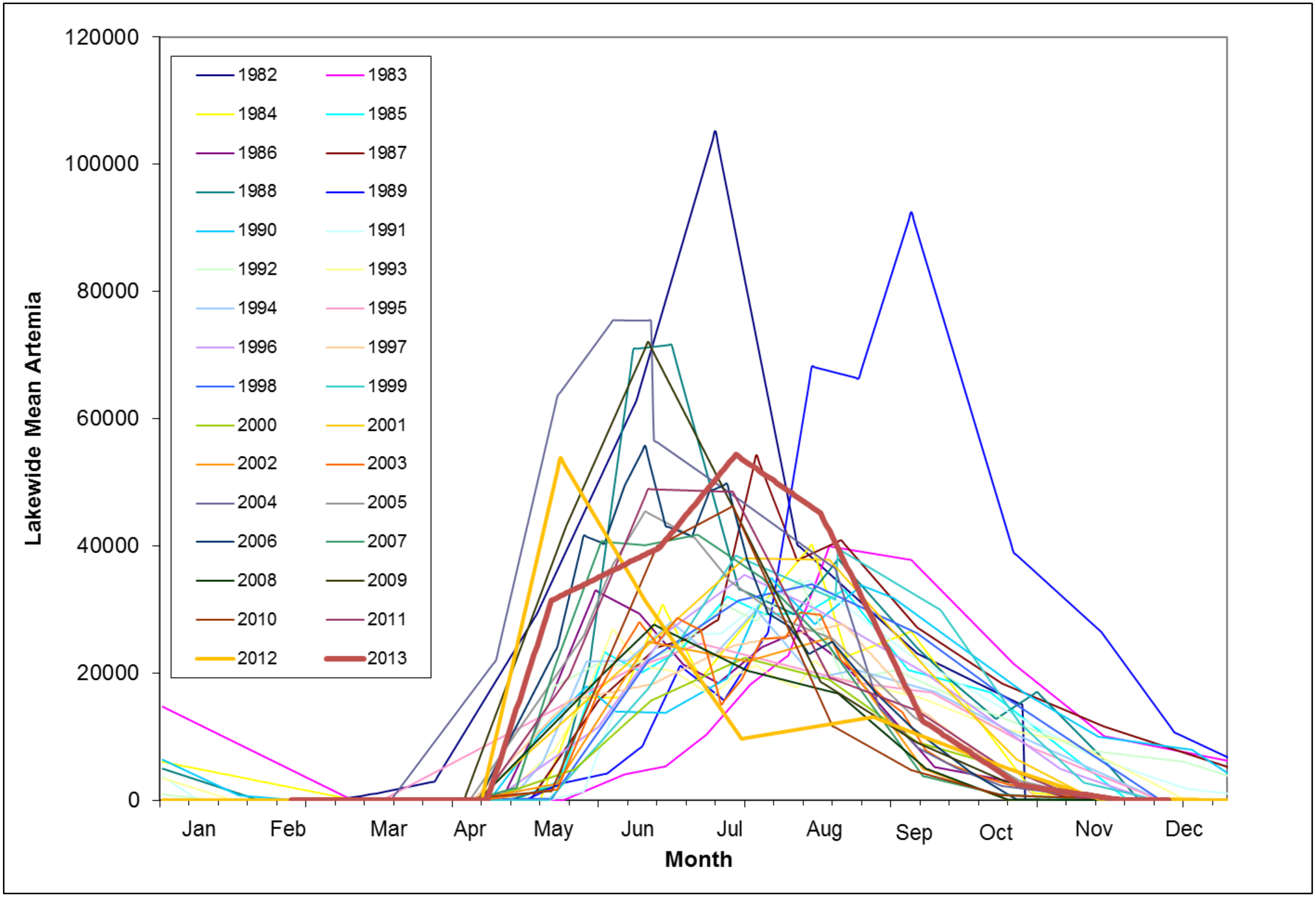


Figure 14. Mean Lakewide *Artemia* abundance 1982-2013.

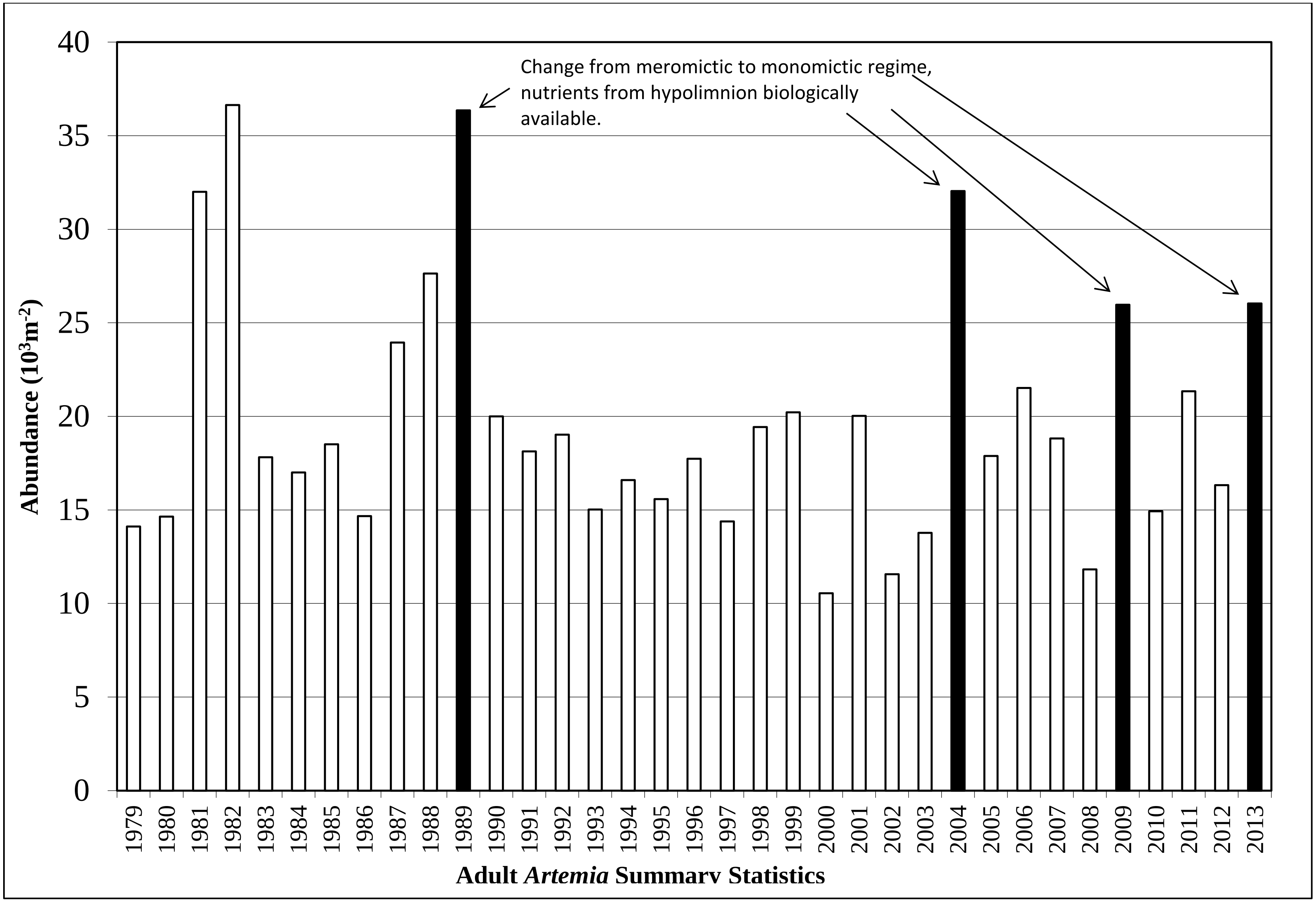


Figure 15. Mean adult *Artemia* abundance from 1979-2013 (May-November), indicating years subsequent to onset of monomixis.

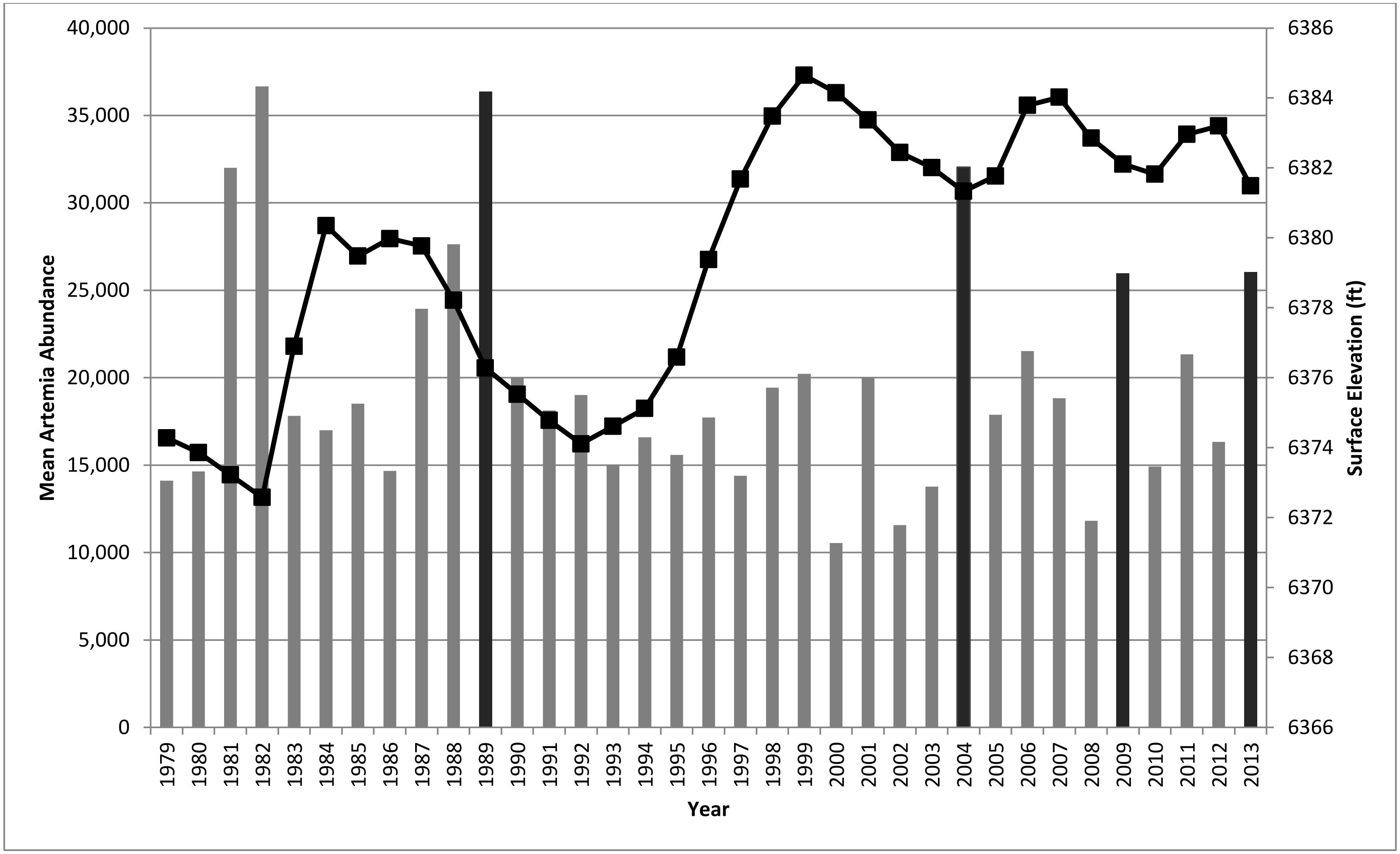


Figure 16. Mean surface elevation of Mono Lake from 1979-2013 denoted by black line. Gray bars indicate mean shrimp abundance per year (May-November). Dark gray bars indicate years subsequent to shift from meromictic to monomictic regime.

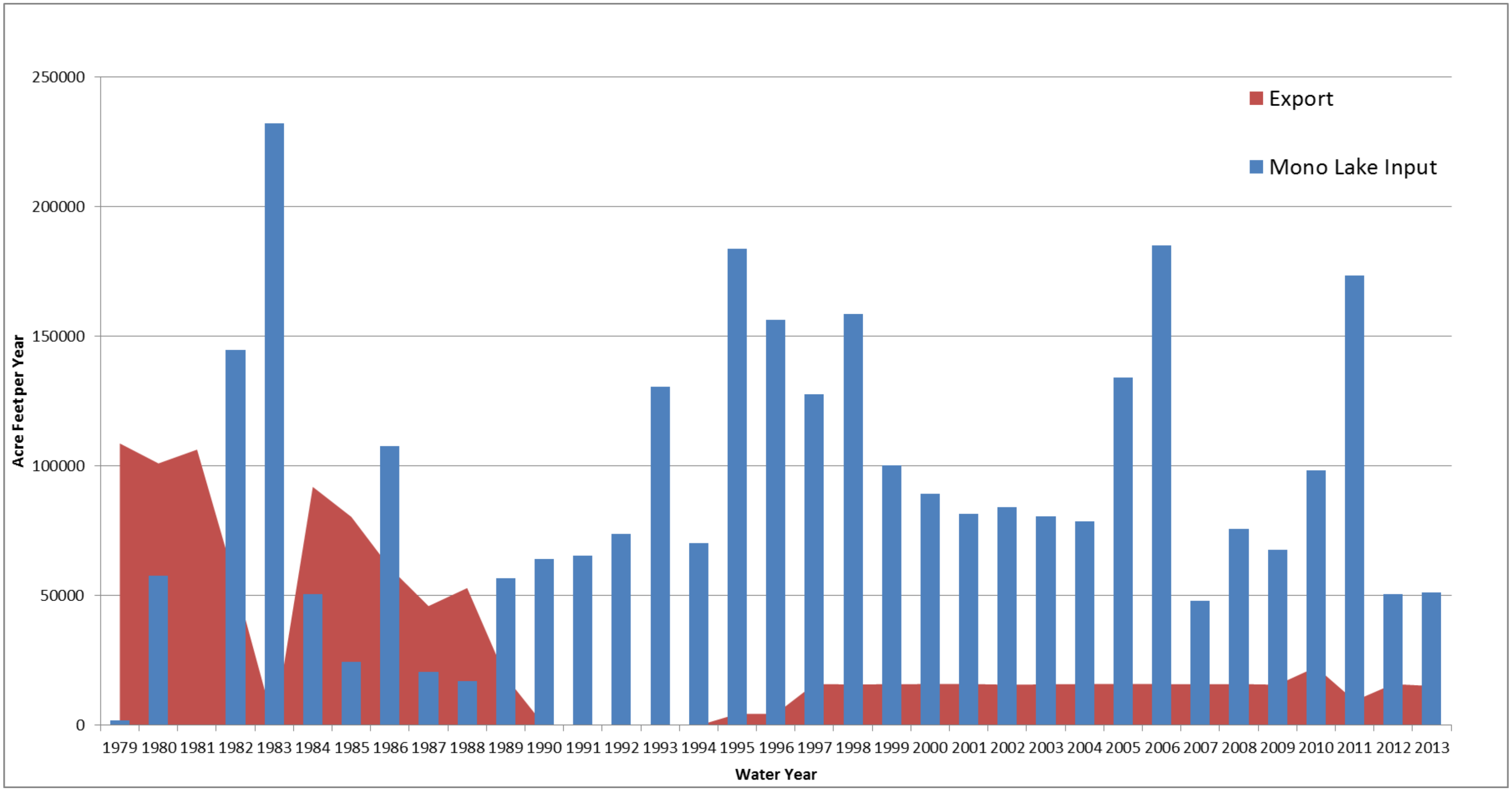


Figure 17. Annual export of water from Mono Lake tributaries and input to Mono Lake from 1979-2013 reported in acre feet per water year (April-March).

APPENDIX 2

Ornithology

- Mono Lake
- Rush Creek

MONO LAKE WATERFOWL POPULATION MONITORING

2013 Annual Report

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
WATERSHED RESOURCES SPECIALIST
BISHOP, CA 93514
April 2013

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EXECUTIVE SUMMARY

Waterfowl populations were monitored in 2013 at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, as a component of the 1996 Mono Basin Waterfowl Habitat Restoration Plan. At Mono Lake, three summer ground surveys were conducted, documenting species composition, habitat use and brood production. Six fall aerial surveys were conducted at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, providing an index of waterfowl numbers using each body of water during fall migration. The fall aerial surveys of Bridgeport and Crowley Reservoirs are being conducted in order to provide data to determine whether or not long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies or are specific to Mono Lake.

The elevation of Mono Lake has undergone annual variations in response to runoff conditions and precipitation regimes. The 2013 runoff year in the Mono Basin was a “dry” year type with 66% of average runoff predicted. Mono Lake was at its highest level in 2013 in April at 6381.8 feet, but dropped a total of 1.8 feet during the year to a low of 6380.0 feet by December.

A total of 1,052 waterfowl of nine species were recorded during summer surveys with Gadwall accounting for 56% of all detections. The four species that used the Mono Lake shoreline habitats for brooding in 2013 were Canada Goose, Gadwall, Green-winged Teal, and Mallard. The number of broods detected along shoreline habitats at Mono Lake in 2013 (36) was the second lowest observed since ground-based surveys were initiated in 2002. The Wilson Creek and South Shore Lagoons areas were the most heavily used areas for brooding. The primary lake-fringing habitats used in 2013 were freshwater ponds, brackish ponds and open water areas. A total of seven broods of were observed at the Restoration Ponds in 2013.

Fall aerial surveys of Mono Lake recorded a total of 23,806 individuals and sixteen waterfowl species. Northern Shoveler and Ruddy Duck were the dominant species during fall migration with Northern Shoveler accounting for 75% (17,771) of all detections and Ruddy Duck accounting for 13% (3,107) of all detections. The peak one-day count of 8,213 waterfowl occurred on the September 19 survey.

A total of 18,656 individuals and fifteen waterfowl species were recorded at Bridgeport Reservoir during fall aerial surveys. The most abundant species were Northern Shoveler, Ruddy Duck, and Gadwall. The peak number of waterfowl detected at Bridgeport Reservoir was 7,430, and occurred on September 3.

A total of 62,362 individuals and 21 waterfowl species were recorded at Crowley Reservoir during the six fall surveys. The most abundant species were Ruddy Duck, Northern Shoveler, and Mallard. The peak number detected at Crowley Reservoir was 16,089 and occurred during the October 15 survey.

There has been no correlation between total fall waterfowl detections and lake elevation in September, lake elevation change, nor between the lake level and numbers of the two most abundant species, Northern Shoveler and Ruddy Duck. There has been no trend in total waterfowl use of the lake in fall for the period 2002-2013. No correlation has been observed between the total waterfowl detected at Mono Lake and either Bridgeport or Crowley Reservoir.

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population survey and study requirement set forth in compliance with the State Water Resources Control Board (SWRCB) Order No. 98-05. The waterfowl monitoring program consists of summer ground counts at Mono Lake, fall migration counts at Mono Lake, fall comparative counts at Bridgeport and Crowley Reservoirs, and photos of waterfowl habitats taken from the air. Three summer grounds counts and six fall aerial surveys were conducted at Mono Lake in 2013. Six comparative fall aerial counts were completed at Bridgeport and Crowley Reservoirs. Photos of shoreline habitats were taken from a helicopter on September 12, 2013.

2013 Mono Lake Waterfowl Population Monitoring
Los Angeles Department of Water and Power
Prepared by Debbie House
Watershed Resources Specialist
Bishop, CA

INTRODUCTION

In 1996, the Mono Basin Waterfowl Habitat Restoration Plan (Plan) was prepared by the Los Angeles Department of Water and Power (LADWP) for the State Water Resources Control Board (SWRCB) (LADWP 1996). This plan identified restoration objectives and potential projects in addition to land management efforts designed to mitigate for the loss of waterfowl habitat due to the lowered elevation of Mono Lake. The key components of the Plan are:

a) increasing the water surface elevation of Mono Lake to 6,392 feet,
b) rewatering Mill Creek,
c) rewatering specific distributaries in the Rush Creek bottomlands,
d) implementation of the DeChambeau Pond and County Pond Restoration Project,
e) development and implementation of a prescribed burn program, and
f) control of saltcedar in lake-fringing wetlands.

The item identified as being the restoration measure of highest importance and priority was to increase the water surface elevation of Mono Lake to 6,392 feet.

SWRCB Order WR 98-05 directed LADWP to implement the above restoration measures in the Plan and conduct monitoring to assess the success of waterfowl habitat restoration efforts. Components of the waterfowl habitat monitoring plan include the monitoring of lake levels, lake limnology and secondary producers, the mapping of riparian and lake-fringing wetland habitats, and waterfowl population surveys. The purpose of the waterfowl population survey component of the Plan is to provide information to track changes in population levels of waterfowl and assess waterfowl use of the various wetland habitats.

This report describes and discusses monitoring efforts related to evaluating waterfowl population responses to increases in Mono Lake water surface elevations. Survey data for the DeChambeau and County Restoration Ponds are also presented.

Summer ground surveys were conducted in order to determine the size of the breeding and/or summering population, species composition, spatial distribution and habitat use of waterfowl during the summer. Fall aerial surveys were conducted to provide an index of waterfowl numbers using Mono Lake during fall migration, as well as provide information on species composition and spatial distribution. Fall waterfowl surveys are also conducted at Bridgeport and Crowley Reservoirs in order to provide data to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies or are specific to Mono Lake.

The monitoring of waterfowl populations in the Mono Basin is expected to continue until at least the year 2014, or until the targeted lake level (6,392 foot elevation) is reached and the lake cycles through a complete wet/dry cycle (LADWP 2000a).

All summer surveys were conducted by the author. Fall surveys were conducted by the author with assistance from Mr. Chris Allen, LADWP Watershed Resources Specialist.

METHODS

Summer Ground Surveys

Three ground-count surveys were conducted at Mono Lake at three-week intervals beginning in early June. All surveys were conducted as area counts, and locations were surveyed either by walking along the shoreline, along creek corridors or by making observations from a stationary point. Ground surveys of all shoreline locations were completed over four to five-days.

Shoreline locations surveyed were those identified in the Plan as current or historic waterfowl concentration areas (Figure 1), namely: South Tufa (SOTU); South Shore Lagoons (SSLA); Sammann's Spring (SASP); Warm Springs (WASP); Wilson Creek (WICR); Mill Creek (MICR); DeChambeau Creek Delta (DECR); Rush Creek Delta (RUCR); and Lee Vining Creek bottomlands and delta (LVCR). Surveys were also conducted at the restoration ponds north of the lake: DeChambeau Ponds (DEPO) and County Ponds (COPO).

Shoreline areas including SOTU, SSLA, SASP, WASP, DECR, WICR, and MICR were surveyed by traversing the entire shoreline segment on foot, following the shoreline. In RUCR and LVCR, the creeks were surveyed from the County Road to the deltas. Surveys along lower Rush Creek were conducted by walking along the southern bluff above the creek, and traversing the delta along existing sandbars. This route offered a good view of the creek while limiting wildlife disturbance and flushing of waterfowl ahead of the observer. In Lee Vining Creek, surveys of the creek channel were conducted by walking along the north bank of the main channel, which offered the best view of the channel. At the mouth of the creek, the main channel splits in two and forms two delta areas separated by a tall earthen berm-like formation. In order to obtain good views of both delta areas, it was necessary to cross the main channel and walk on top of this berm. After viewing both delta areas from the berm, the delta areas were also traversed. In both areas, birds were observed and recorded within 100 meters on either side of the deltas.

At the Restoration Ponds, observations were taken from stationary points that allowed full viewing of each pond. A minimum of five minutes was spent at each observation point at the DeChambeau and County Ponds.

All summer ground surveys began within one hour of sunrise and were completed within approximately six hours. The order in which the various sites were visited was varied in order to minimize the effect of time-of-day on survey results. Total survey time was recorded for each area. The date and time of day for each survey during 2013, are provided in Appendix 1. The common names and scientific names for species referenced in the document can be found in Appendix 2.

Surveys along the shoreline and in Rush and Lee Vining Creeks were conducted by walking at an average rate of approximately 1.5 km/hr, depending on conditions, and recording waterfowl species as they were encountered. Because waterfowl are easily flushed, and females with broods are especially wary, the shoreline was frequently scanned well ahead of the observer in order to increase the probability of detecting broods. The following was recorded for each waterfowl observation: time of the observation; the habitat type being used; and an activity code indicating how the bird; or birds were using the habitat. The activity codes used were resting, foraging, flying over, nesting, brooding, sleeping, swimming, and “other”. Shorebirds were censused in the same manner; however, shorebird data will not be presented in this document.

When a waterfowl brood was detected, the size of the brood was recorded, a GPS reading was taken (UTM, NAD 27, Zone 11, CONUS), and the location of each brood was marked on an aerial photograph while in the field. Each brood was also assigned to an age class based on its plumage and body size (Gollop and Marshall 1954). Since the summer surveys were conducted at three-week intervals, any brood assigned to Class I using the Gollop and Marshall age classification scheme (which includes subclasses Ia, Ib, and Ic), would be a brood that had hatched since the previous visit. Assigning an age class to broods allowed for the determination of the minimum number of "unique broods" using the Mono Lake wetland and shoreline habitats.

The habitat categories used, generally follow the classification system found in the report entitled 1999 Mono Basin Vegetation and Habitat Mapping (LADWP 2000b). The habitat classification system defined in that report is being used for the mapping of lakeshore vegetation and the identification of changes in lake-fringing wetlands associated with changes in lake level. The specific habitat categories used in that mapping effort (and in this project) include: marsh, wet meadow, alkaline wet meadow, dry meadow/forb, riparian scrub, Great Basin scrub, riparian forest, freshwater stream, ria, freshwater pond, brackish ponds, hypersaline ponds, and unvegetated. Salinity measurements of ponds were taken using an Extech EC400 Conductivity/TDS/Salinity probe in order to aid in the proper classification of fresh versus brackish ponds when recording habitat use. Ponds with a salinity of less than 500 ppm were classified as fresh. Ponds with vegetation present and a salinity of greater than 500 ppm were classified as brackish. Ponds which lacked vegetation and freshwater inflow were classified as hypersaline. For reference, the definition of each of these habitat types is provided in Appendix 3. Representative photos of these habitats can be found in the report entitled *Mono Lake Waterfowl Population Monitoring 2002 Annual Report* (LADWP 2003).

Two additional habitat types: open-water near-shore (within 50 meters of shore), and open-water offshore (>50 meters offshore), were added to the existing classification system in order to more completely represent areas used by waterfowl. Although a ">50 meter" category was used at the time of data collection, these observations will not be included in the final calculations unless the presence of waterfowl in the open-water offshore zone was determined to be due to observer influence (e.g., the observer sees that a female duck is leading her brood offshore and is continuing to swim away from shore).

Fall Aerial Surveys

Overview of Methodology

Aerial surveys were conducted in the fall at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir using a small high-winged airplane. A total of six surveys were conducted at two-week intervals, with the first survey beginning during the first week of September, and the final fall survey occurring in the middle of November. A summary of the fall survey schedule has been provided as Appendix 4.

Each aerial survey began at Mono Lake at approximately 0900 hours. Mono Lake was surveyed in approximately one and one-half hours. Bridgeport Reservoir was surveyed next, and Crowley Reservoir was surveyed last. In all cases, surveys of all three waterbodies were completed in a single flight by 1200 hours on the day of the survey.

At Mono Lake, waterfowl and shorebirds were censused, with the primary emphasis on the censusing of waterfowl. The greater concentration and diversity of waterfowl at Bridgeport and Crowley Reservoirs prevents censusing of shorebirds at these locations. This report will only present waterfowl data. Observations were verbally recorded onto a handheld digital audio recorder and later transcribed by the observer.

A second observer was present on all six flights. At Mono Lake, the second observer sat on the same side of the plane as the primary observer during the perimeter flight and censused shorebirds. During the cross-lake transect counts, observers sat on the opposite sides of the plane and counted Ruddy Ducks and other waterfowl, and phalaropes occurring on the open water. At Bridgeport and Crowley, the second observer sat on the same side of the plane as the primary observer during the entire survey, and assisted in waterfowl counts.

Mono Lake Aerial Surveys

Aerial surveys of Mono Lake consisted of a perimeter flight of the shoreline and a set of fixed cross-lake transects. The shoreline was divided into 15 lakeshore segments (Figure 2) in order to document the spatial use patterns of fall migrant waterfowl. Coordinates forming the beginning of each segment were derived from the 2002 aerial photo of Mono Lake (2002 aerial image taken by I. K. Curtis, and processed by Air Photo, USA) and can be found in Appendix 5, along with the four-letter code for each lakeshore segment. The segment boundaries are the same as those used by Jehl (2002), except for minor adjustments made in order to provide the observer with obvious landmarks that are easily seen from the air.

The cross-lake transects covered open water areas of Mono Lake. The eight transects are spaced at one-minute (1/60 of a degree, approximately one nautical mile) intervals and correspond to those used by Boyd and Jehl (1998) for the monitoring of Eared Grebes during fall migration. The latitudinal alignment of each transect is provided in Appendix 6.

Each of the eight transects is further divided into two to four sub-segments of approximately equal length (Figure 2). The total length of each cross-lake transect was first determined from the 2002 aerial photo. These lengths were then sub-divided into the appropriate number of subsections to a total of twenty-five sub-segments, each approximately 2-km in length. This approach creates a grid-like sampling system that allows for the evaluation of the spatial distribution of species occurring offshore. The beginning and ending points for each subsection were determined using landscape features, or, when over open water, by using a stopwatch, since the survey aircraft’s airspeed was carefully controlled and the approximate length of each subsection was known.

LADWP contracted with Black Mountain Air Service to conduct fixed-winged aerial counts. Black Mountain Air Service has obtained a low-altitude flight waiver from the Federal Aviation Administration in order to conduct these flights. Aerial surveys were conducted in a Cessna 180 at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Perimeter surveys were conducted over water while maintaining a distance of approximately 250 meters from the shoreline. When conducting aerial surveys, the perimeter flight was conducted first, and in a counterclockwise direction, starting in the Ranch Cove area. Cross-lake transects were flown immediately afterward, starting with the southernmost transect and working northwards.

In order to reduce the possibility of double-counting, only birds seen from or originating from the observer’s side of the aircraft were recorded. Even though the flight path of the aircraft along the latitudinal transects effectively alternated the observer’s hemisphere of observation in a North-South fashion due to the aircraft’s heading on successive transects, the one-nautical-mile spacing between the transects worked in conjunction with the limited detection distance of the waterfowl (<< 0.5 nautical mile) to effectively prevent double-counting of birds on two adjacent transects.

Bridgeport Reservoir Aerial Surveys

The shoreline of Bridgeport was divided into three segments (Figure 3). Appendix 5 contains the four-letter code for each lakeshore segment and the coordinates of the beginning of each section. Survey flights started at the dam at the north end of the reservoir and proceeded counterclockwise. The distance from shore, flight speed, and height above ground were the same as employed at Mono Lake. Adjustments were made as necessary depending on lighting, lake level and waterfowl distribution. The reservoir was circumnavigated twice during each survey to allow for a second count of often large concentrations of mixed species flocks.

Crowley Reservoir Aerial Surveys

The shoreline of Crowley Reservoir was divided into seven segments (Figure 4). Coordinates forming the beginning of each segment were generated from the 2000 aerial photo of Crowley Reservoir (2000 aerial image taken by I. K. Curtis, and processed by Air Photo, USA) and can be found in Appendix 5, as well as the four-letter code used for each segment. Each survey began at the mouth of the Owens River (UPOW) and proceeded over water in a counterclockwise direction along the shoreline. The distance from shore, flight speed, and height above the water were the same as at Mono Lake during most of each flight. Temporary diversions of distance from shore or height above ground were made by the pilot as necessary to avoid direct or low flight over float-tubers or boats. Adjustments were also made as necessary depending on lighting, lake level and waterfowl distribution. The reservoir was circumnavigated twice during each survey to allow for a second count of often large concentrations of mixed species flocks.

Ground Verification Counts

Ground verification counts were conducted whenever flight conditions (e.g., lighting, background water color, etc.) did not allow the positive identification of a significant percentage of the waterfowl encountered, or to confirm the species or number of individuals present. During a ground validation count, the total number of waterfowl present in an area was recorded first, followed by a count of the number of individuals of each species present.

Photo Documentation

As required by the SWRCB Order 98-05, photo documentation of lake-fringing waterfowl habitats was completed in 2013. Photos were taken from a helicopter at all bodies of water on September 12, 2013. In 2013, shoreline conditions were also documented using a helicopter-mounted, geo-referenced video camera. Photos depicting the condition and available habitats for each shoreline segment are described under Data Summary below.

Data Summary and Analysis

2013 Summer Ground Count Data

Total detections of each species were summed by lakeshore segment for each survey. Total detections were also summed over the entire summer survey period, and the percent of total detections per lakeshore segment was calculated. Total numbers of broods per species, survey and lakeshore segment were also summed.

Chi-square goodness-of-fit analysis was used to determine if individual waterfowl species used any of the various habitats in a disproportionate manner. This analysis was done for the most abundant summering species, provided that the behavior of at least 30 individuals had been recorded. All habitat use observations except those of flyovers were included in this analysis. The waterfowl species for which habitat use data were analyzed were Canada Goose (*Branta canadensis*), Gadwall (*Anas strepera*), Green-winged Teal (*A. crecca*) and Mallard (*A. platyrhynchos*). For all significant goodness-of-fit tests, Bonferonni confidence intervals were calculated for each category, following Byers and Steinhorst (1984), to determine which specific habitats were used out of proportion with respect to the others.

2013 Fall Aerial Count Data

For each survey and water body, the total number of waterfowl of each species was summed by lakeshore segment and survey. The spatial distribution of waterfowl at each body of water was determined by calculating the proportion of all fall detections that occurred in each lakeshore segment or offshore (for Mono Lake). This calculation was done excluding Ruddy Duck numbers. Ruddy Ducks occur on the open water and therefore their occurrence in particular region is not expected to be tied directly to shoreline features affected by lake levels.

Trend Analysis

Although many factors likely affect waterfowl use of Mono Lake, trends in waterfowl use were analyzed relative to lake elevation, which is the primary waterfowl habitat restoration tool identified in the Plan. Pearson Product Moment Correlation (Sigma Stat 3.5) was used to evaluate the relationship between summer waterfowl abundance (each survey and total) and the total number of broods detected and lake elevation. Fall waterfowl populations at Mono Lake were also evaluated for correlations between total waterfowl detections, numbers of Northern Shoveler and Ruddy Duck and September lake elevation, and lake elevation change from previous year. To compare use of each water body by waterfowl, using the waterfowl numbers as an index, the total waterfowl detected each fall was summed for each year 2002-2013. Count data were evaluated for correlations total waterfowl use among each of the three water bodies. In addition, the relative use of the three water bodies by Northern Shoveler and Ruddy Duck was also evaluated using two-way Analysis of Variance.

RESULTS

Description of Shoreline Conditions in 2013

Mono Lake

The 2013 runoff year in the Mono Basin was “Dry” year type with a predicted runoff of 66% of the 1941-1990 average runoff (see Order WR 98-05). After a slight increase in elevation in April 2013 to 6381.8 feet, the lake level steadily declined, lowering a total of 1.8 feet through the summer and fall before stabilizing at 6380.0 in December. In early summer (June) the lake level was 6381.5 feet, or 0.7 feet lower than it had been during the same time in 2012. The lake level continued to decline through the summer and at the start of fall surveys in September, the elevation was 6380.6 feet, which is 2.3 feet lower than September 2012, and 2.9 feet lower than the September 2011 lake elevation. The decrease in lake elevation as compared to 2012 resulted in qualitative differences in lake-fringing habitats for waterfowl during the 2013 monitoring period, some of which are discussed below.

South Shoreline Areas (South Tufa, South Shore Lagoons, and Sammann’s Spring)

In the South Tufa area west of Navy Beach, the drop in lake elevation resulted in extensive mudflats due to spring flow in this portion of the shoreline. East of Navy Beach, only a small brackish pond was present in early June. By late-June however, this pond had dried with decreasing lake level. East of Navy Beach, dry conditions and a sandy shoreline lacking ponds or mudflats continued into fall (Figure 5).

In 2013, resources for waterfowl in the South Shore Lagoons area were primarily limited to Goose Springs and Sand Flat Spring. The brackish pond at the extreme west end of the South Shore Lagoons area was contracted severely in size in early June, and almost dry by September (Figure 6). The freshwater pond approximately 1.2 km farther east from this first pond (Figure 7) was dry all summer. Although small, this pond, when full, has supported several waterfowl broods. At Sand Flat Spring (Figure 8), the drop in lake elevation resulted in water from the spring and pond seeping through the loose sand to the lake. The main area of waterfowl use in 2013 along the South Shore Lagoons area was the Goose Springs outflow area (Figure 9). The shoreline freshwater pond downgradient of Goose Springs persisted, however this pond was smaller in extent than in 2012.

In the Sammann’s Spring shoreline segment west of Sammann’s Spring faultline, a fresh water pond extended approximately 300 m along the length of the shore in early June. Although this pond dried through the summer and became colonized by wetland vegetation, the entire Samman's Spring shoreline area west of the fautline remained wet through fall (Figure 10) due to numerous springs in this reach. Immediately east of the faultline, some brackish shoreline ponds persisted (Figure 11) and receive moderate use by waterfowl in summer and fall.

Warm Springs and Northeast Shore

The "north pond" at Warm Springs (Figure 12) is supported by the outflow of Pebble and Twin Warm Springs. As was the condition in 2012, there was no direct connection of spring flow to the lake. Early in the summer, small remnant brackish, ponds remained down gradient of the north pond. These small ponds contracted in size throughout the summer and by late-July, all unvegetated brackish shoreline ponds had dried. The continued decline in lake elevation resulted in a loss of shoreline brackish ponds, and a loss of connectivity between spring outflow and the lake at Warm Springs (see Figure 12). The south pond, supported by outflow from Warm Springs Marsh Channel, Warm B, and Bug Warm springs, held some water in 2013, and was brackish. Since 2002, this south pond has been much smaller than the northern pond and less attractive to ducks and other waterbirds. In 2013, the Northeast Shore area supported only barren playa (Figure 13).

Bridgeport Creek, DeChambeau Embayment and Black Point

This area of the shoreline typically consists of several small ponds with alkali meadow and/or small areas of wet alkali meadow adjacent. The main springs in this reach are found in the Bridgeport Creek shoreline segment, with Perseverance and Chuck Spring supporting the best waterfowl habitat in the area. Only small isolated ponds existed in the shoreline area between Bridgeport Creek and Black Point in 2013 (Figures 14 - 16). These ponds typically attract small numbers of waterfowl in the fall.

Northwest Shore (Wilson, Mill Creek and DeChambeau Creeks)

In the Wilson Creek area, the decrease in lake elevation resulted in an increase in the amount of exposed sandy shoreline and mudflats (Figure 17). The small beaver dam near the outflow of Black Point Seep has increased in size and extent, and waterfowl, including broods, were observed in the pond created by the dam. In the Mill Creek delta, a sandbar onshore had been breached, draining the large fresh water pond that has been present at the creek mouth for a number of years (Figure 18). In previous years, most of the broods found at Mill Creek were seen in this pond. Several beaver dams occur upstream and the extent of ponding occurring in the Mill Creek delta upstream of the shoreline appears to be expanding. In the DeChambeau Creek area (Figure 19), the decrease in lake elevation resulted in the increase in the amount of exposed shoreline and mudflats. Very small fresh water ponds exist near shore where spring outflow is retained behind small sandbars.

West Shoreline (West Shore, Lee Vining Creek, Ranch Cove and Rush Creek)

The West Shore area (Figure 20) supports primarily meadow and riparian scrub habitats, but lacks ponds. No significant changes were noted in 2013, except a slight increase in exposed shoreline. Due to the dry year conditions, there was no stream restoration flow release in Lee Vining Creek and water was confined to the mainstem. The peak flow reached in Lee Vining in 2013 was 47 cfs on May 1. The continued decline in lake elevation resulted in increased exposure of mudflats and sandbars in the Lee Vining delta (Figure 21). The Ranch Cove area (Figure 22) has limited fresh water input, and does not support ponds due to the gradient. The area continued to be dominated by sandy beach and upland vegetation. The decrease in lake elevation resulted in further increases in the exposure of sandbars and deltaic deposits in Rush Creek delta (Figure 23). There was no stream restoration flow release in Rush Creek due to the dry year conditions. A peak flow in lower Rush Creek of 131 cfs was recorded on June 12.

Restoration Ponds

Both County Ponds were flooded in 2013. There was little open water visible at County Pond West due to the extensive growth of emergent vegetation. DeChambeau Ponds 1 and 5 were dry in 2013 while ponds 2-4 were flooded.

Bridgeport Reservoir

In September, Bridgeport Reservoir held 5,540 acre-feet (Department of Water Resources, California Data Exchange Center, (http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=BDP&d=today), almost 47% fewer acre-feet than at the same time in 2012, and 77% fewer acre-feet as compared to 2011. As a point of reference, the storage capacity of Bridgeport Reservoir is 42,600 acre-feet. Figure 24 shows an overview of the reservoir as viewed from the south end looking north toward the dam. The south end of the reservoir, which includes the area referred to as “West Bay”, and part of the “East Shore” area, receives fresh water inflows from Buckeye and Robinson Creeks and the East Walker River, creating extensive mudflat areas adjacent to these creek inflow areas. The northern arm of the reservoir includes primarily sandy beaches bordered by upland vegetation. The decrease in elevation resulted in a notable contraction of the reservoir extent, a reduction in flooding of small inlets and bays, and the exposure of large areas of mudflats.

Crowley Reservoir

In early September, Crowley Reservoir held 75,724 acre-feet (Department of Water Resources, California Data Exchange Center, http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=crw&d=today) essentially the same as in September 2012. As a point of reference, the storage capacity of Crowley Reservoir is 183,465 acre-feet. Figures 25-31 depict habitat conditions of each shoreline segment at Crowley Reservoir. Due to the low reservoir levels, the increased exposed shore was apparent in all areas. The Upper Owens River delta area (Figure 25) includes large areas of exposed mudflats and reservoir bottom adjacent to the mouth of the Upper Owens River. Most of the length of Sandy Point area (Figure 26) is adjacent to elevated areas and upland vegetation. Small areas of meadow habitat occur in this area also. North Landing is largely bordered by dry meadows with no fresh water input (Figure 27) except near the western border. The McGee Bay area (Figure 28) supports vast mudflat areas immediately adjacent to wet meadow habitats, and receives inflow from McGee Creek. Hilton Bay (Figure 29) is surrounded by meadow habitats, and receives some fresh water input from Hilton Creek. The Chalk Cliffs area (Figure 30) lacks fresh water inflow areas and wetland habitats, and is dominated by sandy beaches adjacent to steep, sagebrush-covered slopes. Layton Springs provide some fresh water input at the southern border of this lakeshore segment. The remainder of the area is bordered by upland vegetation and a large area of sandy beach (Figure 31).

2013 Summer Ground Counts

Waterfowl abundance, distribution and brood counts

A total of 1,052 waterfowl of eight species were recorded during summer surveys (Table 1). Canada Goose, Cinnamon Teal, Gadwall, Green-winged Teal and Mallard were observed all three surveys. The most abundant species was Gadwall accounting for 56% of all detections (604/1075). The next most abundant species were Canada Goose (19.1%) and Mallard (15.9%). The total number of waterfowl using the shoreline (exclusive of dependent young) detected during summer surveys was highest (557) during Survey 1 in early June count and lowest (162) on the late July survey (Survey 3) (Table 1).

The highest proportion of detections was along the northwest shore in the Wilson Creek area (26.8%) and Sammann's Spring area (21.4%) (Table 2). The fewest number of waterfowl were found at South Tufa (41; 3.9% of detections). The most ubiquitous species was Gadwall which was found in all locations surveyed and was most numerous at Wilson Creek. Canada Goose, the second most abundant species, was most abundant at Sammann's Spring and DeChambeau Creek. Mallard were most numerous at Sammann's Spring and Warm Springs.

Waterfowl species observed with broods in the lake-fringing wetlands and creeks at Mono Lake in 2013 were Canada Goose, Gadwall, Green-winged Teal, and Mallard (Table 3). The number of broods detected in lake-fringing habitats (36) was the second fewest seen since ground-based surveys began in 2002. Gadwall broods comprised the majority of broods found (25/36; 69%) while Canada Goose comprised 22% of broods found (8/36). Although Cinnamon Teal and Redhead were seen in small numbers at Mono Lake throughout the summer, no broods of these species were found. Figure 32 shows the locations of all of the broods detected in 2013. The Wilson Creek, DeChambeau Creek South Shore Lagoons areas were the most heavily used for brooding as ten, six and six, broods were detected in these areas respectively.

Habitat Use

All four waterfowl species analyzed showed a disproportionate use of the various shoreline habitats in 2013 (Table 4, Figure 33). Canada Geese were observed using primarily open water, unvegetated, and meadow habitats with unvegetated areas and open water used disproportionally more than other habitats. Gadwall used ria and unvegetated areas. Gadwall were also observed frequently in fresh water ponds and brackish lagoons but these habitats were not used significantly more than other habitats. Green-winged Teal were observed using primarily fresh water ponds which they used significantly more than other habitat types. Mallard used primarily brackish ponds and fresh water ponds which they used disproportionally to other habitat types.

2013 Fall Aerial Surveys

Fall Aerial Survey Weather Conditions

The first series of winter storms moved through the region in September, delaying the mid-September aerial count by four days. Temperatures remained cool through October, moderating by early November. Bridgeport and Crowley Reservoirs were ice-free in mid-November.

Mono Lake

A total of sixteen waterfowl species and 23,806 individuals were recorded at Mono Lake during fall aerial surveys (Table 5). The peak number of waterfowl detected at Mono Lake on any single count was 8,231 and occurred on the September 19 survey (Table 5, Figure 34). While waterfowl abundance was highest in September, waterfowl species richness was lowest. Waterfowl species richness was highest in November after the arrival of late fall migrant species such as swans and diving ducks. In terms of total detections, Northern Shoveler (*Anas clypeata*) and Ruddy Duck (*Oxyura jamaicensis*) were the dominant species during fall migration with Northern Shoveler accounting for 74.6% (17,771), and Ruddy Duck accounting for 13% (3,107) of all detections. The peak number of Northern Shoveler (7,860) occurred on September 19, and the peak number of Ruddy Ducks (1,210) occurred on October 15.

Table 6 shows the number of waterfowl, exclusive of Ruddy Ducks, in each lakeshore segment by survey. The main shoreline areas of waterfowl use during fall 2013 were Wilson Creek and Mill Creek accounting for 46.3% and 20.4% of all waterfowl. Large flocks of Northern Shovelers were observed at both locations in early fall (September to early October). There were no waterfowl observed at Northeast Shore and there was limited use of other areas namely Bridgeport Creek, Black Point and Ranch Cove. Off-shore detections of waterfowl accounted for ten percent of all fall waterfowl detections, and the majority of these (2331 of 2425) were Ruddy Ducks.

Bridgeport Reservoir

A total of 15 waterfowl species and 18,656 individuals were recorded at Bridgeport Reservoir during the 2013 fall aerial surveys (Table 7). The peak number of waterfowl detected on any single count at Bridgeport Reservoir was 7,430 individuals, which occurred on September 3 (Table 7, Figure 34). Waterfowl species richness was greatest in mid-September. The total number of waterfowl at Bridgeport declined steadily after the beginning of September from the high of 7,430 on September 3 to a low of 826 on October 29. The most abundant species in terms of total detections, were Northern Shoveler (33.9%), Ruddy Duck (15.9%) and Gadwall (12.2%). The peak number of Northern Shoveler at Bridgeport was on September 4, and peak Ruddy Duck numbers were recorded on November 12.

The West Bay was the main area of waterfowl use at Bridgeport Reservoir, accounting for over 88% of all detections (Table 8). Most of the waterfowl are generally found resting on the mudflats or on the water off shore along the southwestern part of the reservoir from Robinson and Buckeye Creek north to the ditch. Secondarily, waterfowl were found in the outflow area of the East Walker River.

Crowley Reservoir

A total of 21 waterfowl species and 62,362 individuals were detected at Crowley Reservoir during the 2013 fall aerial surveys (Table 9). The peak number of waterfowl detected on any single count at Crowley Reservoir was 16,089 individuals and occurred on October 15 (Table 9, Figure 34). Waterfowl abundance was highest throughout the month of October, which species richness highest in late October. The most abundant species, in terms of total detections, were Ruddy Duck (24.4%), Northern Shoveler (20.8%), and Mallard (18.1%). Peak numbers of Northern Shoveler at Crowley were recorded on September 19, while peak Ruddy Duck numbers occurred on October 15.

McGee Bay is typically the main area of waterfowl use throughout fall, while the secondary area of use is the Upper Owens River delta (Table 10). Few waterfowl were observed in the Chalk Cliffs area in early fall, but use of this area increased in late October and November, as is typical after waterfowl hunting season opens.

Mono Lake Restoration Ponds

A total of five species and 46 waterfowl were detected at the Restoration Ponds during summer surveys (Table 11). Most of the waterfowl use was in County Pond east and the most abundant species was Gadwall. A total of seven broods were seen at the Restoration Ponds.
A total of 103 waterfowl were detected at the DeChambeau and County Pond complexes during fall surveys (Table 13), with the majority of birds observed in County Pond east.

Trend Analysis

Summer Waterfowl

There has been no relationship between summer lake elevation (June-July) and the total number of waterfowl recorded during the summer surveys (June: $r = 0.511$, $p = 0.089$, Figure 35). The elevation of the lake in June has been significantly positively correlated however with the number of waterfowl present on the third survey conducted during the third week of July when the majority of broods are also recorded (r = 0.684, p = 0.0141) (Figure 35). The number of broods detected has also been significantly, positively correlated with the lake elevation in June and July (June: r =0.931, p < 0.01) (Figure 36).

Fall Waterfowl

There has been no correlation between total fall waterfowl detections and lake elevation in September (r = -0.282, p =0.374) (Figure 37), lake elevation change, nor between the lake level and numbers of the two most abundant species, Northern Shoveler and Ruddy Duck. There has been no trend in total waterfowl use of the lake in fall for the period 2002-2013 (r = 0.263, p = 0.407).

Comparison Counts

There has been no correlation between the total waterfowl detected at Mono Lake and either Bridgeport or Crowley Reservoir, nor between the number of waterfowl detected at Bridgeport and Crowley Reservoirs. Northern Shoveler use of Mono Lake tends to be higher than Bridgeport Reservoir (annual mean of 14,421 vs. 9,167), however this difference is not statistically significant due to annual variations in relative use over the time period 2002-2013. The mean number of Northern Shoveler detected at Crowley Reservoir has been significantly lower than Mono Lake (6,774 vs. 14,421, p=0.0107). Ruddy Duck use of Mono Lake tends to be higher than Crowley Reservoir (annual mean of 11,434 vs. 5,935), however this difference is not statistically significant due to annual variations in relative use over the time period 2002-2013. The mean number of Ruddy Duck detected at Bridgeport Reservoir has been significantly lower than Mono Lake (1,151 vs. 11,434, p=<0.01).

SUMMARY

The numbers of broods seen in 2013 was the second fewest seen since ground-based surveys began in 2002, and was significantly lower than the 14-year mean. During the waterfowl breeding season, the lake elevation in 2013 was approximately the same as that observed in 2004 and 2005, which were the other two years of below average brood numbers. Increases in elevation, (at least within the elevation ranges observed), result in increases in the number and extent of near-shore ponds, especially in the South Shore Lagoons area. Conversely, decreases in elevation result in the contraction in size of ponds, or the complete drying of many ponds used by waterfowl for breeding. In most shoreline areas, increases in lake elevation have been associated with changes to lake-fringing habitats that increase the quality and quantity of potential breeding habitat for waterfowl. Based on field observations, these ponds enlarge due either to increases in the groundwater table or as a result of increased spring flow. Brooding females generally select habitats that have high invertebrate populations and dense vegetative cover (Baldassarre and Bolen 1994). The near-shore ponds, when present, often provide dense vegetative cover, and invertebrates required by ducklings for growth and development. Some of the fresh water ponds at Mono Lake such as those that occur at the outflow of the Goose Springs complex in the South Shore Lagoons area, have been stable and present since at least 2002. Other ponds are ephemeral and vary considerably in size depending on lake elevation. The breeding population of waterfowl at Mono Lake appears to respond positively to increases in pond availability as increases in brood production have been positively correlated with increases in lake elevation.

Summering and breeding waterfowl have shown variability with regard to the proportional use of the various lake-fringing habitats, likely in response to yearly changes in habitat availability and habitat quality. The habitats in which waterfowl at Mono Lake are encountered are ephemeral or highly variable in nature and extent on a yearly basis. In 2013, most waterfowl were observed using ria, unvegetated and brackish ponds. Ria habitat occurs at the mouth of creeks and springs where fresh water flows into Mono Lake and is defined as the area where salt and fresh water stratification occurs. Fresh water outflow areas are areas where waterfowl are typically found feeding, brooding and resting. The availability of ria habitat can vary yearly and seasonally with variations in runoff, creek flow, spring flow, and shoreline configuration that may divert or redirect fresh water flows. Brackish ponds provide feeding and resting areas for waterfowl. The extent and availability of brackish pond varies with lake elevation. Brackish ponds are most limited in extent at low lake elevations. At intermediate and elevated lake elevations, brackish ponds are much more extensive, with the areas around the lake where they occur dependent upon the specific lake elevation. Unvegetated areas vary from dry sandy beach to mudflats depending on whether there is spring flow in an area. Waterfowl often use unvegetated areas for loafing and sleeping, but when spring flow in an area produces mudflats, waterfowl may be found foraging on these unvegetated mudflats. Many habitats used by waterfowl at Mono Lake are ephemeral in nature. Habitat conditions are documented qualitatively through field observations during summer surveys and through annual photography of shoreline areas in the fall. Habitat conditions that may explain waterfowl use and the spatial distribution of waterfowl at Mono Lake, however are not readily quantified during existing vegetation mapping efforts conducted every five years because of their ephemeral nature and small scale.

The use of Mono Lake by fall migrants is much greater than by breeding waterfowl, and is dominated by two species, Northern Shoveler and Ruddy Duck. The aquatic ecosystem of Mono Lake is also dominated by few species, which is typical of highly saline systems. Mono Lake is rich in zooplankton, phytoplankton, and benthic algae, some of which are accessible to waterfowl as a food resource. Due to the salinity of the water, the lake does not support submerged aquatics as a food resource for waterfowl. Plant food resources such aquatic and wetland vegetation, which are an important food resource to many waterfowl species in fall, are limited to lake-fringing wetland areas, which comprise a small fraction of the total area of Mono Lake. The Northern Shoveler, unlike other dabbling duck species in the genus *Anas*, has a bill ideally suited to strain small crustaceans from the water column. Ruddy Ducks are reported to feed primarily on aquatic insects, crustaceans, zooplankton, and other invertebrates, consuming only small amounts of aquatic vegetation and seeds (Brua, 2002). Although no diet study has been conducted on waterfowl at Mono Lake, to varying extents, these species are expected to feed on brine shrimp and alkali flies that are found in abundance at Mono Lake.

At Mono Lake, Northern Shoveler tend to be encountered in large cohesive flocks in fall. In 2013, the main areas of use by shovelers were areas along the northwest shore including Wilson Creek, Mill Creek and DeChambeau Creek. Wilson Creek and Mill Creek deltas consistently attract a large proportion of Northern Shovelers every year.

In 2013, total waterfowl numbers at Mono Lake and Bridgeport during fall fell within the 14-year mean. Use of Crowley Reservoir by waterfowl however was above the 14-year mean. The proportional abundance of waterfowl species at Mono Lake differs greatly from that of the nearby freshwater reservoirs as the fall waterfowl population at Mono Lake is dominated by Northern Shoveler and Ruddy Duck, while waterfowl populations at the reservoirs are much more diverse. Comparison counts between Mono Lake and the two fresh water reservoirs are of limited usefulness. The food resources of a fresh water reservoir little resemble those of Mono Lake, and thus waterfowl using Mono Lake encounter and are responding to a different set of environmental variables. The lack of correlation between waterfowl population numbers at Bridgeport and Crowley with Mono Lake is not surprising. In addition, the greater proportional use of Mono Lake than the nearby reservoirs by Northern Shoveler and Ruddy Ducks is also expected as these species are able to exploit available resources more effectively than other species can.

Migratory waterfowl populations that use Mono Lake are expected to be influenced by a multitude of factors. Short-term and long-term population trends will be affected by conditions on breeding grounds, wintering grounds, and along migratory routes. Mono Lake provides abundant food resources for the limited number of waterfowl species that are able to exploit those resources. Important waterfowl habitats at Mono Lake such as brackish and freshwater ponds are ephemeral in nature as the shoreline configuration is dynamic, changing as a result of lake elevation changes and the effect of wind on the shoreline. The preliminary analysis conducted here indicates no direct and simple relationship between fall waterfowl populations and lake elevation or lake elevation changes.

Further analysis of the trend in waterfowl populations at Mono Lake, the response to changing lake elevations, and comparisons with fall counts at Bridgeport and Crowley Reservoirs will be presented in a future document.

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Table 1. Summary of 2013 Summer Ground Count Data

Species	**Survey 1**	**Survey 2**	**Survey 3**	**Total**	**Percent Detections**
Canada Goose	72	68	61	201	19.1%
Cinnamon Teal	4	7	3	14	1.3%
Gadwall	340	219	63	622	59.1%
Green-winged Teal	12	16	6	34	3.2%
Mallard	119	22	26	167	15.9%
Redhead	7	1	1	9	0.9%
Ruddy Duck	2		2	4	0.4%
Common Merganser	1			1	0.1%
Total Waterfowl	557	333	162	1052	

Table 2. 2013 Summer Ground Count Data

Table shows the total detections of each species in each shoreline area, total waterfowl detections by area, and the percent of total detections by area.

Species	DECR	LVCR	MICR	RUCR	SASP	SOTU	SSLA	WASP	WICR	**Total**
Canada Goose	70	9			74	28			20	**201**
Cinnamon Teal					2			12		**14**
Gadwall	38	67	44	30	79	13	81	28	242	**622**
Green-winged Teal	2		3	7	11		2		9	**34**
Mallard	6	1	6	8	52		18	65	11	**167**
Redhead					7			2		**9**
Ruddy Duck			4							**4**
Common Merganser		1								**1**
Total Detections	116	78	57	45	225	41	101	107	282	**1052**
% of Detections	11.0%	7.4%	5.4%	4.3%	21.4%	3.9%	9.6%	10.2%	26.8%	

Table 3. 2013 Brood Data

Table shows the number of broods by species per visit in shoreline survey area.

	Shoreline Segment	DECR	LVCR	MICR	RUCR	SASP	SOTU	SSLA	WASP	WICR	**Total**
Survey 1	Canada Goose	2				3	3				**8**
	Gadwall			1							**1**
	Green-winged Teal										**0**
	Mallard										**0**
	Total Broods	2	0	1	0	3	3	0	0	0	9
Survey 2	Canada Goose										**0**
	Gadwall				2			1		3	**6**
	Green-winged Teal			1	1						**2**
	Mallard							1			**1**
	Total Broods	0	0	1	3	0	0	2	0	3	9
Survey 3	Canada Goose										**0**
	Gadwall	4		1	2			4		7	**18**
	Green-winged Teal										**0**
	Mallard										**0**
	Total Broods	4	0	1	2	0	0	4	0	7	**18**
Total	Shoreline Segment	DECR	LVCR	MICR	RUCR	SASP	SOTU	SSLA	WASP	WICR	**Total**
	Canada Goose	2				3	3				**8**
	Gadwall	4		2	4			5		10	**25**
	Green-winged Teal			1	1						**2**
	Mallard							1			**1**
	Total broods per area	6	0	3	5	3	3	6	0	10	36

Table 4. Chi Square Goodness-of-Fit Results for Waterfowl Habitat Use Data
Grayed categories were excluded from analysis. The results of the Bonferroni Test are indicated in the “Sign” (= significance) column. NS indicates that there was no significant difference between expected and observed use of a habitat type at the $p < 0.05$ level.

	Canada Goose				Gadwall				Green-winged Teal				Mallard			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh													1	18.5	16.5	-
Dry Meadow	13	25.3	5.9	-												
Wet Meadow					2	80.3	76.3	-					2	18.5	14.7	-
Alkali Wet Meadow	27	25.3	0.1	NS									1	18.5	16.6	-
Riparian Scrub																
Freshwater Stream	2	25.3	21.4	-	19	80.3	46.8	-	6	6.8	0.1	NS	10	18.5	3.9	-
Ria	3	25.3	19.6	-	197	80.3	169.6	+	5	6.8	0.5	NS	10	18.5	3.9	-
Fresh Water Pond					94	80.3	2.3	NS	20	6.8	25.6	+	18	18.5	0.0	NS
Brackish Pond	8	25.3	11.8	-	63	80.3	3.8	NS	2	6.8	3.4	-	109	18.5	442.6	+
Hypersaline Pond																
Unvegetated	44	25.3	13.8	+	159	80.3	77.1	+	1	6.8	4.9	-	10	18.5	3.9	-
Open Water	80	25.3	118.4	+	28	80.3	34.1	-					6	18.5	8.5	-
Total	177		191		562		410		34		34.51		167		510.6	

Table 5. Summary of 2013 Mono Lake Fall Aerial Survey Count Data

Species	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov	Total detections	% Total
Snow Goose					13		13	0.1%
Cackling Goose				5		4	9	<0.1%
Canada Goose			65	45	33	36	179	0.8%
Gadwall	105	51	68	21	3	15	263	1.1%
Mallard	19	40	35	47	8	97	246	1.0%
Blue-winged Teal			2				2	<0.1%
Cinnamon Teal		25					25	0.1%
Northern Shoveler	6008	7860	1633	2227	43		17771	74.9%
Northern Pintail			1316		13	10	1339	5.6%
Green-winged Teal	13	12	55	190	36	120	426	1.8%
Unidentified Teal			1	320	5	1	327	1.4%
Redhead						1	1	<0.1%
Lesser Scaup						1	1	<0.1%
Bufflehead						3	3	<0.1%
Ruddy Duck	62	225	607	1210	538	465	3107	13.1%
Total Waterfowl	**6207**	**8213**	**3782**	**4065**	**692**	**753**	**23712**	
Species Richness	**5**	**6**	**9**	**7**	**8**	**10**		

Table 6. 2013 Fall Spatial Distribution of Waterfowl at Mono Lake

Lakeshore Segment	**3-Sep**	**19-Sep**	**1-Oct**	**15-Oct**	**29-Oct**	**12-Nov**	**Segment Total**	**% by Segment**
BLPO	4	2	5			9	20	0.1%
BRCR						16	16	0.1%
DECR	207	510	688	1475	11	4	2895	13.6%
DEEM	31	72	233			8	344	1.6%
LVCR	31	19	31	15	5	8	109	0.5%
MICR	1550	1802	530	445		10	4337	20.4%
NESH							0	0.0%
RACO	4		13		1	8	26	0.1%
RUCR	5		65	63	16	11	160	0.8%
SASP	258	1105	249	87	36	24	1759	8.3%
SOTU			8	7	86	3	104	0.5%
SSLA	280	440	102		6	30	858	4.0%
WASP	20	30	12	10	35	160	267	1.3%
WESH			305	125	76	28	534	2.5%
WICR	3800	4000	1200	858			9858	46.3%
Lakewide total	6190	7980	3441	3085	272	319	21287	

Table 7. Summary of 2013 Bridgeport Reservoir Fall Aerial Survey Count Data

Species	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov	Total detections	% Total
Canada Goose	45	55	550	250		190	1090	5.8%
Tundra Swan						5	5	<0.1%
Gadwall	1425	440	75	139	80	110	2269	12.2%
American Wigeon		15		8			23	0.1%
Mallard	600	7	102	252	168	540	1669	8.9%
Cinnamon Teal	50						50	0.3%
Northern Shoveler	4375	1802	150				6327	33.9%
Northern Pintail		106	800	330	24	8	1268	6.8%
Green-winged Teal	702	160	132	55	290	210	1549	8.3%
Unidentified Teal	200	940	37		75		1252	6.7%
Canvasback					10		10	0.1%
Ring-necked Duck		10					10	0.1%
Lesser Scaup					25		25	0.1%
Bufflehead					30	56	86	0.5%
Common Merganser	33	17	10				60	0.3%
Ruddy Duck		556	760	405	124	1118	2963	15.9%
Total Waterfowl	7430	4108	2616	1439	826	2237	18656	
Species Richness	7	10	8	7	8	8		

Table 8. 2013 Fall Spatial Distribution of Waterfowl at Bridgeport Reservoir

Lakeshore Segment	**3-Sep**	**19-Sep**	**1-Oct**	**15-Oct**	**29-Oct**	**12-Nov**	**Segment Total**	**% by Segment**
EASH	1203	51	300	141	38	34	1767	9.5%
NOAR	137	74	51	15	98	13	388	2.1%
WEBA	6090	3983	2265	1283	690	2190	16501	88.4%
Lakewide total	7430	4108	2616	1439	826	2237	18656	

Table 9. Summary of 2013 Crowley Reservoir Fall Aerial Survey Count Data

Species	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov	Total detections	% Total
Greater White-fronted Goose			4		1		5	<0.1%
Ross's Goose					1		1	<0.1%
Cackling Goose					1		1	<0.1%
Canada Goose	90	172		42	80		384	0.6%
Tundra Swan						7	7	<0.1%
Gadwall	776	1237	1877	818	1052	667	6427	10.3%
American Wigeon	2	17	15	35	40	288	397	0.6%
Mallard	850	525	1820	3138	2519	2426	11278	18.1%
Blue-winged Teal			5				5	<0.1%
Cinnamon Teal	55	21					76	0.1%
Northern Shoveler	1947	5166	3425	1885	510	15	12948	20.8%
Northern Pintail	125	607	1642	1634	3393	843	8244	13.2%
Green-winged Teal	990	1136	1014	1955	530	1005	6630	10.6%
Unidentified Teal	30			2			32	0.1%
Canvasback						3	3	<0.1%
Redhead		58	4	4	10		76	0.1%
Ring-necked Duck	35	6		34	20		95	0.2%
Lesser Scaup					14	127	141	0.2%
Bufflehead	2		1	18	127	265	413	0.7%
Hooded Merganser						4	4	<0.1%
Common Merganser					5		5	<0.1%
Ruddy Duck	367	579	1353	6524	3967	2400	15190	24.4%
Total Waterfowl	5269	9524	11160	16089	12270	8050	62362	
Species Richness	11	11	11	11	16	12		

Table 10. 2013 Fall Spatial Distribution of Waterfowl at Crowley Reservoir

Lakeshore Segment	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov	Segment Total	% by Segment
CHCL		15	130	189	437	551	1322	2.1%
HIBA	144	227	375	540	82	334	1702	2.7%
LASP	102	341	257	366	703	1447	3216	5.2%
MCBA	3098	6972	6581	12276	9051	4107	42085	67.5%
NOLA		35	160	247	521	189	1152	1.8%
SAPO	37	9	80	231	80	429	866	1.4%
UPOW	1888	1925	3577	2240	1396	993	12019	19.3%
Lakewide total	5269	9524	11160	16089	12270	8050	62362	

Table 11. Mono Lake Restoration Ponds - Total Summer Detections

Species	COPOE	COPOW	DEPO_1	DEPO_2	DEPO_3	DEPO_4	DEPO_5	**Total**
Cinnamon Teal	1							1
Gadwall	21					2		23
Green-winged Teal	3			1				4
Mallard	2							2
Ruddy Duck	5				7	4		16
Pond Totals	32	0	0	1	7	6	0	46

Table 12. Mono Lake Restoration Ponds - Total Waterfowl Broods

Species	County Ponds	DeChambeau Ponds
Gadwall	4	1
Green-winged Teal		1
Ruddy Duck		1
Total Broods	4	3

Table 13. Mono Lake Restoration Ponds - 2013 Fall Survey Counts

County Ponds	**3-Sep**	**19-Sep**	**1-Oct**	**15-Oct**	**29-Oct**	**12-Nov**	**Total Fall Detections**
Tundra Swan						1	1
Gadwall	4						4
Mallard	3				2	1	6
Unidentified Teal	10	12		20			42
Ring-necked Duck			3				3
Total Waterfowl	24	12	3	20	4	3	66

DeChambeau Ponds	**3-Sep**	**19-Sep**	**1-Oct**	**15-Oct**	**29-Oct**	**12-Nov**	**Total Fall Detections**
Mallard	3		1		5		9
Gadwall	4		5	5			14
Unidentified Teal	3	6		5			14
Bufflehead						1	1
Total Waterfowl	10	6	6	10	5	1	38

Figure 1. Summer Ground Count Survey Areas

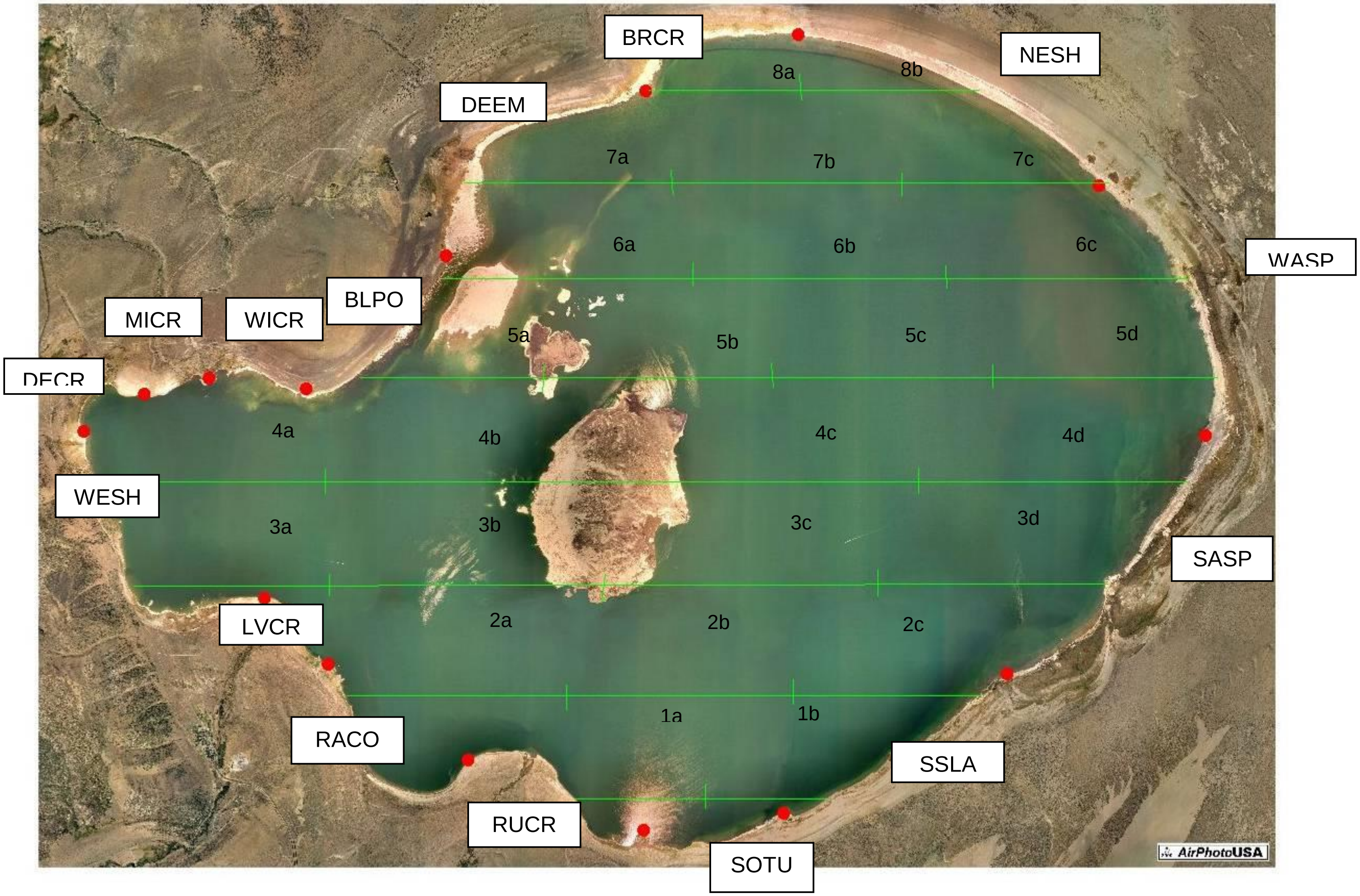

Figure 2. Mono Lake Fall Aerial Survey Lakeshore Segments, Boundaries, and Cross-Lake Transects

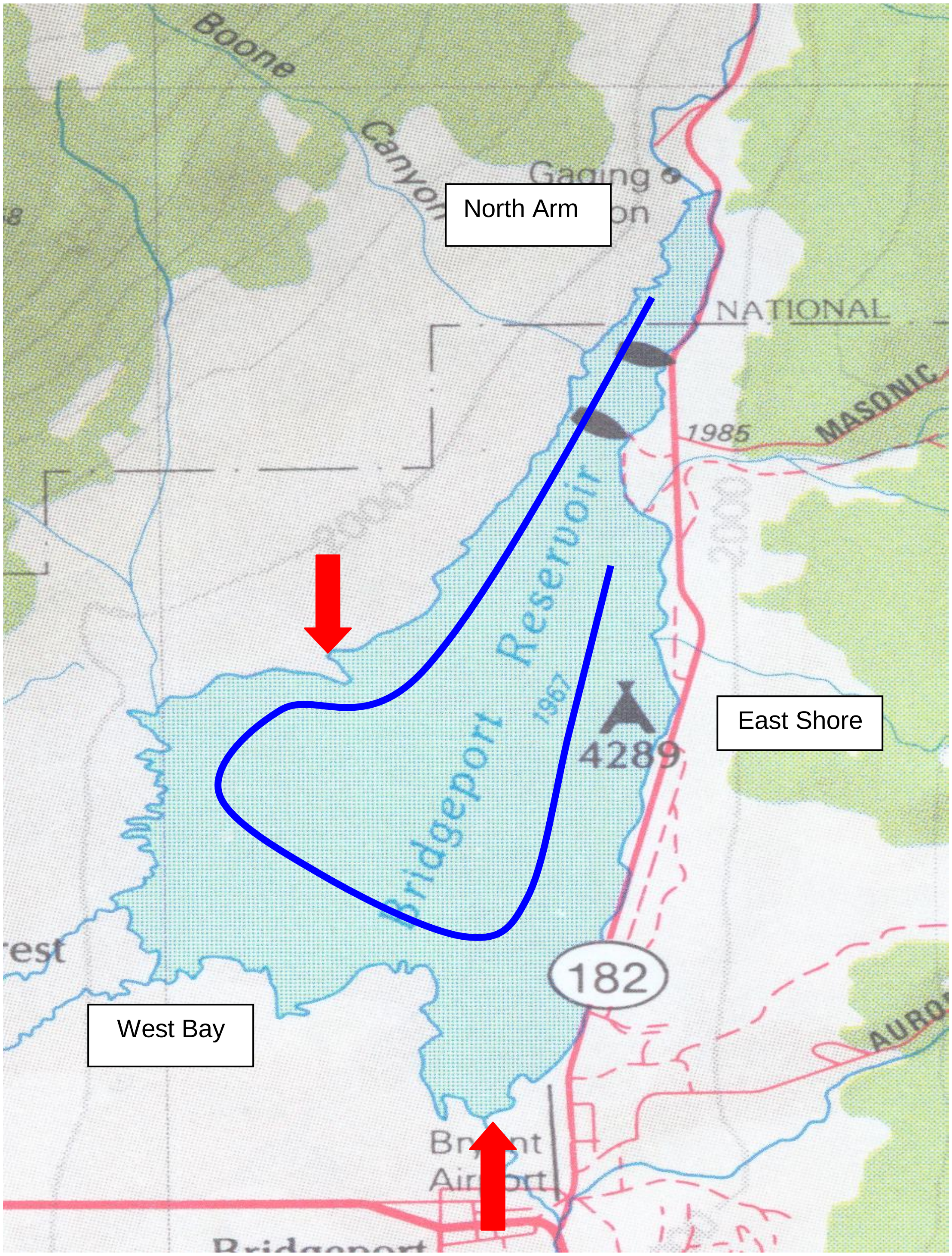

Figure 3. Bridgeport Reservoir Lakeshore Segments and Segment Boundaries

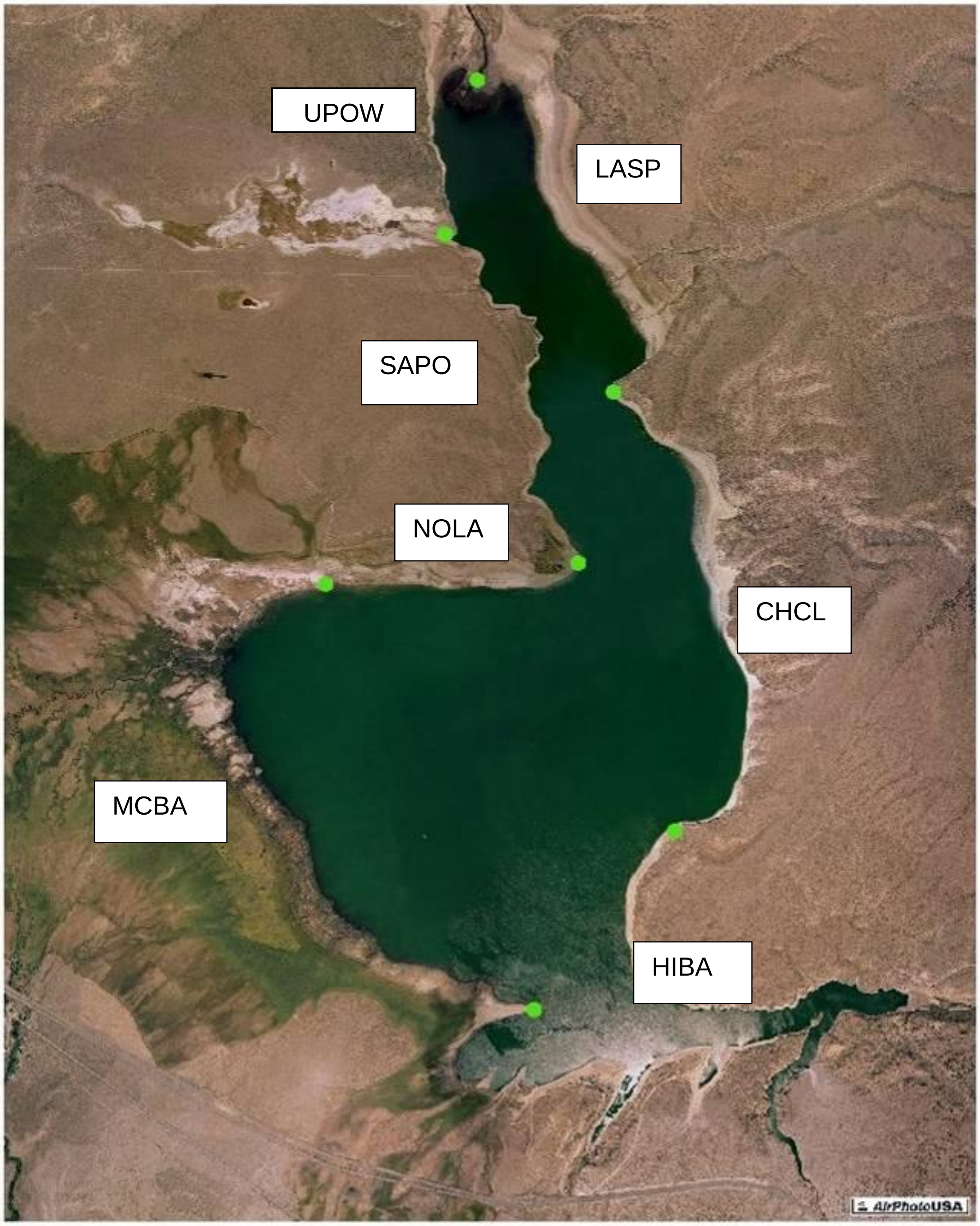

Figure 4. Crowley Reservoir Lakeshore Segments and Segment Boundaries

Figure 5. South Tufa, East of Navy Beach

Figure 6. South Shore Lagoons Area – First Pond

Figure 7. South Shoreline – Freshwater Pond

Figure 8. South Shore Lagoons – Sand Flat Spring

Figure 9. South Shore Lagoons Goose Springs Outflow Area

Figure 10. Sammann's Spring West of Tufa Grove

Figure 11. Sammann's Spring, east of Tufa grove

Figure 12. Warm Springs – North Pond

Figure 13. Northeast Shore

Figure 14. Bridgeport Creek Shoreline Area

Figure 15. DeChambeau Embayment

Figure 16. Black Point

Figure 17. Wilson Creek Shoreline Area

Figure 18. Mill Creek Delta

Figure 19. DeChambeau Creek Shoreline Area

Figure 20. West Shore

Figure 21. Lee Vining Creek Delta

Figure 22. Ranch Cove Shoreline Area

Figure 23. Rush Creek Delta

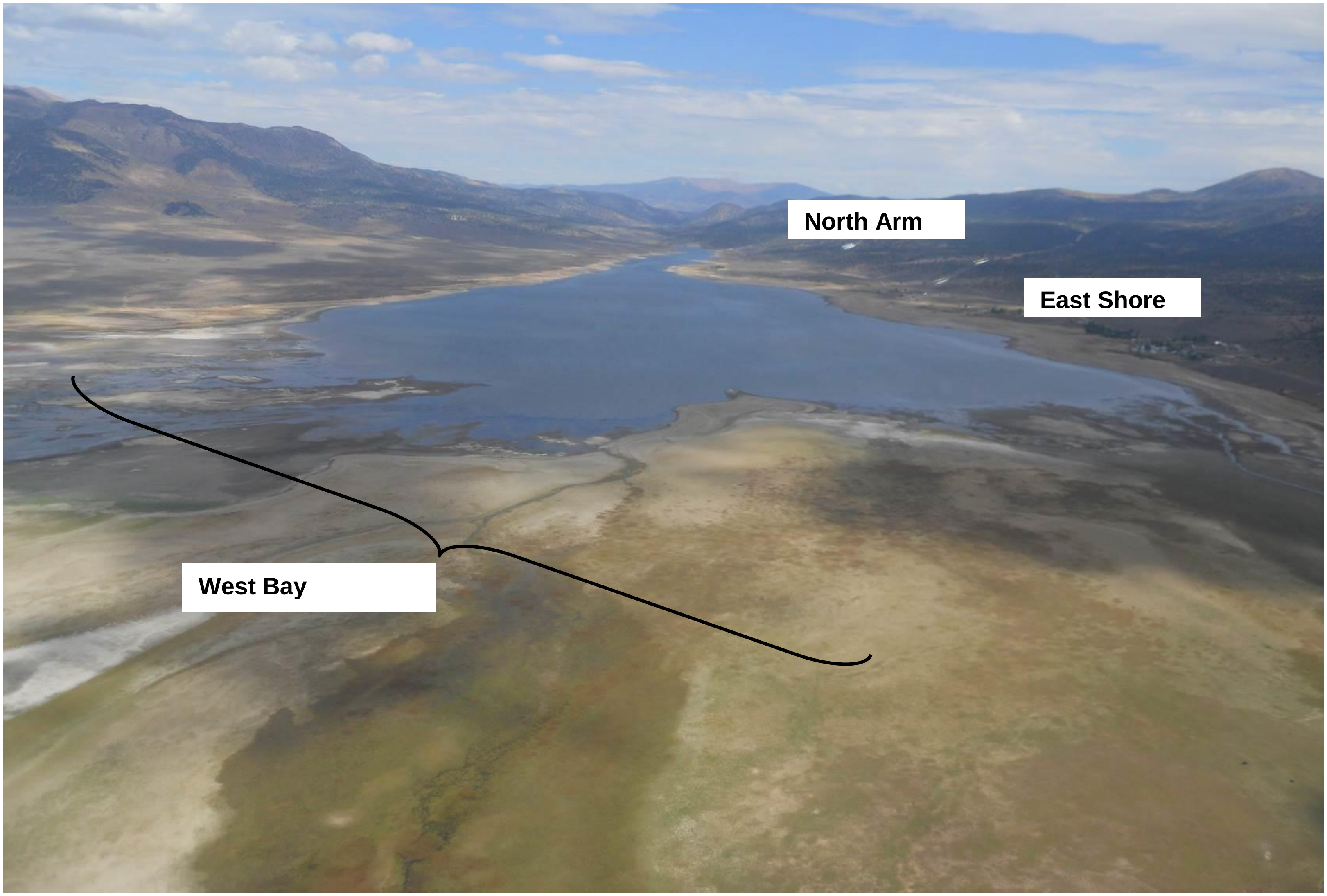

Figure 24. Photo of Bridgeport Reservoir, Looking North
Photo shows the West Bay area and the south end of the East Shore area. The majority of waterfowl that use Bridgeport Reservoir in the fall congregate in this southern end of the reservoir.

Figure 25. Crowley- Upper Owens River Delta

Figure 26. Crowley -Sandy Point Shoreline Area

Figure 27. Crowley -North Landing Shoreline Area

Figure 28. Crowley - McGee Bay

Figure 29. Crowley -Hilton Bay

Figure 30. Crowley - Chalk Cliffs

Figure 31. Crowley - Layton Springs

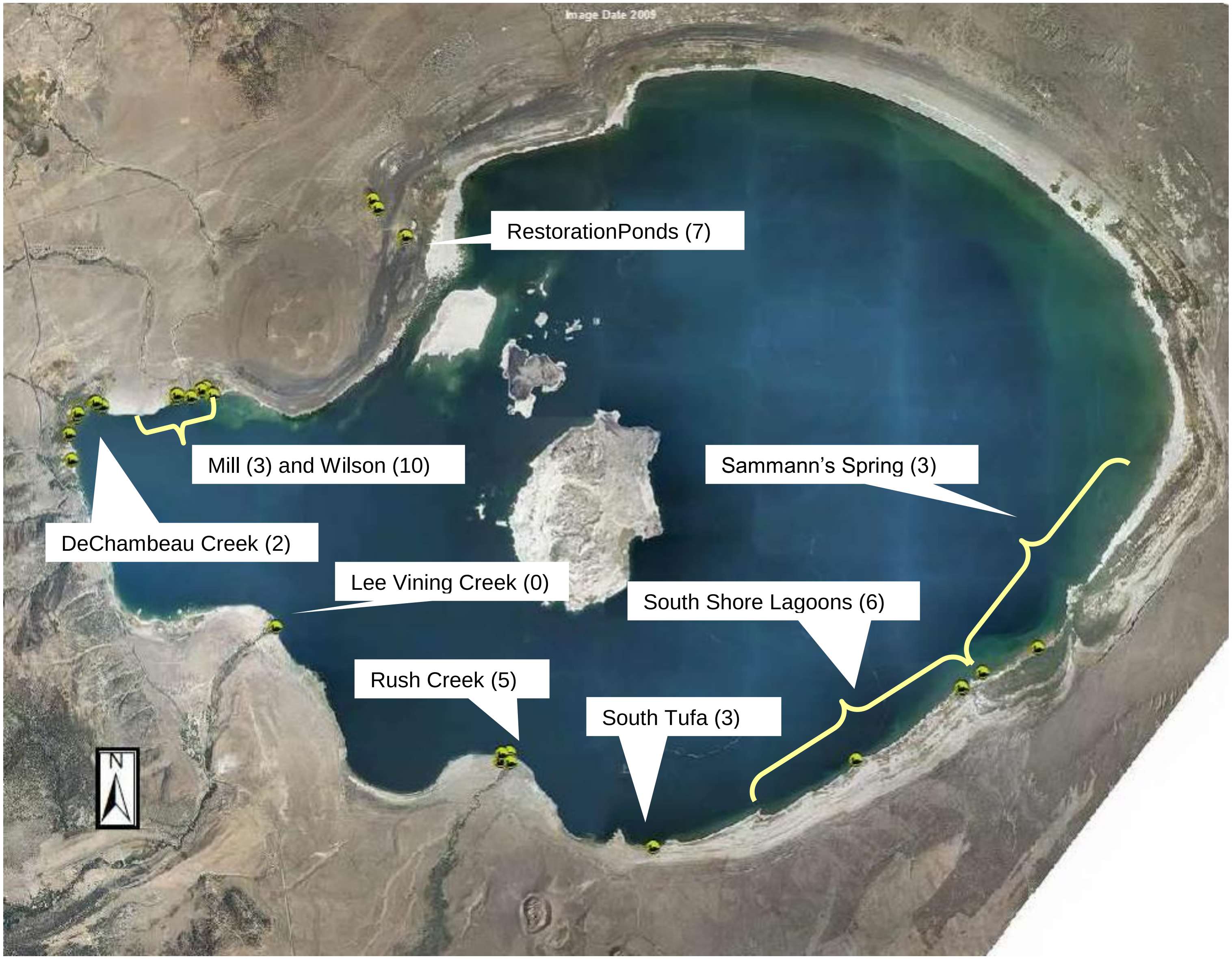

Figure 32. 2013 Brood Locations
The number in parentheses indicates the number of broods found in each area.

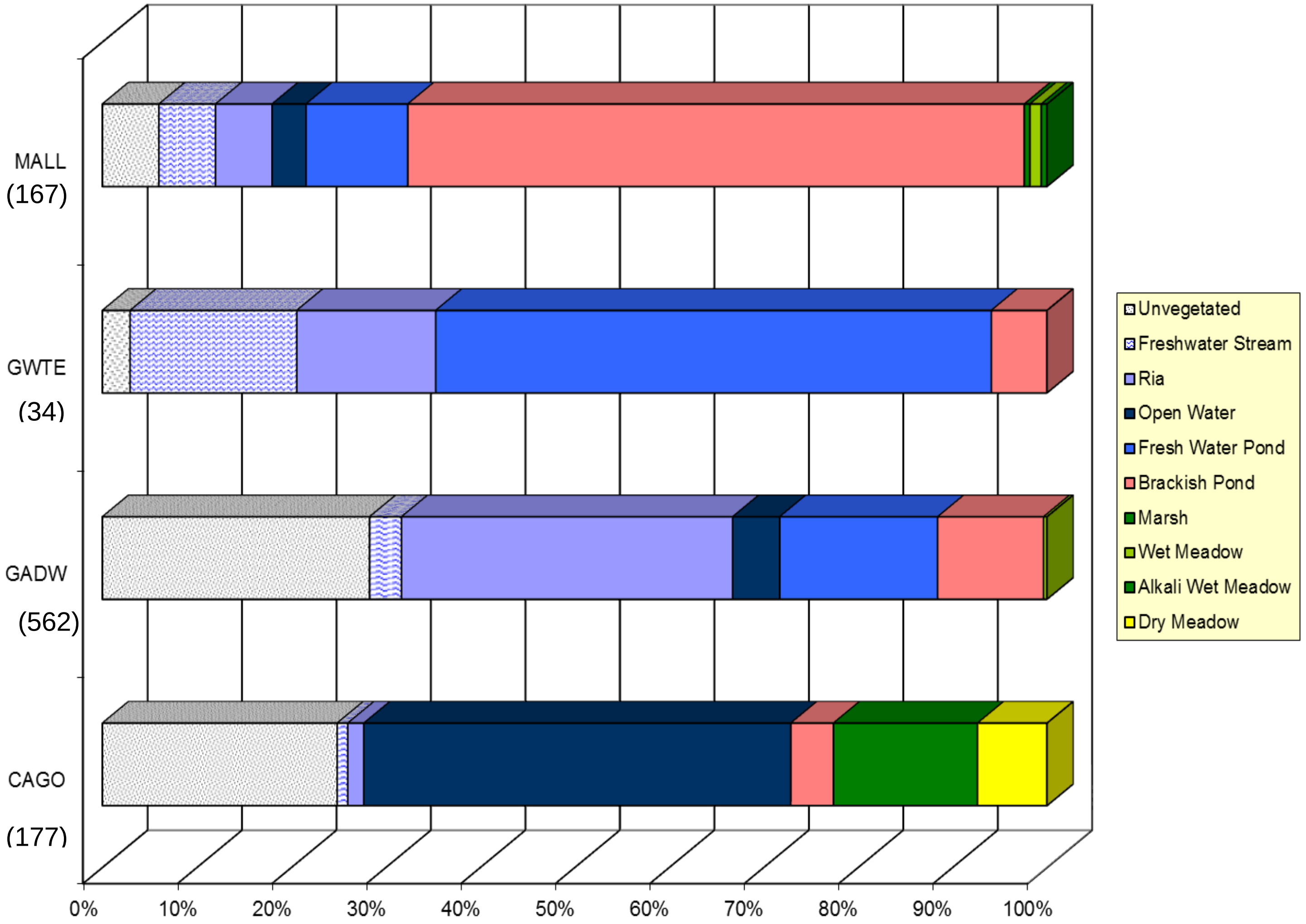

Figure 33. Waterfowl Habitat Use
The numbers in parentheses indicate sample size. The bars represent the percent of the total observations.

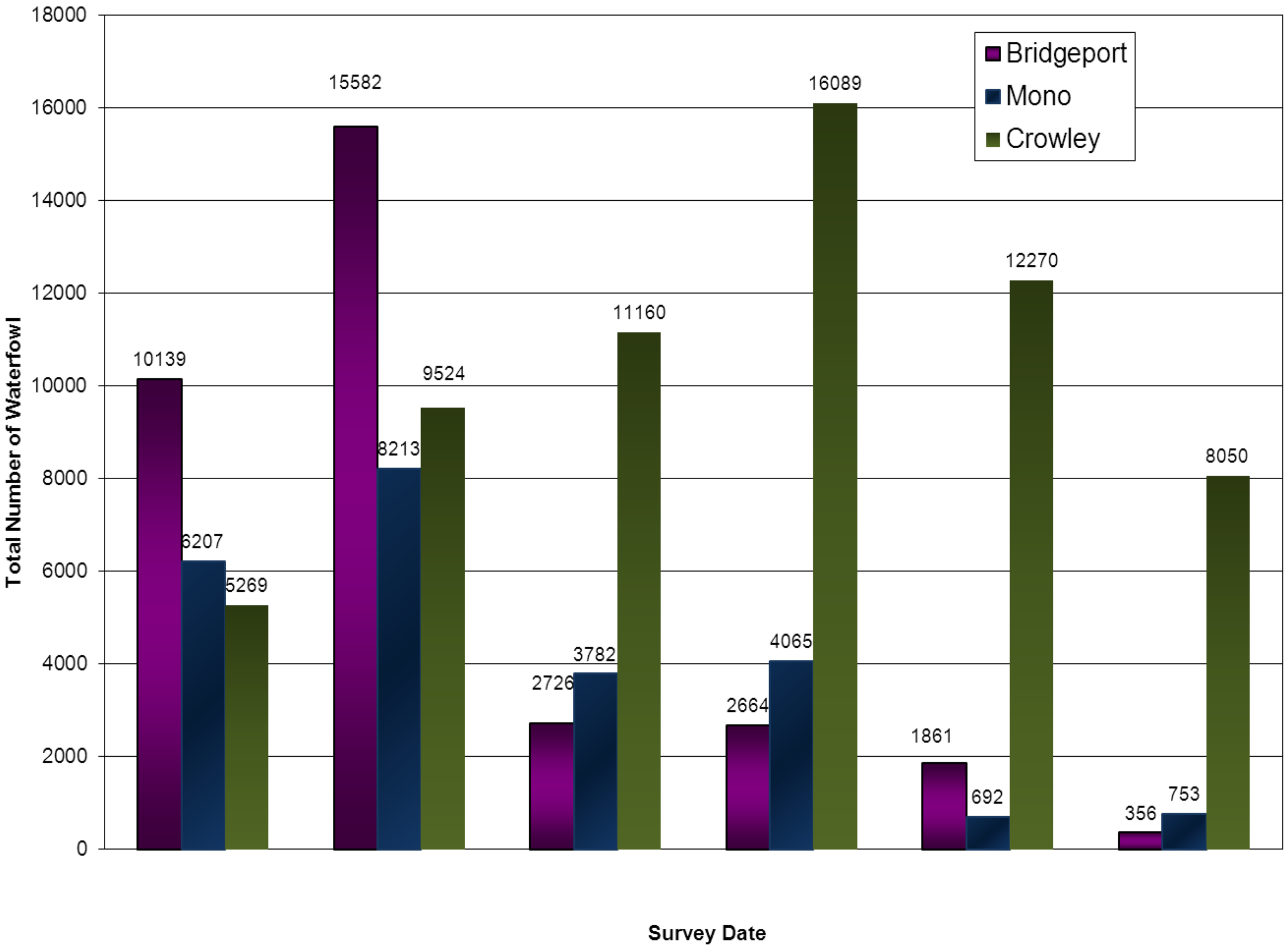

Figure 34. Total Fall Detections by Waterbody

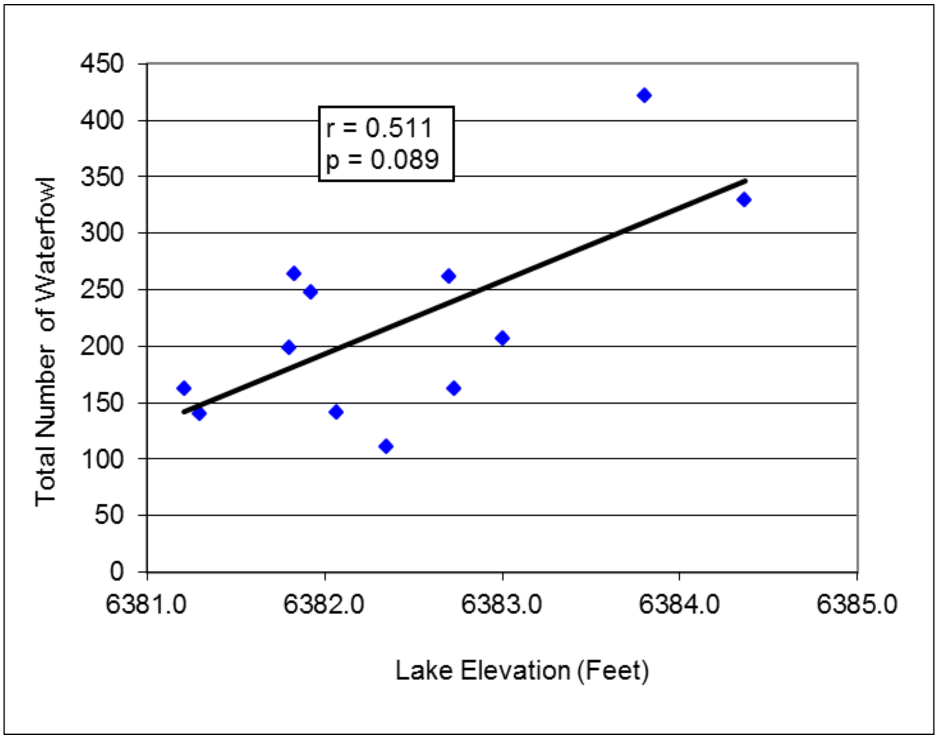

Figure 35. Relationship Between Total Waterfowl and Lake Elevation in June

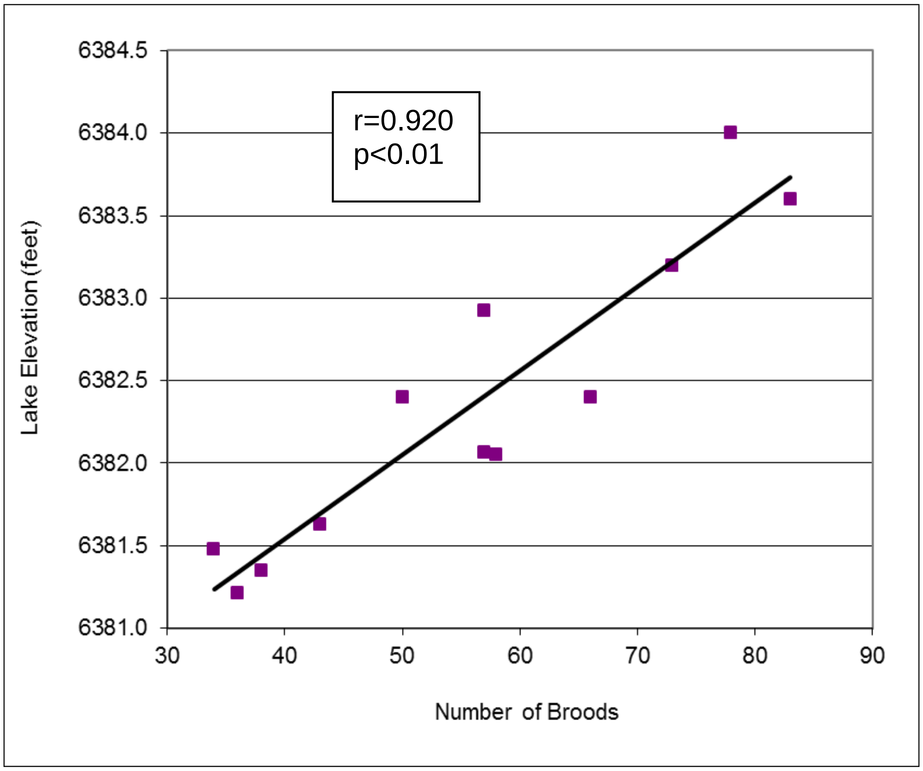

Figure 36. Number of Waterfowl Broods versus Lake Elevation in June

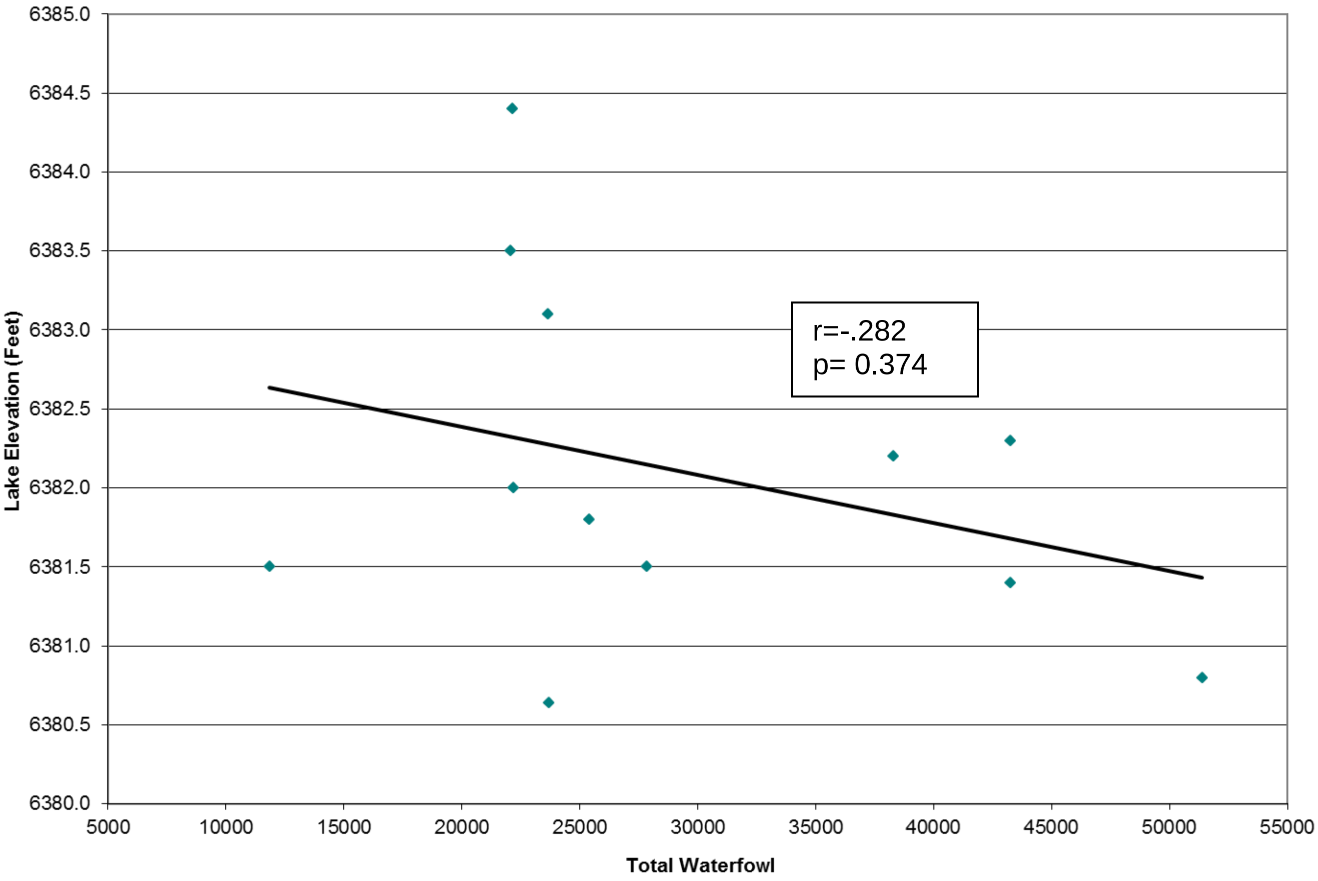

Figure 37. Total Fall Waterfowl Use of Mono Lake versus Lake Elevation in September

APPENDICES

Appendix 1. 2013 Ground Count Survey Dates and Times

Survey 1

Survey Area	Survey Date and Time			
	3-Jun	4-Jun	5-Jun	6-Jun
RUCR		1223 - 1350 hrs		
SOTU	0915-1053 hrs			
SSLA		1141 - 1442 hrs		0610 - 0903 hrs
DECR		0545 - 0700 hrs		
MICR		0700 - 0813 hrs		
WICR		0815 - 0900 hrs		
LVCR		1035 - 1135 hrs		
DEPO	1300-1400 hrs			
COPO	1300-1400 hrs			
SASP			1108 - 1445 hrs	
WASP			0715 - 1108 hrs	

Survey 2

Survey Area	Survey Date and Time			
	24-Jun	25-Jun	26-Jun	27-Jun
RUCR	0538 - 0702 hrs			
SOTU				0537 - 0616 hrs
SSLA	0807 - 1020 hrs			
DECR		0550 - 0640 hrs		
MICR		0640 - 0738 hrs		
WICR		0730 - 0825 hrs		
LVCR		1107 - 1155 hrs		
DEPO		1000 - 1032 hrs		
COPO		1000 - 1032 hrs		
SASP			0600 - 0845 hrs	
WASP				0828 - 1000 hrs

Survey 3

Survey Area	Survey Date and Time			
	15-Jul	16-Jul	17-Jul	18-Jul
RUCR	0540 - 0645 hrs			
SOTU				0550 - 0645 hrs
SSLA	0751 - 1010 hrs			
DECR		0555 - 0645 hrs		
MICR		0645 - 0728 hrs		
WICR		0728 - 0810 hrs		
LVCR		1445 - 1515 hrs		
DEPO		1339 - 1425 hrs		
COPO		1339 - 1425 hrs		
SASP			0655 - 0942 hrs	
WASP				0850 - 1023 hrs

Appendix 2. Common and Scientific Names for Species Referenced in the Document.

Common Name	Scientific Name
Greater White-fronted Goose	*Anser albifrons*
Snow Goose	*Chen caerulescens*
Ross's Goose	*Chen rossii*
Cackling Goose	*Branta hutchinsii*
Canada Goose	*Branta canadensis*
Tundra Swan	*Cygnus columbianus*
Gadwall	*Anas strepera*
American Wigeon	*Anas americana*
Mallard	*Anas platyrhynchos*
Blue-winged Teal	*Anas discors*
Cinnamon Teal	*Anas cyanoptera*
Northern Shoveler	*Anas clypeata*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Unidentified Teal	*Anas* (sp)
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Lesser Scaup	*Aythya affinis*
Bufflehead	*Bucephala albeola*
Hooded Merganser	*Lophodytes cucullatus*
Common Merganser	*Mergus merganser*
Ruddy Duck	*Oxyura jamaicensis*

Appendix 3. Habitat Categories Used for Documenting Use by Waterfowl Species (from 1999 Mono Basin Habitat and Vegetation Mapping, Los Angeles Department of Water and Power 2000).

Marsh

Areas with surface water usually present all year and dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typhus latifolia*), three-square (*Scirpus pungens*), alkali bulrush (*Scirpus maritimus*) and beaked sedge (*Carex utriculata*).

Wet Meadow

Vegetation with seasonally or permanently wet ground dominated by lower stature herbaceous plant species, such as sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and some forbs (e.g. monkey flower [*Mimulus* spp.], paintbrush [*Castilleja exilis*]). Wet meadow vegetation was in areas where alkaline or saline soils did not appear to be present. This class included the "mixed marsh" series from Jones and Stokes 1993 mapping.

Alkaline Wet Meadow

This type was similar in stature to the wet meadow class but occurred in areas clearly affected by saline or alkaline soils. Vegetation was typically dominated by dense stands of Nevada bulrush (*Scirpus nevadensis*), Baltic rush (*Juncus balticus*), and/or saltgrass (*Distichlis spicata*). The high density and lushness of the vegetation indicated that it had a relatively high water table with at least seasonal inundation and distinguished it from the dry meadow vegetation class.

Dry meadow/forb

This vegetation class included moderately dense to sparse (at least 15 percent) cover of herbaceous species, including a variety of grasses and forbs and some sedges (e.g. *Carex douglasii*). As with the alkaline wet meadow type above, comparison to vegetation series in Jones and Stokes (1993) was sometimes problematic due to difficulty in distinguishing dry meadow from wet meadow types.

Riparian and wetland scrub

Areas dominated by willows (*Salix* spp.) comprised most of the vegetation classified as riparian.wetlands scrub. Small amounts of buffalo berry (*Shepardia argentea*) and Wood's rose (*Rosa woodsii*) usually mixed with willow also were included in this class.

Great Basin scrub

Scattered to dense stands of sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and/or bitterbrush (*Purshia tridentata*) were classified as Great Basin scrub. This vegetation type included a range of soil moisture conditions, as rabbitbrush was often found in moist areas close to the lakeshore and sagebrush was typically in arid upland areas.

Riparian forest and woodland

Aspen (*Populus tremuloides*) and black cottonwood (*Populus trichocarpa*) were the two tree species most common in the riparian forest/woodland vegetation type.

Freshwater-stream

Freshwater-stream habitats are watered; freshwater channels such as exist in Rush Creek and Lee Vining Creeks.

Freshwater-ria

Freshwater-ria areas were surface water areas at the mouths of streams that likely have some salt/freshwater stratification.

Freshwater-pond

This type included ponds fed by springs within marsh areas or artificially by diversions from streams (e.g. DeChambeau/County ponds).

Ephemeral Brackish Pond

Ponds along the shoreline created by the formation of littoral bars with an extensive area of marsh or wet meadow indicating the presence of springs was present landward, were identified as ephemeral brackish ponds. In some cases, ponds were not completely cut off from lake water, but were judged to still have brackish water due to freshwater input and reduced mixing.

Ephemeral Hypersaline Pond

Ponds along the shoreline created by the formation of littoral bars, but without an extensive area of marsh or wet meadow present landward, were identified as ephemeral hypersaline ponds. These were presumed to contain concentrated brine due to evaporation.

Unvegetated

Unvegetated areas were defined as those that were barren to sparsely vegetated (<15 percent cover). This class included sandy areas, alkaline flats, tufa, and delta outwash deposits.

Appendix 4. 2013 Fall Aerial Survey Dates

Survey Number	**1**	**2**	**3**	**4**	**5**	**6**
Mono Lake	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov
Bridgeport Reservoir	3-Sep	19-Sep	**1-Oct**	15-Oct	29-Oct	12-Nov
Crowley Reservoir	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov

Appendix 5. Lakeshore Segment Boundaries

(UTM, Zone 11, NAD 27, CONUS)

Mono Lake	**Lakeshore Segment**	**Code**	**Easting**	**Northing**
	South Tufa	SOTU	321920	4201319
	South Shore Lagoons	SSLA	324499	4201644
	Sammann’s Spring	SASP	328636	4204167
	Warm Springs	WASP	332313	4208498
	Northeast Shore	NESH	330338	4213051
	Bridgeport Creek	BRCR	324773	4215794
	DeChambeau Embayment	DEEM	321956	4214761
	Black Point	BLPT	318252	4211772
	Wilson Creek	WICR	315680	4209358
	Mill Creek	MICR	313873	4209544
	DeChambeau Creek	DECR	312681	4209246
	West Shore	WESH	315547	4208581
	Lee Vining Creek	LVCR	314901	4205535
	Ranch Cove	RACO	316077	4204337
	Rush Creek	RUCR	318664	4202603
Crowley Reservoir				
	Upper Owens	UPOW	346150	4168245
	Sandy Point	SAPO	345916	4167064
	North Landing	NOLA	346911	4164577
	McGee Bay	MCBA	345016	4164414
	Hilton Bay	HIBA	346580	4161189
	Chalk Cliff	CHCL	347632	4162545
	Layton Springs	LASP	347177	4165868
Bridgeport Reservoir				
	North Arm	NOAR	306400	4244150
	West Bay	WEBA	304100	4240600
	East Shore	EASH	305600	4237600

Appendix 6. Mono Lake Cross-Lake Transect Positions

Cross-Lake Transect Number	Latitude
1	37º 57’00”
2	37º 58’00”
3	37º 59’00”
4	38º 00’00”
5	38º 01’00”
6	38º 02’00”
7	38º 03’00”
8	38º 04’00”