Section 5

Mono Basin Waterfowl
Habitat and Population Monitoring
2006-2007

Waterfowl Monitoring

In RY 2006-07, LADWP continued the waterfowl habitat monitoring and restoration program. The following is a summary of activities:

- Monitored Mono Lake Hydrology;
- Monitored Mono Lake Limnology
- Monitored Mono Lake Ornithology
- Monitored Mono Lake Vegetation
- Aerial/Satellite Imagery Analysis and Reporting

Mono Lake Hydrology

The elevation of Mono Lake was monitored on 39 occasions during the runoff year over which time the lake elevation ranged from 6382.8 feet amsl on April 6, 2006 to 6384.3 feet amsl on March 14, 2007.

Mono Lake Limnology

UC Santa Barbara conducted eleven limnological surveys. Annual primary production was 46% higher than the long-term mean. Average *Artemia* biomass was 26% lower than the long-term mean though total annual cyst production was 10% higher.

Mono Basin Ornithology

Ms. Deborah House, Watershed Resources Specialist with LADWP, conducted three summer waterfowl ground surveys and six fall aerial surveys. Photos of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoirs were taken from an airplane on September 25, 2006.

Mono Basin Vegetation

Dr. David Martin, Watershed Resources Specialist with LADWP, analyzed and ground-truthed satellite imagery of the Mono Basin captured in August 2005 by Space Imaging, presently known as GeoEye.

Mono Lake Waterfowl Restoration Project
Compliance Checklist
2006

Hydrology †	**Chapter 2**
Mono Lake Elevation	☑
Walker Creek Flows	☑
Parker Creek Flows	☑
Lee Vining Creek Flows	☑
Rush Creek Flows	☑
Mono Basin Exports	☑
Limnology ‡	**Appendix 1**
Meteorology	☑
Physicochemical Variables	☑
Primary Producers	☑
Secondary Producers	☑
Ornithology	**Appendix 2**
Population Surveys	☑
Aerial Photos	☑
Time Activity Budget	**Required at Stabilization**
Vegetation	**Appendix 3**
Vegetation Mapping	☑
Spring Survey	**Appendix 4**

Brian White

Brian White
Waterfowl Coordinator

---

† Several weekly elevation reads missed due to inclement weather.

‡ Due to equipment malfunctions, Cain Ranch PAR data were not collected from Jan 1- Feb 8 and Paoha Island precipitation was not measured from Dec 13 to Dec 31.

APPENDIX 1

Limnology

2006 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison & Kimberly Rose

Marine Science Institute
University of California
Santa Barbara, CA 93106

Submitted: 29 March 2007

TABLE OF CONTENTS

Executive Summary ii

Acknowledgments iv

Compliance page v

List of Tables vi

List of Figures vii

Chapter 1: Introduction

Background 1
Seasonal mixing regime and plankton dynamics, 1964–2005 1
Long-term integrative measures of productivity 12
Scientific publications 13

Chapter 2: Methods

Meteorology 16
Sampling regime 16
Field procedures 16
Laboratory procedures 18
Long-term integrative measures of productivity 19

Chapter 3: Results and discussion

Overview 21
Meteorology 21
Surface elevation 22
Temperature 23
Conductivity & salinity 25
Density stratification 25
Transparency and light attenuation 26
Dissolved Oxygen 27
Nutrients 27
Phytoplankton (algal biomass) 28
Artemia population dynamics 28
Long-term integrative measures of productivity 31

References 35

Tables 39

Figures 68

EXECUTIVE SUMMARY

Limnological monitoring of Mono Lake was conducted during 2006 as part of a long-term monitoring program begun in 1982. Chapter 1 describes previous results of limnological studies of the seasonal plankton dynamics observed from 1979 through 2005, a period which encompassed a wide range of varying hydrologic and annual vertical mixing regimes including two periods of persistent chemical stratification or meromixis (1983–88 and 1995–2003) and the initiation of a third episode of meromixis in 2005.

In brief, long-term monitoring has shown that Mono Lake is highly productive compared to other temperate salt lakes and that primary productivity is nitrogen-limited. The year-to-year variation in the plankton dynamics and productivity has largely been determined by the complex interplay between varying climatic and hydrologic regimes and the resultant seasonal patterns of thermal and chemical stratification which modify internal recycling of nitrogen. The importance of internal nutrient cycling to productivity is highlighted in the years immediately following the onset of persistent chemical stratification (meromixis) when upward fluxes of ammonium are attenuated. These seasonal variations in the physical and nutrient environments have obscured any real or potential impacts due to the effects of changing salinity over the range observed during the period of regular limnological monitoring (1982-present).

Laboratory, field, and analytical methods are described in Chapter 2.

Results of the 2006 limnological monitoring program including a number of integrative measures encompassing the long-term record (1982–2006) are presented in Chapter 3. Two consecutive winters of above average snowfall have resulted in the initiation of a third episode of meromixis at Mono Lake. Although salinity stratification was weak in late 2005, freshwater inputs in December 2005 were sufficient to prevent the annual winter period of holomixis. Despite the absence of holomixis, deep mixing occurred in January-February 2006 resulting in significant upward fluxes of ammonia and the effects of the initiation of meromixis on the 2006 spring plankton dynamics were minimal.

On the 13 February 2006 survey, hatching of over-wintering cysts had already begun and then increased further during March. Unusually warm conditions in early May and possibly decreased salinity resulted in the 3rd largest 1st generation of adult *Artemia* for the entire 28-yr period of record (1979-2006). A pulse of ovoviviparous reproduction by the 1st generation adults led to a large second generation in early July. There was little further recruitment into the adult population in late summer and the *Artemia* population declined rapidly and by mid-October was virtually gone. While the absence of adult *Artemia* in mid-October has only been observed in one other year (2002), low (<5,000 m^{-2}) mid-October abundances were also observed in 1986, 2000, 2003, and 2004.

Integrative measures of primary and secondary productivity in 2006 were within the ranges observed in previous years. In 2006, annual primary production was 852 g C m^{-2} or 46 % higher than the long-term mean of 584 g C m^{-2} but much less than the highest estimated productivity of 1,645 g C m^{-2} in 2003. In 2006, average *Artemia* biomass, a measure of secondary production, was 6.8 g m^{-2} or 26 % below the long-term mean. Total annual cyst production was 4.8 million m^{-2} or 10 % higher than the long-term mean of 4.4 million m^{-2}.

Annually-filtered (365-day running mean) mixed-layer chlorophyll *a* concentration and adult *Artemia* abundance provide two measures of long-term ecological trends. They both highlight the role of year-to-year changes in the annual mixing regime (meromixis/monomixis), the muted response of *Artemia* relative to phytoplankton, and the absence of any marked long-term trend over the period 1982–2006. Neither measure indicates a long-term trend in phytoplankton or *Artemia* abundance.

A second year of above average snowmelt runoff resulted in a net annual rise in surface elevation of 2.2 ft, increased salinity stratification, and strengthening and continuation of the 3rd episode of meromixis. The lake was more strongly stratified through the winter of 2006-2007 compared to the previous winter and plankton productivity is expected to decrease in 2007 due to the lack of a winter period of holomixis and reduced nutrient availability.

ACKNOWLEDGMENTS

This work was supported by a grant from the Los Angeles Department of Water and Power to R. Jellison and J. M. Melack at the Marine Science Institute, University of California, Santa Barbara. Laboratory work was performed at the Sierra Nevada Aquatic Research Laboratory, University of California. Kimberly Rose assisted with all aspects of the monitoring program including field sampling, laboratory analyses, and data analysis.

LIMNOLOGICAL MONITORING COMPLIANCE

This report fulfills the Mono Lake limnological monitoring requirements set forth in compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07. The limnological monitoring program consists of four components: meteorological, physical/chemical, phytoplankton, and brine shrimp population data. Meteorological data are collected continuously at a station on Paoha Island, while the other three components are assessed on monthly surveys (except January) supplemented by additional surveys as conditions warrant. A summary of previous monitoring is included in Chapter 1, the methodology employed is detailed in Chapter 2, and results and discussion of the monitoring during 2006 and long-term integrative measures presented in Chapter 3. The relevant pages of text, tables, and figures for the specific elements of each of the four required components are given below.

	Text	Tables	Figures
Meteorological			
Wind Speed	21		71
Wind Direction	21		
Air Temperature	22		72
Incident Radiation	22		73
Humidity	22		74
Precipitation	22		75
Physical/Chemical			
Water Temperature	23-24	39,42	77, 79
Transparency	26	43	80, 81
Underwater light	26		82
Dissolved Oxygen	27	44	83
Conductivity	25	40 42	78, 79
Nutrients (ammonium)	27-28	45	84, 85
Plankton			
Chlorophyll *a*	27-28	47,48	86, 87, 95, 96, 101
Primary production	31-33	66-67	94-98
Artemia Abundance	28-31	49-54	89, 90, 92, 93, 102
Artemia Instar distribution	28-31	55-56	
Artemia Fecundity/Length	28-31	63-64	
Artemia Reproductive parameters	28-31	57-62	91, 100
Artemia Biomass	33-34	67	99

LIST OF TABLES

Table Page

1. Temperature profiles at Station 6, 2006 39
2. Conductivity profiles at Station 6, 2006 40
3. Density profiles at Station 6, 2006 41
4. Density stratification at Station 6, 2006 42
5. Trasnparency (secchi depth) during 2006 43
6. Dissolved oxygen profiles at Station 6, 2006 44
7. Ammonia profiles at Station 6, 2006 45
8. Ammonia in upper 9 m of water column at 7 stations, 2006 46
9. Chlorophyll *a* profiles at Station 6, 2006 47
10. Chlorophyll *a* in upper 9 m of water column at 7 stations, 2006 48

11a. *Artemia* population lake and sector means, 2006 49
11b. Standard errors for table 11a 51
11c. Percentages for table 11a 53
12. *Artemia* instar analysis, 2006 55
13a. *Artemia* reproductive summary, 2006 57
13b. Standard errors for table 13a 59
13c. Percentages for table 13a 61
14. *Artemia* fecundity, 2006 63
15. Summary statistics of adult *Artemia*, 1979–2006 65
16. Photosynthetic parameters for 2006 66
17. Long-term integrative measures of productivity, 1982–2006 67

LIST OF FIGURES

Figure **Page**

1. UCSB sampling stations at Mono Lake....70
2. Mean daily wind speed, 2006....71
3. Daily air temperature, 2006....72
4. Daily sum of photosynthetically available incident radiation, 2006....73
5. Mean daily percent relative humidity, 2006....74
6. Daily sum precipitation, 2006....75
7. Mono Lake surface elevation, 1979–06....76
8. Temperature profiles at station 6, 2006....77
9. Conductivity profiles at station 6, 2006....78
10. Density stratification between 2 and 32 m, 1991–06....79
11. Seasonal transparency, 1994–06....80
12. Log_{10} transparency, 1979–06....81
13. Light attenuation profiles at station 6, 2006....82
14. Dissolved oxygen profiles at station 6, 2006....83
15. Ammonium profiles at station 6, 2006....84
16. Ammonium in upper 9 m of the water column at 7 stations, 2006....85
17. Chlorophyll *a* profiles at station 6, 2006....86
18. Chlorophyll *a* in upper 9 m of the water column at 7 stations, 2006....87
19. Seasonal profiles of fluorescence at station 6, 2006....88
20. Lakewide *Artemia* abundance, 2006....89
21. Lakewide adult *Artemia* abundance, 1982–06....90
22. *Artemia* reproductive parameters, 2006....91
23. Adult *Artemia* Summary Statistics....92
24. Adult *Artemia* temporal distribution....93
25. Photosynthetic parameters, March, August, December, 2006....94
26. Chlorophyll-specific maximum photosynthetic rate, chlorophyll (2 m), and calculated daily primary production, 2006....95
27. Comparison of 2002–06 A) Chlorophyll-specific maximum photosynthetic rates, B) Mixed-layer chlorophyll concentrations....96
28. Comparison of 2002–06 calculated daily primary production....97
29. Annual phytoplankton production estimates, 1982–06....98
30. Mean annual *Artemia* biomass, 1983–06....99
31. *Artemia* reproduction, 1983–06....100
32. Long-term variation in algal biomass, 1982–06....101

33. Long-term variation in adult *Artemia* abundance, 1982–06 102

CHAPTER 1
INTRODUCTION

Background

Saline lakes are widely recognized as highly productive aquatic habitats, which in addition to harboring distinctive assemblages of species, often support large populations of migratory birds. Saline lake ecosystems throughout the world are threatened by decreasing size and increasing salinity due to diversions of freshwater inflows for irrigation and other human uses (Williams 1993, 2002); notable examples in the Great Basin of North America include Mono Lake (Patten et al. 1987), Walker Lake (Cooper and Koch 1984), and Pyramid Lake (Galat et al. 1981). At Mono Lake, California, diversions of freshwater streams out of the basin beginning in 1941 led to a 14 m decline in surface elevation and an approximate doubling of the lake's salinity.

In 1994, following two decades of scientific research, litigation, and environmental controversy, the State Water Resources Control Board (SWRCB) of California issued a decision to amend Los Angeles' water rights to "establish fishery protection flows in streams tributary to Mono Lake and to protect public trust resources at Mono Lake and in the Mono Lake Basin" (Decision 1631). The decision restricts water diversions until the surface elevation of the lake reaches 1,948 m (6391 ft) and requires long-term limnological monitoring of the plankton dynamics.

Long-term monitoring of the plankton and their physical, chemical, and biological environment is essential to understanding the effects of changing lake levels. Measurements of the vertical distribution of temperature, oxygen, conductivity, and nutrients are requisite for interpreting how variations in these variables affect the plankton populations. Consistent methodologies have been employed during the 28-yr period, 1979–2006, and have yielded a standardized data set from which to analyze seasonal and year-to-year changes in the plankton. The limnological monitoring program at Mono Lake includes the interpretation of a wide array of limnological data collected during monthly surveys conducted during February through December.

Seasonal Mixing Regime and Plankton Dynamics

Limnological monitoring at Mono Lake can be divided into several periods corresponding to two different annual circulation patterns, meromixis and monomixis, and the transition between them.

Monomictic and declining lake levels, 1964–82

The limnology of Mono Lake, including seasonal plankton dynamics, was first documented in the mid 1960s (Mason 1967). During this period Mono Lake was characterized by declining lake levels, increasing salinity, and a monomictic thermal regime. No further limnological research was conducted until summer 1976 when a broad survey of the entire Mono Basin ecosystem was conducted (Winkler 1977). Subsequent studies (Lenz 1984; Melack 1983, 1985) beginning in 1979, further described the seasonal dynamics of the plankton. During the period 1979–81, Lenz (1984) documented a progressive increase in the ratio of peak summer to spring abundances of adult brine shrimp. The smaller spring generations resulted in greater food availability and much higher ovoviviparous production by the first generations, leading to larger second generations. Therefore, changes in the size of the spring hatch can result in large changes in the ratio of the size of the two generations.

In 1982, an intensive limnological monitoring program funded by LADWP was established to monitor changes in the physical, chemical, and biological environments in Mono Lake. This monitoring program has continued to the present. Detailed descriptions of the results of the monitoring program are contained in a series of reports to LADWP (Dana *et al.* 1986, 1992; Jellison *et al.* 1988, 1989, 1990, 1991, 1994, 1995a, 1996a, 1997, 1998a, 1999, 2001, 2002, 2003; Jellison and Melack 2000; Jellison 2004, 2005, 2006) and are summarized below.

Meromixis, 1983–87

In 1983, a large influx of freshwater into Mono Lake resulted in a condition of persistent chemical stratification (meromixis). A decrease in surface salinities resulted in a chemical gradient of ca. 15 g total dissolved solids l^{-1} between the mixolimnion (the mixed layer) and monimolimnion (layer below persistent chemocline). In subsequent years evaporative concentration of the surface water led to a decrease in this gradient and in November 1988 meromixis was terminated.

Following the onset of meromixis, ammonium and phytoplankton were markedly affected. Ammonium concentrations in the mixolimnion were reduced to near zero during spring 1983 and remained below 5 µM until late summer 1988. Accompanying this decrease in mixolimnetic ammonium concentrations was a dramatic decrease in the algal bloom associated with periods when the *Artemia* are less abundant (November through April). At the same time, ammonification of organic material and release from the anoxic sediments resulted in a gradual buildup of ammonium in the monimolimnion over the six years of meromixis to 600 to 700 µM. Under previous monomictic conditions, summer ammonium accumulation beneath the thermocline was 80–100 µM, and was mixed into the upper water column during the autumn overturn.

Artemia dynamics were also affected by the onset of meromixis. The size of the first generation of adult *Artemia* in 1984 (~31,000 m^{-2}) was nearly ten times as large as observed in 1981 and 1982, while peak summer abundances of adults were much lower. Following this change, the two generations of *Artemia* were relatively constant during the meromictic period from 1984 to 1987. The size of the spring generation of adult *Artemia* only varied from 23,000 to 31,000 m^{-2} while the second generation of adult *Artemia* varied from 33,000 to 54,000 m^{-2}. The relative sizes of the first and second generation are inversely correlated. This is at least partially mediated by food availability as a large first generation results in decreased algal levels for second generation nauplii and vice versa. During 1984 to 1987, recruitment into the first generation adult class was a nearly constant but small percentage (about 1 to 3%) of the cysts calculated to be available (Dana *et al.* 1990). Also, fecundity showed a significant correlation with ambient algal concentrations (r^2, 0.61).

In addition to annual reports submitted to Los Angeles and referenced herein, a number of published manuscripts document the limnological conditions and algal photosynthetic activity during the onset, persistence, and breakdown of meromixis, 1982–90 (Jellison *et al.* 1992; Jellison and Melack 1993a, 1993b; Jellison *et al.* 1993; Miller *et al.* 1993).

Response to the breakdown of meromixis, 1988–89

Although complete mixing did not occur until November 1988, the successive deepening of the mixed layer during the period 1986–88 led to significant changes in the plankton dynamics. By spring 1988, the mixed layer included the upper 22 m of the lake and included 60% of the area and 83% of the lake's volume. In addition to restoring an annual mixing regime to much of the lake, the deepening of the mixed layer increased the nutrient supply to the mixolimnion by entraining water with very high ammonium concentrations (Jellison *et al.* 1989). Mixolimnetic ammonium concentrations were fairly high during the spring (8–10 μM), and March algal populations were much denser than in 1987 (53 vs. 15 μg chl *a* l^{-1}).

The peak abundance of spring adult *Artemia* in 1988 was twice as high as any previous year from 1979 to 1987. This increase could have been due to enhanced hatching and/or survival of nauplii. The pool of cysts available for hatching was potentially larger in 1988 since cyst production in 1987 was larger than in the four previous years (Dana *et al.* 1990) and significant lowering of the chemocline in the autumn and winter of 1987 allowed oxygenated water to reach cysts in sediments which had been anoxic since 1983. Cysts can remain dormant and viable in anoxic water for an undetermined number of years. Naupliar survival may also have been enhanced since chlorophyll *a* levels in the spring of 1988 were higher than the previous four years. This hypothesis is corroborated by the results of the 1988 development experiments (Jellison *et al.* 1989). Naupliar survival was higher in the ambient food treatment relative to the low food treatment.

Mono Lake returned to its previous condition of annual autumnal mixing from top to bottom with the complete breakdown of meromixis in November 1988. The mixing of previously isolated monimolimnetic water with surface water affected biotic components of the ecosystem. Ammonium, which had accumulated to high levels (> 600 μM) in the monimolimnion during meromixis, was dispersed throughout the water column raising surface concentrations above previously observed values (>50 μM). Oxygen was diluted by mixing with the anoxic water and consumed by the biological and chemical oxygen demand previously created in the monimolimnion. Dissolved oxygen concentration immediately fell to zero. *Artemia* populations experienced an immediate and total die-off following deoxygenation. Mono Lake remained anoxic for a few months following the breakdown of meromixis in November 1988. By mid-February 1989, dissolved oxygen concentrations had increased (2–3 mg l^{-1}) but were still below those observed in previous years (4–6 mg l^{-1}). The complete recovery of dissolved oxygen concentrations occurred in March when levels reached those seen in other years.

Elevated ammonium concentrations following the breakdown of meromixis led to high chlorophyll *a* levels in spring 1989. Epilimnetic concentrations in March and April were the highest observed (40–90 µg chl *a* l^{-1}). Subsequent decline to low midsummer concentrations (<0.5–2 µg chl *a* l^{-1}) due to brine shrimp grazing did not occur until late June. In previous meromictic years this decline occurred up to six weeks earlier. Two effects of meromixis on the algal populations, decreased winter-spring concentrations and a shift in the timing of summer clearing are clearly seen over the period 1982–89.

The 1989 *Artemia* population exhibited a small first generation of adults followed by a summer population over one order of magnitude larger. A similar pattern was observed from 1980–83. In contrast, the pattern observed during meromictic years was a larger first generation followed by a summer population of the same order of magnitude. The timing of hatching of *Artemia* cysts was affected by the recovery of oxygen. The initiation of hatching occurred slightly later in the spring and coincided with the return of oxygenated conditions. First generation numbers in 1989 were initially high in March (~30,000 individuals m^{-2}) and within the range seen from 1984–88, but decreased by late spring to ~4,000 individuals m^{-2}. High mortality may have been due to low temperatures, since March lake temperatures (2–6°C) were lower than the suspected lethal limit (ca. 5–6°C) for *Artemia* (Jellison *et al.* 1989). Increased mortality may also have been associated with elevated concentrations of toxic compounds (H_2S, NH_4+, As) resulting from the breakdown of meromixis.

High spring chlorophyll levels in combination with the low first generation abundance resulted in a high level of fecundity that led to a large second generation of shrimp. Spring chlorophyll *a* concentrations were high (30–44 µg chl *a* l^{-1}) due to the elevated ammonium levels (27–44 µM) and are typical of pre-meromictic levels. This abundant food source (as indicated by chlorophyll *a*) led to large *Artemia* brood sizes and high ovigerity during the period of ovoviviparous reproduction and resulted in the large observed summer abundance of *Artemia* (peak summer abundance, ~93,000 individuals m^{-2}). Negative feedback effects were apparent when the large summer population of *Artemia* grazed the phytoplankton to very low levels (<0.5–2 µg chl *a* l^{-1}). The low algal densities led to decreased reproductive output in the shrimp population. Summer brood size, female length, and ovigerity were all the lowest observed in the period 1983–89.

Small peak abundance of first generation adults were observed in 1980–83, and 1989. However, the large (2–3 times the mean) second generations were only observed in 1981, 1982, and 1989. During these years, reduced spring inflows resulted in less than usual density stratification and higher than usual vertical fluxes of nutrients thus providing for algal growth and food for the developing *Artemia* population.

Monomictic conditions with relatively stable lake levels, 1990–94

Mono Lake was monomictic from 1990 to 1994 (Jellison *et al.* 1991, Dana *et al.* 1992, Jellison *et al.* 1994, Jellison *et al.* 1995b) and lake levels (6374.6 to 6375.8 ft asl) were similar to those in the late 1970s. Although the termination of meromixis in November 1988 led to monomictic conditions in 1989, the large pulse of monimolimnetic ammonium into the mixed layer led to elevated ammonium concentrations in the euphotic zone throughout 1989, and the plankton dynamics were markedly different than 1990–94. In 1990–94, ammonium concentrations in the euphotic zone decreased to levels observed prior to meromixis in 1982. Ammonium was low, 0–2 μM, from March through April and then increased to 8–15 μM in July. Ammonium concentrations declined slightly in late summer and then increased following autumn turnover. This pattern of ammonium concentrations in the euphotic zone and the hypolimnetic ammonium concentrations were similar to those observed in 1982. The similarities among the years 1990–94 indicate the residual effects of the large hypolimnetic ammonium pulse accompanying the breakdown of meromixis in 1988 were gone. This supports the conclusion by Jellison *et al.* (1990) that the seasonal pattern of ammonium concentration was returning to that observed before the onset of meromixis.

Spring and summer peak abundances of adult *Artemia* were fairly constant throughout 1990 to 1994. Adult summer population peaks in 1990, 1991, and 1992 were all ~35,000 m^{-2} despite the large disparity of second generation naupliar peaks (~280,000, ~68,000, and ~43,000 m^{-2} in 1990, 1991, and 1992, respectively) and a difference in first generation peak adult abundance (~18,000, ~26,000, and ~21,000 m^{-2} in 1990, 1991, and 1992, respectively). Thus, food availability or other environmental factors are more important to determining summer abundance than recruitment of second generation nauplii. In 1993, when freshwater inflows were higher than usual and thus density stratification enhanced, the summer generation was slightly smaller (~27,000 m^{-2}). Summer abundance of adults increased slightly (~29,000 m^{-2}) in 1994 when runoff was lower and lake levels were declining.

Meromictic conditions with rising (1995-1999) and falling (1999-2002) lake levels

1995

The winter (1994/95) period of holomixis injected nutrients which had previously accumulated in the hypolimnion into the upper water column prior to the onset of thermal and chemical stratification in 1995 (Jellison *et al*. 1996a). During 1995, above normal runoff in the Mono Basin coupled with the absence of significant water diversions out of the basin led to rapidly rising lake levels. The large freshwater inflows resulted in a 3.4 ft rise in surface elevation and the onset of meromixis, a condition of persistent chemical stratification with less saline water overlying denser more saline water. Due to holomixis during late 1994 and early 1995, the plankton dynamics during the first half of 1995 were similar to those observed during the past four years (1991–94). Therefore 1995 represents a transition from monomictic to meromictic conditions. In general, 1995 March mixed-layer ammonium and chlorophyll *a* concentrations were similar to 1993. The peak abundance of summer adult *Artemia* (~24,000 m^{-2}) was slightly lower to that observed in 1993 (~27,000 m^{-2}) and 1994 (~29,000 m^{-2}). The effects of increased water column stability due to chemical stratification only became evident later in the year. As the year continued, a shallower mixed layer, lower mixed-layer ammonium and chlorophyll *a* concentrations, slightly smaller *Artemia,* and smaller brood sizes compared to 1994 were all observed. The full effects of the onset of meromixis in 1995 were not evident until 1996.

1996

Chemical stratification persisted and strengthened throughout 1996 (Jellison *et al*. 1997). Mixolimnetic (upper water column) salinity ranged from 78 to 81 g kg^{-1} while monimolimnetic (lower water column) were 89–90 g kg^{-1}. The maximum vertical density stratification of 14.6 kg m^{-3} observed in 1996 was larger than any year since 1986. During 1996, the annual maximum in Secchi depth, a measure of transparency, was among the highest observed during the past 18 years and the annual minimum was higher than during all previous years except 1984 and 1985 during a previous period of meromixis. While ammonium concentrations were <5 µM in the mixolimnion throughout the year, monimolimnetic concentrations continued to increase. The spring epilimnetic chlorophyll *a* concentrations (5–23 µg chl *a* l^{-1}) were similar to those observed in previous meromictic years, but were much lower than the concentrations observed in March 1995 before the onset of the current episode of meromixis. During previous monomictic years, 1989–94, the spring maximum epilimnetic chlorophyll *a* concentrations ranged between 87–165 µg chl *a* l^{-1}.

A single mid-July peak in adults characterized *Artemia* population dynamics in 1996 with little evidence of recruitment of second generation *Artemia* into the adult population during late summer. The peak abundance of first generation adults was observed on 17 July (~35,000 m^{-2}), approximately a month later than in previous years. The percent ovigery during June 1996 (42%) was lower than that observed in 1995 (62%), and much lower than that observed 1989–94 (83–98%). During the previous meromictic years (1984–88) the female population was also slow to attain high levels of ovigery due to lower algal levels. The maximum of the mean female length on sampling dates through the summer, 10.7 mm, was shorter than those observed during 1993, 1994, and 1995 (11.7, 12.1, and 11.3 mm, respectively). In 1996, brood size ranged from 29 to 39 eggs $brood^{-1}$ during July through November. The summer and autumn brood sizes were smaller than those observed during 1993–95 (40 to 88 eggs $brood^{-1}$), with the exception of September 1995 (34 eggs $brood^{-1}$) when the brood size was of a similar size to September 1996 (33 eggs $brood^{-1}$).

1997

Chemical stratification continued to increase in 1997 as the surface elevation rose an additional 1.6 ft during the year. The midsummer difference in density between 2 and 28 m attributable to chemical stratification increased from 10.4 kg m^{-3} in 1996 to 12.3 kg m^{-3} in 1997. The lack of holomixis during the previous two winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. In 1997, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (2–3 µg chl *a* l^{-1}) were lower than those observed during 1996 (5–8 µg chl *a* l^{-1}), and other meromictic years 1984–89 (1.6–57 µg chl *a* l^{-1}), and much lower than those observed during the spring months in the last period of monomixis, 1989–95 (15–153 µg chl *a* l^{-1}). Concomitant increases in transparency and the depth of the euphotic zone were also observed. As in 1996, a single mid-July peak in adults characterized the *Artemia* population dynamics in 1997 with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (~27,000 m^{-2}) was slightly lower than 1996 but similar to 1995 (~24,000 m^{-2}). The mean length of adult females was 0.2–0.3 mm shorter than the lengths observed in 1996 and the brood sizes lower, 26–33 eggs $brood^{-1}$ in 1997 compared to 29 to 53 eggs $brood^{-1}$ in 1996.

1998

In 1998 the surface elevation of the lake rose 2.2 ft. The continuing dilution of saline mixolimnetic water and absence of winter holomixis led to increased chemical stratification. The peak summer difference in density between 2 and 28 m attributable to chemical stratification increased from 12.3 kg m^{-3} in 1997 to 14.9 kg m^{-3} in August 1998. The 1998 peak density difference due to chemical stratification was higher than that seen in any previous year, including 1983–84. The lack of holomixis during the previous three winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. Chlorophyll *a* concentrations at 2 m generally decreased from 14.3 µg chl *a* l^{-1} in February to 0.3 µg chl *a* l^{-1} in June, when the seasonal chlorophyll *a* concentration minimum was reached. After that it increased to 1–2 µg chl *a* l^{-1} during July–October and to ~8 µg chl *a* l^{-1} in early December. In general, the seasonal pattern of mixolimnetic chlorophyll *a* concentration was similar to that observed during the two previous meromictic years, 1996 and 1997, in which the spring and autumn algal blooms are much reduced compared to monomictic years.

As in 1996 and 1997, a single mid-July peak in adults characterized the Artemia population dynamics in 1998 with little evidence of recruitment of second generation *Artemia* into adults. The peak abundance of adults observed on 10 August (~34,000 m^{-2}) was slightly higher than that observed in 1997 (~27,000 m^{-2}) and, while similar to the timing in 1997, approximately two weeks to a month later than in most previous years. The mean female length ranged from 9.6 to 10.3 mm in 1998 and was slightly shorter than observed in 1996 (10.1–10.7 mm) and 1997 (9.9–10.4 mm). Mean brood sizes in 1998 were 22–50 eggs $brood^{-1}$. The maximum brood size (50 eggs $brood^{-1}$) was within the range of maximums observed in 1995–97 (62, 53, and 33 eggs $brood^{-1}$, respectively), but was significantly smaller than has been observed in any other previous year 1987–94 (81–156 eggs $brood^{-1}$).

1999

Meromixis continued but weakened slightly in 1999 as the net change in surface elevation over the course of the year was -0.1 ft. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 14.9 kg m^{-3} in 1998 to 12.2 kg m^{-3}. The lack of holomixis during the past four winters resulted in depleted inorganic nitrogen concentrations in the mixolimnion and reduced abundance of phytoplankton. In 1999, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (10–16 µg chl *a* l^{-1}) were similar to those observed in 1998 but slightly higher than the two previous years of meromixis, 1997 (2–3 µg chl *a* l^{-1}) and 1996 (5–8 µg chl *a* l^{-1}). However, they are considerably lower than those observed during the spring months of the last period of monomixis, 1989–95 (15–153 µg chl *a* l^{-1}). As in all of the three immediately preceding years of meromixis, 1996–98, the *Artemia* population dynamics in 1999 were characterized by a single late-summer peak in adults with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (~38,000 m^{-2}) was slightly higher than 1996 (~35,000 m^{-2}), 1997 (~27,000 m^{-2}), and 1998 (~34,000 $m^{-}2$). The mean length of adult females was slightly longer (10.0–10.7 mm) than 1998 (9.6–10.3 mm) and similar to 1996 (10.1–10.7

mm) and 1997 (9.9–10.4 mm), while the range of mean brood sizes (27–48 eggs brood^{-1}) was similar (22–50 eggs brood^{-1}; 1996–98).

2000

In 2000, persistent chemical stratification (meromixis) continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.7 ft annual decline in surface elevation and slight freshening of water beneath the chemocline. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 12.2 kg m^{-3} in 1999 to 10.5 kg m^{-3} in 2000. Most likely of greater significance to the overall plankton dynamics is the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake is now effectively meromictic; only 38% of the lake's area and 16% of the volume were beneath the chemocline.

Algal biomass, as characterized by the concentration of chlorophyll *a*, was higher in 2000 compared to 1999 and varied in the mixolimnion from a midsummer low of 1.4 µg chl *a* l^{-1} to the December high of 54.2 µg chl *a* l^{-1}. The December value is the highest observed during the entire 21 years of study. Although adult *Artemia* abundance (peak of ~22,000 m^{-2}) was anomalously low (50% of the long-term mean), *Artemia* biomass and total annual cyst production were only slightly below the long-term mean, 12 and 16%, respectively. Thus, while meromixis persisted in 2000, the combined effects of declining lake levels, the reduced proportion of the lake beneath the chemocline, and increased upward fluxes of ammonium due to the large buildup of monimolimnetic ammonium offset, to some degree, the effect of the absence of winter holomixis.

2001

Persistent chemical stratification (meromixis) continued but weakened in 2001 due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. Colder than average mixolimnetic temperatures (1.5–2.2ºC) observed in February 2001 enhanced deep mixing. The midsummer difference in density between 2 and 28 m attributable to chemical stratification has declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001. Most likely of greater significance to the overall plankton dynamics was the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake was effectively meromictic. At the end of 2001, only 33% of the lake's area and 12% of the volume were beneath the chemocline. Ammonium concentrations in the monimolimnion continued their 6-year increase with concentrations at 28 and 35 m generally 900–1200 µM.

Algal biomass, as characterized by chlorophyll *a* concentration, was similar to that observed during 2000 except that the autumn bloom was somewhat later as adult *Artemia* were more abundant in September and October compared to 2000.

As in 2000, the 2001 *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, peak of adult abundance in July at ~38,000 m^{-2}, followed by a decline to very low numbers by November. In 2000, the autumn decline was very rapid and resulted in the lowest seasonal mean abundance of any year studied. In 2001 the autumn decline was less rapid and resulted in a seasonal mean abundance identical to the long-term mean of ~20,000 m^{-2}. The 2001 mean annual *Artemia* biomass was 8.8 g m^{-2} or 9 % below the long-term mean of 9.7 g m^{-2} and slightly higher than calculated in 2000 (8.2 g m^{-2}).

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction. Although adult *Artemia* were more abundant in 2001 compared to 2000, total annual cyst production was lower, 3.02×10^6 m^{-2} compared to 4.03×10^6 m^{-2} in 2000. While this is 37% below the long-term mean of 4.77×10^6 m^{-2}, it is not expected to have a significant impact on 2002 abundance as food availability is a much stronger determinant of the spring generation of *Artemia.*

2002

Meromixis continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. The peak difference in density between 2 and 28 m attributable to chemical stratification declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001 to 5.5 kg m^{-3} in 2002. More importantly the chemical stratification between 2 and 32 m decreased to ~1 kg m^{-3} and the chemocline was eroded downward several meters to ~30 m. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but only 14% by area and 3% by volume of the lake is below the chemocline.

Algal biomass, as characterized by chlorophyll *a* concentration, was high during both spring (60-78 μg chl *a* l^{-1}, February and March) and autumn (60-80 μg chl *a* l^{-1}, November). Annual estimates of lakewide primary production were 723 g C m^{-2} y^{-1} and continued the consistent upward trend from the lowest value of 149 g C m^{-2} y^{-1} in 1997.

As in 2000 and 2001, the *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, adult abundance peak in August at ~26,000 m^{-2}, followed by a decline to very low numbers by November. In 2002, the mean annual *Artemia* biomass was 4.9 g m^{-2} almost 50% below the long-term mean of 9.7 g m^{-2}. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation, dramatically affects recruitment into the summer generation. In 2002, a larger spring hatch and spring adult generation lowered algal biomass and led to decreased recruitment into the summer adult population. This inter-generational compensatory interaction is a dominant feature of the seasonal and annual variation of adult abundance observed in the long-term monitoring (1982-present).

Total annual cyst production (2.5×10^6 m^{-2}), along with abundance of ovigerous females, was less than in the previous three years ($3.0\text{-}4.2 \times 10^6$ m^{-2}), though the size of ovigerous females was larger than in these years. Annual cyst production was the same as in 1997, and was 53% below the long term mean of 4.77×10^6 m^{-2}.

Response to the breakdown of an 8-yr period of meromixis (2003–2004)

2003

The persistent chemical stratification (meromixis) initiated in 1995 nearly broke down early in the year (February-March) prior to the onset of seasonal thermal stratification. This resulted in an upward pulse of nutrients (ammonia) into the upper mixed layer early in the year. Following a small rise in surface elevation and slight freshening of the mixed layer due to snowmelt runoff, decreased inflow and evaporative concentration led to an inverse chemical gradient with slightly more saline mixolimnetic water overlying the monimolimnion (region beneath the chemocline). Thus, autumn cooling led to holomixis (complete mixing of the lake) in mid-November and the end of an 8-yr period of meromixis (1995-2003).

Algal biomass, as characterized by chlorophyll *a* concentration, was high throughout the winter and spring (50-96 µg chl *a* l^{-1}, January through May) and autumn (50-62 µg chl *a* l^{-1}, October through November). While *Artemia* grazing and nutrient limitation normally result in low summer algal biomass (~1µg chl *a* l^{-1}), values in summer 2003 never fell below 3 µg chl *a* l^{-1} despite near average *Artemia* abundance. Thus, primary production was unusually high. The 2003 estimated annual primary production was 1,645 g C m^{-2} y^{-1}, more than twice that observed in 2002 (763 g C m^{-2} y^{-1}), and the highest of any year from 1982-2003.

In 2003, the *Artemia* population was characterized by early development of a moderate 1st generation (18 June, 24,600 m^{-2}) followed by recruitment balancing mortality through the summer (13 August, 27,300 m^{-2}). Mean annual *Artemia* biomass increased 53% from 4.9 g m^{-2} in 2002 to 7.5 g m^{-2} in 2003, although it was still slightly below the long-term (1983-2003) average of 9.2 g m^{-2}. Recruitment of ovoviviparous (live-bearing) reproduction into the 2nd generation was low and accounts for below average mean annual biomass. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation dramatically affects recruitment into the summer generation. A detailed cohort analysis of stage-specific *Artemia* data is being conducted. Total annual cyst production also increased over 2002 and was 4.2 x 10^6 m^{-2}, close to the long-term (1983-2003) mean of 4.5 x 10^6 m^{-2}.

2004

The breakdown of an 8-yr period of meromixis in November 2003 mixed nutrient-rich bottom waters throughout the water column. Thus, 2004 began with high ammonia concentrations (10–29 µM) throughout the water column, and a large algal bloom (105 µg chl *a* $liter^{-1}$) had developed by the February survey. While the upper mixed-layer ammonia concentrations decreased to <1 µM by mid-March, algal biomass remained high (89–95 µg chl *a* $liter^{-1}$). Dissolved oxygen concentrations in the lake had recovered following low values observed in November 2003 associated with the breakdown of meromixis and hatching of over-wintering *Artemia* cysts began in February as indicated by the presence of abundant (47,324 m^{-2}) 1st instar nauplii on 24 February. Record high (68,746 m^{-2}) naupliar abundance was observed on the 19 March survey. A large hatch, abundant food, and warmer than average water temperatures led to the largest and earliest 1st generation of adult *Artemia* in Mono Lake observed during the 26-yr period of record (1979-2004). This large 1st generation of adults depleted algal biomass and suppressed fecundity and recruitment into subsequent generations resulting in an early decline in adult abundance.

Artemia grazing maintained low phytoplankton abundance throughout the summer and annual primary production was lower (864 g C m^{-2}) than the record levels (1645 g C m^{-2}) observed in 2003 as meromixis weakened and broke down. However, the mean annual *Artemia* biomass increased 46% from 7.5 g m^{-2} in 2003 to 11.0 g m^{-2} in 2004 and was 18% above the long-term (1983-2004) average of 9.4 g m^{-2}. Total annual cyst production decreased to 2.6 x 10^6 m^{-2} from the 4.2 x 10^6 m^{-2} observed in 2003. While this was among the lowest estimates of annual cyst production, there is little correlation between cyst production and the subsequent year's population of *Artemia*.

2005

On the March 2005 survey, nutrient levels were similar to those observed in 2004, with ammonia concentrations <1 µM in the near-surface mixed layer and 30–40 µM in the hypolimnion. However, the spring algal bloom was somewhat smaller in 2005, with chlorophyll concentrations at 2 and 8 m depth of 57–59 µg chl *a* $liter^{-1}$ compared to 91–105 µg chl *a* $liter^{-1}$ in 2004. The March survey indicated the spring *Artemia* hatch was well underway with abundance across 12 stations ranging from 18,000 to 57,000 m^{-2} with a lakewide mean of 31,800 m^{-2}. While not as large as 2004 (75,500 m^{-2}), abundant food and above average water temperatures in 2005 led to the third largest 1st generation of adults (45,400 m^{-2}) observed during the entire 27-yr period (1979-2005). Although ovoviviparous reproduction was 25 % above the long-term mean, the large 1st generation of adults depleted food availability and reduced recruitment into the second generation resulting in a rapid late summer decline in adults.

Annual primary production was 1,111 g C m^{-2} or double the long-term mean of 584 g C m^{-2}. Average *Artemia* biomass, a measure of secondary production, was 11.8 g m^{-2}, 25 % above the long-term mean. Total annual cyst production was 3.8 million m^{-2} or 15 % below the long-term mean of 4.4 million m^{-2}. However, secondary productivity is not limited by cyst production and there is little correlation between annual cyst production and the subsequent year's population of *Artemia*.

Snowmelt runoff into the epilimnion of Mono Lake causes seasonal salinity stratification which typically breaks down in November following late summer evaporative concentration, epilimnetic cooling, and declining lake levels. In 2005, above average snowmelt runoff led to a 1.8 ft seasonal rise in surface elevation. While late summer evaporative concentration and cooling of the upper mixed-layer decreased vertical stratification and almost initiated holomixis, freshwater inputs late in 2005 increased salinity stratification just enough to prevent winter holomixis and initiated a third period of meromixis.

Long-term integrative measures: annual primary productivity, mean annual *Artemia* biomass and egg production

The availability of dissolved inorganic nitrogen or phosphorus has been shown to limit primary production in a wide array of aquatic ecosystems. Soluble reactive phosphorus concentrations are very high (>400 µM) in Mono Lake and thus will not limit growth. However, inorganic nitrogen varies seasonally, and is often low and potentially limiting to algal growth. A positive response by Mono Lake phytoplankton in ammonium enrichments performed during different periods from 1982 to 1986 indicates inorganic nitrogen limits the standing biomass of algae (Jellison 1992, Jellison and Melack 2001). In Mono Lake, the two major sources of inorganic nitrogen are brine shrimp excretion and vertical mixing of ammonium-rich monimolimnetic water.

Algal photosynthetic activity was measured from 1982 to 1992 (Jellison and Melack, 1988, 1993a; Jellison *et al.* 1994) and clearly showed the importance of variation in vertical mixing of nutrients to annual primary production. Algal biomass during the spring and autumn decreased following the onset of meromixis and annual photosynthetic production was reduced (269–462 g C m^{-2} yr^{-1}; 1984 to 1986) compared to non-meromictic conditions (499–641 g C m^{-2} yr^{-1}; 1989 and 1990) (Jellison and Melack 1993a). Also, a gradual increase in photosynthetic production occurred even before meromixis was terminated because increased vertical fluxes of ammonium accompanied deeper mixing with ammonium-rich monimolimnetic water. Annual production was greatest in 1988 (1,064 g C m^{-2} yr^{-1}) and 2003 (1,645 g C m^{-2} y^{-1}) when the weakening of chemical stratification and eventual breakdown of meromixis in November resulted in large fluxes of ammonium into the euphotic zone.

Estimates of annual primary production integrate annual and seasonal changes in photosynthetic rates, algal biomass, temperature, and insolation. Although measurements of photosynthetic rates were discontinued after 1992 (restarted in 2002), most of the variation in photosynthetic rates can be explained by regressions on environmental covariates (i.e. temperature, nutrient, and light regimes) (Jellison and Melack 1993a, Jellison *et al.* 1994). Therefore, estimates of annual primary production using previously derived regressions and current measurements of algal biomass, temperature, and insolation were made during 1993-2001. These estimates of annual primary production indicate a period of declining productivity (1994–1997) associated with the onset of meromixis and increasing chemical stratification, followed by continually increasing estimates of annual primary production through the breakdown of meromixis in 2003 when the highest estimated annual primary production occurred (1,645 g C m^{-2} y^{-1}). Estimated annual productivity declined to 864 and 1,111 g C m^{-2} y^{-1} in 2004 and 2005, respectively.

The mean annual biomass of *Artemia* was estimated from instar-specific abundance and length-weight relationships for the period 1983–99 and by direct weighing from 2000 to the present. The mean annual biomass has varied from 5.3 to 17.6 g m^{-2} with a 24-yr (1983-2006) mean of 9.2 g m^{-2}. The highest estimated mean annual biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton.

The lowest annual estimate was in 1997 following two years of meromixis and increasing density stratification. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the 1980s episode of meromixis and then above the mean the next 3 years as meromixis weakened and ended. The lowest annual biomass of *Artemia* (5.3 g m^{-2}) was observed in 1997, the second year of the 1990s episode of meromixis. However, mean annual *Artemia* biomass increased in 2003 to 7.5 g m^{-2} as meromixis weakened, and further to 11.0 g m^{-2} in 2004 following the breakdown of meromixis in late 2003 before declining to 8.8 g m^{-2} in 2005.

Scientific publications

In addition to the long-term limnological monitoring, the City of Los Angeles has partially or wholly funded a number of laboratory experiments, analyses, and analytical modeling studies resulting in a large number of peer-reviewed research publications by University of California, Santa Barbara (UCSB) researchers. In addition to directly-funded research on mixing dynamics, nutrient cycling, and primary and secondary productivity, data collected as part of the long-term limnological monitoring has also contributed to peer-reviewed publications on other aspects of Mono Lake's ecology including bacteria, viruses, and avian populations.

Brum, J. R., G. F. Steward, S. C. Jiang, and R. Jellison. 2005. Spatial and temporal variability of prokaryotes, viruses, and viral infections of prokaryotes in an alkaline, hypersaline lake. Aquatic Microbial Ecology 41:247-260.

Dana, G. L. and P.H. Lenz. 1986. Effects of increasing salinity on an *Artemia* population from Mono Lake, California. Oecologia 68:428-436.

Dana, G. L., R. Jellison, and J. M. Melack. 1990. *Artemia monica* egg production and recruitment in Mono Lake, California, USA. Hydrobiologia 197:233-243.

Dana, G. L., R. Jellison, and J. M. Melack. 1995. Effects of different natural regimes of temperature and food on survival, growth, and development of Artemia. J. Plankton Res. 17:2115-2128.

Dana, G. L., R. Jellison, J. M. Melack, and G. Starrett. 1993. Relationships between *Artemia monica* life history characteristics and salinity. Hydrobiologia 263:129-143.

Dana, G.L., C. Foley, G. Starrett, W. Perry and J.M. Melack. 1988. In situ hatching of *Artemia monica* cysts in hypersaline Mono Lake, Pages 183-190. In: J.M. Melack, ed., Saline Lakes. Developments in Hydrobiology. Dr. W. Junk Publ., The Hague (also appeared in Hydrobiologia 158: 183-190.)

Hollibaugh, J.T., S. Carini, H. Gurleyuk, R. Jellison, S. B. Joye, G. LeCleir, L. Vasquex, and D. Wallschlager. 2005. Geochimica et Cosmochimica Acta 69:1925-1937.

Jellison, R. 1987. Study and modeling of plankton dynamics in Mono Lake, California. Report to Community and Organization Research Institute, Santa Barbara.

Jellison, R. and J. M. Melack. 1988. Photosynthetic activity of phytoplankton and its relation to environmental factors in hypersaline Mono Lake, California. Hydrobiologia 158:69-88.

Jellison, R. and J. M. Melack. 2001. Nitrogen limitation and particulate elemental ratios of seston in hypersaline Mono lake, California, USA. Hydrobiol. 466:1-12.

Jellison, R. and J. M. Melack. 2001. Nitrogen limitation and sestonic elemental ratios in hypersaline Mono Lake, California. Hydrobiologia 466:1-12.

Jellison, R., and J. M. Melack. 1993. Algal photosynthetic activity and its response to meromixis in hypersaline Mono Lake, California. Limnol. Oceanogr. 38:818–837.

Jellison, R., and J. M. Melack. 1993. Meromixis in hypersaline Mono Lake, California I. Vertical mixing and density stratification during the onset, persistence, and breakdown of meromixis. Limnol. Oceanogr. 38:1008–1019.

Jellison, R., G. L. Dana, and J. M. Melack. 1992. Ecosystem responses to changes in freshwater inflow to Mono Lake, California, p. 107–118. In C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski [eds.] The history of water: Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains. White Mountain Research Station Symposium 4. Univ. of Calif., Los Angeles.

Jellison, R., G. L. Dana, and J. M. Melack. 1995. Zooplankton cohort analysis using systems identification techniques. J. Plankton Res. 17:2093–2115.

Jellison, R., H. Adams, and J. M. Melack. 2001. Re-appearance of rotifers in hypersaline Mono Lake, California, during a period of rising lake levels and decreasing salinity. Hydrobiologia 466:39-43.

Jellison, R., J. Romero, and J. M. Melack. 1998a. The onset of meromixis during restoration of Mono Lake, California: Unintended consequences of reducing water diversions. Limnol. Oceanogr. 43:706-711.

Jellison, R., L. G. Miller, J. M. Melack, and G. L. Dana. 1993. Meromixis in hypersaline Mono Lake, California II. Nitrogen fluxes. Limnol. Oceanogr. 38:1020–1039.

Jellison, R., R. Anderson, J. M. Melack, and D. Heil. 1996. Organic matter accumulation in Mono Lake sediments during the past 170 years. Limnol. Oceanogr. 41:1539–1544.

Jellison, R., S. MacIntyre, and F. Millero. 1999. The density characteristics of Mono Lake brine. Int. J. Salt Lake Res. **8:** 41-53.

Jiang, S., G. F. Steward, R. Jellison, W. Chu, and S. Choi. 2004. Abundance, Distribution, and Diversity of Viruses in Alkaline, Hypersaline Mono Lake, California. Microbial Ecology 47:9-17.

Joye, S.B., Connell, T. L. Miller, L. G. Oremland, R. S. Jellison, R. 1999. Oxidation of ammonia and methane in an alkaline, saline lake. Limnol. Oceanogr. **44**:178-188.

MacIntyre, S. and R. Jellison. 2001. Nutrient Fluxes from Upwelling and High Turbulence at the Top of the Pycnocline in Mono Lake, CA. Hydrobiologia 466:13-29.

MacIntyre, S., K. Flynn, R. Jellison, J. Romero. 1999. Boundary mixing and nutrient fluxes in Mono Lake, California. Limnol. Oceanogr. 44: 512-529.

Melack, J.M. and R. Jellison. 1998. Limnological conditions in Mono Lake: Contrasting monomixis and meromixis in the 1990s. Hydrobiologia 384:21-39.

Miller, L. G., R. Jellison, R. S. Oremland, and C. W. Culbertson. 1993. Meromixis in hypersaline Mono Lake, California III. Breakdown of stratification and biogeochemical response to overturn. Limnol. Oceanogr. 38:1040–1051.

Romero, J. R., R. Jellison, J. M. Melack. 1998. Stratification, vertical mixing, and upward ammonium flux in hypersaline Mono Lake, California. Archiv fur Hydrobiol. 142: 283-315.

Romero, J.R. and J.M. Melack. 1996. Sensitivity of vertical mixing to variations in runoff. Limnol. Oceanogr. 41:955–965.

Romero, J.R., J.C. Patterson, and J. M. Melack. 1996. Simulation of the effect of methane bubble plumes on vertical mixing in Mono Lake. Aquat. Sci. 58:210–223.

Steward, G. F., J. P. Zehr., R. Jellison., J. P. Montoya, and J.T. Hollibaugh. 2004. Vertical Distribution of Nitrogen-Fixing Phylotypes in a Meromictic, Hypersaline Lake. Microbial Ecology 47:30-40.

Wrege, P. H., W. D. Shuford, D. W. Winkler, and R. Jellison. 2006. Annual variation in numbers of breeding California Gulls at Mono Lake, California: the importance of natal philopatry and local and regional conditions. Condor 108:82-96.

CHAPTER 2
METHODS

Meteorology

Continuous meteorological data is collected at the Paoha station located on the southern tip of Paoha Island. The station is approximately 30 m from the shoreline of the lake with the base located at 1948 m asl, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten minute or hourly values. A Campbell Scientific CR10 datalogger records up to 6 weeks of measurements. Data is downloaded to a storage module which is collected monthly during the regular sampling trips to the lake.

Wind speed and direction (RM Young wind monitor) are measured at a height of 3 m above the surface of the island and are averaged over a 10-minute interval. The maximum wind speed during the ten-minute interval is also recorded. The 10-minute wind vector magnitude, wind vector direction, and the standard deviation of the wind vector direction are computed from the measurements of wind speed and wind direction and stored. Hourly measurements of photosynthetically available radiation (PAR, 400 to 700 nm, Li-Cor 192-S), total rainfall (Qualimetrics 601 I-B tipping bucket), and ten minute averages of relative humidity (Vaisalia HMP35C) and air temperature (Vaisalia HNV35C and Omnidata ES-060) are also made and stored.

The Cain Ranch meteorological station is located approximately 7 km southwest of the lake at an elevation of 2088 m. Throughout the 1980s, LADWP measured wind and temperature at this station. Currently UCSB maintains and records hourly averages of incoming shortwave (280 to 2800 nm; Eppley pyranometer), longwave radiation (3000 to 50000 nm; Eppley pyrgeometer) and PAR (400 to 700 nm; Li-Cor 192-S) at this site.

Sampling Regime

The limnological monitoring program for Mono Lake specifies monthly surveys from February through December. Additional lakewide *Artemia* surveys are taken when warranted to better characterize the seasonal development of the *Artemia* population. Surveys are conducted over one or two days depending on the weather conditions, the number of depths at which productivity is being estimated, and meteorological station maintenance requirements. When conducted over two days, every effort is made to collect the lakewide survey and the station 6 profiles including productivity data on consecutive days.

Field Procedures

In situ profiles

Water temperature and conductivity were measured at nine buoyed, pelagic stations (2, 3, 4, 5, 6, 7, 8, 10 and 12) (Fig. 1). Profiles were taken with a high-precision, conductivity-temperature-depth profiler (CTD) (Seabird Electronics model Seacat 19) (on loan from the University of Georgia) equipped with sensors to additionally measure photosynthetically available radiation (PAR) (LiCor 191S), fluorescence (695 nm) (WETLabs WETStar miniature fluorometer), and transmissivity (660 nm) (WETlabs C-Star Transmissometer). The CTD was deployed by lowering it at a rate of ~0.25 m s^{-1}. An analysis of salinity spiking from the mismatch in the time response of the conductivity and temperature sensors indicated a 1.7 s displacement of the temperature data provided the best fit. The pumped fluorometer data required a 3.7 s shift, and other sensors (pressure, PAR, transmissivity) required a distance offset based on their relative placement. As density variations in Mono Lake can be substantial due to chemical stratification, pressure readings were converted to depth by integrating the mass of the water column above each depth.

Conductivity readings at in situ temperatures (C_t) were standardized to 25°C (C_{25}) using

$$C_{25} = \frac{C_t}{1 + 0.02124(t - 25) + 9.16 \times 10^{-5}(t - 25)^2}$$

where t is the in situ temperature. To describe the general seasonal pattern of density stratification, the contributions of thermal and chemical stratification to overall density stratification were calculated based on conductivity and temperature differences between 2 and 28 m at station 6 and the following density equation:

$$\begin{aligned}\rho(t, C_{25}) = 1.0034 + 1.335 \times 10^{-5} t - 6.20 \times 10^{-6} t^2 + 4.897 \times 10^{-4} C_{25} \\ + 4.23 \times 10^{-6} C_{25}^2 - 1.35 \times 10^{-6} t C_{25}\end{aligned}.$$

The relationship between total dissolved solids and conductivity for Mono Lake water was given by:

$$TDS(g\ kg^{-1}) = 3.386 + 0.564 \times C_{25} + 0.00427 \times C_{25}^2.$$

To obtain TDS in grams per liter, the above expression was multiplied by the density at 25°C for a given standardized conductivity given by:

$$\rho_{25}(C) = 0.99986 + 5.2345 \times 10^{-4} C + 4.23 \times 10^{-6} C^2$$

A complete description of the derivation of these relationships is given in Chapter 4 of the 1995 Annual Report.

Dissolved oxygen was measured at one centrally located station (Station 6). Dissolved oxygen concentration was measured with a Yellow Springs Instruments temperature-oxygen meter (YSI, model 58) and probe (YSI, model 5739). The oxygen electrode is calibrated at least once each year against Miller titrations of Mono Lake water (Walker *et al.* 1970).

Water samples

Chlorophyll and nutrient samples were collected from seven to eleven depths at one centrally located station (Station 6). In addition, 9-m integrated samples for chlorophyll *a* determination and nutrient analyses were collected with a 2.5 cm diameter tube at seven stations (Station 1, 2, 5, 6, 7, 8, and 11) (Fig. 1). Samples for nutrient analyses were filtered immediately upon collection through Gelman A/E glass-fiber filters, and kept chilled and dark until returned to the lab. Water samples used for the analysis of chlorophyll *a* were filtered through a 120-µm sieve to remove all stages of *Artemia*, and kept chilled and dark until filtered in the laboratory.

Artemia samples

The *Artemia* population was sampled by one net tow from each of twelve, buoyed stations (Fig. 1). Samples were taken with a plankton net (1 m x 0.30 m diameter, 120 µm Nitex mesh) towed vertically through the water column. Samples were preserved with 5% formalin in lake water. Two additional samples were collected at Stations 1, 6, and 8, to analyze for presence of rotifers, and to archive a representative of the population. When adults were present, an additional net tow is taken from Stations 1, 2, 5, 6, 7, 8 and 11 to collect adult females for brood size and length analysis.

Laboratory Procedures

Water samples

Upon return to the laboratory samples were immediately processed for ammonium and chlorophyll determinations. Ammonium concentrations were measured immediately, while chlorophyll samples were filtered onto 47 mm Whatman GF/F filters and kept frozen until the pigments were analyzed within two weeks of collection.

Chlorophyll *a* was extracted and homogenized in 90% acetone at room temperature in the dark. Following clarification by centrifugation, absorption was measured at 750 and 663 ηm on a spectrophotometer (Unico, model 2100UV). The sample was then acidified in the cuvette, and absorption was again determined at the same wavelengths to correct for phaeopigments. Absorptions were converted to phaeophytin-corrected chlorophyll *a* concentrations with the formulae of Golterman (1969). During periods of low phytoplankton concentrations (<5 µg chl *a* l^{-1}), the fluorescence of extracted pigments was measured on a fluorometer (Turner Designs, model TD-700) which was calibrated using a fluorometer solid standard and an acetone blank.

Ammonium concentrations were measured using the indophenol blue method (Strickland and Parsons 1972). In addition to regular standards, internal standards were analyzed because the molar extinction coefficient is less in Mono Lake water than in distilled water. Oxygen gas was bubbled into Mono Lake water and used for standards and sample dilutions. Oxygenating saline water may help reduce matrix effects that can occur in the spectrophotometer (S. Joye, pers. comm.) When calculating concentration, the proportion of ammonium in the Mono Lake dilution water in diluted (deep) samples was subtracted from the total concentration.

Artemia samples

Artemia abundances were counted under a stereo microscope (6x or 12x power). Depending on the density of shrimp, counts were made of the entire sample or of subsamples made with a Folsom plankton splitter. Samples were split so that a count of >100 animals was obtained. Shrimp were classified into adults (instars > 12), juveniles (instars 8–11), and nauplii (instar 1–7) according to Heath's classification (Heath 1924). Adults were sexed and the adult females were divided into ovigerous and non-ovigerous. Ovigerous females included egg-bearing females and females with oocytes. Adult ovigerous females were further classified according to their reproductive mode, ovoviviparous or oviparous. A small percentage of ovigerous females were unclassifiable if eggs were in an early developmental stage. Nauplii at seven stations (Stations 1, 2, 5, 6, 7, 8, and 11) were further classified as to instars 1–7.

Live females collected for brood size and length analysis are kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females are randomly selected, isolated in individual vials, and preserved. Brood size was determined by counting the number of eggs in the ovisac including those dropped in the vial, and egg type and shape were noted. Female length was measured from the tip of the head to the end of the caudal furca (setae not included).

Long-term integrative measures of productivity

Primary Production

Photosynthetically available radiation (PAR, 400-700 nm) was recorded continuously at Cain Ranch, seven kilometers southwest of the lake, from 1982 to 1994 and on Paoha Island in the center of the lake beginning in 1991 with a cosine-corrected quantum sensor. Attenuation of PAR within the water column was measured at 0.5-m intervals with a submersible quantum sensor. Temperature was measured with a conductivity-temperature-depth profiler (Seabird, SB19) (see Methods, Chapter 2). Phytoplankton samples were filtered onto glass fiber filters and extracted in acetone (see above).

Photosynthetic activity was measured using the radiocarbon method. Carbon uptake rates were measured in laboratory incubations within five hours of sample collection. Samples were kept near lake temperatures and in the dark during transport. Samples were incubated in a "photosynthetron", a temperature-controlled incubator in which 28 20-ml samples are exposed to a range of light intensities from 0 to 1500 μE m^{-2} s^{-1}. After a 4-h incubation, samples were filtered through a Whatman GF/F filter at a pressure not exceeding 125 mm of Hg and rinsed three times with filtered Mono Lake water. Filters were then soaked for 12 h in 1 ml of 2.0 N HCl, after which 10 ml of scintillation cocktail were added and activity measured on a liquid scintillation counter. Chlorophyll-normalized light-limited (α^B) and saturated (P_m^B) parameters were determined via non-linear least-squared fitting to a hyperbolic tangent equation: $P^B = P_m{}^B \tanh\left(\frac{\alpha^B I}{P_m{}^B}\right)$ where I is the light intensity and P^B is the measured chlorophyll-specific uptake of carbon.

Estimates of daily integral production were made using a numerical interpolative model (Jellison and Melack 1993a). Inputs to the model include the estimated photosynthetic parameters, insolation, the vertical attenuation of photosynthetically available irradiance and vertical water column structure as measured by temperature at 1 m intervals and chlorophyll a from samples collected at 4–6 m intervals. Chlorophyll-specific uptake rates based on temperature were multiplied by ambient chlorophyll a concentrations interpolated to 1-m intervals. The photosynthetically available light field was calculated from hourly-integrated values at Paoha meteorological station, measured water column attenuation, and a calculated albedo. The albedo was calculated based on hourly solar declinations. All parameters, except insolation that was recorded continuously, were linearly interpolated between sampling dates. Daily integral production was calculated by summing hourly rates over the upper 18 m.

Artemia biomass and reproduction

Average daily biomass and annual cyst and naupliar production provide integrative measures of the *Artemia* population allowing simple comparison among years. Prior to 2000, *Artemia* biomass was estimated from stage specific abundance and adult length data, and weight-length relationship determined in the laboratory simulating in situ conditions of food and temperature (see Jellison and Melack 2000 for details). Beginning in 2000, biomass was determined directly by drying and weighing of *Artemia* collected in vertical net tows.

The resulting biomass estimates are approximate because actual instar-specific weights may vary within the range observed in the laboratory experiments. However, classifying the field samples into one of the three categories will be more accurate than using a single instar-specific weight-length relationship. Because length measurements of adult females are routinely made, they were used to further refine the biomass estimates. The adult female weight was estimated from the mean length on a sample date and one of the three weight-length regressions determined in the laboratory development experiments. As the lengths of adult males are not routinely determined, the average ratio of male to female lengths determined from individual measurements on 15 dates from 1996 and 1999 was used to estimate the average male length of other dates.

Naupliar and cyst production was calculated using a temperature-dependent brood interval, ovigery, ovoviviparity versus oviparity, fecundity, and adult female abundance data from seven stations on each sampling date.

Long-term trends in annual algal biomass and adult Artemia abundance

The seasonality in algal biomass and adult *Artemia* abundance can be removed by calculating yearly moving averages. Because the intervals between sampling dates varied among years, daily values are derived by linearly interpolating between sample dates prior to calculating a 365-day moving average. Thus, each point represents a moving average of 365 days centered on each sample. This seasonally-filtered data can be used to detect long-term trends in algal biomass and adult *Artemia*.

CHAPTER 3
RESULTS AND DISCUSSION

Overview

The plankton dynamics during 2006 continued a multi-year trend of above average primary productivity, and a large spring generation of *Artemia* followed by a smaller than average late summer population of *Artemia* and rapid autumn decline. The inverse correlation between the sizes of spring and summer *Artemia* generations has been observed during many years. Warm springtime temperatures can markedly increase the size of the 1st generation of *Artemia.* Large spring generations of adult *Artemia* reduce phytoplankton to concentrations which become severely limiting to the growth and survival of ovoviviparously produced nauplii of the spring generation. Thus recruitment into the summer population is reduced. This larval recruitment bottleneck is key to understanding and interpreting the observed spatial and temporal variation in *Artemia* population dynamics.

Previous modeling analysis has indicated more frequently collected data is necessary to accurately determine seasonal differences in recruitment and survival. Therefore, in addition to the routine monthly surveys, weekly *Artemia* surveys were conducted in 2006 from mid-May to mid-August followed by biweekly sampling until mid-October. Data from these surveys will be used in developing a more accurate *Artemia* population model capable of describing the larval recruitment bottleneck.

Here, we describe the limnological conditions observed during 2006 and calculate several long-term integrative measures of ecosystem productivity.

Meteorological Data

The Mono Lake limnological monitoring program includes collection of a full suite of meteorological data at a station located on the southern tip of Paoha Island and radiation (shortwave, longwave, and photosynthetically available radiation) at Cain Ranch. Meteorological data is collected at 10-minute intervals at the Paoha Island station during most of the year. However, during midwinter the upper water column is well-mixed, *Artemia* and avian populations are virtually absent, and phytoplankton populations change slowly. For these reasons, the difficulty of access, and data storage limitations, meteorological data is only collected at hourly intervals during December through February.

Wind Speed and Direction

Mean daily wind speed varied from 0.7-10.6 m s^{-1} over the year, with an overall annual mean of 3.5 m s^{-1} (Fig. 2). This annual mean is the same as observed in 2005 and only slightly higher than the 3.2 m s^{-1} annual mean observed in 2001, 2002, and 2003; and 3.1 m s^{-1} observed in 2004. The daily maximum 10-min averaged wind speeds averaged 2.3 times mean daily wind speeds. The maximum recorded gust (25.7 m s^{-1}, 57.5 mph) occurred on the evening of Feb 14 (Fig. 2). The mean monthly wind speed varied from 2.7 to 4.5 m s^{-1} (coefficient of variation, 16 %). This was similar to 2005 and

2004 when the mean monthly wind speed varied only from 3.0 to 4.5 and 2.1 to 4.1 m s^{-1}, respectively. As observed in the past, winds were predominately from the southwest (mean, 189.0 deg).

Air Temperature

Mean daily air temperatures ranged from a minimum of –7.4°C on 20 January to a maximum of 24.1°C on 28 July (Fig. 3). Air temperatures ranged from 3.7°C to 33.1°C during the summer (June through August) with a mean daily range of 12.0°C to 24.1°C and from –10.4°C to 13.3°C during the winter (December through February) with a mean daily range of -7.2°C to 8.4°C.

Incident Photosynthetically Available Radiation (PAR)

Photosynthetically available radiation (400-700 nm) exhibits a regular sinusoidal curve dictated by the temperate latitude (38°N) of Mono Lake. Maximum daily values typically range from about ~19 Einsteins m^{-2} day^{-1} at the winter solstice to ~64 Einsteins m^{-2} day^{-1} in mid-June (Fig. 4). Daily values that diverge from the curve indicate overcast or stormy days. During 2006, the annual mean was 38.0 Einsteins m^{-2} day^{-1}, with daily values ranging from 2.5 Einsteins m^{-2} day^{-1} on 2 January to 65.2 Einsteins m^{-2} day^{-1} on 13 June. The 2006 annual mean was between those observed in 2002, 2003, 2004 and 2005 (39.9, 35.0, 37.5, 39.0 Einsteins m^{-2} day^{-1}) respectively. PAR values were collected at Cain Ranch except for the period from January 1 - February 8 when Cain Ranch data were unavailable due to sensor failure and data collected at the Sierra Nevada Aquatic Research Laboratory, located approximately 35 miles south of Mono Lake are presented.

Relative Humidity and Precipitation

Mean daily relative humidity followed a general pattern of high values (mostly 60-90 %) in January, decreasing to lows (mostly 40-60 %) in April through September, and increasing to 60-80 % through December (Fig. 5). The yearly mean was 56.4 %, similar to that observed in during 2003 (54.3 %), 2004 (54 %), and 2005 (57.9%).

During 2006, annual precipitation, collected at Paoha meteorological station was 242.5 mm (9.5 in) (Fig. 6). Total precipitation was higher than in 2001, 2002, 2003, 2004 and 2005 (87.9 mm, 69.1 mm, 101.1 mm, 102.7 mm and 230.9 mm, respectively). Four large precipitation events occurred between late February and early April with the largest occurring over a two day period in April. April 3 - 4 delivered 56 mm of precipitation (32.3 mm on 3 April and 23.7 mm on 4 April). March 6 registered 44.9 mm of precipitation while February 27 registered 28.6 mm. The detection limit for the tipping bucket gage is 1 mm of water. As the tipping bucket is not heated, the instrument is less accurate during periods of freezing due to sublimation of ice and snow. The Paoha tipping bucket malfunctioned in December, and data collected in Lee Vining by the Mono Lake Committee is presented for the period, December 13 through 31.

Surface Elevation

For the second year in a row, above average snowfall and snowmelt runoff has led to significant rise in the surface elevation of Mono Lake. Surface elevation rose 2.8 ft from 6382.3 ft at the beginning of the year to 6385.1 ft by early August (Fig. 7). Following this seasonal peak, evaporation and reduced inflows led to a 0.6 ft decline to 6384.5 at the end of the year for a net annual gain of 2.2 ft. In 2005, the winter period of holomixis was prevented by freshwater inputs in December and this year salinity stratification strengthened significantly. Thus a third episode of meromixis has been initiated at Mono Lake.

Temperature

The annual pattern of thermal stratification in Mono Lake results from seasonal variations in climatic factors (e.g. air temperature, solar radiation, wind speed, humidity) and their interaction with density stratification arising from the timing and magnitude of freshwater inputs. The annual pattern of seasonal thermal stratification observed during 1990–94 is typical of large temperate lakes, with the lake being vertically isothermal during holomixis in the late autumn through early winter. This pattern was altered during two episodes of meromixis (1982–88 and 1995–03) due to the lack of mixing associated with vertical salinity gradients and the absence of winter holomixis (Fig. 7). Following the breakdown of meromixis in late 2003, the annual pattern of thermal stratification returned to that associated with a monomictic annual mixing regime. However, large freshwater inputs resulting from two consecutive winters of high snowfall has initiated a third period of meromixis (2005–present).

The annual period of holomixis typically extends from late November to early February after which seasonal thermal and salinity stratification are initiated due to warming air temperatures, increased insolation, and increased inflows. January represents a period of low biological activity due to cold water temperatures, low light levels, and absence of *Artemia* and January surveys are only conducted when unusual circumstances warrant it and weather permitting. Monthly surveys are typically begun in February.

A lakewide survey and deep station profile were conducted on 14 February 2006. The water column showed an inverted temperature gradient with cooler water at the surface overlying warmer water near the bottom (Table 1, Fig. 8). At 1 meter, the water had warmed to 4.6 °C, between 2 and 8 m temperature decreased gradually from 3.8 - 3.0 °C. The temperature remained between 2.9 - 3.0 °C between 8 m and 14 m below which it gradually increased to 4.8 °C at 32 m.

On 15 March, the upper mixed layer was near isothermal between 2 m and 23 m with temperatures steady at 2.9–3.1 °C. A sharp thermocline between 23 m and 25 m increased the temperature by 0.5 °C to 3.6 °C with a gradual increase to 4.2 °C at 34 m.

By 19 April strong seasonal thermal stratification was present. Near-surface (0-4 m) water temperatures ranged from 7.3 -7.6 °C. Below this water temperatures decreased in a series of small steps to 4.0 °C at 20 m. Deep water temperatures (>25 m) were near isothermal at 3.7 °C. By 16 May, water temperatures in the upper 3 m of the water column had warmed to 18.4–19.7 °C and decreased only slightly to 16.1 °C at 4 m where there was a sharp decrease to 9.2 °C at 7 m. Below this the temperature decreased slowly to 4.4 °C at 19 m and further to 3.8 at 29 m. In May, hypolimnetic water was approximately 1.5 °C warmer than in 2005 and near-surface temperatures up to 4 °C warmer. These warmer surface temperatures resulted in a large spring generation of *Artemia* (see *Artemia* section below).

Thermal stratification continued to increase despite a slight cooling of the epilimnetic water temperatures between mid May and mid June. In 2005, above normal runoff and continuous inputs of freshwater to the surface resulted in the upper water column being salinity stratified and well-mixed only to 4.5 m depth. The same effect due to high runoff was observed in 2006. However, the well mixed layer increased to 8 m by mid June. On 15 June, temperature in the upper 8 m ranged from 15.5 to 17.5 °C. Between 9 m and 14 m the temperature dropped 8.3 °C to 6.0 °C below which it slowly decreased to 4.0 °C at 35 m. By 14 July epilimnetic temperature (upper 7 m) had increased to 21.1 - 22.1 °C. An 11.7 °C temperature drop occurred between 7 and 12 m, followed by a decline to 5.4 °C at 17 m and 4.1 °C near the bottom (37 m).

By mid-August, the upper water column was still only well-mixed to 8 m with temperatures remaining between 21.1 and 21.5 °C. Below this, water temperature decreased almost linearly to 6.7 °C at 16 m and then more slowly to 4.3 °C near the bottom (33–37 m). In Jun-Aug, near bottom water temperatures ranged 4.0 - 4.3 °C. The absence of significant warming in near-bottom waters indicates low rates of vertical mixing.

Convective mixing associated with seasonal cooling and evaporative concentration of surface waters leads to deepening of the thermocline and a well-mixed epilimnion. By mid-September water temperatures in the epilimnion (upper mixed layer; <10 m) were 16.6–17.3 °C. Below this, water temperature decreased almost linearly to 6.2 °C at 17 m and then more gradually to 4.4 °C near the bottom (35 m). On 19 October, the upper water column was well-mixed down to 12 m with water temperatures ranging only from 12.3 to 12.7 °C in the epilimnion. A sharp thermocline extended from 12 to 16 m with water temperature decreasing to 6.8 °C at 16 m. Temperatures decreased gradually below this to 4.5°C near the bottom (36 m). This vertical thermal structure is typical for this time of year. On 15 November the upper mixed-layer had deepened from 12 to 14 m and epilimnetic water temperatures were 8.9-9.3 °C. Near-bottom temperatures were 4.6 °C, only 0.1 °C warmer than observed in mid-October.

On 14 December mixed-layer (< 16 m) water temperatures were 4.7-4.9 °C with somewhat colder temperatures near the surface (4.4 °C at 1 m). Temperature increased to 6.2°C at 18 m and then slowly decreased to 4.8 °C at 36 m. The temperature and salinity profiles (see below) indicated a strong chemocline existed between a distinct mixolimnion and monimolimnion with very little chance of mixing. Profiles collected in February 2007 confirm an absence of holomixis during winter 2006–07 and show an upper mixed layer of approximately 20 m depth.

Conductivity and Salinity

Salinity, expressed as total dissolved solids, can be calculated from conductivity measurements corrected to a reference temperature (25 °C, see Methods). Because total dissolved solids are conservative at the current salinities in Mono Lake, salinity varies with volume and stratification due to changes in the balance between freshwater inputs (streams and precipitation) and evaporative losses.

Winter storms and snowmelt runoff had already resulted in significant seasonal salinity stratification by the 14 Feb 2006 (Table 2, Fig. 9). Standardized (25 °C) conductivities were 80.9 mS cm^{-1} near the surface (1m), 81.3-81.9 mS cm^{-1} between 2 and 21 m, and 83.1 mS cm^{-1} near the bottom. In mid-March conductivities were 81.1 S cm^{-1} at 1 m and nearly uniform at 81.3–4 mS cm^{-1} between 2 m and 21 m below which it slowly increased to 82.6 mS cm^{-1} at 34 m. On 19 April conductivity was fairly constant in the upper 17 m ranging from 80.9-81.1 mS cm^{-1} before increasing nearly linearly to 82.2 mS cm^{-1} at 33m.

Salinity stratification continued to increase as snowmelt runoff increased and epilimnetic conductivity declined during May through July. May conductivities were 79.3 mS cm^{-1} near the surface, 80.0-80.9 mS cm^{-1} between 3 and 14 m, and slowly increased to 82.0 at 35 m. June conductivities were 78.5 mS cm^{-1} at 1 m, 79.0-79.1 between 2 - 5m, increasing quickly to 80.9 mS cm^{-}1 at 13m and more slowly to 81.9 at 32m. July conductivities were 75.7 mS cm^{-1} at 1 m and 76.4–78.4 mS cm^{-1} from 2 to 8 m. Beneath the mixolimnion conductivity gradually increased to 81.9 mS cm^{-1} at 31 m. August conductivities were 75.9-76.0, 77.6-80.7 and 81.5-82.0 mS cm^{-1} in the upper (0-5 m), mid (8-14 m), and lower water column (17–37 m).

Decreased runoff and little precipitation resulted in a 0.3 ft drop in surface elevation during September. Evaporative concentration led to ~1.8 mS cm^{-1} increase in mixed-layer conductivities (or 2.2 g kg^{-1} increase in salinity). Conductivity increased from 77.8-78.3 mS cm^{-1} in the epilimnion (<11 m) to 81.3 mS cm^{-1} at 17 m and then more slowly to 81.8 mS cm^{-1} near the bottom (30 m).

Surface elevation fluctuated only 0.1 ft during 1 October - 31 December and thus standardized (to 25°C) conductivities increased only slightly in the epilimnion to 78.2-78.7 mS cm^{-1} in October (<12), 78.7-79.3 mS cm^{-1} in November (<14 m) and 78.8-79.4 mS cm^{-1} in December (<17 m). At 18 m, conductivities remained constant at 81.4 mS cm^{-1}, while increasing only slightly to 81.5, 81.6 and 81.9 mS cm^{-1} at 37 m in October, November and December, respectively. The monimolimnion was well-mixed from 20 to 37 m throughout October through December.

Over the year, conductivities between 1 and 37 m ranged from 75.7 mS cm^{-1} to 83.1 mS cm^{-1}. This corresponds to 70.5 to 79.7 g kg^{-1} salinity.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows associated with a temperate climate and year-to-year climatic variation have led to complex patterns of seasonal density stratification over the last 25 years. Much of the year-to-year variation in the plankton dynamics observed at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows and its affect on nutrient cycling.

Excess density varies as a function of thermal and salinity stratification and ranged from 60.0 to 72.7 kg m^{-3} over the course of the year (Table 3).

In mid-February salinity stratification between 2 and 32 m contributed 2.14 kg m^{-3} to stratification while slight inverse thermal stratification reduced overall density stratification by 0.15 kg m^{-3} (Table 4, Fig 10). Density stratification increased to annual maximum of 12.31 kg m^{-3} in late July when thermal and salinity stratification contributed 4.96 and 7.34 kg m^{-3}, respectively. Density stratification decreased due to evaporative concentration and cooling to 3.29 kg m^{-3} on 13 December. Although cooling of the mixolimnion continued through the winter, the overall density stratification was still 2.97 kg m^{-3} on the first survey (15 February) of 2007.

Transparency and Light Attenuation

In Mono Lake, variation in transparency is predominately due to changes in algal biomass. Standing algal biomass reflects the balance between all growth and loss processes. Thus, variation in transparency as measured by Secchi depth often reflects the detailed development of the *Artemia* population as much as any changes in nutrient availability and primary productivity.

In 2006, average lakewide transparency during spring was close to the lowest observed (Fig. 11, Table 5) indicating high algal biomass. The average lakewide Secchi depth was 0.75, 0.93 and 0.59 m in February, March, and April, respectively. As *Artemia* grazing reduced phytoplankton transparency increased to a maximum of 8.47 m in mid-July before decreasing to 1.35–1.86 m during October through December. As observed in most years, the midsummer transparencies were higher at western stations with a peak July transparency of 10.1±0.44 m compared to 7.12±0.68 m at the eastern stations.

Secchi depth is an integrative measure of light attenuation within the water column. Because absorption is exponential with depth, the long-term variation in Secchi depth is most appropriately viewed on a logarithmic scale. The annual pattern of Secchi depths during 2006 was within the range observed during the past 26 years (Fig. 12). However, the February transparencies were among the lowest observed.

The attenuation of PAR within the water column varies seasonally, primarily as a function of changes in algal biomass. In 2006, the depth of the euphotic zone, operationally defined as the depth at which only 1 % of the surface insolation is present, increased from a low of 6 m during the spring, to 16 m during midsummer, and then to 10-15 m during the autumn (September-November) phytoplankton bloom (Fig. 13).

Dissolved Oxygen

Dissolved oxygen concentrations are primarily a function of salinity, temperature, and the balance between photosynthesis and overall community respiration. In the euphotic zone of Mono Lake, dissolved oxygen concentrations are typically highest during the spring algal bloom. As the water temperature and *Artemia* population increase through the spring, dissolved oxygen concentrations decrease. Beneath the euphotic zone, bacterial and chemical processes deplete the oxygen once the lake stratifies. During meromictic periods, the monimolimnion (the region beneath the persistent chemocline) remains anoxic throughout the year.

In 2006, epilimnetic dissolved oxygen concentrations ranged from 3.5 to 10.2 mg l^{-1} (Table 6, Fig. 14)) with the highest concentrations occurring at 4 m depth during the February survey. Beneath the chemocline, the monimolimnion was anoxic (<0.5 mg l^{-1} all year. Deep mixing occurred between the February and March surveys as evidenced by temperature, conductivity, and dissolved oxygen changes. During the 14 July survey several zones of lower dissolved oxygen were present above the persistent chemocline. The absence of autumn turnover and holomixis is indicated by anoxic conditions below 18 m observed during the 13 December survey.

Nutrients (ammonia/ammonium)

Nitrogen is the primary limiting macronutrient in Mono Lake as phosphate is in super-abundance (350-450 µM) throughout the year (Jellison *et al.* 1994). External inputs of nitrogen are low relative to recycling fluxes within the lake (Jellison and Melack 1993). Ammonium concentrations in the euphotic zone reflect the dynamic balance between excretion by shrimp, uptake by algae, upward vertical fluxes through thermo- and chemocline(s), release from sediments, ammonium volatilization, and small external inputs. Because a large portion of particulate nitrogen, in the form of algal debris and *Artemia* fecal pellets, sink to the bottom and are remineralized to ammonium in the hypolimnion (or monimolimnion during meromixis), vertical mixing controls much of the annual internal recycling of nitrogen.

In absence of a winter period of holomixis, epilimnetic ammonium concentrations remained low (≤1 µM) throughout the winter and spring (Table 7, Fig. 15). Epilimnetic concentrations only increased in June as *Artemia* ammonium excretion increased and phytoplankton demand decreased. Ammonium in the upper 9-m integrated samples ranged from 0.2 to 6.6 µM across 7 lakewide stations (Table 8, Fig. 16). The highest values were observed at the western stations in mid-summer and are associated with the much higher mid-summer densities of *Artemia* observed in this sector of the lake. While this seasonal feature of increased midsummer epilimnetic ammonium is observed during both meromictic and monomictic conditions, it is generally larger during monomictic periods. The causal connection to grazing is highlighted by the variation in the prominence of this feature across the lake which shows an inverse correlation with adult *Artemia* abundance. The peak is much more prominent at stations 1, 2, and 5 where larger midsummer peaks of *Artemia* occurred compared to stations in the eastern basin (7, 8, and 11). In mid-July a strong thermocline had formed between 7 and 8 m depth and ammonium was somewhat elevated (8.2 µM) at 8 m.

Beneath the chemocline, monimolimnetic ammonium concentrations increased through the season with the highest measured value of 91.7 µM at 35 m depth on 15 November. This amount of seasonal ammonium accumulation is typical and within the range observed in other years.

Phytoplankton (algal biomass and fluorescence)

The phytoplankton community, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation. A large algal bloom was present during February through April with chlorophyll concentrations ranging from 44 to 80 throughout the water column (Table 9, Fig. 17) and across the lake (Table 10, Fig. 18). Mixed-layer concentrations declined slightly in April due to *Artemia* grazing and then markedly in May as the large 1st generation of adult *Artemia* matured. Although chlorophyll concentration in the 2 m May sample from mid-lake was only 4.3 µg chl l^{-1}, the mean lakewide mean concentration in upper 9-m integrated samples was 26.8 µg liter^{-1}; ranging from 20.6 at station 11 to 32.6 µg liter^{-1} at station 1. Mixed-layer chlorophyll remained relatively low through September.

In general, the 9-m integrated samples collected from 7 stations showed lower epilimnetic chlorophyll concentrations in the eastern half of the lake during the spring and slightly higher concentration in the east during midsummer (Fig. 18). This is due to spatial variation in *Artemia* hatching and 2nd generation abundance.

An autumn bloom associated with declining *Artemia* abundance and entrainment of nutrients due to deepening of the thermocline is a perennial feature in Mono Lake and chlorophyll increased late in the year from September through December. By the December survey chlorophyll had increased to 26–32 in the mixolimnion. Monimolimnetic chlorophyll concentrations (24 and 28 m depth) were 42–57 µg chl l^{-1} throughout the year.

We use in-situ fluorescence primarily to locate mid-depth peaks in phytoplankton populations. These are particularly prominent under meromictic conditions. During 2006, mid-depth maxima were present below 15 m during July, August, and September surveys (Fig. 19). While phytoplankton populations increase in this region which is excluded from the heavy *Artemia* grazing of the mixolimnion, their contribution to the overall primary productivity of the lake is small. These features were eroded by subsequent deeper mixing in October through December.

Artemia Population Dynamics

Zooplankton populations in temperate lakes are highly variable across multiple spatial and temporal scales. The Mono Lake monitoring program collects samples from 12 stations distributed across the lake and the relative standard errors of lakewide estimates are typically 10-20 %. However, on a given sample date the standard error of a lakewide estimate may be smaller or larger depending on the observed spatial variability occurring on that date. In extreme cases, local convergences of water masses may concentrate shrimp to well above the overall mean. For these reasons, a single level of significant figures in presenting data (e.g. rounding to 10s, 100s, 1000s or even 10,000s) is inappropriate and we include the standard error of each lakewide estimate using the "±" notation. The reader is cautioned to always consider the standard errors when making inferences from the data.

Hatching of over-wintering cysts, and maturation and decline of 1st generation

Hatching of over-wintering cysts is initiated by warming water temperatures and oxic conditions. The peak of hatching usually occurs during March but significant hatching may also occur during February. A small amount of hatching may even occur during January in shallow nearshore regions during periods of above normal air temperatures. By the 13 February survey the spring *Artemia* hatch was in progress with abundance across 12 stations ranging from 3,461 to 60,080 m^{-2} with a lakewide mean of 13,707±4,601 m^{-2} (Table 11a-b). The population consisted mostly of instars 1 (92.9 %) and 2 (3.7 %) (Table 12). Instars 3-6 and a few juveniles were also present. A few adults were present resulting in a lakewide estimate of 35±12 m^{-2}. It is unusual to observe adults at this time of year, but a warm, calm period in late January allowing individuals to hatch and mature in warm semi-isolated nearshore waters is likely responsible. The presence of low numbers of adults in February has been observed in a couple other years.

Cyst hatching increased in March with naupliar abundance ranged from 3,219 to 190,584 m^{-2} across the 12 lakewide stations with a mean of 46,843±16,417 m^{-2}. Nauplii were nearly 14 times (87,404 versus 6,281) more abundant in the eastern half of the lake (stations 7-12) compared to the western half (station 1-6). As in February the population consisted almost entirely of naupliar instars with most still in the instar 1 (89.1 %) or instar 2 (9.5 %) developmental stages. Adults were present but in insignificant numbers (males, 10 m^{-2}; females 12 m^{-2}).

In April, early *Artemia* instars were abundant and highly variable across the lake. In the western sector naupliar instars numbered 245,000–326,000 m^{-2} at stations 4, 5, and 6. While there were only 2700 m^{-2} at station 1. The overall lakewide mean was 92,894±34,591. The high standard error of the estimate reflects the extreme patchiness. The population consisted entirely of naupliar instars with instars 1, 2, and 3 constituting 27.2, 62.2, and 8.8 percent of the total population. Only a few juveniles and adults were present.

Larval development continued with 53.1 % of population on the 15 May survey having reached the adult stage. The May lakewide mean *Artemia* abundance (12 stations) was 45,540±5989 m^{-2}, with all age classes about twice as abundant in the eastern sector of the lake (stations 7-12) versus the western sector (stations 1-6). While many adult females were present, few (0.3 %) were carrying eggs. All instars were present, but most were instars 4-7, while instars 1 were only 0.9 % of the total population. Thus, the spring hatch was mostly over.

Recruitment into the adult population continued during early June and the annual peak was observed on 14 June when lakewide adult abundance was 55,748±7882 m^{-2}. This June 2006 adult *Artemia* abundance was the third largest spring generation observed in the 26-yr (1981 to 2006) record (Fig. 21).

Ovoviviparous reproduction and the second generation

Ovoviviparous reproduction depends on the ambient food levels and the age of the individual. *Artemia* produce multiple broods and ovoviviparous reproduction in the lake occurs, if at all, almost exclusively with the first brood, rarely occurring in an individual's second and subsequent broods.

While adult females were abundant on the 24 May survey, only 7.6 % of the adult females were carrying eggs and nearly all (82.4 %) of these were still undifferentiated (Table 13a-c, Fig. 22). Ovigery increased to 19.1 % a week later on 31 May and 25 % of differentiated egg masses were naupliar eggs (as opposed to encapsulated cysts) (Table 13c). This pulse of ovoviviparous reproduction led to a second prominent peak of adult *Artemia* in mid July when lakewide mean adult abundance was 49,772±10,634 m^{-2} (Table 11a-b).

While ovigerity increased throughout the summer to 65.6 % by 12 July, a smaller proportion of females were reproducing ovoviviparously (6.0 %) (Table 13c). Lakewide mean ovigerity continued to increase and was above 90 % by 17 August. While the adult female population declined rapidly from the peak in mid-July, individual ovigerity remained high through early October.

Fecundity (eggs per brood) is a function of food availability and adult female size. Fecundity varied from 25.2 to 51.6 eggs $brood^{-1}$ from the appearance of the first mature females in late May to early September (Table 14). Mean lakewide fecundity increased almost 100 eggs $brood^{-1}$ in early October but by then female abundance had declined to only 1,849±1,081 m^{-2}.

The absence of late summer recruitment led to a rapid decline of adult *Artemia*. By 19 October adult *Artemia* were virtually gone with an average lakewide abundance of only 122±26 m^{-2}. There were no ovigerous adult females present. While the virtual absence of adult *Artemia* in mid-October has only been observed in one other year (2002) over the past 28 years, low (<5,000 m^{-2}) mid-October abundances were also observed in 1986, 2000, 2003, and 2004.

Due to winter conditions and the absence of *Artemia*, only three stations were sampled on the December survey. The deep centrally-located Station 6 to represent vertical structure and a nearshore station in the west (Station 1) and east (Station 8) primarily to assess the abundance of rotifer abundance.

Artemia Population Statistics, 1979–2006

Year to year variation in climate, hydrological conditions, vertical stratification, food availability, and possibly salinity have led to large inter-year differences in *Artemia* dynamics. During years when the first generation was small due to reduced hatching, high mortality, or delayed development (1981, 1982, and 1989) the second generation peak of adults was 2–3 times the long term average (Table 15, Fig. 23). Seasonal peak abundances were also significantly higher (1.5–2 times the mean) in 1987 and 1988 as the 1980s episode of meromixis weakened and nutrients that had accumulated beneath the chemocline were transported upward and during 2004 following breakdown of the 1990s episode of meromixis. However, in most years the seasonal peaks of adult abundance were similar (30–40,000 m^{-2}) and the seasonal (1 May to November 30) mean of adult abundance varied less within a range of 14–37,000 m^{-2}. The overall mean seasonal abundance of adult *Artemia* from 1979 to 2006 was ~19,900 m^{-2}. During this 28-yr record, mean seasonal abundance was lowest in 2000 (~10,500 m^{-2}) and 2002 (~11,600 m^{-2}) and highest in 1982 (~36,600 m^{-2}), 1989 (~36,400 m^{-2}), and 2004 (~32,000 m^{-2}). In 2006, mean seasonal abundance was 21,518 m^{-2} or ~8 % above the long-term mean.

During most years, the seasonal distribution of adult abundance is roughly normal or lognormal. However, in several years the seasonal abundance was not described well by either of these distributions. Therefore, the abundance-weighted centroid of temporal occurrence was calculated to compare overall seasonal shifts in the timing of adult abundance. The center of the temporal distribution of adults varied from day 180 (28 June) to 252 (9 September) in the 28-yr record from 1979 to 2006 (Table 15, Fig. 24). During five years when there was a small spring hatch (1980–83, and 1989) the overall temporal distribution of adults was much later (24 August – 9 September) and during 2004 the exceptionally large and early 1st generation shifted the seasonal temporal distribution much earlier to 28 June. The 3rd largest spring generation of adults was observed in 2006 and the overall temporal occurrence of adults was also the 3rd earliest at day 186 or 5 July.

Long term integrative measures of productivity

Planktonic primary production

Photosynthetic rates were determined by laboratory radiocarbon uptake measurements from 1982-1992 (Jellison and Melack 1988, 1993b) and combined with an interpolative model of chlorophyll, temperature, and in situ photosynthetically-available light (PAR) to estimate annual productivity. While radiocarbon uptake measurements were not conducted from 1993-2001, a significant fraction of the chlorophyll-specific variance in maximum (P_m^B) and light-limited uptake rates (α^B) is explained by temperature (Jellison and Melack 1988, 1993b) and estimates of primary production in subsequent years were made employing measurements of light, chlorophyll, temperature and estimates of P_m^B and $\alpha^{B.}$ As 1989 and 1990 had elevated ammonium concentrations due to the breakdown of meromixis, regressions were performed on just 1991 and 1992 for use in subsequent years. The exponential equation:

$$P_m^B = 0.237 \times 1.183^T \qquad n=42,\ r^2=0.86$$

where T is temperature (°C) explained 86 % of the overall variation. As found in previous analyses (Jellison and Melack 1993b), there was a strong correlation between light-limited and light-saturated rates. A linear regression on light-saturated rates explained 82 % of the variation in light-limited rates:

$$\alpha^B = 2.69 + (1.47 \times P_m^B) \qquad n=42,\ r^2=0.82$$

Both light-limited and light-saturated carbon uptake rates reported here are within the range reported in other studies (Jellison and Melack 1993b).

In 1995, rising lake levels and greater salinity stratification reduced the vertical flux of nutrients and may have affected the photosynthetic rates, but previous regression analyses (Jellison and Melack 1993b) using an extensive data set collected during periods of different nutrient supply regimes indicated little of the observed variance in photosynthetic rates can be explained by simple estimates of nutrient supply. The differences in annual phytoplankton production throughout the period, 1982–1992, resulted primarily from changes in the amount of standing biomass; year to year changes in photosynthetic parameters during the years they were measured (1983–92) were not correlated with annual production. Thus, we suggested the above regressions might explain most of the variance in photosynthetic rates and provide a reasonable alternative to frequent, costly field and laboratory measurements using radioactive tracers.

In 2001, new "photosynthetrons" (see Methods, Chapter 2) were constructed and direct measurements of carbon uptake were resumed to determine photosynthetic parameters. The new "photosynthetrons" provide more light levels and better control and measurement of the incubator's light and temperature. Thus, more accurate measurements of P_m^B and α^B are possible and carbon uptake experiments are now routinely conducted with a sample from the upper mixed layer (2 m) and a sample from a depth near the bottom of the epilimnion (10-16 m). These measurements enable annual productivity changes associated with varying nutrient regimes or changing phytoplankton composition to be estimated more accurately than during 1993 to 2001 when P_m^B and α^B were estimated from previously derived regressions.

During 2006, thirteen carbon uptake experiments were conducted with natural phytoplankton assemblages from either the mixed-layer or near the bottom of the epilimnion (Table 16). Chlorophyll-specific maximum carbon uptakes (P_m^B) rates and light-limited rates (α^B) were determined for each sample by fitting a hyperbolic tangent curve to the data using least-squares nonlinear estimation (see Fig. 25 for examples). Chlorophyll-specific maximum carbon uptakes (P_m^B) rates for samples collected at 2 m depth ranged from 1.3–1.4 g C g Chl a^{-1} h^{-1} in February and March to 14.4 g C g Chl a^{-1} h^{-1} on 15 June (Table 16, Fig. 26), while light-limited rates (α^B) for these samples ranged from 5.2 to 19.9 g C g Chl a^{-1} $Einst^{-1}$ m^2 (Table 16). Chlorophyll-specific maximum rates for samples collected at 10 m during June and July were 2.6 and 4.2 g C g Chl a^{-1} h^{-1}, respectively.

Using the interpolative model to integrate the photosynthetic parameters with in situ temperature, chlorophyll, and light resulted in an annual productivity estimate of 852 g C m^{-2} during 2006 (Table 17, Figs. 26-27). The maximum uptakes rates are primarily a function of temperature and thus the seasonal pattern and magnitudes were roughly similar during 2002–2006 (Fig. 27). The most notable differences occurred in August when the maximum uptake rate was much lower in 2002 and higher in 2004. Changes in standing algal biomass are a dominant factor in variation in daily and annual primary productivity (Jellison and Melack 1988, 1993b). While the seasonal trends were roughly similar during 2002–06, higher algal biomass throughout the summer in 2003 (Figs. 27–28) led to the highest estimates of annual primary productivity in the entire period of record. Daily production rates ranged from 0.4 to 5.3, 1.4 to 10.8, 0.1 to 7.7, 0.3 to 5.8, and 0.8 to 5.1 g C m^{-2} in 2002, 2003, 2004, 2005, and 2006, respectively (Fig. 28).

Annual primary production in 2006 was 46 % higher than the long-term mean (1982–2006) of 584 g C m^{-2} (Table 17, Fig. 29). Estimates from previous years ranged from 149 g C m^{-2} in 1997 to 1645 g C m^{-2} in 2003. In 1988, a 5-yr episode of meromixis was breaking down and nutrients which had accumulated beneath the thermocline were mixed into the euphotic zone leading to higher algal biomass and estimated annual production of 1064 g C m^{-2}. During 2003, an 8-yr period of chemical stratification broke down and significant amounts of ammonium were entrained into the mixed layer. Estimates of planktonic photosynthesis at Mono Lake are generally higher than other hypersaline lakes in the Great Basin: Great Salt Lake (southern basin), 145 g C m^{-2} yr^{-1} (Stephens and Gillespie 1976); Soap Lake, 391 g C m^{-2} yr^{-1} (Walker 1975); and Big Soda, 500 g C m^{-2} yr^{-1} (350 g C m^{-2} yr^{-1} phototrophic production) (Cloern *et al.* 1983).

Artemia biomass and egg production

Artemia biomass was estimated from instar-specific population data and previously derived weight-length relationships for the period 1982–99. Variation in weight-length relationships among sampling dates was assessed from 1996–99 and found to lead to errors of up to 20 % in the annual estimates. Thus, in 2000 we implemented direct drying and weighing of vertical net tow samples collected explicitly for biomass determinations.

In 2006, *Artemia* biomass was 0.07 g dry weight m^{-2} on 13 February and increased to the yearly peak of 30.7 g dry weight m^{-2} on 14 June. This was almost identical to that observed on 14 June 2005 (30.5 g dry weight m^{-2}). *Artemia* biomass remained above 12.6 g dry weight m^{-2} through 13 September and then decreased to 5.4 g dry weight m^{-2} on 3 October and to 0.06 g dry weight m^{-2} by 19 October. Biomass was near zero (<0.02 g dry weight m^{-2}) on the November and December surveys. The 2006 mean annual biomass of 6.8 g m^{-2} was 26 % below the long-term (1983-2006) mean of 9.2 g m^{-2} (Table 17, Fig. 30)

The highest estimated mean annual *Artemia* biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the 1980s episode of meromixis and then above the mean during the next 3 years as meromixis weakened and ended. Except for lower values in 1997 and in 2002, *Artemia* biomass has remained relatively constant since 1993 and was only slightly higher during 1990–92. The higher value in 2004 is associated with the largest spring generation observed.

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction (Fig. 31, Table 17). In 2006, total annual naupliar production (0.32 x 10^6 m^{-2}) was almost identical to that observed in 2005 (0.31 x 10^6 m^{-2}) and 29 % above the long-term mean of 0.25 x 10^6 m^{-2}. Total annual cyst production in 2006 (4.8 x 10^6 m^{-2}) was 10 % higher than the long-term mean of 4.4 x 10^6 m^{-2}.

Long-term trends in inter-year variation in algal biomass and adult Artemia abundance

The long-term record of plankton dynamics in Mono Lake show marked seasonal and inter-year variation (Figs. 32-33). Multi-year episodes of meromixis have markedly increased the inter-year variation compared to periods of monomixis in which an annual winter period of holomixis occurs. The large variations caused by changes in mixing regime preclude the possibility of determining the effects of variation in salinity from any small subset of years. Here, we examine the long-term trends in algal biomass in the upper water column (< 10 m) and adult *Artemia* biomass from 1982 through 2006.

The seasonal trend can be removed by calculating a yearly moving average. Because the intervals between sampling dates varied among years, daily values were derived by linearly interpolating between sample dates prior to calculating a 365-day moving average. Thus, each point represents a moving average of 365 days centered about a given day. The seasonally-filtered chlorophyll *a* concentrations (Fig. 32, heavy line) show the marked impact of the two episodes of meromixis. The seasonally-filtered mean chlorophyll ranged from a minimum of 2.8 μg $liter^{-1}$ following the onset of meromixis in 1984 to 50.3 μg $liter^{-1}$ in late 2003 as the longer 1980s episode of meromixis ended. This represents an 18-fold difference. The seasonally-filtered adult *Artemia* abundance show much less inter-year variation (Fig. 33) with mean abundance ranging from 6,200 m^{-2} in 2000 to 24,000 m^{-2} in 1982 or about a 4-fold difference. Thus, inter-year variation in seasonally-filtered adult *Artemia* abundance is much less than that of algal abundance. Also, it is clear that any long-term trend in either measure is either small or obscured by the inter-year variation due to varying mixing regimes.

REFERENCES

Clark, J. F. and G. B. Hudson. 2001. Quantifying the flux of hydrothermal fluids into Mono Lake by use of helium isotopes. Limnol. Oceanogr. **46:** 189-196.

Cloern, J. E., B. E. Cole, and R. S. Oremland. 1983. Autotrophic processes in meromictic Big Soda Lake, Nevada. Limnol. Oceanogr. **28:** 1049–1061.

Cooper, J. J.and D. L. Koch 1984. Limnology of a desertic terminal lake, Walker Lake, Nevada, U.S.A. Hydrobiologia **118:** 275-292.

Dana, G. L. 1981. Comparative population ecology of the brine shrimp *Artemia.* Master thesis. San Francisco State Univ.

Dana, G. L. and P.H. Lenz. 1986. Effects of increasing salinity on an *Artemia* population from Mono Lake, California. Oecologia **68:**428-436.

Dana, G. L., R. Jellison, and J. M. Melack. 1990. *Artemia monica* egg production and recruitment in Mono Lake, California, USA. Hydrobiologia **197:**233-243.

Dana, G. L., R. Jellison, and J. M. Melack. 1995. Effects of different natural regimes of temperature and food on survival, growth, and development of *Artemia*. J. Plankton Res. **17:**2115-2128.

Dana, G. L., R. Jellison, and J. M. Melack. 1986. Abundance and life history variations of an *Artemia* population in a changing environment (Mono Lake, California). Final Report to LADWP.

Dana, G. L., R. Jellison, J. M. Melack, and G. Starrett. 1993. Relationships between *Artemia monica* life history characteristics and salinity. Hydrobiologia **263:**129-143.

Dana, G. L., R. Jellison, J. Romero, and J. M. Melack. 1992. Mixing and plankton dynamics in Mono Lake, California. 1991 Annual Report to LADWP.

Galat, D. L., E. L. Lider, S. Vigg, and S. R. Robertson. 1981. Limnology of a large, deep, North American terminal lake, Pyramid Lake, Nevada, U.S.A. Hydrobiologia **82:** 281-317.

Golterman, H. L. 1969. [ed.] Methods for chemical analysis of fresh waters. International Biological Program Handbook. No. 8. Blackwell Scientific Publications, Oxford. 166p.

Heath, H. 1924. The external development of certain phyllopods. J. Morphol. **38:**453–83.

Imberger, J. and J.C. Patterson. 1981. A dynamic reservoir simulation model-DYRESM, p. 310-361. *In* H.B. Fischer [ed.], Transport models for inland and coastal waters. Academic.

Jellison, R, S. K. Roll, and J. M. Melack. 2001. Mixing and plankton dynamics in Mono Lake, California. 2000 Annual report to the Los Angeles Department of Water and Power. 100 p.

Jellison, R, S. K. Roll, and J. M. Melack. 2002. Mixing and plankton dynamics in Mono Lake, California. 2001 Annual report to the Los Angeles Department of Water and Power. 99 p.

Jellison, R, S. K. Roll, and J. M. Melack. 2003. Mixing and plankton dynamics in Mono Lake, California. 2002 Annual report to the Los Angeles Department of Water and Power. 117 p.

Jellison, R. 1987. Study and modeling of plankton dynamics in Mono Lake, California. Report to Community and Organization Research Institute, Santa Barbara.

Jellison, R. 1992. Limnology of hypersaline Mono Lake, California during the onset, persistence, and breakdown of meromixis. Ph. D. dissertation. University of California, Santa Barbara. 247 pp.

Jellison, R. 2004. Mixing and plankton dynamics in Mono Lake, California. 2003 Annual report to the Los Angeles Department of Water and Power. 108 p.

Jellison, R. 2005. Mixing and plankton dynamics in Mono Lake, California. 2004 Annual report to the Los Angeles Department of Water and Power. 95 p.

Jellison, R. 2006. Mixing and plankton dynamics in Mono Lake, California. 2005 Annual report to the Los Angeles Department of Water and Power. 103 p.

Jellison, R. and J. M. Melack. 1988. Photosynthetic activity of phytoplankton and its relation to environmental factors in hypersaline Mono Lake, California. Hydrobiologia **158:**69-88.

Jellison, R. and J. M. Melack. 2000. Mixing and plankton dynamics in Mono Lake, California. 1999 Final Report to LADWP. 114p.

Jellison, R. and J. M. Melack. 2001. Nitrogen limitation and particulate elemental ratios of seston in hypersaline Mono lake, California, USA. Hydrobiol. **466**:1-12.

Jellison, R., and J. M. Melack. 1993a. Algal photosynthetic activity and its response to meromixis in hypersaline Mono Lake, California. Limnol. Oceanogr. **38:**818–837.

Jellison, R., and J. M. Melack. 1993b. Meromixis in hypersaline Mono Lake, California I. Vertical mixing and density stratification during the onset, persistence, and breakdown of meromixis. Limnol. Oceanogr. **38:**1008–1019.

Jellison, R., G. L. Dana, and J. M. Melack. 1988. Phytoplankton and brine shrimp dynamics in Mono Lake, California. 1987 Final Report to LADWP.

Jellison, R., G. L. Dana, and J. M. Melack. 1989. Phytoplankton and brine shrimp dynamics in Mono Lake, California. 1988 Final Report to LADWP.

Jellison, R., G. L. Dana, and J. M. Melack. 1990. Phytoplankton and brine shrimp dynamics in Mono Lake, California. 1989 Report to LADWP.

Jellison, R., G. L. Dana, and J. M. Melack. 1992. Ecosystem responses to changes in freshwater inflow to Mono Lake, California, p. 107–118. In C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski [eds.] The history of water: Eastern Sierra

Nevada, Owens Valley, White-Inyo Mountains. White Mountain Research Station Symposium 4. Univ. of Calif., Los Angeles.

Jellison, R., G. L. Dana, and J. M. Melack. 1995b. Zooplankton cohort analysis using systems identification techniques. J. Plankton Res. **17:**2093–2115.

Jellison, R., G. L. Dana, Romero, J., and J. M. Melack. 1991. Phytoplankton and brine shrimp dynamics in Mono Lake, California. 1990 Report to LADWP.

Jellison, R., J. M. Melack, and D. Heil. 1999. Mixing and plankton dynamics in Mono Lake, California. 1998 Final Report to LADWP. 144 p.

Jellison, R., J. Romero, and J. M. Melack. 1998b. The onset of meromixis during restoration of Mono Lake, California: unintended consequences of reducing water diversions. Limnol. Oceanogr. **43:**706–711.

Jellison, R., J. Romero, J. M. Melack, and D. Heil. 1994. Mixing and plankton dynamics in Mono Lake, California. 1992 Annual report to the Los Angeles Department of Water and Power. 184p.

Jellison, R., J. Romero, J. M. Melack, and D. Heil. 1996a. Mixing and plankton dynamics in Mono Lake, California. 1995 Annual report to the Los Angeles Department of Water and Power. 163p.

Jellison, R., J. Romero, J. M. Melack, and D. Heil. 1997. Mixing and plankton dynamics in Mono Lake, California. 1996 Annual report to the Los Angeles Department of Water and Power. 186p.

Jellison, R., J. Romero, J. M. Melack, D. Heil, and G. L. Dana. 1995a. Mixing and plankton dynamics in Mono Lake, California. 1993–94 Annual report to the Los Angeles Department of Water and Power. 248p.

Jellison, R., L. G. Miller, J. M. Melack, and G. L. Dana. 1993. Meromixis in hypersaline Mono Lake, California II. Nitrogen fluxes. Limnol. Oceanogr. **38:**1020–1039.

Jellison, R., R. Anderson, J. M. Melack, and D. Heil. 1996b. Organic matter accumulation in Mono Lake sediments during the past 170 years. Limnol. Oceanogr. **41:**1539–1544.

Jellison, R., Romero, J., J. M. Melack, and D. Heil. 1998a. Mixing and plankton dynamics in Mono Lake, California. 1997 Final Report to LADWP. 147 p.

Lenz, P. H. 1984. Life-history analysis of an *Artemia* population In a changing environment. J. Plankton Res. 6: 967-983.

MacIntyre, S., K. Flynn, R. Jellison, and J. Romero. 1999. Boundary mixing and nutrient fluxes in Mono Lake, California. Limnol. Oceanogr. **44:** 512-529.

MacInytre, S. and R. Jellison. 2001. Nutrient fluxes from upwelling and enhanced turbulence at the top of the pycnocline in Mono Lake, California. Hydrobiologia **466:** 13-29.

Mason, D. T. 1967. Limnology of Mono Lake, California. Univ. Calif. Publ. Zool. 83:1-110.

Melack, J. M. 1983. Large, deep salt lakes: a comparative limnological analysis. Hydrobiologia 105: 223-230.

Melack, J. M. 1985. The ecology of Mono Lake. National Geographic Society Research Reports. 1979 Projects. pp. 461–470.

Melack, J. M., R. Jellison. 1998. Limnological conditions in Mono Lake: Contrasting monomixis and meromixis in the 1990s. Hydrobiologia **384:** 21-39.

Miller, L. G., R. Jellison, R. S. Oremland, and C. W. Culbertson. 1993. Meromixis in hypersaline Mono Lake, California III. Breakdown of stratification and biogeochemical response to overturn. Limnol. Oceanogr. **38:**1040–1051.

Patten, D. T., F. P. Conte, W. E. Cooper, J. Dracup, S. Dreiss, K. Harper, G. L. Hunt, P. Kilham, H. E. Klieforth, J. M. Melack, and S. A. Temple. 1987. The Mono Basin ecosystem: Effects of changing lake level. National Academy Press, Washington, D.C. 272 p.

Romero, J. R., R. Jellison, J. M. Melack. 1998. Stratification, vertical mixing, and upward ammonium flux in hypersaline Mono Lake, California. Archiv fur Hydrobiologia **142:** 283-315.

Romero, J.R. and J.M. Melack. 1996. Sensitivity of vertical mixing to variations in runoff. Limnol. Oceanogr. **41:**955–965.

Romero, J.R., J.C. Patterson, and J. M. Melack. 1996. Simulation of the effect of methane bubble plumes on vertical mixing in Mono Lake. Aquat. Sci. **58:**210–223.

Stephens, D. W., and D. M. Gillespie. 1976. Phytoplankton production in the Great Salt Lake, Utah, and a laboratory study of algal response to enrichment. Limnol. Oceanogr. **21:** 74-87.

Strickland, J. D. and T. R. Parsons. 1972. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Can. 167p.

Walker, K. F. 1975. The seasonal phytoplankton cycles for two saline lakes in central Washington. Limnol. Oceanogr. **20:** 40-53.

Walker, K. F., W. D. Williams, and U. T. Hammer. 1970. The Miller method for oxygen determination applied to saline lakes. Limnol. Oceanogr. **15:**814-815.

Williams, W. D. 1993. Conservation of salt lakes. Hydrobiologia **267:** 291-306.

Williams, W. D. 2002. Environmental threats to salt lakes and the likely status of inland saline ecosystems in 2025. Environ. Cons. **29**(2):154–167.

Winkler, D.W. 1977. [ed.] An ecological study of Mono Lake, California. Institute of Ecology Publication No. 12. University of California, Davis, California.

Wrege, P.H., D. W. Shuford, D. W. Winkler, and R. Jellison. 2006. Annual variation in numbers of breeding California Gulls at Mono Lake, California: The importance of natal philopatry and local and regional conditions. Condor **108**(1):82-96.

Table 1. Temperature (ºC) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	4.6	3.5	7.6	19.0	16.5	21.6	21.1	17.3	12.3	8.9	4.4
2	3.8	2.9	7.3	19.7	17.3	22.0	21.1	17.3	12.3	8.9	4.9
3	3.6	2.9	7.4	18.4	17.5	22.1	21.1	17.3	12.3	9.1	4.8
4	3.4	2.9	7.3	16.1	17.2	22.0	21.1	17.2	12.3	9.1	4.8
5	3.3	2.9	6.7	14.0	16.9	21.9	21.2	17.2	12.4	9.2	4.8
6	3.2	2.9	6.5	11.2	15.8	21.7	21.4	17.0	12.5	9.2	4.8
7	3.1	2.9	6.5	9.2	15.6	21.1	21.5	16.9	12.6	9.2	4.7
8	3.0	2.9	6.4	8.3	15.5	19.3	21.4	16.9	12.6	9.1	4.7
9	3.0	2.9	6.4	7.4	14.3	16.0	18.7	16.8	12.7	9.2	4.7
10	2.9	2.9	6.3	6.7	11.8	14.0	16.3	16.6	12.6	9.2	4.7
11	2.9	2.9	6.1	6.2	10.4	11.2	13.2	14.5	12.6	9.2	4.8
12	2.9	2.9	6.1	6.1	7.7	9.4	11.2	11.9	12.4	9.1	4.8
13	2.9	2.9	5.9	5.8	6.7	7.8	10.0	10.3	10.6	9.2	4.8
14	3.0	2.9	5.8	5.6	6.0	7.2	8.4	8.9	9.1	9.3	4.8
15	3.1	2.9	5.5	5.3	5.8	6.7	7.5	7.4	7.9	8.4	4.8
16	3.2	2.9	5.1	5.1	5.5	5.9	6.7	6.6	6.8	7.5	4.8
17	3.2	2.9	4.8	4.9	5.2	5.4	6.2	6.2	6.1	6.8	5.6
18	3.2	2.9	4.4	4.7	5.0	5.2	5.8	5.9	5.7	6.2	6.2
19	3.3	2.9	4.2	4.4	4.8	5.1	5.6	5.6	5.4	5.7	6.1
20	3.4	3.0	4.0	4.3	4.7	5.0	5.3	5.3	5.4	5.5	5.9
21	3.4	3.0	3.8	4.1	4.6	4.9	5.0	5.1	5.2	5.4	5.8
22	3.6	3.0	3.7	4.0	4.5	4.8	4.9	5.0	5.2	5.3	5.6
23	3.8	3.1	3.6	4.0	4.4	4.7	4.8	4.9	5.1	5.2	5.5
24	3.9	3.4	3.6	4.0	4.4	4.6	4.7	4.8	5.0	5.2	5.4
25	4.2	3.6	3.6	3.9	4.4	4.6	4.7	4.8	4.9	5.1	5.3
26	4.4	3.7	3.7	3.9	4.3	4.5	4.6	4.8	4.9	5.0	5.2
27	4.6	3.8	3.7	3.9	4.3	4.5	4.6	4.7	4.8	5.0	5.2
28	4.6	3.9	3.7	3.9	4.2	4.4	4.5	4.6	4.7	4.9	5.1
29	4.6	3.9	3.7	3.8	4.2	4.3	4.5	4.6	4.7	4.9	5.1
30	4.7	4.0	3.7	3.8	4.1	4.3	4.4	4.5	4.6	4.8	5.1
31	4.7	4.0	3.7	3.8	4.1	4.3	4.4	4.5	4.6	4.8	5.0
32	4.8	4.1	3.7	3.8	4.1	4.3	4.4	4.5	4.6	4.7	4.9
33	4.8	4.1	3.7	3.8	4.1	4.2	4.3	4.5	4.6	4.7	4.9
34	4.8	4.2	3.7	3.8	4.1	4.2	4.3	4.5	4.6	4.7	4.9
35	4.8	4.2	3.7	3.8	4.0	4.2	4.3	4.4	4.6	4.7	4.9
36	4.8	4.2	3.7	3.8	4.0	4.2	4.3	4.4	4.5	4.7	4.8
37	-	4.2	3.7	3.8	4.0	4.1	4.3	4.4	4.5	4.6	4.8

Table 2. Conductivity (mS cm^{-1} at 25ºC) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	80.9	81.1	80.9	79.3	78.5	75.7	75.9	77.8	78.2	78.7	78.8
2	81.3	81.3	81.1	79.8	79.0	76.4	75.9	77.8	78.4	78.7	79.0
3	81.4	81.4	80.9	80.0	79.1	76.5	75.9	77.8	78.4	78.8	79.0
4	81.3	81.4	81.1	80.2	79.0	76.6	76.0	77.8	78.4	78.8	79.1
5	81.5	81.4	81.0	80.3	79.1	76.7	76.0	77.8	78.5	78.8	79.1
6	81.5	81.4	81.1	80.3	79.3	77.1	76.2	77.8	78.6	78.8	79.1
7	81.5	81.4	81.1	80.7	79.5	77.5	76.4	77.9	78.6	78.8	79.2
8	81.5	81.4	81.1	80.7	79.7	78.4	77.6	78.0	78.6	78.9	79.2
9	81.5	81.4	81.1	80.6	79.8	79.4	79.2	78.1	78.6	78.9	79.2
10	81.6	81.4	81.0	80.8	80.1	80.0	79.5	78.3	78.6	79.0	79.2
11	81.6	81.4	81.0	80.9	80.4	80.1	80.0	79.7	78.7	79.0	79.2
12	81.6	81.4	81.0	80.9	80.6	80.4	80.4	80.3	80.1	79.0	79.3
13	81.6	81.4	81.0	80.9	80.9	80.8	80.4	80.7	80.7	79.3	79.3
14	81.7	81.4	81.0	80.9	81.1	80.8	80.7	80.8	80.8	80.3	79.3
15	81.7	81.4	81.0	81.1	81.2	80.8	81.0	80.8	81.0	80.9	79.3
16	81.7	81.4	81.0	81.1	81.4	81.0	81.2	81.0	81.1	81.1	79.4
17	81.7	81.4	81.1	81.2	81.5	81.5	81.5	81.3	81.3	81.2	80.8
18	81.8	81.4	81.3	81.3	81.5	81.5	81.6	81.5	81.4	81.4	81.4
19	81.9	81.4	81.4	81.4	81.6	81.5	81.5	81.6	81.5	81.5	81.6
20	81.9	81.4	81.4	81.5	81.6	81.6	81.6	81.5	81.6	81.7	81.7
21	81.9	81.4	81.5	81.6	81.6	81.5	81.6	81.6	81.6	81.7	81.7
22	82.2	81.5	81.6	81.6	81.6	81.6	81.7	81.6	81.6	81.7	81.7
23	82.4	81.6	81.6	81.7	81.7	81.6	81.7	81.6	81.6	81.7	81.7
24	82.6	82.0	81.8	81.7	81.7	81.7	81.8	81.7	81.6	81.7	81.7
25	82.8	82.0	81.9	81.7	81.7	81.7	81.8	81.6	81.6	81.7	81.8
26	82.8	82.1	82.0	81.8	81.7	81.8	81.8	81.7	81.6	81.7	81.8
27	82.8	82.2	82.0	81.8	81.7	81.7	81.8	81.7	81.6	81.7	81.8
28	82.9	82.2	82.1	81.8	81.8	81.8	81.8	81.7	81.6	81.7	81.8
29	82.9	82.3	82.1	81.9	81.8	81.8	81.9	81.7	81.6	81.7	81.8
30	83.0	82.4	82.1	81.9	81.8	81.8	81.9	81.8	81.6	81.7	81.8
31	83.1	82.4	82.1	81.9	81.8	81.9	81.9	81.8	81.6	81.6	81.8
32	83.1	82.5	82.1	81.9	81.9	81.9	81.9	81.8	81.6	81.7	81.8
33	83.1	82.5	82.2	81.9	81.9	81.9	81.9	81.8	81.6	81.6	81.8
34	83.1	82.6	82.2	81.9	81.9	81.9	81.9	81.8	81.6	81.6	81.8
35	83.1	82.6	82.2	82.0	81.9	81.9	81.9	81.8	81.6	81.6	81.8
36	83.1	82.6	82.2	82.0	81.9	81.9	81.9	81.8	81.6	81.6	81.9
37	-	82.6	82.2	82.0	81.9	81.9	82.0	81.8	81.5	81.6	81.9

Table 3. Excess density (kg m^{-3}) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	70.2	70.5	69.6	64.8	64.7	60.0	60.3	63.7	65.5	66.8	67.7
2	70.7	70.8	69.9	65.2	65.0	60.5	60.3	63.7	65.7	66.9	67.9
3	70.8	71.0	69.7	65.9	65.0	60.5	60.3	63.7	65.7	66.9	67.9
4	70.8	71.0	69.9	66.8	65.1	60.7	60.4	63.7	65.8	66.9	68.0
5	71.0	71.0	69.9	67.4	65.2	60.9	60.4	63.7	65.8	66.9	68.0
6	71.0	71.0	70.0	68.1	65.9	61.5	60.5	63.8	65.9	66.9	68.0
7	71.1	71.0	70.0	69.1	66.2	62.0	60.7	63.9	65.9	66.9	68.1
8	71.1	71.0	70.0	69.3	66.3	63.7	62.1	64.0	65.9	66.9	68.1
9	71.1	71.0	70.0	69.3	66.9	65.8	64.8	64.2	65.9	67.0	68.1
10	71.2	71.0	70.0	69.6	67.8	67.1	65.8	64.4	65.9	67.1	68.2
11	71.2	71.0	70.0	69.9	68.5	67.9	67.3	66.7	65.9	67.1	68.2
12	71.2	71.0	70.1	69.9	69.2	68.6	68.2	68.0	67.7	67.2	68.2
13	71.2	71.0	70.1	69.9	69.8	69.5	68.6	68.8	68.8	67.5	68.2
14	71.3	71.0	70.1	69.9	70.1	69.6	69.2	69.3	69.2	68.6	68.2
15	71.3	71.0	70.1	70.2	70.3	69.7	69.7	69.6	69.6	69.5	68.3
16	71.3	71.0	70.2	70.3	70.6	70.1	70.1	69.9	70.0	69.8	68.3
17	71.3	71.0	70.3	70.4	70.7	70.7	70.5	70.3	70.4	70.1	69.8
18	71.4	71.0	70.6	70.6	70.8	70.7	70.8	70.6	70.6	70.4	70.5
19	71.5	71.0	70.8	70.8	70.9	70.7	70.7	70.7	70.7	70.7	70.7
20	71.5	71.0	70.8	70.9	70.9	70.8	70.9	70.8	70.8	70.9	70.8
21	71.5	71.0	70.9	71.0	70.9	70.8	70.9	70.8	70.8	70.9	70.9
22	71.8	71.0	71.1	71.1	70.9	70.9	71.0	70.9	70.9	70.9	70.9
23	72.0	71.2	71.1	71.1	71.0	71.0	71.1	70.9	70.9	71.0	71.0
24	72.2	71.6	71.3	71.2	71.1	71.1	71.1	71.0	70.9	71.0	71.0
25	72.4	71.6	71.4	71.2	71.1	71.1	71.1	71.0	70.9	71.0	71.0
26	72.4	71.7	71.6	71.3	71.1	71.1	71.2	71.0	70.9	71.0	71.0
27	72.4	71.8	71.6	71.3	71.2	71.1	71.2	71.0	70.9	71.0	71.0
28	72.5	71.8	71.7	71.3	71.2	71.2	71.2	71.1	70.9	71.0	71.1
29	72.5	71.9	71.7	71.4	71.2	71.2	71.3	71.1	70.9	71.0	71.1
30	72.6	71.9	71.7	71.4	71.3	71.3	71.3	71.1	70.9	71.0	71.1
31	72.6	72.0	71.7	71.4	71.3	71.3	71.3	71.2	70.9	71.0	71.1
32	72.7	72.1	71.7	71.5	71.3	71.3	71.3	71.2	70.9	71.0	71.2
33	72.7	72.1	71.8	71.5	71.3	71.3	71.4	71.2	70.9	71.0	71.2
34	72.7	72.1	71.8	71.5	71.4	71.3	71.4	71.2	70.9	71.0	71.2
35	72.7	72.2	71.8	71.5	71.4	71.4	71.4	71.2	70.9	71.0	71.2
36	72.7	72.2	71.8	71.5	71.4	71.4	71.4	71.2	70.9	71.0	71.2
37	-	72.2	71.8	71.5	71.4	71.4	71.4	71.2	70.9	71.0	71.2

Table 4. Temperature, conductivity, and density stratification (kg m^{-3}) at Station 6, February – December 2006 (monthly profiles, weekly surveys).

Date	Temperature		Conductivity		Density Difference due to		
	2 m	32 m	2 m	32 m	Temperature	Conductivity	Both
2/14	3.8	4.8	81.3	83.1	-0.15	2.14	2.00
3/15	2.9	4.1	81.3	82.5	-0.17	1.45	1.29
4/19	7.3	3.7	81.1	82.1	0.59	1.21	1.81
5/16	19.7	3.8	79.8	81.9	3.84	2.41	6.25
5/24	14.0	3.9	80.0	81.9	2.10	2.24	4.34
5/31	15.8	3.9	80.1	81.9	2.59	2.10	4.69
6/7	18.0	4.0	78.8	81.9	3.26	3.55	6.81
6/15	17.3	4.1	79.0	81.9	3.01	3.32	6.33
6/21	19.8	4.1	78.3	81.7	3.81	4.00	7.81
6/30*	20.8	4.1	77.1	81.8	4.12	5.43	9.56
7/6	20.5	4.2	76.7	81.2	4.01	5.13	9.14
7/14	22.0	4.3	76.4	81.9	4.54	6.27	10.81
7/19	23.2	4.3	76.4	81.8	4.99	6.26	11.25
7/26	23.2	4.3	75.3	81.8	4.96	7.34	12.31
8/2	22.9	4.3	75.7	81.8	4.87	7.00	11.88
8/9	21.9	4.4	76.1	81.7	4.50	6.39	10.89
8/16	21.1	4.4	75.9	81.9	4.19	6.81	11.00
9/1	20.1	4.4	76.8	81.8	3.86	5.69	9.55
9/13	20.1	4.4	77.1	81.8	3.85	5.39	9.24
9/19	17.3	4.5	77.8	81.8	2.93	4.54	7.48
10/3	15.4	4.5	78.1	81.8	2.38	4.22	6.60
10/19	12.3	4.6	78.4	81.6	1.53	3.72	5.25
11/15	8.9	4.7	78.7	81.7	0.76	3.37	4.13
12/13	4.9	4.9	79.0	81.8	0.00	3.29	3.29
2/15/07	2.1	4.9	78.9	81.7	-0.39	3.35	2.97

*Profile from nearby Station 7 on this date due to equipment malfunction at Station 6

Table 5. Secchi Depths (m), March – December 2006.

	Dates										
Station	2/13	3/15	4/18	5/15	6/14	7/12	8/17	9/13	10/19	11/15	12/13
Western Sector											
1	0.60	0.75	0.50	0.85	7.60	10.50	10.20	9.50	1.80	1.85	1.40
2	0.70	0.80	0.50	0.75	6.60	9.80	9.80	6.00	1.85	1.80	1.30
3	0.80	0.75	0.75	0.90	7.10		9.00	7.00	1.85	1.60	-
4	0.70	0.70	0.65	1.15	6.60	11.60	8.80	6.50	1.90	1.60	-
5	0.70	0.75	0.60	1.50	6.10	9.40	7.50	7.50	1.50	1.80	-
6	0.80	0.75	0.55	1.40	5.50	9.20	7.00	5.90	1.90	2.10	1.30
Avg.	0.72	0.75	0.59	1.09	6.58	10.10	8.72	7.07	1.80	1.79	1.33
S.E.	0.03	0.01	0.04	0.13	0.30	0.44	0.51	0.55	0.06	0.08	0.03
n	6	6	6	6	6	5	6	6	6	6	3
Eastern Sector											
7	0.80	1.70	0.55	1.70	5.20	5.50	7.30	5.40	1.80	2.00	-
8	0.70	0.70	0.65	1.70	5.90	9.50	7.40	5.90	1.70	2.00	1.40
9	0.75	0.75	0.65	1.70	5.40	8.00	8.50	5.60	1.70	1.90	-
10	0.80	1.90	0.60	1.90	5.60	8.10	7.00	5.40	1.80	1.90	-
11	0.80	0.75	0.50	1.60	5.60	5.50	7.20	3.50	1.70	1.90	-
12	0.80	0.80	0.60	1.85	5.50	6.10	7.00	5.50	1.90	1.90	-
Avg.	0.78	0.74	0.59	1.74	5.53	7.12	7.40	5.22	1.77	1.93	1.40
S.E.	0.02	0.02	0.02	0.05	0.10	0.68	0.23	0.35	0.03	0.02	-
n	6	6	6	6	6	6	6	6	6	6	1
Total Lakewide											
Avg.	0.75	0.93	0.59	1.42	6.06	8.47	8.06	6.14	1.78	1.86	1.35
S.E.	0.02	0.12	0.02	0.12	0.22	0.62	0.33	0.42	0.03	0.04	0.03
n	12	12	12	12	12	11	12	12	12	12	4

Table 6: Dissolved Oxygen (mg l^{-1}) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	7.1	4.9	5.7	3.9	3.7	3.8	3.7	4.2	4.5	4.6	4.9
2	8.8	5.0	6.5	3.4	3.5	4.5	3.6	4.2	4.5	4.6	5.1
3	9.6	5.0	6.6	3.0	3.6	4.9	3.6	4.2	4.6	4.5	5.3
4	10.2	4.8	6.7	3.6	3.6	4.9	3.5	4.1	4.6	4.5	4.7
5	8.4	4.6	6.5	4.8	3.5	4.6	3.5	3.9	4.6	4.5	4.4
6	8.4	4.5	6.1	6.8	3.5	3.7	3.7	3.9	4.6	4.5	4.4
7	7.3	4.5	5.7	7.1	3.6	3.0	3.8	3.8	4.6	4.4	4.6
8	5.6	4.5	5.6	7.3	3.7	2.3	3.9	3.7	4.6	4.4	4.6
9	5.5	4.5	5.4	6.0	3.7	1.7	3.6	3.7	4.5	4.3	4.6
10	5.0	4.4	5.2	5.4	3.8	1.7	3.9	3.6	4.4	4.3	4.6
11	5.0	4.4	5.1	4.4	3.5	3.1	3.7	3.4	4.4	4.1	4.5
12	5.1	4.4	4.9	3.0	4.1	3.2	1.9	3.8	4.4	4.0	4.5
13	4.8	4.4	4.8	3.0	2.8	3.3	2.0	4.1	3.1	3.9	4.5
14	4.6	4.4	4.6	2.7	1.2	3.3	1.9	4.1	1.6	3.3	4.5
15	4.2	4.4	4.5	2.3	0.6	1.6	1.2	3.6	<0.5	0.9	4.5
16	3.6	4.4	4.3	1.5	<0.5	0.7	1.5	1.8	<0.5	<0.5	4.4
17	3.0	4.3	4.0	1.2	-	1.2	1.2	<0.5	<0.5	<0.5	4.3
18	2.8	4.3	3.1	0.5	-	1.7	<0.5	<0.5	<0.5	<0.5	3.6
19	2.5	4.3	1.2	<0.5	-	1.8	<0.5	-	<0.5	<0.5	<0.5
20	2.0	4.1	0.5	-	-	<0.5	-	-	-	-	-
21	1.4	3.9	<0.5	-	-	<0.5	-	-	-	-	-
22	1.2	3.7	-	-	-	<0.5	-	-	-	-	-
23	<0.5	3.5	-	-	-	<0.5	-	-	-	-	-
24	<0.5	2.6	-	-	-	<0.5	-	-	-	-	-
25	<0.5	1.7	-	-	-	-	-	-	-	-	-
26	<0.5	<0.5	-	-	-	-	-	-	-	-	-
27	-	<0.5	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-

Table 7. Ammonium (µM) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	-	-	-	-	-	-	-	-	-	-	-
2	1.0	0.4	0.9	0.9	3.2	1.3	2.1	0.9	0.1	1.1	1.2
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	1.0	0.6	1.0	1.0	2.0	8.2	1.6	1.5	0.1	1.2	1.1
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	1.1	-	-	-	-	-	-
12	1.0	0.6	0.9	0.9	1.1	2.9	4.1	0.3	0.1	1.1	1.3
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	1.9	0.4	1.0	0.8	5.4	1.5	1.2	0.2	16.5	23.8	1.1
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	9.3	0.8	5.1	12.1	29.6	26.0	34.5	29.3	30.5	68.3	59.3
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	18.0	5.1	6.0	24.8	30.8	38.9	43.7	41.8	39.6	71.6	74.0
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	48.2	54.4	43.5	37.6	39.0	41.8	54.3	49.2	59.0	70.3	83.7
29	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-
35	82.0	82.4	45.8	-	47.6	58.0	68.1	66.4	77.6	91.7	80.3
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-

Table 8. Ammonium (µM) at 7 stations in upper 9 m of water column, February – December, 2006.

Station	2/13	3/15	4/18	5/15	6/14	7/12	8/17	9/13	10/19	11/15	12/13
1	1.1	0.2	0.9	1.1	6.1	5.9	3.3	3.3	2.1	0.8	1.3
2	1.0	0.2	1.1	1.0	4.4	4.8	2.4	1.0	1.3	0.9	
5	1.0	0.2	1.0	1.1	5.2	6.6	1.4	1.0	1.2	1.9	
6	1.0	0.4	0.9	1.3	3.0	3.3	1.5	0.9	1.1	1.0	1.3
7	1.1	0.2	1.1	1.1	2.9	1.1	1.4	1.0	1.4	0.9	
8	1.1	0.2	1.1	1.1	3.4	3.7	1.3	0.9	1.3	1.5	1.3
11	1.0	0.3	1.1	0.9	3.9	1.1	2.9	1.0	1.4	1.9	
Mean	1.1	0.3	1.0	1.1	4.1	3.8	2.0	1.3	1.4	1.3	1.3
SE	0.02	0.03	0.03	0.04	0.45	0.81	0.31	0.34	0.12	0.18	0.01

Table 9. Chlorophyll *a* (µg l^{-3}) at Station 6, February – December 2006.

Depth (m)	2/14	3/15	4/19	5/16	6/15	7/14	8/16	9/19	10/19	11/15	12/13
1	-	-	-	-	-	-	-	-	-	-	-
2	55.8	58.7	50.8	4.3	1.5	2.9	1.4	3.5	9.7	11.8	32.1
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	79.6	62.9	53.4	47.5	3.2	1.2	2.1	3.1	7.3	11.0	26.4
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	5.9	-	-	-	-	-	-
12	65.3	62.6	59.9	57.7	6.8	2.0	4.6	13.9	8.9	11.4	27.0
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	44.1	63.2	58.7	59.2	65.6	31.2	17.8	60.8	59.3	52.8	27.2
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	51.3	70.5	66.7	56.4	51.4	46.2	52.0	58.7	52.5	47.6	49.3
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	49.6	53.8	56.7	52.4	53.4	49.4	43.2	47.1	47.4	48.8	46.3
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	48.8	47.8	54.6	49.6	54.9	44.7	48.9	48.2	45.2	45.8	41.9
29	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-

Table 10. Chlorophyll *a* (µg l^{-3}) at 7 stations in upper 9 m of water column, February – December 2006.

Station	2/13	3/15	4/18	5/15	6/14	7/12	8/17	9/13	10/19	11/15	12/13
1	67.6	65.0	57.2	32.6	1.0	0.6	0.9	1.2	9.7	11.2	26.7
2	61.5	66.8	51.9	31.8	1.5	0.7	1.5	3.3	9.7	11.1	
5	63.6	61.8	52.5	29.0	1.2	0.7	2.3	2.5	8.5	12.1	
6	61.3	60.3	52.7	26.2	2.3	1.3	2.7	2.5	9.1	12.2	26.0
7	59.9	62.6	51.1	22.9	2.5	3.9	2.7	3.3	6.9	10.7	
8	61.8	70.2	58.0	24.8	3.3	1.8	2.0	3.1	6.5	11.6	24.5
11	51.8	58.2	52.0	20.6	1.4	5.3	2.7	6.8	7.8	10.2	
Mean	61.1	63.6	53.6	26.8	1.9	2.0	2.1	3.2	8.3	11.3	25.8
SE	1.81	1.54	1.04	1.71	0.32	0.70	0.26	0.65	0.50	0.27	0.66

Table 11a. *Artemia* lake and sector means, 2006.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Lakewide Mean:										
2/13	13,707	15	23	0	12	0	0	12	35	13,758
3/15	46,843	13	10	0	12	0	0	12	22	46,878
4/18	92,894	0	2	0	3	0	0	3	5	92,899
5/15	15,345	6,009	10,181	40	13,964	0	0	14,004	24,185	45,540
5/24	7,539	1,972	20,550	1,315	19,463	174	107	21,060	41,610	51,120
5/31	7,445	1,154	20,282	2,763	16,231	805	268	20,067	40,349	48,947
6/7	12,931	885	26,117	2,508	15,909	4,239	724	23,380	49,497	63,313
6/14	12,636	1,368	30,745	2,200	13,441	8,665	698	25,003	55,748	69,752
6/21	13,508	483	23,159	1,147	10,107	7,981	765	20,000	43,159	57,150
6/30	9,873	268	22,522	1,395	8,317	8,826	456	18,994	41,516	51,657
7/6	12,918	456	26,318	1,516	8,813	11,268	637	22,233	48,551	61,925
7/12	11,301	543	26,740	1,476	7,914	12,824	818	23,032	49,772	61,616
7/19	8,665	188	21,972	1,087	4,910	9,162	564	15,721	37,693	46,546
7/26	7,357	80	17,907	879	3,286	7,022	309	11,496	29,403	36,841
8/2	4,326	0	16,848	798	2,395	6,962	429	10,584	27,431	31,757
8/9	3,689	13	13,521	771	1,335	7,049	362	9,517	23,038	26,740
8/17	2,817	0	15,312	671	959	7,565	396	9,591	24,903	27,720
9/1	2,708	7	10,813	362	432	5,077	124	5,996	16,809	19,524
9/13	1,727	8	8,018	188	137	2,965	179	3,469	11,487	13,223
10/3	1,211	99	2,659	45	121	1,598	85	1,849	4,509	5,818
10/19	527	48	59	0	64	0	0	64	122	697
11/15	349	7	17	0	2	0	0	2	18	374
12/13	879	7	0	0	7	0	0	7	7	892
Western Sector Mean:										
2/13	9,182	13	20	0	3	0	0	3	23	9,219
3/15	6,281	0	0	0	0	0	0	0	0	6,281
4/18	152,227	0	3	0	7	0	0	7	10	152,237
5/15	11,751	3,810	5,500	27	7,324	0	0	7,351	12,850	28,410
5/24	6,707	1,046	16,955	966	12,904	134	215	14,219	31,174	38,927
5/31	7,995	966	17,250	1,959	11,053	483	81	13,575	30,825	39,786
6/7	14,755	912	30,369	2,897	15,667	5,097	858	24,520	54,889	70,557
6/14	11,482	1,985	42,871	1,986	14,594	11,536	805	28,920	71,791	85,258
6/21	13,521	483	31,818	1,019	12,663	11,107	1,073	25,862	57,679	71,683
6/30	8,853	322	32,515	1,234	11,536	9,121	537	22,428	54,943	64,118
7/6	10,677	805	42,817	1,932	14,004	16,204	966	33,105	75,922	87,404
7/12	11,804	1,020	41,583	1,771	14,433	16,418	1,073	33,696	75,279	88,102
7/19	7,753	349	34,769	1,583	8,719	13,092	671	24,064	58,833	66,935
7/26	5,070	161	28,223	1,449	5,956	9,121	429	16,955	45,178	50,409
8/2	3,622	0	20,939	1,047	3,528	8,397	523	13,494	34,433	38,055
8/9	3,353	0	19,624	1,207	2,240	8,504	335	12,287	31,911	35,265
8/17	3,031	0	23,796	966	1,664	10,490	537	13,655	37,452	40,483
9/1	2,817	0	17,223	577	764	8,250	188	9,779	27,002	29,819
9/13	1,724	7	11,932	262	215	3,796	235	4,507	16,439	18,169
10/3	1,358	114	4,722	91	171	2,985	158	3,404	8,125	9,598
10/19	547	43	74	0	74	0	0	74	148	738
11/15	168	0	17	0	3	0	0	3	20	188
12/13	262	10	0	0	0	0	0	0	0	272

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11a (cont.). *Artemia* lake and sector means, 2006.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Eastern Sector Mean:										
2/13	18,233	17	27	0	20	0	0	20	47	18,296
3/15	87,404	27	20	0	23	0	0	23	44	87,475
4/18	33,561	0	0	0	0	0	0	0	0	33,561
5/15	18,940	8,209	14,863	54	20,604	0	0	20,657	35,520	62,669
5/24	8,370	2,897	24,145	1,663	26,023	215	0	27,901	52,046	63,313
5/31	6,895	1,342	23,313	3,568	21,408	1,127	456	26,559	49,873	58,109
6/7	11,107	858	21,865	2,119	16,150	3,380	590	22,240	44,105	56,070
6/14	13,789	751	18,618	2,415	12,287	5,795	590	21,087	39,705	54,246
6/21	13,494	483	14,500	1,274	7,552	4,856	456	14,138	28,638	42,616
6/30	10,892	215	12,529	1,556	5,097	8,531	376	15,560	28,089	39,195
7/6	15,158	107	9,819	1,100	3,622	6,331	309	11,362	21,180	36,445
7/12	10,798	67	11,898	1,181	1,395	9,229	564	12,368	24,266	35,131
7/19	9,578	27	9,175	590	1,100	5,231	456	7,377	16,553	26,157
7/26	9,645	0	7,592	309	617	4,923	188	6,036	13,628	23,273
8/2	5,030	0	12,757	550	1,261	5,526	335	7,673	20,429	25,459
8/9	4,024	27	7,418	335	429	5,594	389	6,747	14,165	18,216
8/17	2,603	0	6,828	375	255	4,641	255	5,527	12,354	14,956
9/1	2,599	13	4,403	147	100	1,905	60	2,213	6,616	9,229
9/13	1,730	10	4,105	114	60	2,133	124	2,432	6,536	8,277
10/3	1,063	84	597	0	70	211	13	295	892	2,039
10/19	507	54	43	0	54	0	0	54	97	657
11/15	530	13	17	0	0	0	0	0	17	560
12/13	2,113	0	0	0	20	0	0	20	20	2,133

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11b. Standard errors of *Artemia* sector means (Table 11a), 2006.

	Instars 1-7	8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
SE of Lakewide Mean:										
2/13	4,601	8	8	0	6	0	0	6	12	4,616
3/15	16,417	9	6	0	7	0	0	7	12	16,427
4/18	34,591	0	2	0	3	0	0	3	5	34,594
5/15	1,667	945	1,739	29	2,285	0	0	2,284	3,842	5,989
5/24	603	328	1,789	336	2,529	61	57	2,707	4,283	4,901
5/31	711	133	1,565	415	2,385	139	109	2,761	4,048	4,026
6/7	1,594	213	2,632	381	1,675	486	159	2,397	4,648	5,530
6/14	1,124	412	5,646	408	1,561	1,286	153	2,649	7,882	8,292
6/21	1,845	109	3,338	155	1,183	1,433	172	2,541	5,720	6,069
6/30	1,077	85	3,549	186	1,476	681	101	1,957	4,952	4,895
7/6	1,935	174	5,637	235	1,723	1,971	182	3,786	9,239	9,002
7/12	2,070	217	5,626	340	2,604	2,761	227	5,573	10,634	12,264
7/19	1,147	106	7,042	305	1,956	2,488	109	4,754	11,737	12,296
7/26	1,352	42	3,306	218	847	1,131	83	1,960	5,181	4,850
8/2	1,181	0	3,893	123	829	1,154	111	1,857	5,613	5,876
8/9	347	13	2,499	206	405	934	62	1,438	3,756	3,729
8/17	396	0	5,362	257	514	1,870	154	2,757	8,084	8,302
9/1	333	4	3,166	154	203	1,587	32	1,943	5,091	5,031
9/13	224	5	2,472	56	53	511	36	621	3,015	3,000
10/3	134	19	1,364	27	34	970	52	1,081	2,442	2,529
10/19	107	15	17	0	12	0	0	12	26	139
11/15	66	4	3	0	2	0	0	2	4	69
12/13	622	7	0	0	7	0	0	7	7	626
SE of Western Sector Mean:										
2/13	2,335	13	13	0	3	0	0	3	12	2,356
3/15	737	0	0	0	0	0	0	0	0	737
4/18	61,257	0	3	0	7	0	0	7	10	61,262
5/15	884	841	1,611	27	1,410	0	0	1,418	2,936	4,455
5/24	556	185	2,297	335	1,239	65	99	1,366	3,306	3,531
5/31	1,062	161	1,710	370	1,028	131	55	1,236	2,722	3,265
6/7	1,863	347	3,766	715	2,568	502	284	3,708	6,689	6,934
6/14	1,456	745	8,442	799	2,730	1,516	260	4,180	11,784	12,587
6/21	1,592	199	3,788	211	1,444	2,059	230	3,023	6,422	6,464
6/30	1,130	144	3,776	226	2,288	1,123	136	3,151	5,430	5,621
7/6	1,194	285	4,645	332	968	2,145	276	2,441	6,165	6,438
7/12	3,455	337	5,780	574	3,545	4,722	429	8,916	13,414	16,894
7/19	1,661	197	12,302	523	3,309	4,509	146	8,368	20,550	22,090
7/26	795	72	1,987	260	517	1,796	136	2,047	3,834	4,039
8/2	870	0	6,931	165	1,448	1,528	163	2,538	9,403	9,927
8/9	318	0	3,397	319	627	1,416	107	2,220	5,223	5,393
8/17	485	0	9,826	486	970	3,369	296	5,079	14,861	15,251
9/1	412	0	5,201	291	369	2,639	45	3,282	8,455	8,168
9/13	341	7	4,411	100	97	764	57	951	5,239	5,118
10/3	157	34	2,541	49	64	1,831	98	2,039	4,573	4,725
10/19	132	13	32	0	17	0	0	17	45	182
11/15	35	0	6	0	3	0	0	3	7	40
12/13	141	10	0	0	0	0	0	0	0	151

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11b (cont.). Standard errors of *Artemia* sector means (Table 11a), 2006.

	Instars 1-7	8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Eastern Sector Mean:										
2/13	8,916	10	11	0	10	0	0	10	20	8,943
3/15	22,962	17	10	0	12	0	0	12	22	22,968
4/18	10,206	0	0	0	0	0	0	0	0	10,206
5/15	2,507	1,133	1,394	54	1,831	0	0	1,799	2,219	4,537
5/24	1,008	311	1,906	578	3,066	107	0	3,416	5,122	5,808
5/31	986	193	2,045	603	3,641	161	188	3,894	5,332	5,203
6/7	2,525	281	3,010	258	2,394	703	154	3,319	6,218	8,093
6/14	1,706	198	3,192	272	1,653	1,296	175	2,697	5,614	6,921
6/21	3,526	110	2,168	234	1,208	939	197	2,353	4,285	5,982
6/30	1,847	99	1,103	302	457	864	154	1,483	2,506	3,420
7/6	3,611	54	3,059	251	1,157	1,656	164	3,135	6,158	7,447
7/12	2,611	53	4,213	378	519	2,465	130	3,412	7,576	9,785
7/19	1,642	27	1,155	193	274	845	163	1,248	2,250	3,314
7/26	2,306	0	1,261	107	193	803	77	884	1,969	3,678
8/2	2,277	0	3,454	122	640	1,644	156	2,310	5,531	6,126
8/9	619	27	1,021	94	27	994	73	1,052	1,815	1,742
8/17	660	0	1,088	136	151	787	96	1,019	1,929	2,343
9/1	560	8	780	31	36	297	31	330	998	1,508
9/13	323	7	1,142	43	25	538	32	600	1,654	1,902
10/3	213	19	182	0	13	121	8	133	298	325
10/19	182	27	11	0	19	0	0	19	25	225
11/15	68	7	3	0	0	0	0	0	3	74
12/13	0	0	0	0	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11c. Percentage in different classes for *Artemia* sector means (Table 11a), 2006.

	Instars 1-7	8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Lakewide (%):										
2/13	99.6	0.1	0.2	0.0	100.0	0.0	0.0	0.1	0.3	100
3/15	99.9	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100
4/18	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100
5/15	33.7	13.2	22.4	0.3	99.7	0.0	0.0	30.8	53.1	100
5/24	14.7	3.9	40.2	6.2	92.4	0.8	0.5	41.2	81.4	100
5/31	15.2	2.4	41.4	13.8	80.9	4.0	1.3	41.0	82.4	100
6/7	20.4	1.4	41.3	10.7	68.0	18.1	3.1	36.9	78.2	100
6/14	18.1	2.0	44.1	8.8	53.8	34.7	2.8	35.8	79.9	100
6/21	23.6	0.8	40.5	5.7	50.5	39.9	3.8	35.0	75.5	100
6/30	19.1	0.5	43.6	7.3	43.8	46.5	2.4	36.8	80.4	100
7/6	20.9	0.7	42.5	6.8	39.6	50.7	2.9	35.9	78.4	100
7/12	18.3	0.9	43.4	6.4	34.4	55.7	3.6	37.4	80.8	100
7/19	18.6	0.4	47.2	6.9	31.2	58.3	3.6	33.8	81.0	100
7/26	20.0	0.2	48.6	7.6	28.6	61.1	2.7	31.2	79.8	100
8/2	13.6	0.0	53.1	7.5	22.6	65.8	4.1	33.3	86.4	100
8/9	13.8	0.1	50.6	8.1	14.0	74.1	3.8	35.6	86.2	100
8/17	10.2	0.0	55.2	7.0	10.0	78.9	4.1	34.6	89.8	100
9/1	13.9	0.0	55.4	6.0	7.2	84.7	2.1	30.7	86.1	100
9/13	13.1	0.1	60.6	5.4	4.0	85.5	5.2	26.2	86.9	100
10/3	20.8	1.7	45.7	2.4	6.5	86.4	4.6	31.8	77.5	100
10/19	75.5	6.9	8.4	0.0	100.0	0.0	0.0	9.1	17.5	100
11/15	93.3	1.8	4.5	0.0	100.0	0.0	0.0	0.4	4.9	100
12/13	98.5	0.7	0.0	0.0	100.0	0.0	0.0	0.7	0.7	100
Western Sector (%):										
2/13	99.6	0.1	0.2	0.0	100.0	0.0	0.0	0.0	0.3	100
3/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
4/18	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100
5/15	41.4	13.4	19.4	0.4	99.6	0.0	0.0	25.9	45.2	100
5/24	17.2	2.7	43.6	6.8	90.8	0.9	1.5	36.5	80.1	100
5/31	20.1	2.4	43.4	14.4	81.4	3.6	0.6	34.1	77.5	100
6/7	20.9	1.3	43.0	11.8	63.9	20.8	3.5	34.8	77.8	100
6/14	13.5	2.3	50.3	6.9	50.5	39.9	2.8	33.9	84.2	100
6/21	18.9	0.7	44.4	3.9	49.0	42.9	4.1	36.1	80.5	100
6/30	13.8	0.5	50.7	5.5	51.4	40.7	2.4	35.0	85.7	100
7/6	12.2	0.9	49.0	5.8	42.3	48.9	2.9	37.9	86.9	100
7/12	13.4	1.2	47.2	5.3	42.8	48.7	3.2	38.2	85.4	100
7/19	11.6	0.5	51.9	6.6	36.2	54.4	2.8	36.0	87.9	100
7/26	10.1	0.3	56.0	8.5	35.1	53.8	2.5	33.6	89.6	100
8/2	9.5	0.0	55.0	7.8	26.1	62.2	3.9	35.5	90.5	100
8/9	9.5	0.0	55.6	9.8	18.2	69.2	2.7	34.8	90.5	100
8/17	7.5	0.0	58.8	7.1	12.2	76.8	3.9	33.7	92.5	100
9/1	9.4	0.0	57.8	5.9	7.8	84.4	1.9	32.8	90.6	100
9/13	9.5	0.0	65.7	5.8	4.8	84.2	5.2	24.8	90.5	100
10/3	14.2	1.2	49.2	2.7	5.0	87.7	4.6	35.5	84.7	100
10/19	74.1	5.9	10.0	0.0	100.0	0.0	0.0	10.0	20.0	100
11/15	89.4	0.0	8.9	0.0	100.0	0.0	0.0	1.8	10.6	100
12/13	96.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11c (cont.). Percentage in different classes for *Artemia* sector means (Table 11a), 2006.

	Instars 1-7	8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Eastern Sector Mean:										
2/13	99.7	0.1	0.1	0.0	100.0	0.0	0.0	0.1	0.3	100
3/15	99.9	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100
4/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
5/15	30.2	13.1	23.7	0.3	99.7	0.0	0.0	33.0	56.7	100
5/24	13.2	4.6	38.1	6.0	93.3	0.8	0.0	44.1	82.2	100
5/31	11.9	2.3	40.1	13.4	80.6	4.2	1.7	45.7	85.8	100
6/7	19.8	1.5	39.0	9.5	72.6	15.2	2.7	39.7	78.7	100
6/14	25.4	1.4	34.3	11.5	58.3	27.5	2.8	38.9	73.2	100
6/21	31.7	1.1	34.0	9.0	53.4	34.3	3.2	33.2	67.2	100
6/30	27.8	0.5	32.0	10.0	32.8	54.8	2.4	39.7	71.7	100
7/6	41.6	0.3	26.9	9.7	31.9	55.7	2.7	31.2	58.1	100
7/12	30.7	0.2	33.9	9.5	11.3	74.6	4.6	35.2	69.1	100
7/19	36.6	0.1	35.1	8.0	14.9	70.9	6.2	28.2	63.3	100
7/26	41.4	0.0	32.6	5.1	10.2	81.6	3.1	25.9	58.6	100
8/2	19.8	0.0	50.1	7.2	16.4	72.0	4.4	30.1	80.2	100
8/9	22.1	0.1	40.7	5.0	6.4	82.9	5.8	37.0	77.8	100
8/17	17.4	0.0	45.7	6.8	4.6	84.0	4.6	37.0	82.6	100
9/1	28.2	0.1	47.7	6.7	4.5	86.1	2.7	24.0	71.7	100
9/13	20.9	0.1	49.6	4.7	2.5	87.7	5.1	29.4	79.0	100
10/3	52.1	4.1	29.3	0.0	23.8	71.6	4.5	14.5	43.7	100
10/19	77.1	8.1	6.6	0.0	100.0	0.0	0.0	8.1	14.8	100
11/15	94.6	2.4	3.0	0.0	0.0	0.0	0.0	0.0	3.0	100
12/13	99.1	0.0	0.0	0.0	100.0	0.0	0.0	0.9	0.9	100

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 12. Lakewide *Artemia* instar analysis, 2006

	Instars									
	1	2	3	4	5	6	7	8-11	adults	total
Mean:										
2/13	8,793	354	190	63	32	6		6	20	9,462
3/15	24,740	2,630	279	46		46		23	17	27,781
4/18	27,675	63,271	8,991	1,454	368					101,759
5/15	368	989	1,656	3,403	3,472	2,920	2,070	5,013	21,868	41,759
5/24	1,127	460	851	1,334	1,150	1,196	1,012	2,093	40,241	49,462
5/31	3,495	828	276	897	552	437	391	1,150	35,091	43,116
6/7	9,957	897	92	575	276	345	690	690	48,704	62,225
6/14	8,416	1,886	506	230	184	230	276	1,610	57,810	71,147
6/21	9,830	1,276	138	115	184	149	103	322	45,289	57,407
6/30	5,772	2,506	92	184		69	115	299	39,092	48,129
7/6	6,496	2,541	11	92		103	92	621	59,454	69,411
7/12	6,404	4,530	483	195	184	92	195	414	57,051	69,549
7/19	4,392	2,989	253	92		23	276	276	43,783	52,084
7/26	3,656	2,460	724	207				92	32,814	39,954
8/2	2,070	2,426	885	115	23				31,653	37,171
8/9	2,058	713	195	115					25,594	28,675
8/17	1,552	1,046	161	46	69	34	23		27,318	30,250
9/1	874	1,020	221	129	86		11	11	17,973	20,328
9/13	460	299	201	239	63	75	3	14	13,150	14,504
10/3	141	236	256	270	299	138	66	112	6,821	8,339
10/19	52	83	100	118	141	106	75	60	152	888
11/15	141	112	54	31	20	9	14	6	26	414
12/13	610	161	33	47	20		7	7	7	892
Standard error of the mean:										
2/13	2,553	93	84	19	22	6		4	8	2,729
3/15	8,500	1,273	191	46		46		15	14	9,938
4/18	11,173	32,560	4,886	811	237					48,848
5/15	160	242	392	736	614	626	327	832	4,662	7,229
5/24	256	174	210	459	174	260	152	480	6,960	7,916
5/31	638	194	110	179	195	160	121	181	4,069	3,424
6/7	1,900	276	48	210	109	181	255	255	7,156	7,982
6/14	1,134	317	271	153	96	116	130	681	13,417	14,297
6/21	1,593	419	96	76	55	94	57	99	9,141	10,407
6/30	936	523	69	119		48	91	124	6,131	6,365
7/6	1,074	633	11	92		91	92	278	12,638	13,540
7/12	2,288	982	168	99	184	92	116	182	15,799	18,841
7/19	795	807	105	48		23	192	175	20,022	21,272
7/26	827	777	294	58				59	7,836	7,400
8/2	521	937	568	91	23				8,988	9,238
8/9	404	105	93	34					5,617	5,796
8/17	438	200	86	34	45	24	15		13,855	14,233
9/1	174	278	78	41	45		7	7	8,303	8,243
9/13	102	86	94	73	31	26	3	7	5,063	5,036
10/3	38	39	50	44	89	34	19	29	4,061	4,171
10/19	17	39	23	34	39	25	32	24	40	209
11/15	28	38	14	13	9	4	7	6	4	99
12/13	455	121	13	18	12		7	7	7	626

(continued on next page)

All data in this table are from stations 1, 2, 5, 6, 7, 8, and 11 only.

Table 12 (cont.). Lakewide *Artemia* instar analysis, 2006

	Instars									
	1	2	3	4	5	6	7	8-11	adults	total
Percentage in different age classes:										
2/13	92.9	3.7	2.0	0.7	0.3	0.1		0.1	0.2	100
3/15	89.1	9.5	1.0	0.2		0.2		0.1	0.1	100
4/18	27.2	62.2	8.8	1.4	0.4					100
5/15	0.9	2.4	4.0	8.1	8.3	7.0	5.0	12.0	52.4	100
5/24	2.3	0.9	1.7	2.7	2.3	2.4	2.0	4.2	81.4	100
5/31	8.1	1.9	0.6	2.1	1.3	1.0	0.9	2.7	81.4	100
6/7	16.0	1.4	0.1	0.9	0.4	0.6	1.1	1.1	78.3	100
6/14	11.8	2.7	0.7	0.3	0.3	0.3	0.4	2.3	81.3	100
6/21	17.1	2.2	0.2	0.2	0.3	0.3	0.2	0.6	78.9	100
6/30	12.0	5.2	0.2	0.4		0.1	0.2	0.6	81.2	100
7/6	9.4	3.7	0.0	0.1		0.1	0.1	0.9	85.7	100
7/12	9.2	6.5	0.7	0.3	0.3	0.1	0.3	0.6	82.0	100
7/19	8.4	5.7	0.5	0.2		0.0	0.5	0.5	84.1	100
7/26	9.2	6.2	1.8	0.5				0.2	82.1	100
8/2	5.6	6.5	2.4	0.3	0.1				85.2	100
8/9	7.2	2.5	0.7	0.4					89.3	100
8/17	5.1	3.5	0.5	0.2	0.2	0.1	0.1		90.3	100
9/1	4.3	5.0	1.1	0.6	0.4		0.1	0.1	88.4	100
9/13	3.2	2.1	1.4	1.6	0.4	0.5	0.0	0.1	90.7	100
10/3	1.7	2.8	3.1	3.2	3.6	1.7	0.8	1.3	81.8	100
10/19	5.8	9.4	11.3	13.3	15.8	12.0	8.4	6.8	17.1	100
11/15	34.0	27.1	13.1	7.6	4.8	2.1	3.5	1.4	6.2	100
12/13	68.4	18.0	3.7	5.2	2.2		0.7	0.7	0.7	100

All data in this table are from stations 1, 2, 5, 6, 7, 8, and 11 only.

Table 13a. *Artemia* reproductive summary, lake and sector means, 2006.

		Adult Females				
	Total	Ovigery	e	?	c	n
Lakewide Mean:						
2/13	12	0	12	0	0	0
3/15	12	0	12	0	0	0
4/18	3	0	3	0	0	0
5/15	14,004	40	13,964	40	0	0
5/24	21,060	1,596	19,463	1,315	174	107
5/31	20,067	3,837	16,231	2,763	805	268
6/7	23,380	7,471	15,909	2,508	4,239	724
6/14	25,003	11,563	13,441	2,200	8,665	698
6/21	20,000	9,893	10,107	1,147	7,981	765
6/30	18,994	10,677	8,317	1,395	8,826	456
7/6	22,233	13,421	8,813	1,516	11,268	637
7/12	23,032	15,117	7,914	1,476	12,824	818
7/19	15,721	10,812	4,910	1,087	9,162	564
7/26	11,496	8,209	3,286	879	7,022	309
8/2	10,584	8,189	2,395	798	6,962	429
8/9	9,517	8,182	1,335	771	7,049	362
8/17	9,591	8,632	959	671	7,565	396
9/1	5,996	5,563	432	362	5,077	124
9/13	3,469	3,332	137	188	2,965	179
10/3	1,849	1,729	121	45	1,598	85
10/19	64	0	64	0	0	0
11/15	2	0	2	0	0	0
12/13	7	0	7	0	0	0
Western Sector Mean:						
2/13	3	0	3	0	0	0
3/15	0	0	0	0	0	0
4/18	7	0	7	0	0	0
5/15	7,351	27	7,324	27	0	0
5/24	14,219	1,315	12,904	966	134	215
5/31	13,575	2,522	11,053	1,959	483	81
6/7	24,520	8,853	15,667	2,897	5,097	858
6/14	28,920	14,327	14,594	1,986	11,536	805
6/21	25,862	13,199	12,663	1,019	11,107	1,073
6/30	22,428	10,892	11,536	1,234	9,121	537
7/6	33,105	19,101	14,004	1,932	16,204	966
7/12	33,696	19,262	14,433	1,771	16,418	1,073
7/19	24,064	15,346	8,719	1,583	13,092	671
7/26	16,955	10,999	5,956	1,449	9,121	429
8/2	13,494	9,967	3,528	1,047	8,397	523
8/9	12,287	10,047	2,240	1,207	8,504	335
8/17	13,655	11,992	1,664	966	10,490	537
9/1	9,779	9,014	764	577	8,250	188
9/13	4,507	4,293	215	262	3,796	235
10/3	3,404	3,233	171	91	2,985	158
10/19	74	0	74	0	0	0
11/15	3	0	3	0	0	0
12/13	0	0	0	0	0	0

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 13a (continued). *Artemia* reproductive summary, lake and sector means, 2006.

	Adult Females					
	Total	Ovigery	e	?	c	n
Eastern Sector Mean:						
2/13	20	0	20	0	0	0
3/15	23	0	23	0	0	0
4/18	0	0	0	0	0	0
5/15	20,657	54	20,604	54	0	0
5/24	27,901	1,878	26,023	1,663	215	
5/31	26,559	5,151	21,408	3,568	1,127	456
6/7	22,240	6,090	16,150	2,119	3,380	590
6/14	21,087	8,800	12,287	2,415	5,795	590
6/21	14,138	6,586	7,552	1,274	4,856	456
6/30	15,560	10,463	5,097	1,556	8,531	376
7/6	11,362	7,740	3,622	1,100	6,331	309
7/12	12,368	10,973	1,395	1,181	9,229	564
7/19	7,377	6,278	1,100	590	5,231	456
7/26	6,036	5,419	617	309	4,923	188
8/2	7,673	6,412	1,261	550	5,526	335
8/9	6,747	6,318	429	335	5,594	389
8/17	5,527	5,271	255	375	4,641	255
9/1	2,213	2,112	100	147	1,905	60
9/13	2,432	2,371	60	114	2,133	124
10/3	295	225	70	0	211	13
10/19	54	0	54	0	0	0
11/15	0	0	0	0	0	0
12/13	20	0	20	0	0	0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 13b. Standard errors of *Artemia* reproductive summary (Table 13a), 2006.

	Adult Females					
	Total	Ovigery	e	?	c	n
Standard Error of Lakewide Mean:						
2/13	6	0	6	0	0	0
3/15	7	0	7	0	0	0
4/18	3	0	3	0	0	0
5/15	2,284	29	2,285	29	0	0
5/24	2,707	362	2,529	336	61	57
5/31	2,761	482	2,385	415	139	109
6/7	2,397	850	1,675	381	486	159
6/14	2,649	1,480	1,561	408	1,286	153
6/21	2,541	1,518	1,183	155	1,433	172
6/30	1,957	807	1,476	186	681	101
7/6	3,786	2,190	1,723	235	1,971	182
7/12	5,573	3,249	2,604	340	2,761	227
7/19	4,754	2,834	1,956	305	2,488	109
7/26	1,960	1,344	847	218	1,131	83
8/2	1,857	1,285	829	123	1,154	111
8/9	1,438	1,103	405	206	934	62
8/17	2,757	2,255	514	257	1,870	154
9/1	1,943	1,754	203	154	1,587	32
9/13	621	578	53	56	511	36
10/3	1,081	1,047	34	27	970	52
10/19	12	0	12	0	0	0
11/15	2	0	2	0	0	0
12/13	7	0	7	0	0	0
Standard Error of Western Sector Mean:						
2/13	3	0	3	0	0	0
3/15	0	0	0	0	0	0
4/18	7	0	7	0	0	0
5/15	1,418	27	1,410	27	0	0
5/24	1,366	419	1,239	335	65	99
5/31	1,236	329	1,028	370	131	55
6/7	3,708	1,198	2,568	715	502	284
6/14	4,180	1,913	2,730	799	1,516	260
6/21	3,023	2,095	1,444	211	2,059	230
6/30	3,151	1,237	2,288	226	1,123	136
7/6	2,441	2,020	968	332	2,145	276
7/12	8,916	5,585	3,545	574	4,722	429
7/19	8,368	5,071	3,309	523	4,509	146
7/26	2,047	1,997	517	260	1,796	136
8/2	2,538	1,651	1,448	165	1,528	163
8/9	2,220	1,699	627	319	1,416	107
8/17	5,079	4,129	970	486	3,369	296
9/1	3,282	2,946	369	291	2,639	45
9/13	951	871	97	100	764	57
10/3	2,039	1,976	64	49	1,831	98
10/19	17	0	17	0	0	0
11/15	3	0	3	0	0	0
12/13	0	0	0	0	0	0

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 13b (continued). *Artemia* reproductive summary, lake and sector means, 2006.

	Adult Females					
	Total	Ovigery	e	?	c	n
Standard Error of Eastern Sector Mean:						
2/13	10	0	10	0	0	0
3/15	12	0	12	0	0	0
4/18	0	0	0	0	0	0
5/15	1,799	54	1,831	54	0	0
5/24	3,416	608	3,066	578	107	0
5/31	3,894	470	3,641	603	161	188
6/7	3,319	989	2,394	258	703	154
6/14	2,697	1,709	1,653	272	1,296	175
6/21	2,353	1,174	1,208	234	939	197
6/30	1,483	1,148	457	302	864	154
7/6	3,135	2,029	1,157	251	1,656	164
7/12	3,412	2,897	519	378	2,465	130
7/19	1,248	1,188	274	193	845	163
7/26	884	918	193	107	803	77
8/2	2,310	1,810	640	122	1,644	156
8/9	1,052	1,036	27	94	994	73
8/17	1,019	904	151	136	787	96
9/1	330	308	36	31	297	31
9/13	600	584	25	43	538	32
10/3	133	127	13	0	121	8
10/19	19	0	19	0	0	0
11/15	0	0	0	0	0	0
12/13	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 13c. *Artemia* percentages in different reproductive categories (Table 13a), 2006.

		Adult Females				
	Total	Ovigery	e	?	c	n
Lakewide Mean (%):						
2/13	100	0.0	100.0	0.0	0.0	0.0
3/15	100	0.0	100.0	0.0	0.0	0.0
4/18	100	0.0	100.0	0.0	0.0	0.0
5/15	100	0.3	99.7	100.0	0.0	0.0
5/24	100	7.6	92.4	82.4	61.9	38.1
5/31	100	19.1	80.9	72.0	75.0	25.0
6/7	100	32.0	68.0	33.6	85.4	14.6
6/14	100	46.2	53.8	19.0	92.5	7.5
6/21	100	49.5	50.5	11.6	91.3	8.7
6/30	100	56.2	43.8	13.1	95.1	4.9
7/6	100	60.4	39.6	11.3	94.6	5.4
7/12	100	65.6	34.4	9.8	94.0	6.0
7/19	100	68.8	31.2	10.1	94.2	5.8
7/26	100	71.4	28.6	10.7	95.8	4.2
8/2	100	77.4	22.6	9.7	94.2	5.8
8/9	100	86.0	14.0	9.4	95.1	4.9
8/17	100	90.0	10.0	7.8	95.0	5.0
9/1	100	92.8	7.2	6.5	97.6	2.4
9/13	100	96.0	4.0	5.6	94.3	5.7
10/3	100	93.5	6.5	2.6	94.9	5.1
10/19	100	0.0	100.0	0.0	0.0	0.0
11/15	100	0.0	100.0	0.0	0.0	0.0
12/13	100	0.0	100.0	0.0	0.0	0.0
Western Sector Mean (%):						
2/13	100	0.0	100.0	0.0	0.0	0.0
3/15	0	0.0	0.0	0.0	0.0	0.0
4/18	100		100.0	0.0	0.0	0.0
5/15	100	0.4	99.6	100.0	0.0	0.0
5/24	100	9.2	90.8	73.5	38.5	61.5
5/31	100	18.6	81.4	77.7	85.7	14.3
6/7	100	36.1	63.9	32.7	85.6	14.4
6/14	100	49.5	50.5	13.9	93.5	6.5
6/21	100	51.0	49.0	7.7	91.2	8.8
6/30	100	48.6	51.4	11.3	94.4	5.6
7/6	100	57.7	42.3	10.1	94.4	5.6
7/12	100	57.2	42.8	9.2	93.9	6.1
7/19	100	63.8	36.2	10.3	95.1	4.9
7/26	100	64.9	35.1	13.2	95.5	4.5
8/2	100	73.9	26.1	10.5	94.1	5.9
8/9	100	81.8	18.2	12.0	96.2	3.8
8/17	100	87.8	12.2	8.1	95.1	4.9
9/1	100	92.2	7.8	6.4	97.8	2.2
9/13	100	95.2	4.8	6.1	94.2	5.8
10/3	100	95.0	5.0	2.8	95.0	5.0
10/19	100	0.0	100.0	0.0	0.0	0.0
11/15	100	0.0	100.0	0.0	0.0	0.0
12/13	0	0.0	0.0	0.0	0.0	0.0

(continued on next page)

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 13c (cont.). *Artemia* percentages in different reproductive categories (Table 13a), 2006.

	Adult Females					
	Total	Ovigery	e	?	c	n
Eastern Sector Mean (%):						
2/13	100	0.0	100.0	0.0	0.0	0.0
3/15	100	0.0	100.0	0.0	0.0	0.0
4/18	0	0.0	0.0	0.0	0.0	0.0
5/15	100	0.3	99.7	100.0	0.0	0.0
5/24	100	6.7	93.3	88.6	100.0	0.0
5/31	100	19.4	80.6	69.3	71.2	28.8
6/7	100	27.4	72.6	34.8	85.1	14.9
6/14	100	41.7	58.3	27.4	90.8	9.2
6/21	100	46.6	53.4	19.3	91.4	8.6
6/30	100	67.2	32.8	14.9	95.8	4.2
7/6	100	68.1	31.9	14.2	95.4	4.6
7/12	100	88.7	11.3	10.8	94.2	5.8
7/19	100	85.1	14.9	9.4	92.0	8.0
7/26	100	89.8	10.2	5.7	96.3	3.7
8/2	100	83.6	16.4	8.6	94.3	5.7
8/9	100	93.6	6.4	5.3	93.5	6.5
8/17	100	95.4	4.6	7.1	94.8	5.2
9/1	100	95.5	4.5	7.0	96.9	3.1
9/13	100	97.5	2.5	4.8	94.5	5.5
10/3	100	76.2	23.8	0.0	94.1	5.9
10/19	100	0.0	100.0	0.0	0.0	0.0
11/15	0	0.0	0.0	0.0	0.0	0.0
12/13	100	0.0	100.0	0.0	0.0	0.0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii
Total, ovigery, and e given as percentages of total number of females.
? given as percentage of ovigerous females.
Cyst and naup given as percentages of individuals with differentiated egg masses.

Table 14. *Artemia* fecundity summary, 2006.

	#eggs/brood				female length		
	mean	SE	%cyst	%intended	mean	SE	n
Lakewide Mean:							
5/24	39.4	3.2	0.9	0.4	10.0	0.1	7
5/31	42.1	1.3	0.9	0.7	10.3	0.1	7
6/7	37.6	1.8	0.9	0.4	9.9	0.1	7
6/14	34.2	1.4	0.9	0.6	10.0	0.1	7
6/21	30.8	0.6	1.0	0.6	9.8	0.1	7
6/30	26.7	1.5	0.9	0.6	9.9	0.1	7
7/6	25.2	1.3	0.9	0.4	10.1	0.1	7
7/12	36.2	2.7	0.9	0.5	10.6	0.1	7
7/19	51.8	3.9	0.9	0.5	10.7	0.1	7
7/26	41.2	4.2	1.0	0.5	10.4	0.1	7
8/2	40.8	3.2	0.9	0.6	10.9	0.2	7
8/9	40.3	3.3	1.0	0.7	10.5	0.1	6
8/17	38.4	3.5	1.0	0.5	11.1	0.2	7
9/1	51.6	3.2	1.0	0.4	11.2	0.1	7
9/13	67.3	4.7	0.9	0.6	11.5	0.1	7
10/3	96.2	4.3	0.9	0.6	11.7	0.1	6
Western Sector Mean:							
5/24	44.5	3.1	1.0	0.3	10.1	0.1	4
5/31	42.4	2.3	0.8	0.7	10.3	0.1	4
6/7	40.1	2.6	1.0	0.3	10.0	0.2	4
6/14	34.4	2.3	0.9	0.6	10.0	0.1	4
6/21	31.2	0.6	1.0	0.6	9.9	0.2	4
6/30	26.1	1.1	0.9	0.6	9.9	0.1	4
7/6	23.5	1.6	1.0	0.4	10.1	0.1	4
7/12	32.2	2.9	0.9	0.5	10.5	0.1	4
7/19	45.2	4.4	0.9	0.6	10.6	0.2	4
7/26	34.4	4.2	1.0	0.5	10.3	0.2	4
8/2	37.5	5.0	1.0	0.6	10.8	0.3	4
8/9	39.6	4.1	1.0	0.7	10.5	0.2	4
8/17	36.3	6.2	1.0	0.5	10.9	0.4	4
9/1	46.1	2.3	1.0	0.4	11.0	0.1	4
9/13	60.0	6.0	1.0	0.6	11.5	0.2	4
10/3	99.7	5.4	0.9	0.6	11.8	0.1	4

(continued on next page)

‘n’ in last column refers to number of stations averaged.
Ten females were collected and measured from each station.

Table 14 (continued). *Artemia* fecundity summary, 2006.

	#eggs/brood				female length		
	mean	SE	%cyst	%intended	mean	SE	n
Western Sector Mean:							
5/24	32.6	3.3	0.9	0.6	9.8	0.1	3
5/31	41.7	0.9	1.0	0.7	10.2	0.1	3
6/7	34.4	0.3	0.9	0.5	9.6	0.1	3
6/14	34.0	1.6	1.0	0.6	10.1	0.2	3
6/21	30.3	1.0	1.0	0.7	9.8	0.1	3
6/30	27.5	3.7	0.9	0.6	9.9	0.3	3
7/6	27.5	1.2	0.9	0.4	10.1	0.1	3
7/12	41.6	2.9	1.0	0.5	10.7	0.2	3
7/19	60.6	0.4	0.9	0.4	10.9	0.2	3
7/26	50.2	4.1	1.0	0.4	10.5	0.1	3
8/2	45.2	1.8	0.9	0.6	11.1	0.1	3
8/9	41.7	7.8	1.0	0.6	10.3	0.2	2
8/17	41.2	1.9	1.0	0.5	11.4	0.2	3
9/1	58.9	4.0	1.0	0.4	11.4	0.2	3
9/13	77.1	1.1	0.9	0.7	11.4	0.1	3
10/3	89.1	5.0	0.8	0.5	11.6	0.1	2

‘n’ in last column refers to number of stations averaged.
Ten females were collected and measured from each station.

Table 15. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979–2006.

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
Mean	**19,888**	**19,110**	**44,805**	**216**

*Centroid calculated as the abundance-weighted mean day of occurrence.

Table 16. Photosynthetic parameters for 2006.

Date	Depth (m)	Temperature (C)	α^B (g C g Chl a^{-1} h^{-1})	P_m^B (g C g Chl a^{-1} Einst^{-1} m^2)
2/14/2006	2	3.8	6.65	1.32
3/15/2006	2	3	5.16	1.37
4/19/2006	2	7.4	5.46	2.11
5/16/2006	2	18.8	11.27	5.64
6/15/2006	2	16.3	12.60	14.37
6/15/2006	10	10.4	9.31	2.61
7/14/2006	2	21	10.31	6.96
7/14/2006	10	9.9	19.85	4.23
8/17/2006	2	20.5	18.46	10.73
9/19/2006	2	16.8	16.45	4.22
10/19/2006	2	12	19.93	4.02
11/15/2006	2	8.5	19.85	2.71

P_m^B: Chlorophyll-specific maximum carbon uptakes rates (g C g Chl a^{-1} h^{-1})

α^B: Chlorophyll-specific light-limited uptake rates (g C g Chl a^{-1} Einst^{-1} m^2)

Table 17. Long term Integrative Measures of Productivity: Annual Primary Production, *Artemia* biomass and egg production (see Chapter 2 for methods), 1982-2006.

Year	**Planktonic Primary Production** (g C m^{-2} y^{-1})	***Artemia*** **Biomass** (g dry weight m^{-2})	***Artemia*** **Naupliar Production** (10^{6} m^{-2})	***Artemia*** **Cyst Production** (10^{6} m^{-2})
1982	1,107	-	-	-
1983	523	9.3	0.15	4.8
1984	269	7.8	0.08	3.7
1985	399	7.8	0.22	4.6
1986	462	7.7	0.44	3.0
1987	371	12.5	0.23	6.4
1988	1,064	15.2	0.21	4.7
1989	499	17.6	0.11	6.7
1990	641	11.0	1.02	6.1
1991	418	9.7	0.69	5.5
1992	435	10.2	0.26	5.8
1993	602	8.9	0.35	6.3
1994	446	8.7	0.16	5.6
1995	227	8.4	0.40	4.9
1996	221	8.2	0.05	3.6
1997	149	5.3	0.01	2.5
1998	228	8.0	0.01	2.8
1999	297	8.9	0.03	4.2
2000	484	8.2	0.08	4.0
2001	532	8.8	0.10	3.0
2002	763	4.9	0.10	2.5
2003	1,645	7.5	0.60	4.2
2004	864	11.0	0.04	2.6
2005	1,111	8.8	0.31	3.8
2006	852	6.8	0.32	4.8
Mean	**584**	**9.2**	**0.25**	**4.4**

*Carbon uptake measurements not conducted during 1982, 1993-2001. Estimates in these years are based on temperature, chlorophyll, light, and regressions of photosynthetic rates (P_m^B) and (α^B) versus temperature (see methods).

FIGURE CAPTIONS

Fig. 1. UCSB sampling stations at Mono Lake. Solid circles represent permanently moored buoys. Open circles represent old intermediate stations.

Fig. 2. Wind speed; daily mean and 10-min. maximum, 2006.

Fig. 3. Daily air temperature; mean, maximum, and minimum, 2006.

Fig. 4. Daily photosynthetically available radiation, 2006.

Fig. 5. Mean daily relative humidity, 2006.

Fig. 6. Daily precipitation, 2006.

Fig. 7. Mono Lake surface elevation (ft asl), 1979–06, USGS datum.

Fig. 8. Temperature (°C) at station 6, 2006.

Fig. 9. Conductivity (mS cm^{-1} corrected to 25°C) at station 6, 2006.

Fig.10. Density difference (kg m^{-3}) between 2 and 32 m at station 6 due to temperature and chemical stratification from 1991–2006.

Fig. 11. Transparency as measured by mean lakewide Secchi depth (m), 1994–06. Error bars show standard errors of the lakewide estimate based on 12-20 stations.

Fig. 12. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–06.

Fig. 13. Light attenuation (% of surface) at station 6, 2006.

Fig. 14. Dissolved oxygen (mg O_2 l^{-1}) at station 6, 2006. Dots denote the dates and depths of samples.

Fig. 15. Ammonium (µM) at station 6, 2006. Dots denote the dates and depths of samples.

Fig. 16. Ammonium (µM) in upper 9 m of the water column at 7 stations, 2006.

Fig. 17. Chlorophyll *a* (µg chl *a* l^{-1}) at station 6, 2006. Dots denote the dates and depths of samples.

Fig. 18. Chlorophyll *a* (µg chl *a* l^{-1}) in upper 9 m of the water column at 7 stations, 2006.

Fig. 19. Seasonal fluorescence profiles at station 6, 2006.

Fig. 20. Lakewide *Artemia* abundance during 2006: nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).

Fig. 21. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1982–06 (see Methods). The mean relative error of the lakewide estimates is 20-25%.

Fig. 22. Reproductive characteristics of *Artemia* during 2006: lakewide mean abundance of total females and ovigerous females (top), percent of females ovoviviparous and ovigerous (middle), and brood size (bottom). Vertical lines are the standard error of the estimate.

Fig. 23. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–06. Values are based on interpolated daily abundances.

Fig. 24. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–06. Centroid is based on interpolated daily abundances of adult *Artemia*.

Fig. 25. Chlorophyll-specific uptake rates during March, August, and December 2006 for samples collected from the surface mixed layer and the deep chlorophyll maximum.

Fig. 26. Chlorophyll-specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}), algal biomass (mg m^{-3}), and daily primary production (g C m^{-2}), 2006.

Fig. 27. Comparison of 2002–06 photosynthetic rates and algal biomass. A) Chlorophyll-specific specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}) B) Mixed-layer (2 m depth) chlorophyll *a* concentrations µg Chl l^{-1}.

Fig. 28. Comparison of 2002–06 daily primary production (g C m^{-2} y^{-1}) calculated with a numerical interpolative model of chlorophyll, temperature, insolation, attenuation, and photosynthetic parameters.

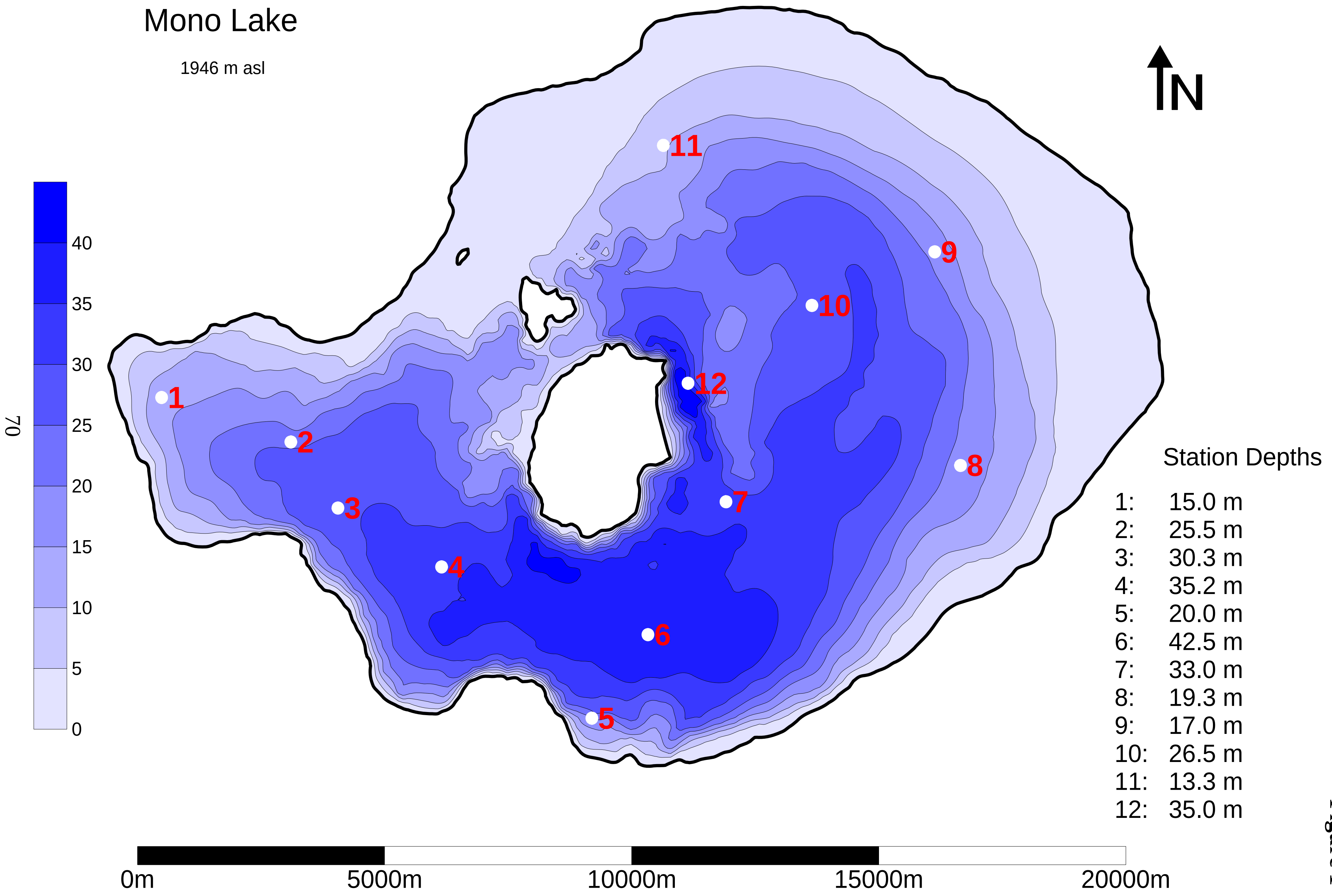
Fig. 29. Annual phytoplankton production estimates (g C m^{-2}), 1982–06.

Fig. 30. Mean annual *Artemia* biomass, 1983–04. Data for the period 1982–99 estimated from instar-specific population data and previously derived weight-length relationships. In 2000–06, *Artemia* biomass was measured directly by determining dry weights of plankton tows.

Fig. 31. Annual *Artemia* reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–06.

Fig. 32. Lakewide mean of mixolimnetic (<10 m) chlorophyll *a*, 1982–06. Heavy line shows seasonally filtered data formed by linearly interpolating between sampling dates to daily values and then calculating a 365-day running mean.

Fig. 33. Lakewide mean of adult *Artemia* abundance, 1982–06. Heavy line shows seasonally filtered data formed by linearly interpolating between sampling dates to daily values and then calculating a 365-day running mean.



Station Depths

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

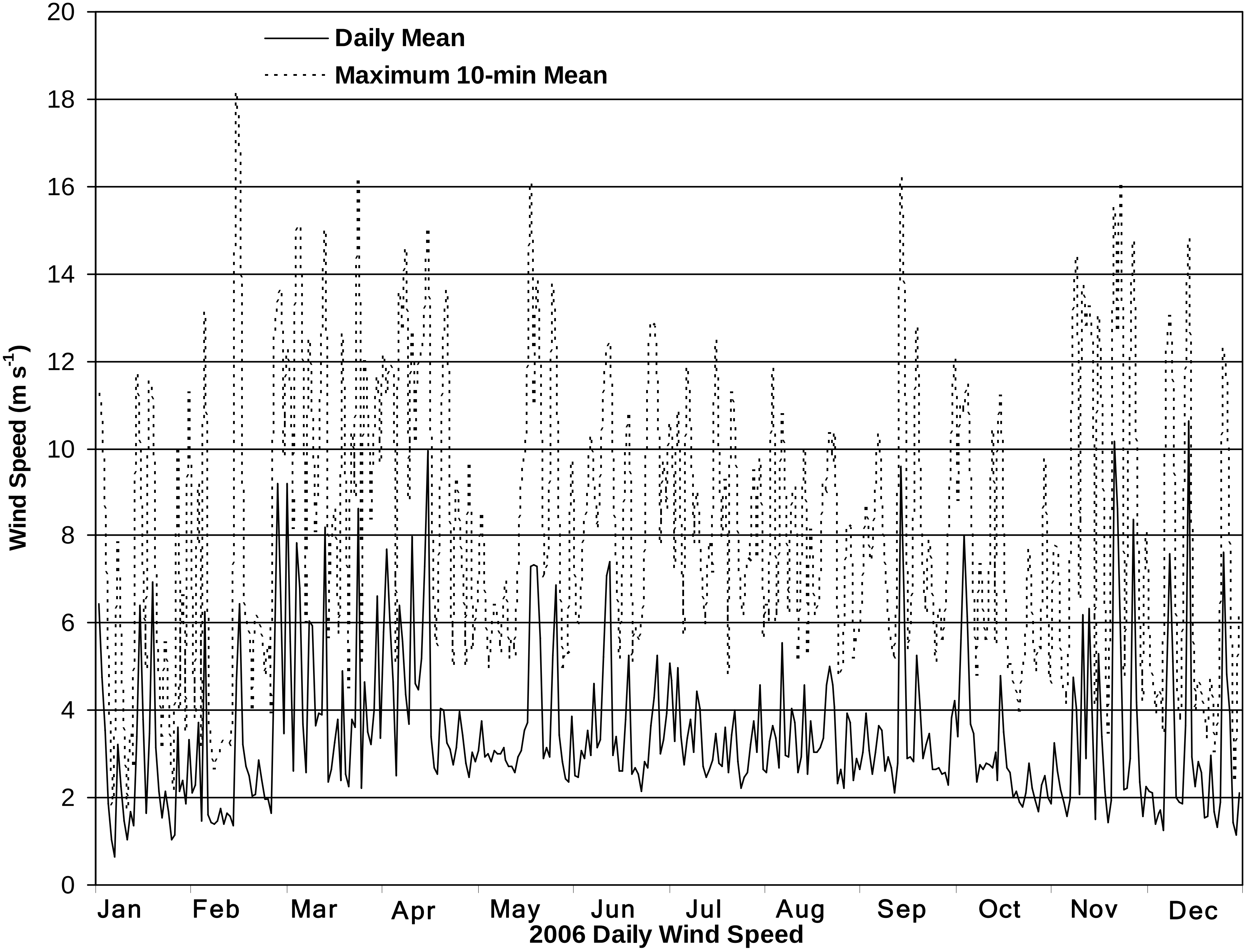

Daily Mean
Maximum 10-min Mean
Wind Speed (m s^{-1})
0
2
4
6
8
10
12
14
16
18
20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2006 Daily Wind Speed

Figure 2

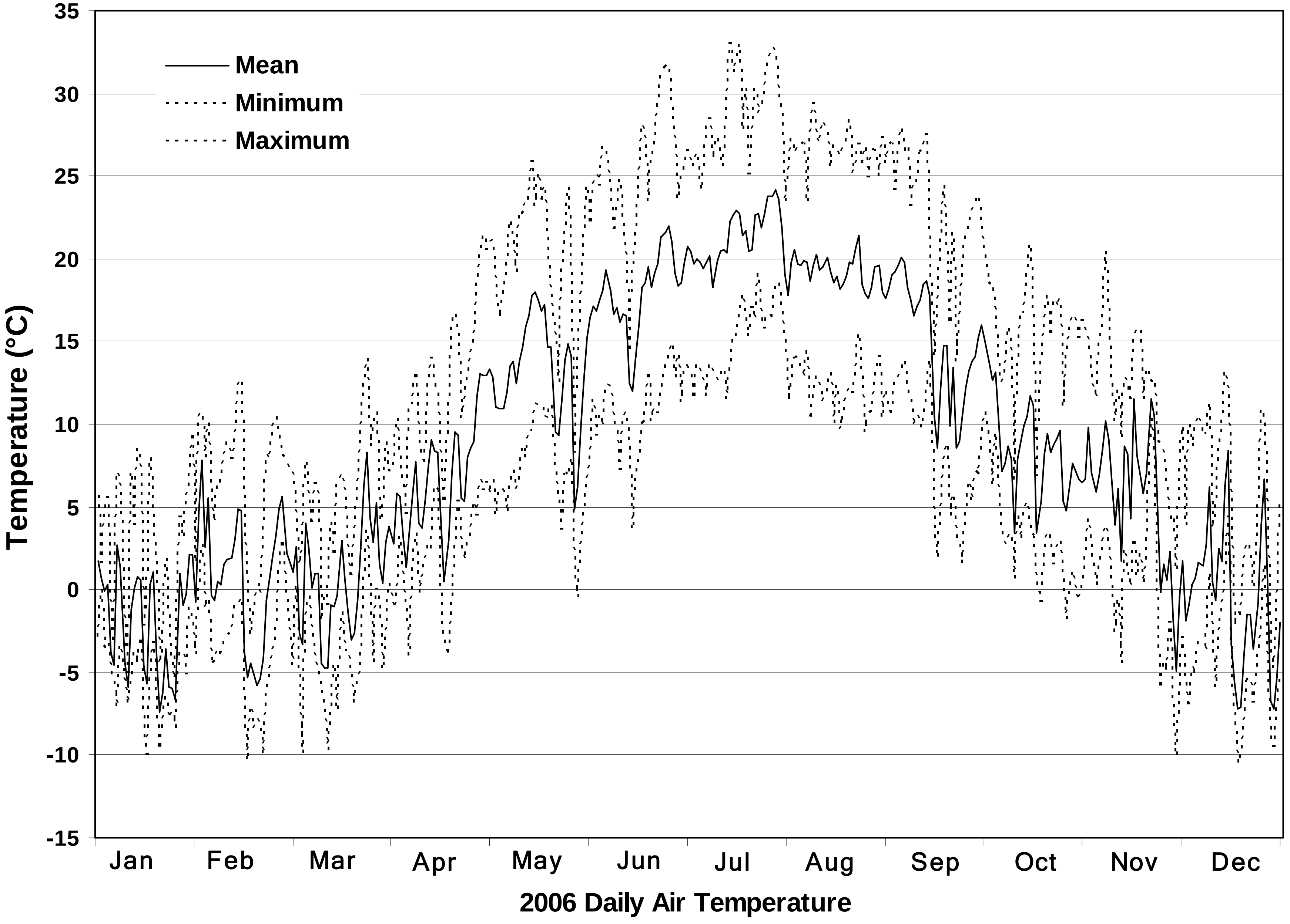

Mean
Minimum
Maximum
Temperature (°C)
35
30
25
20
15
10
5
0
-5
-10
-15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2006 Daily Air Temperature

Figure 3

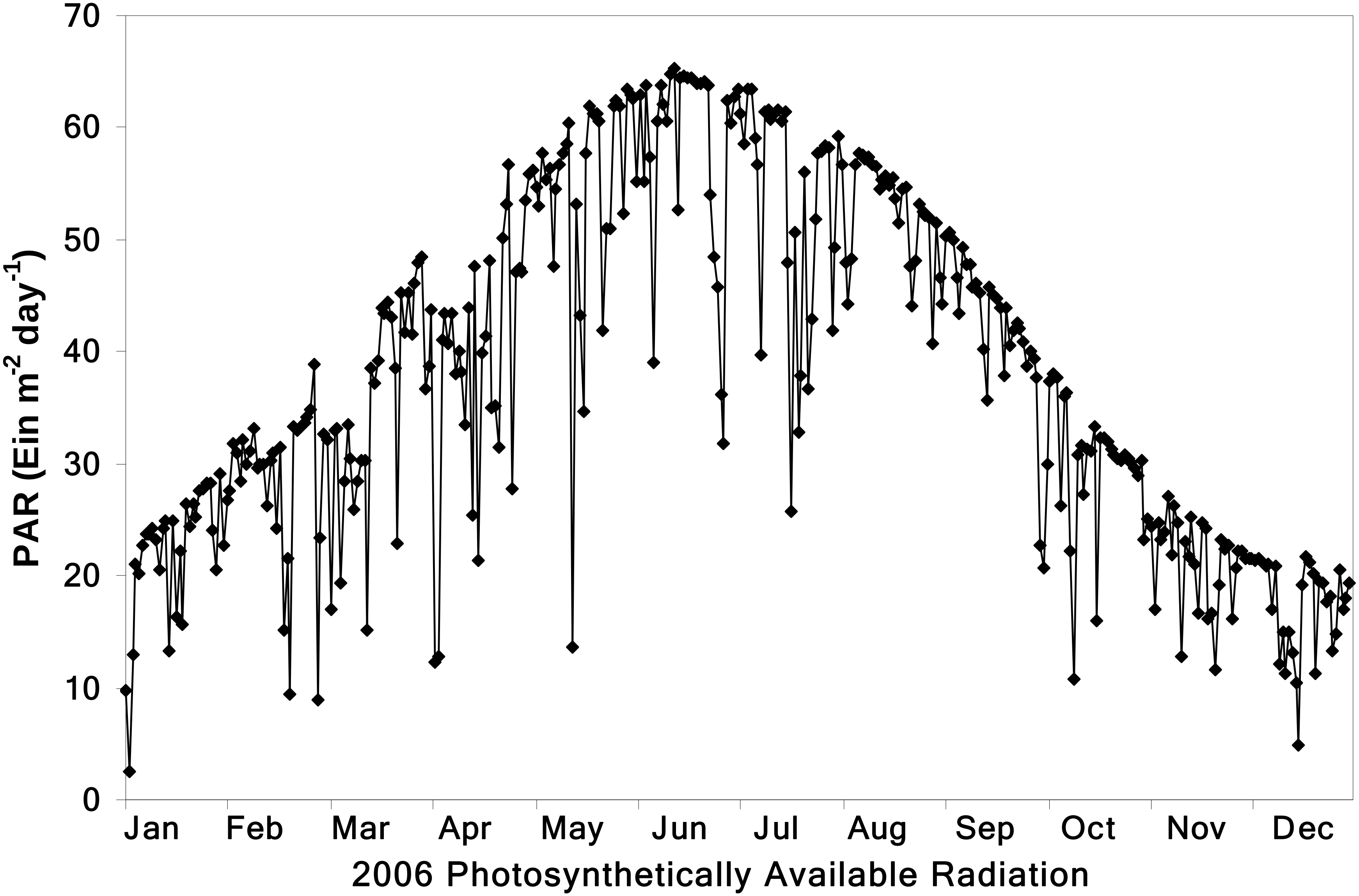
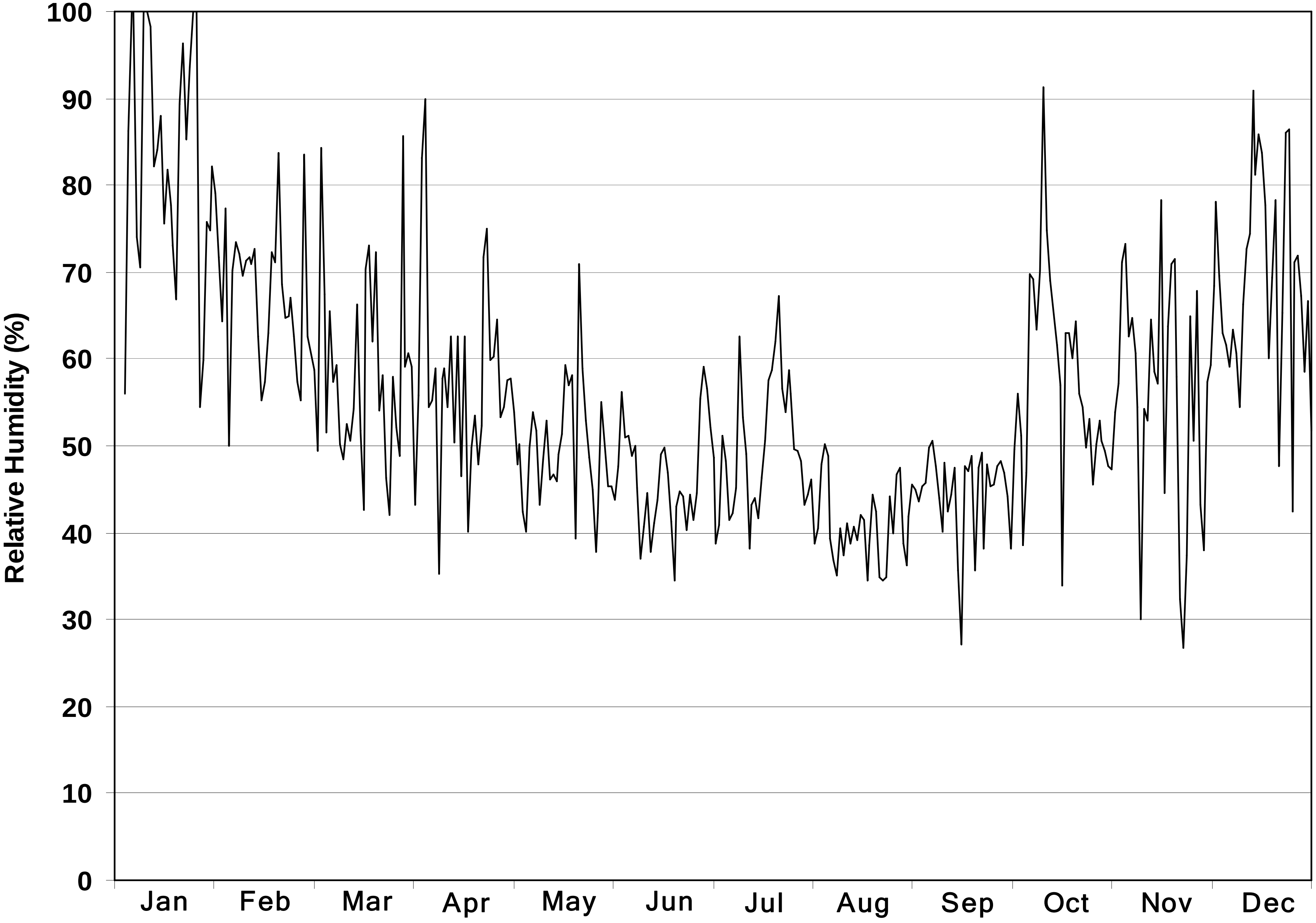
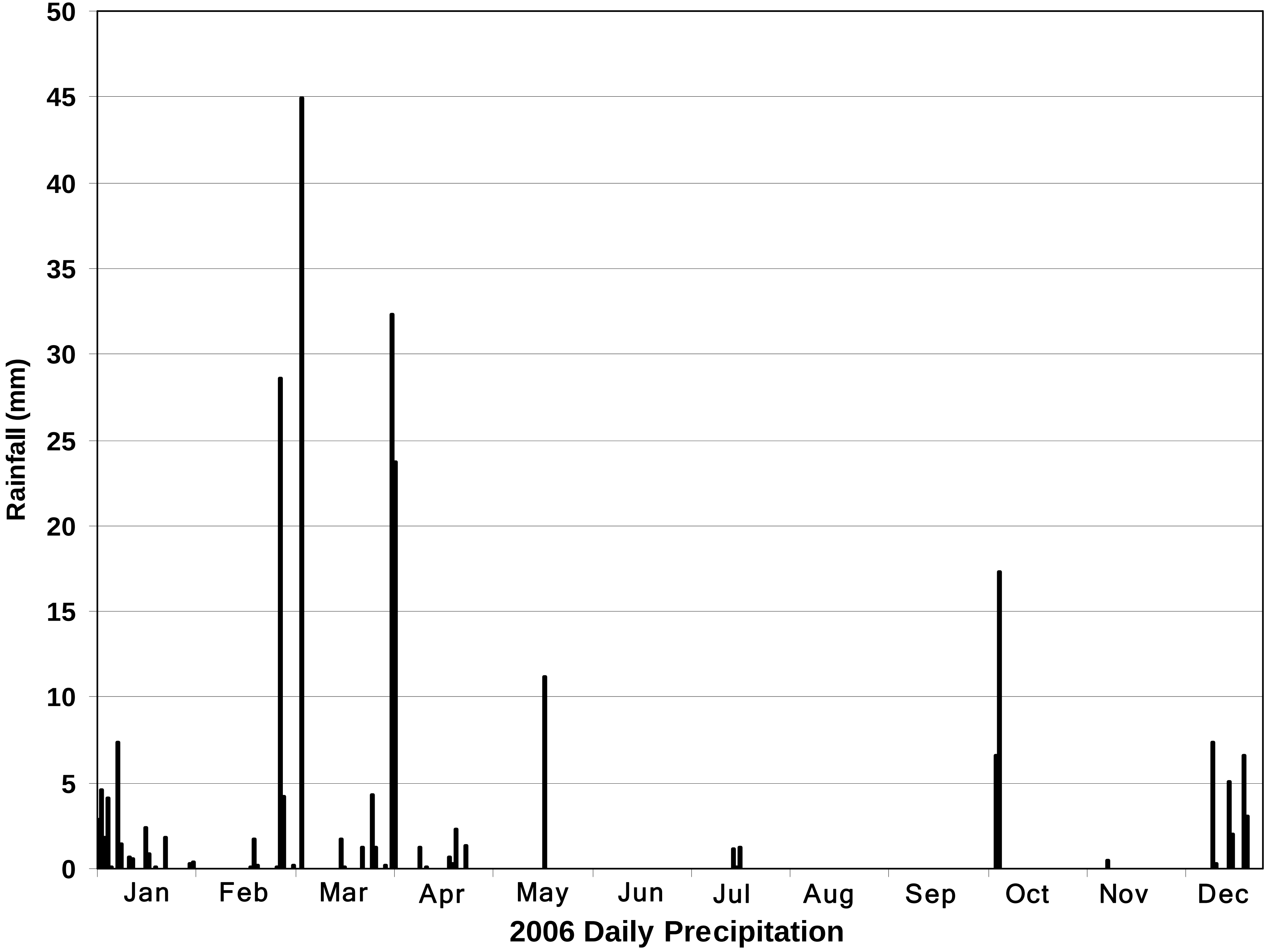

PAR (Ein m^{-2} day^{-1})
0
10
20
30
40
50
60
70
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2006 Photosynthetically Available Radiation

Figure 4



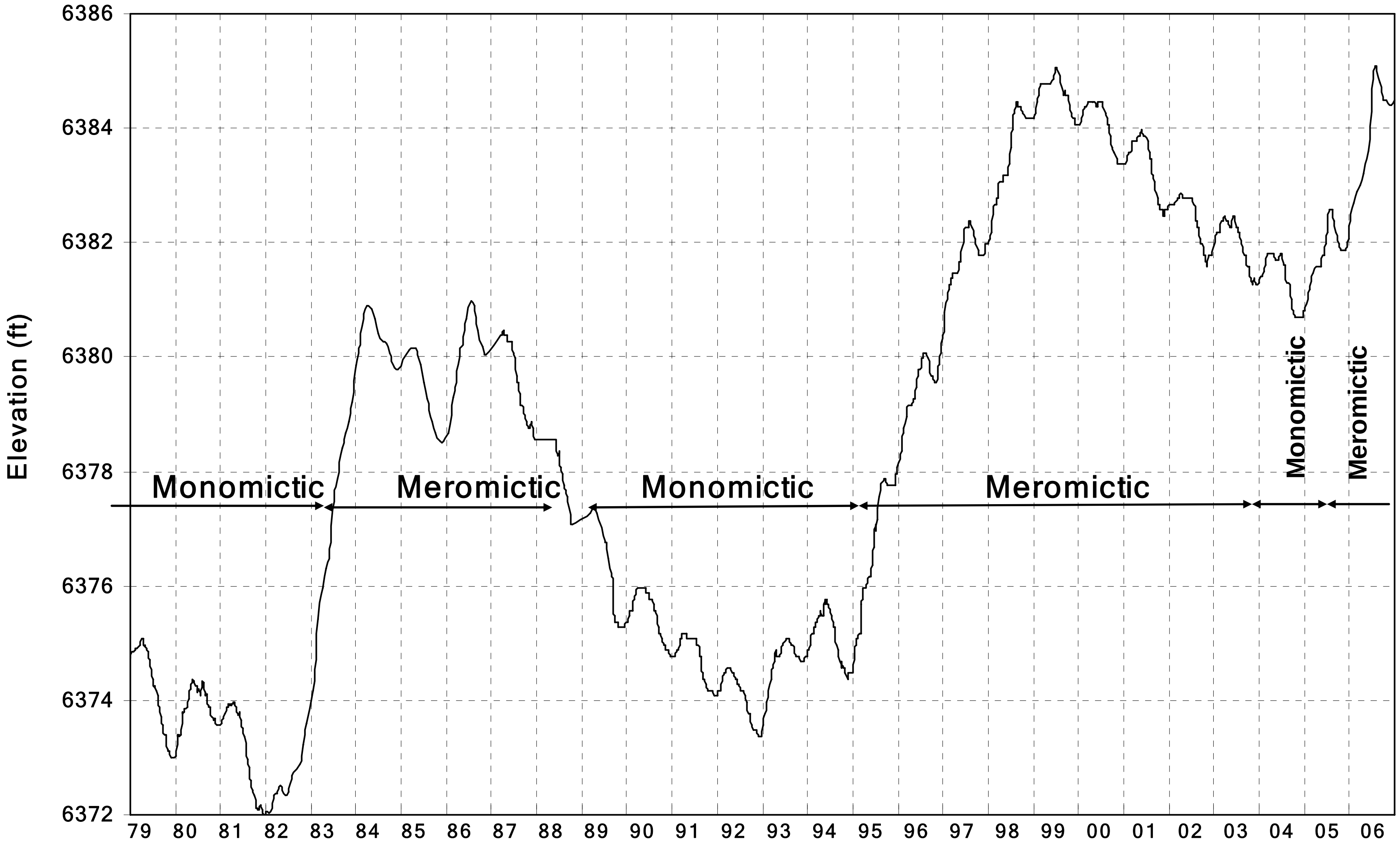
2006 Mean Daily Relative Humidity

Figure 5



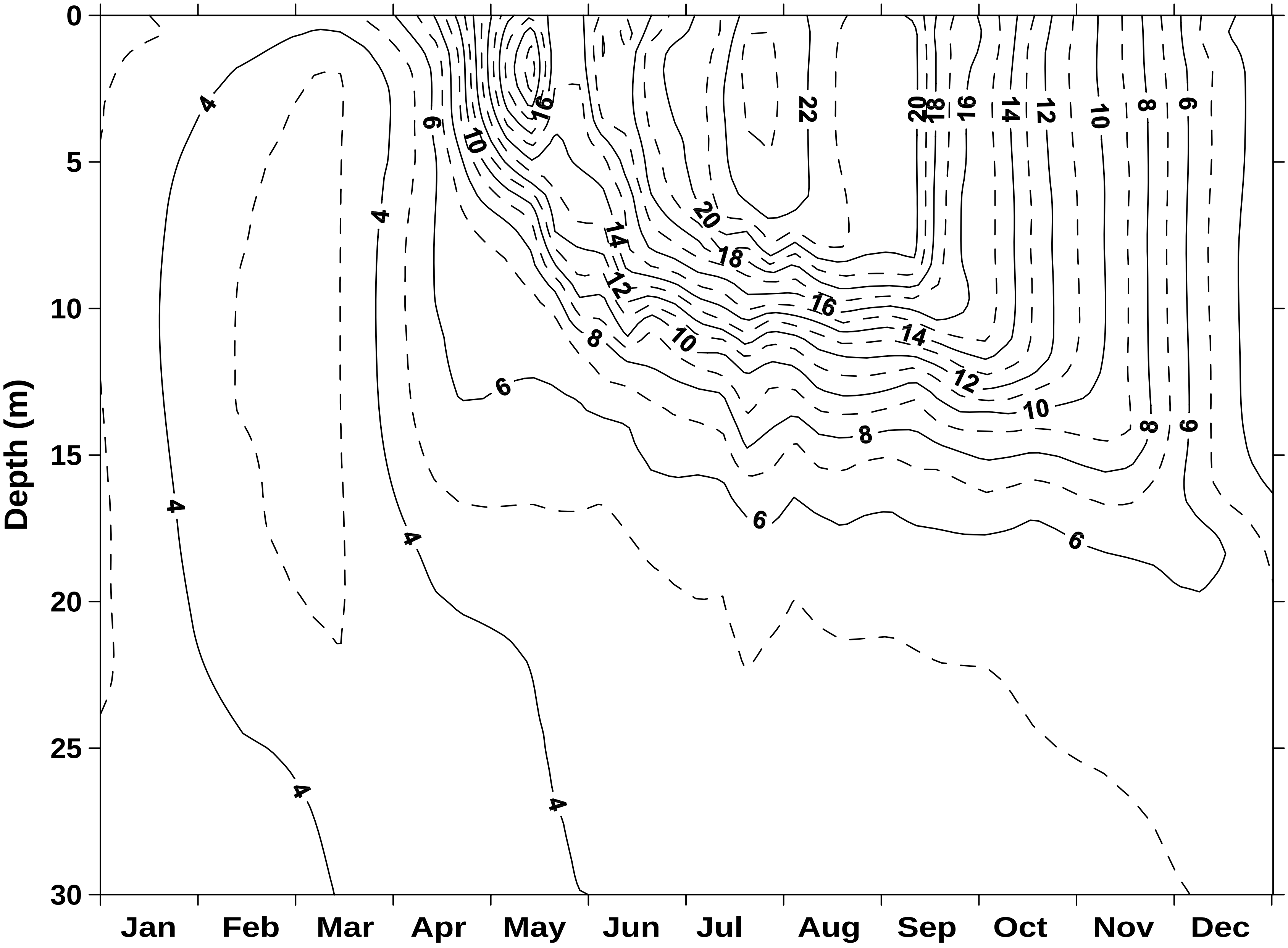
Rainfall (mm)
50
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2006 Daily Precipitation

Figure 6



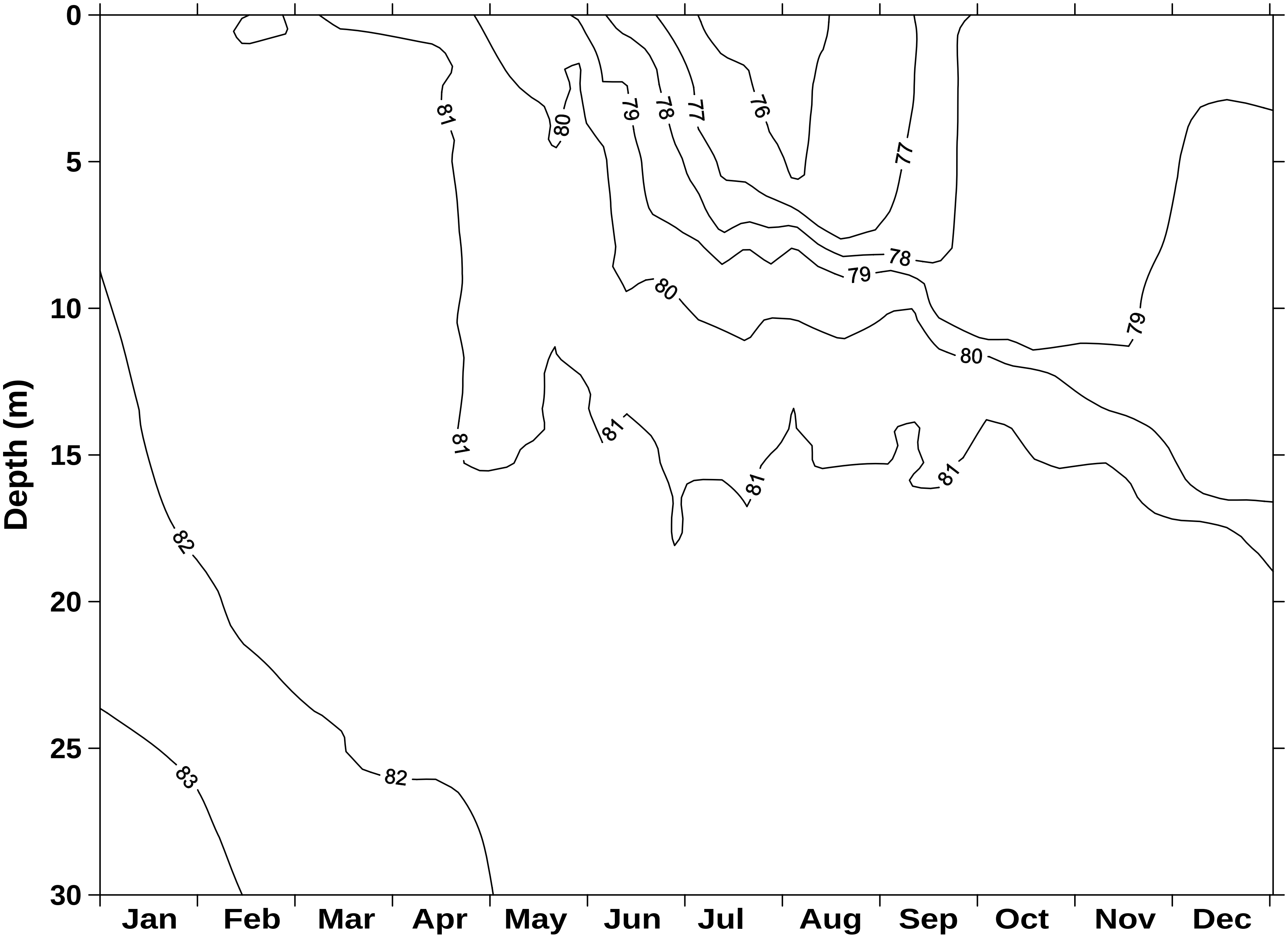
Mono Lake Surface Elevation

Figure 7



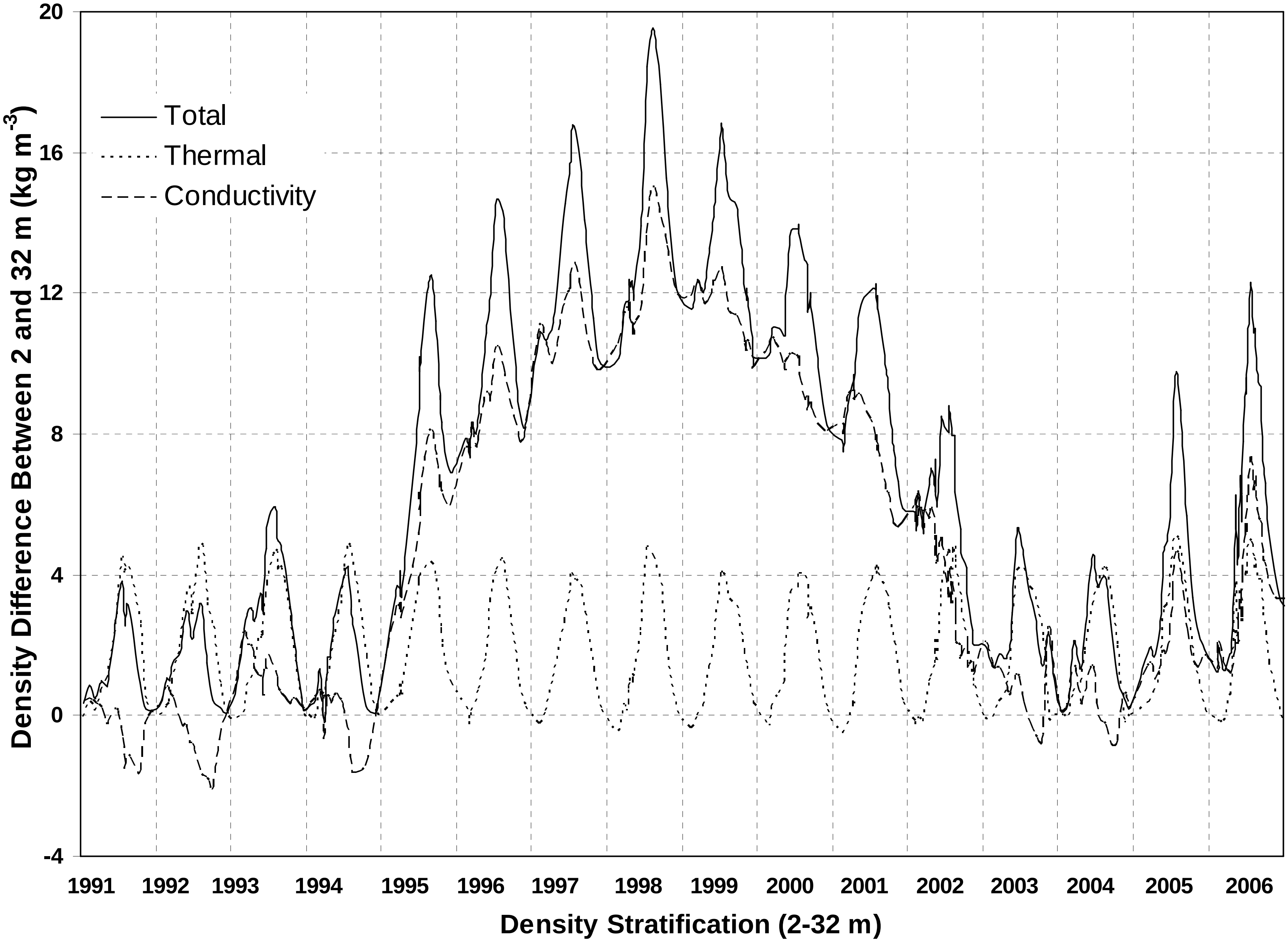
Temperature (°C) at Station 6, 2006

Figure 8



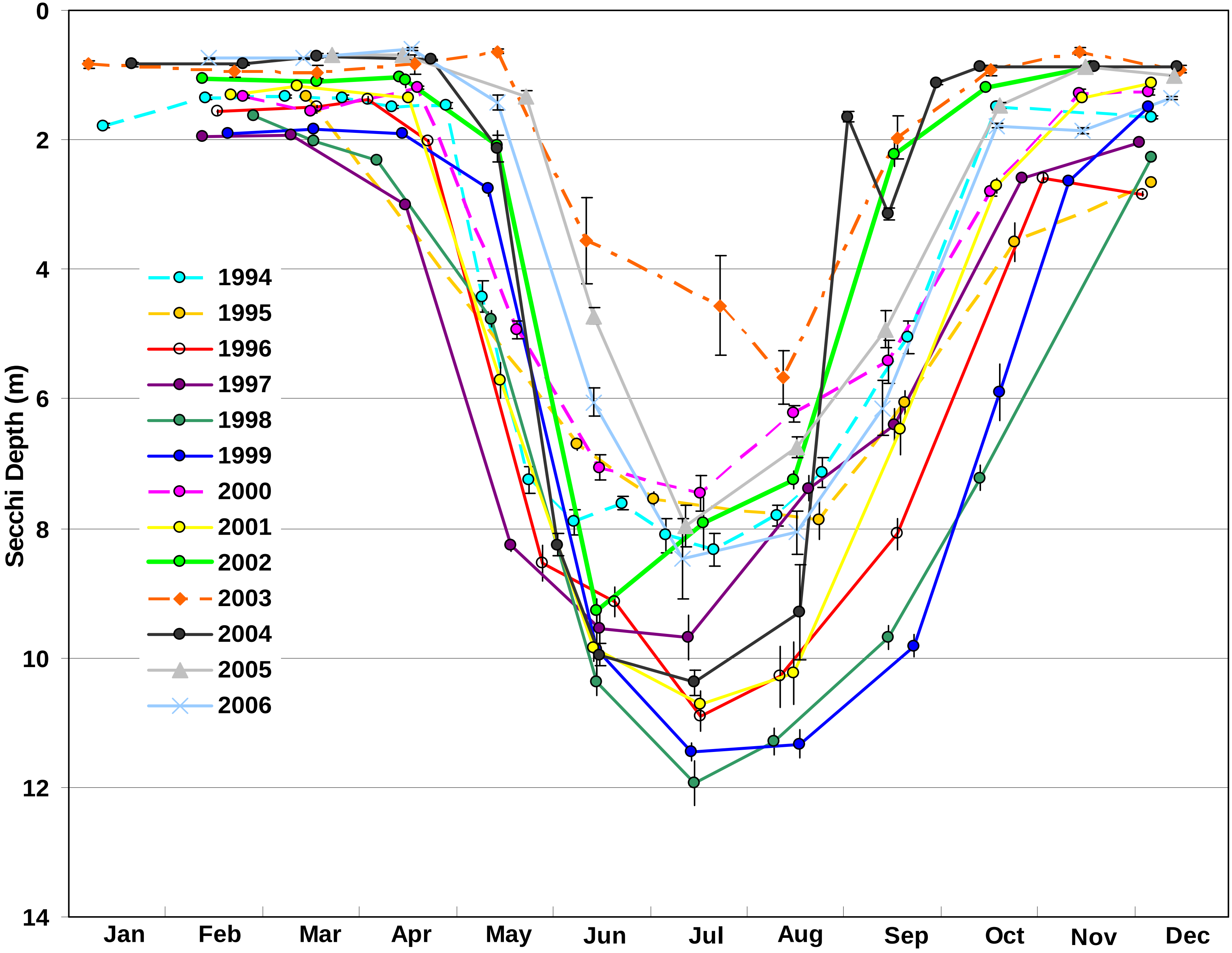
Specific Conductivity (mS/cm) at Station 6, 2006

Figure 9



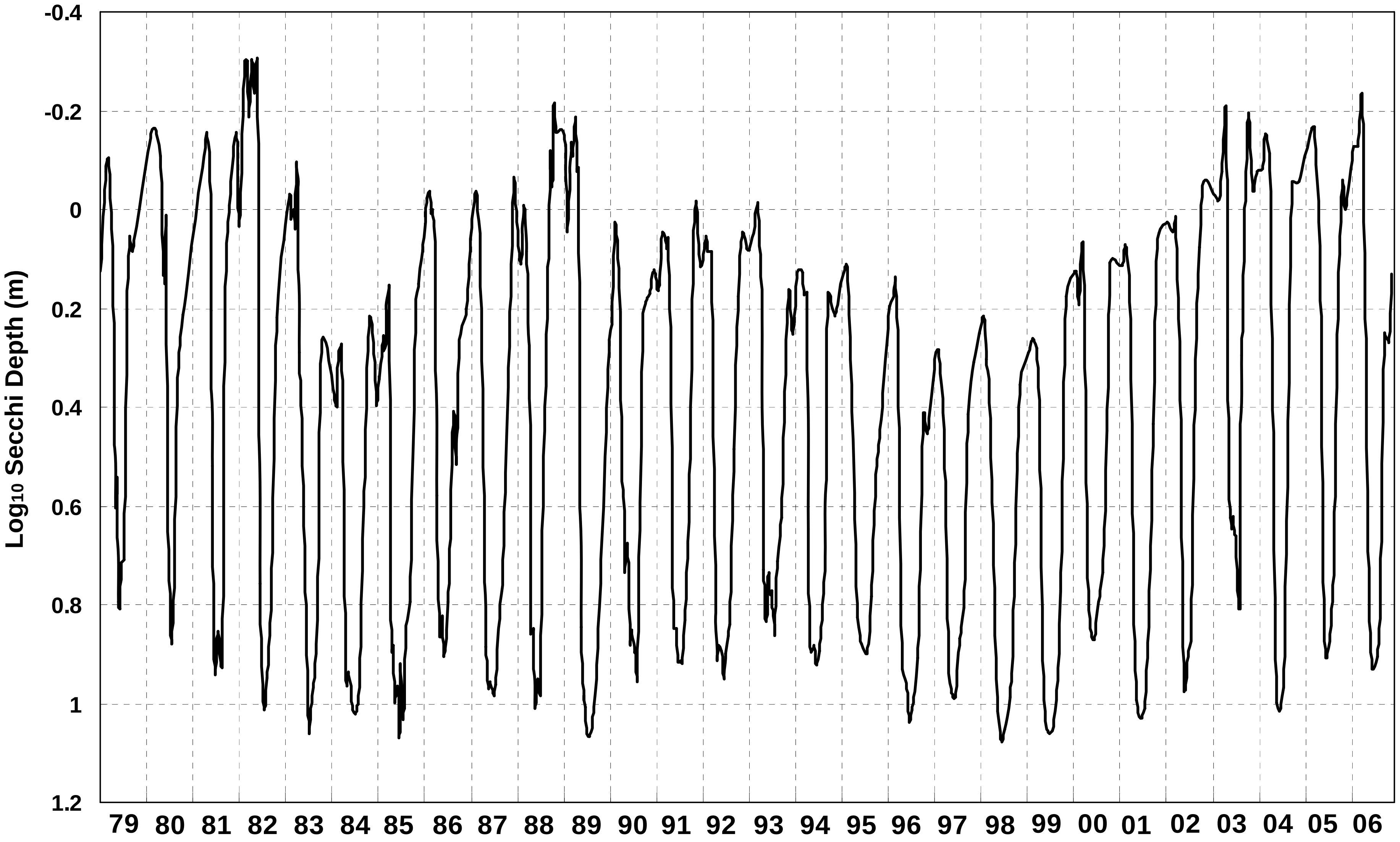
Density Difference Between 2 and 32 m (kg m^{-3})
20
16
12
8
4
0
-4
Total
Thermal
Conductivity
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Density Stratification (2-32 m)

Figure 10



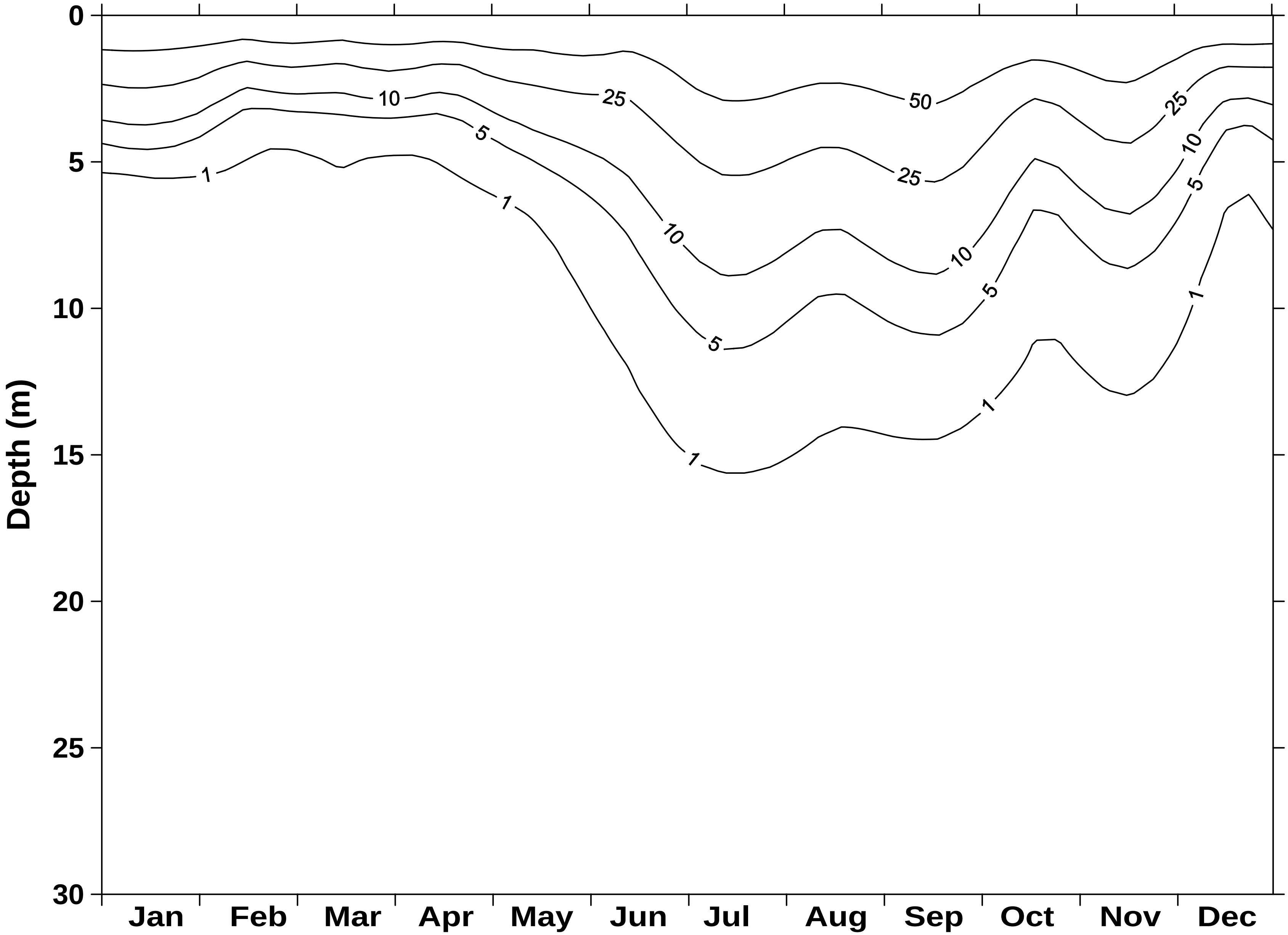
Mono Lake Transparency

Figure 11



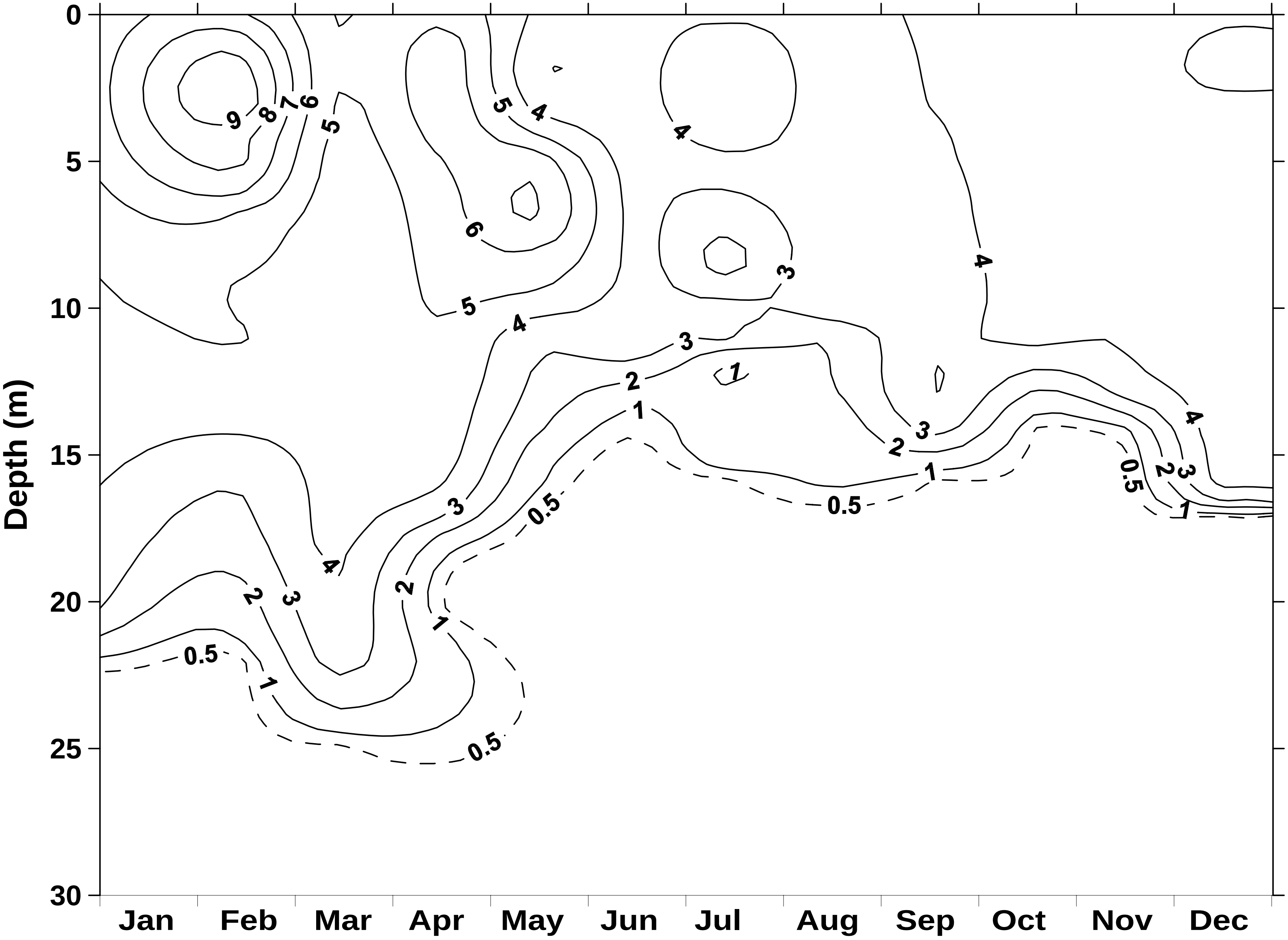
Transparency in Mono Lake

Figure 12



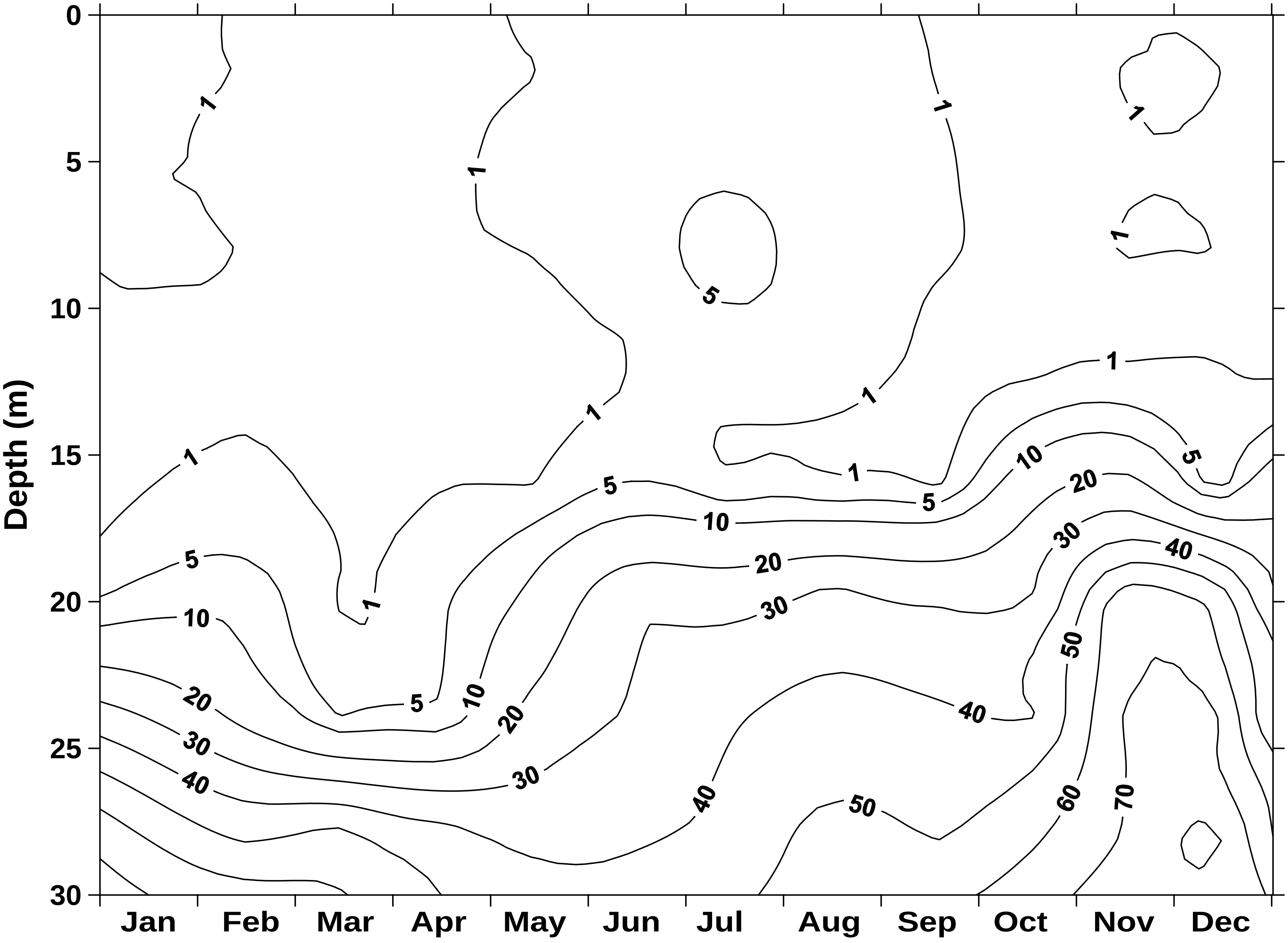
Light Attenuation (% of Surface) at Station 6, 2006

Figure 13



Dissolved oxygen (mg/l) at Station 6, 2006

Figure 14



Ammonia (μM) at Station 6, 2006

Figure 15

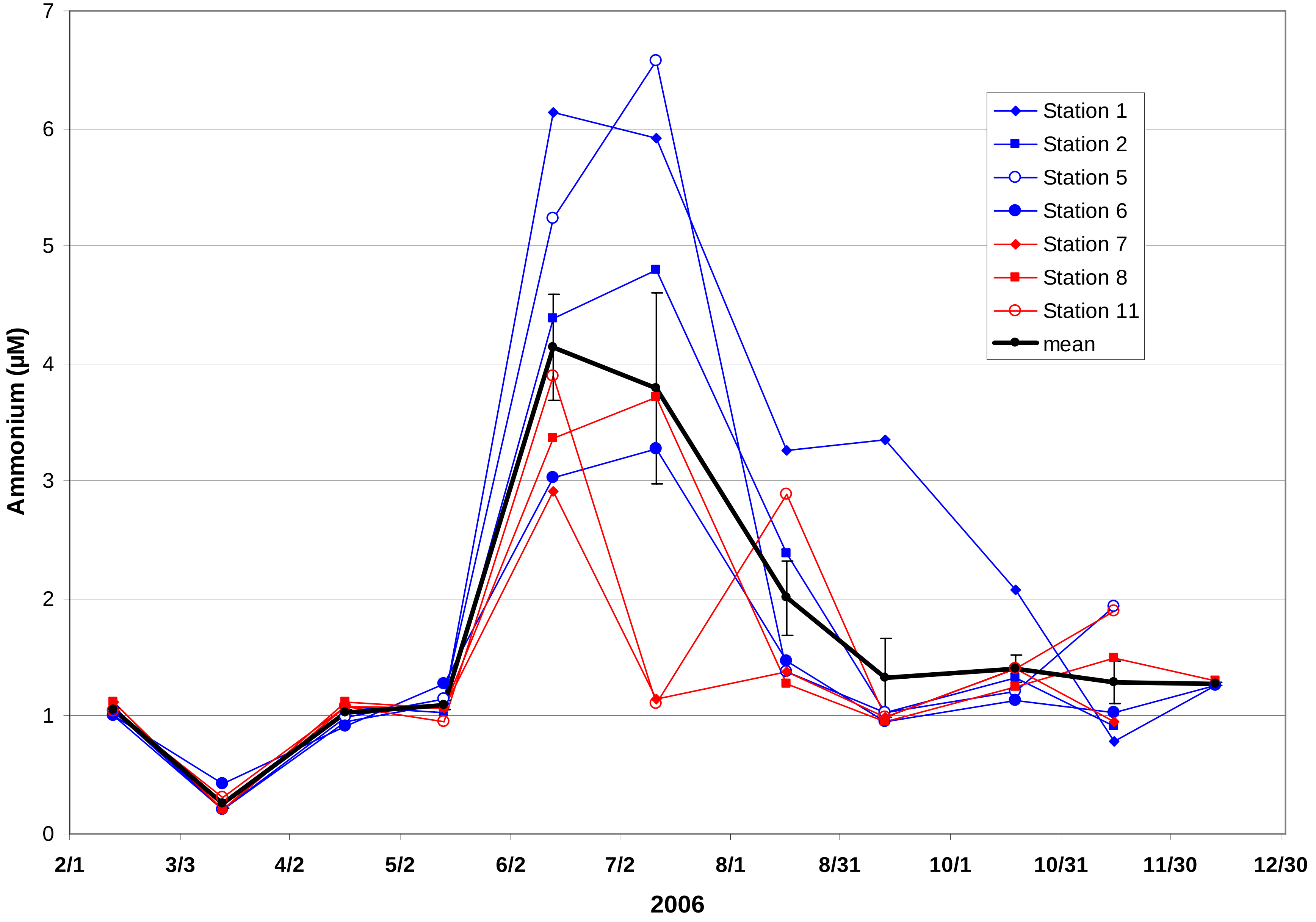

Ammonium (µM)
0
1
2
3
4
5
6
7
2/1
3/3
4/2
5/2
6/2
7/2
8/1
8/31
10/1
10/31
11/30
12/30
2006
Station 1
Station 2
Station 5
Station 6
Station 7
Station 8
Station 11
mean

Figure 16

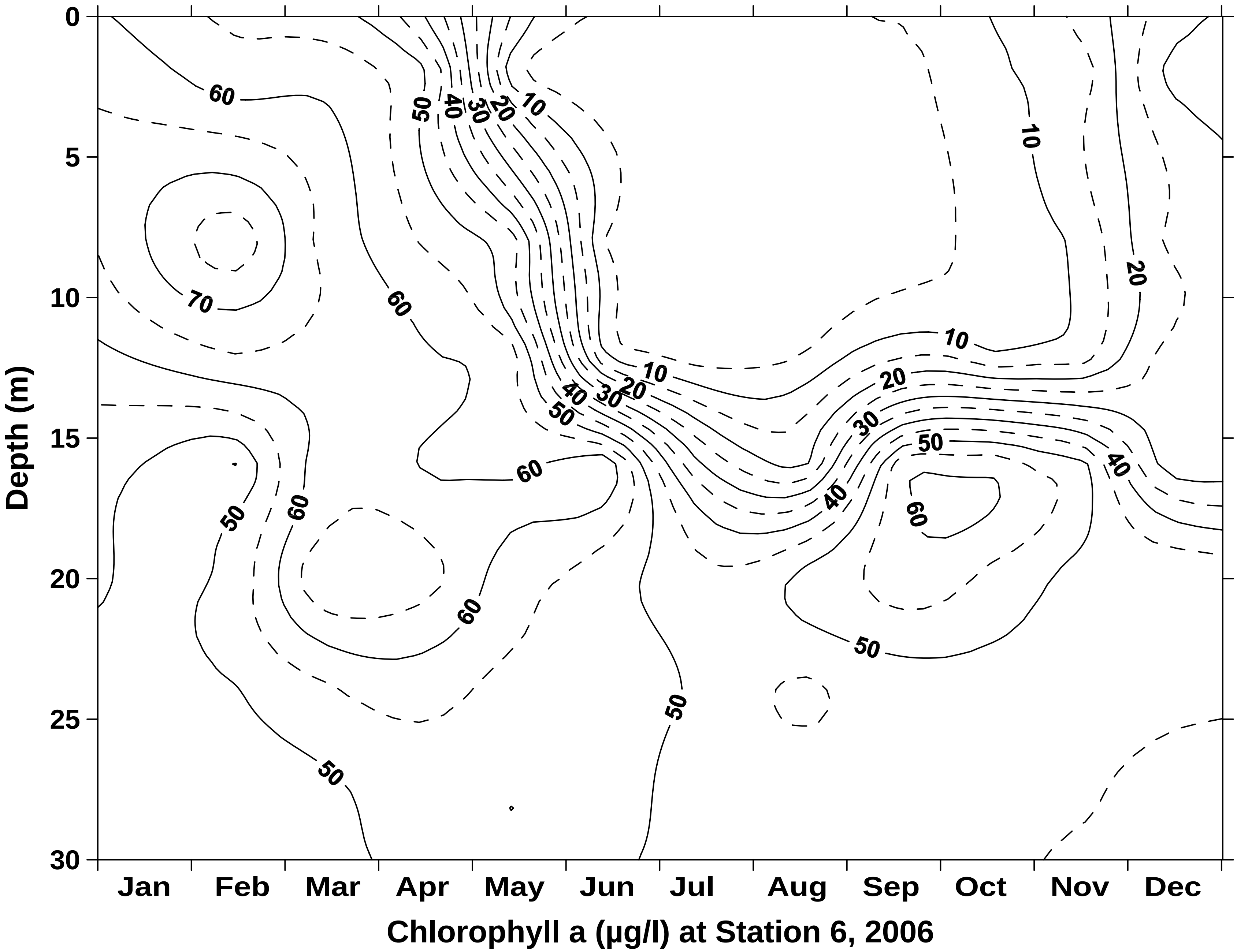

Depth (m)
0
5
10
15
20
25
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Chlorophyll a (µg/l) at Station 6, 2006
60
70
60
50
40
30
20
10
10
20
60
10
10
20
40
30
20
50
30
50
60
40
40
50
60
50
60
60
50
50
50

Figure 17

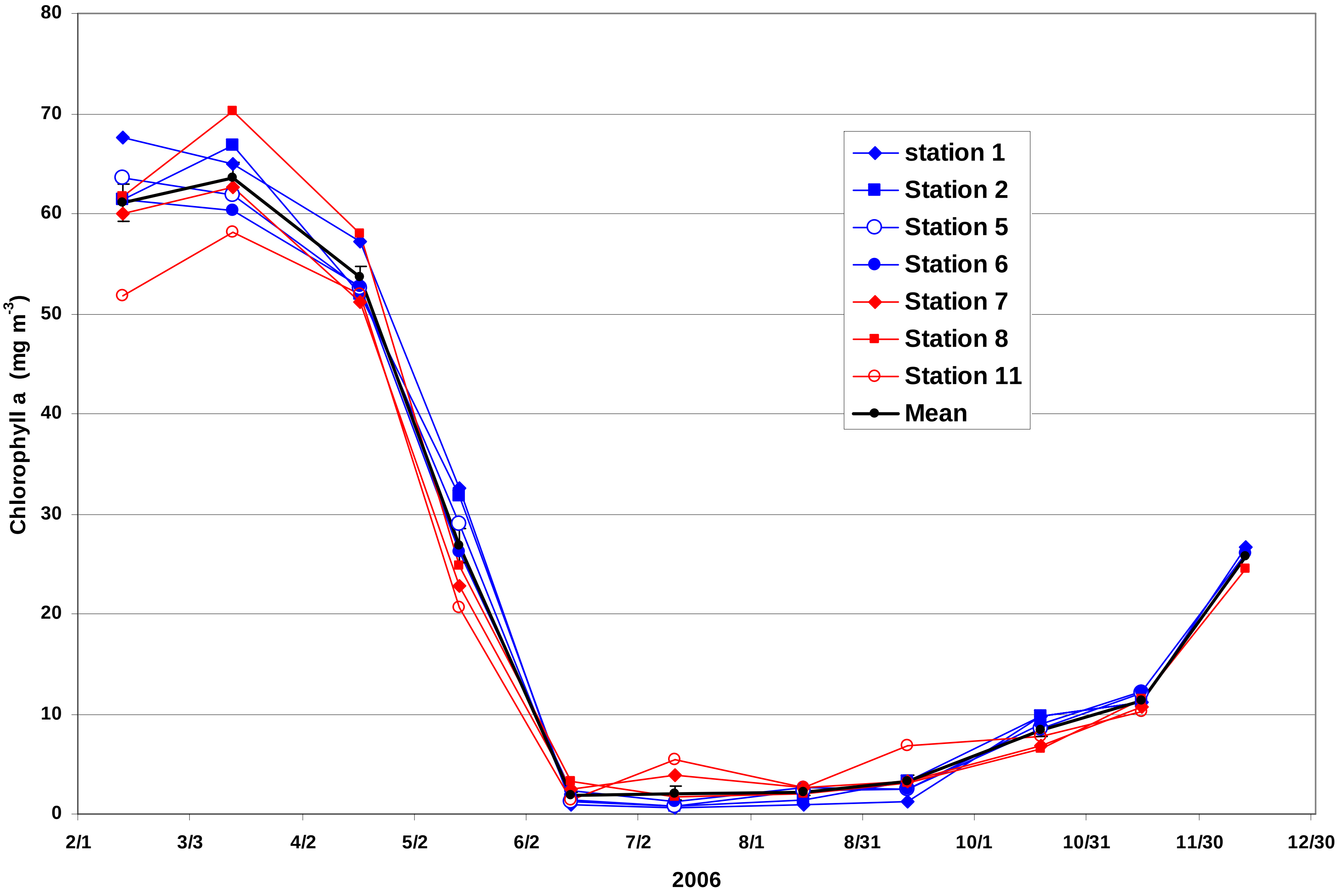
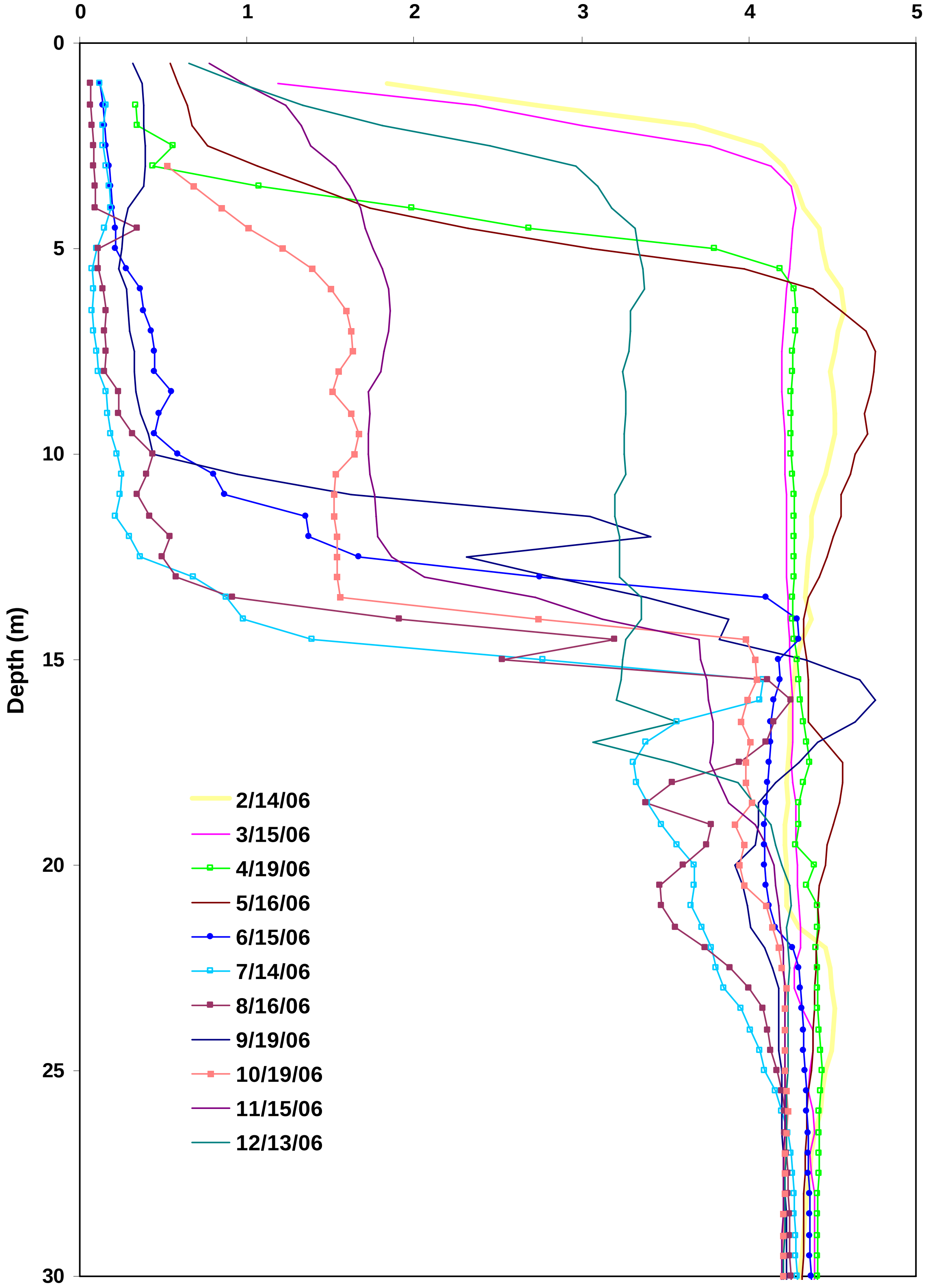

80
70
60
50
40
30
20
10
0
Chlorophyll a (mg m^{-3})
2/1
3/3
4/2
5/2
6/2
7/2
8/1
8/31
10/1
10/31
11/30
12/30
2006
station 1
Station 2
Station 5
Station 6
Station 7
Station 8
Station 11
Mean

Figure 18



2006 Seasonal fluorescence profiles at Station 6

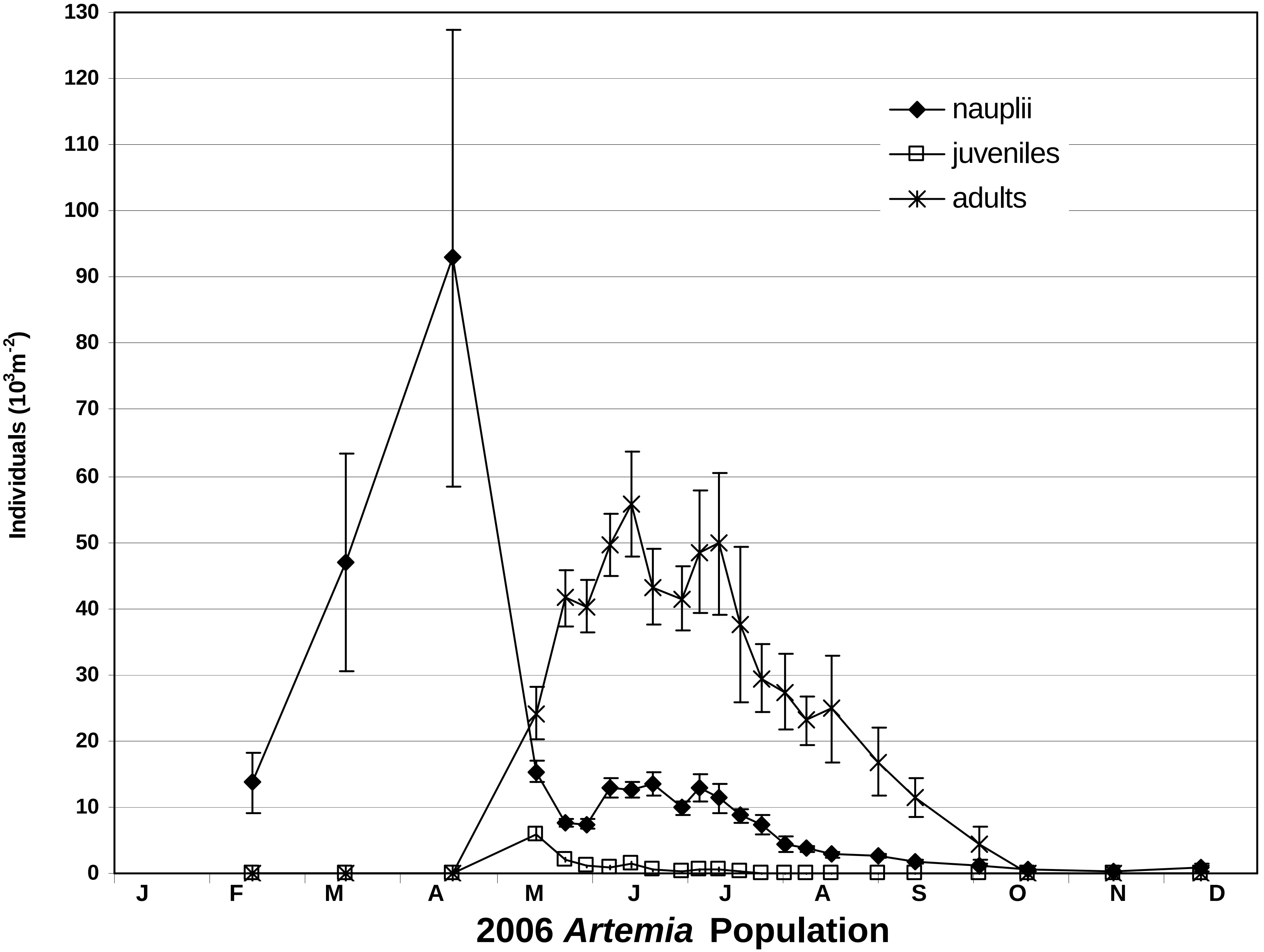

130
120
110
100
90
80
70
60
50
40
30
20
10
0
Individuals ($10^3 m^{-2}$)
nauplii
juveniles
adults
J
F
M
A
M
J
J
A
S
O
N
D
2006 *Artemia* Population

Figure 20

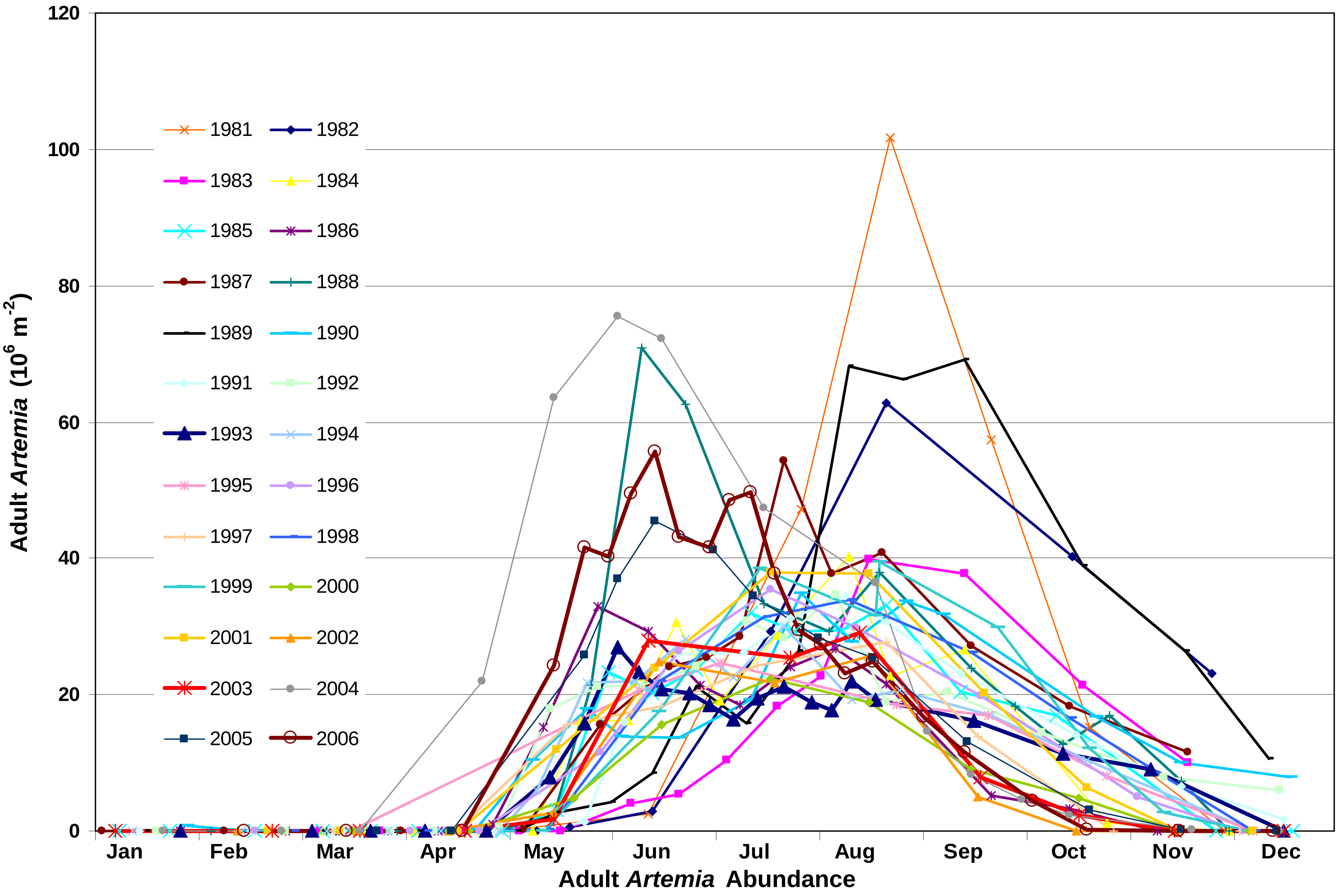
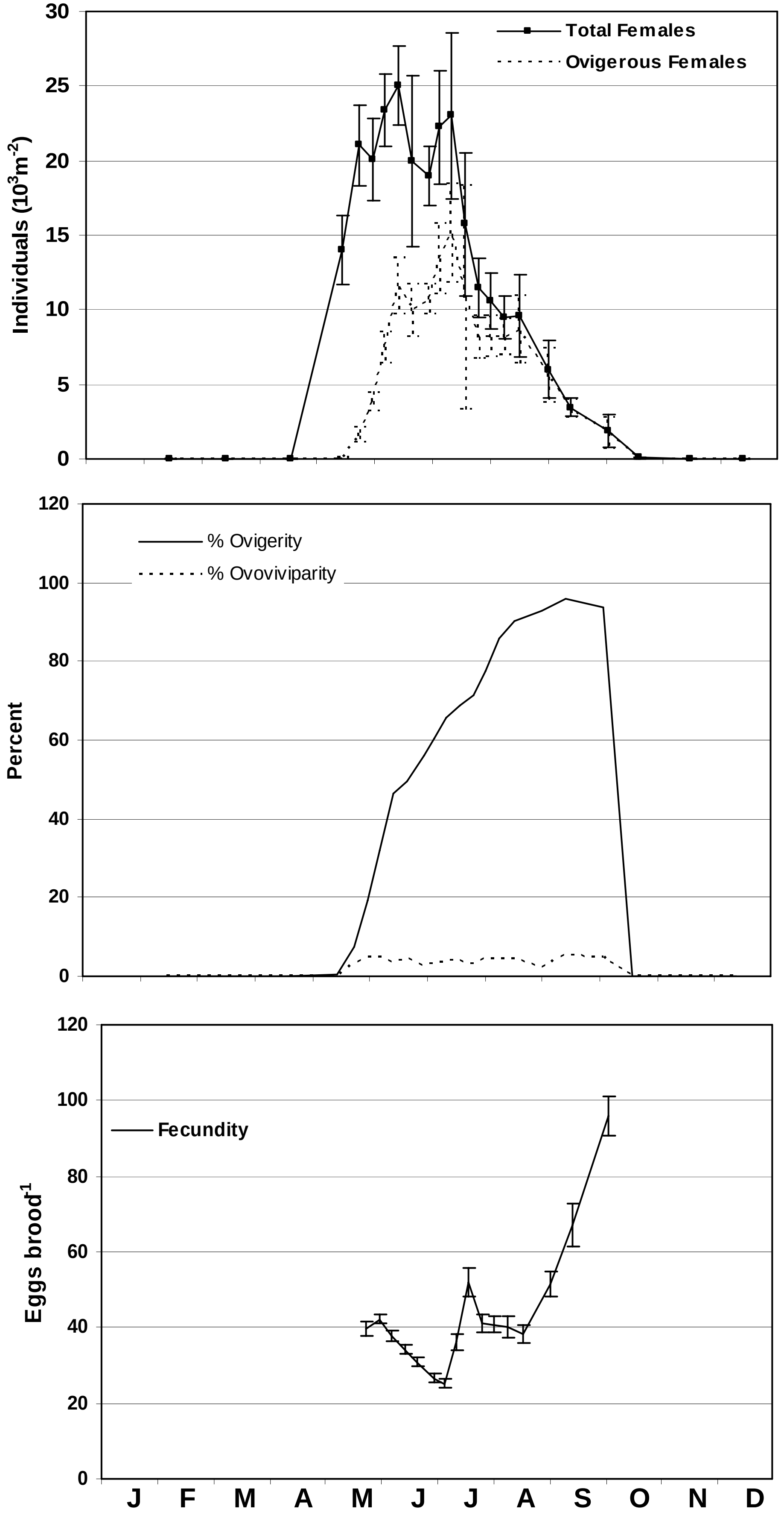
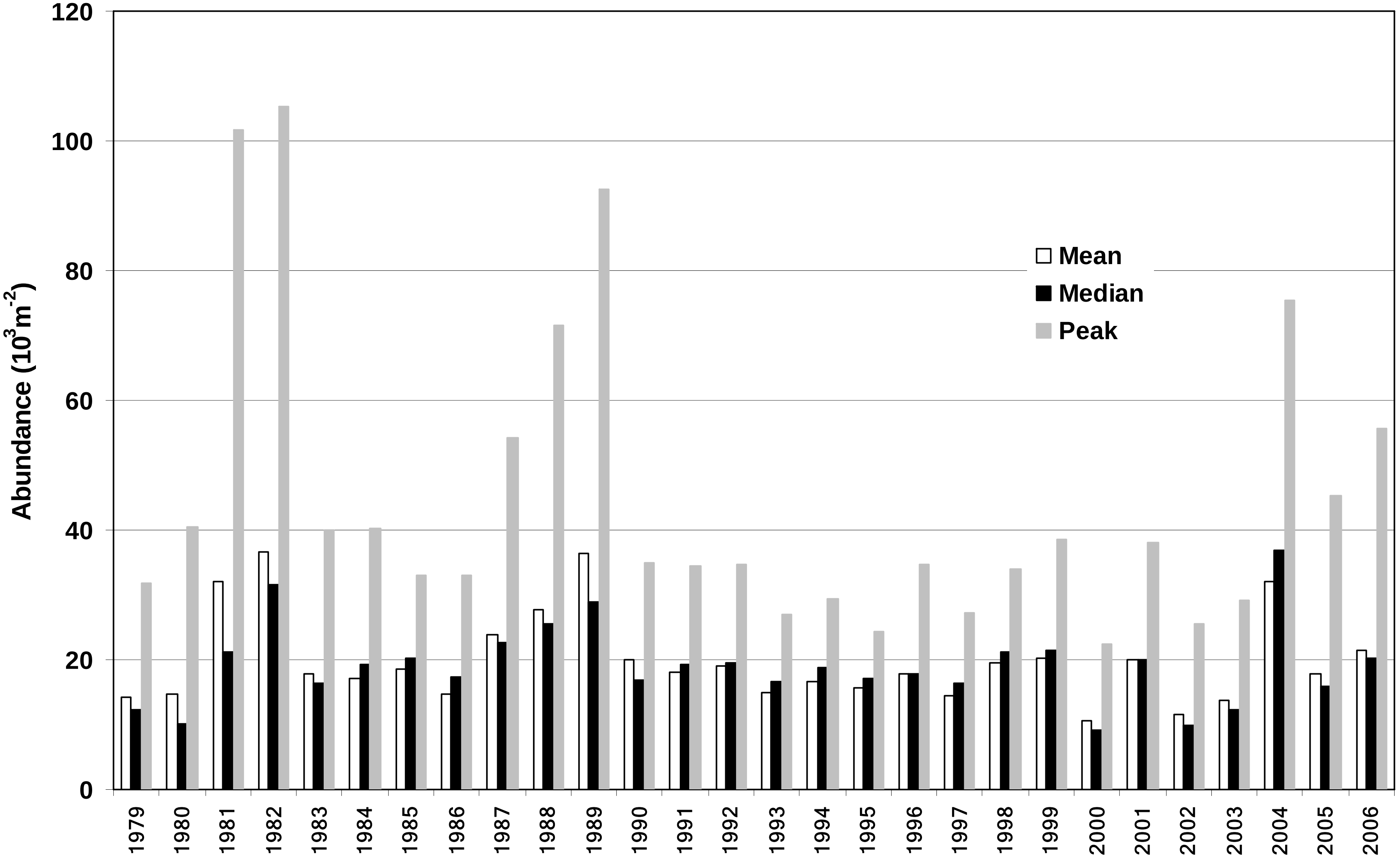

120
100
80
60
40
20
0
Adult *Artemia* (10^6 m^{-2})
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Adult *Artemia* Abundance
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

Figure 21

Figure 22



2006 *Artemia* Reproduction



Adult *Artemia* Summary

Figure 23

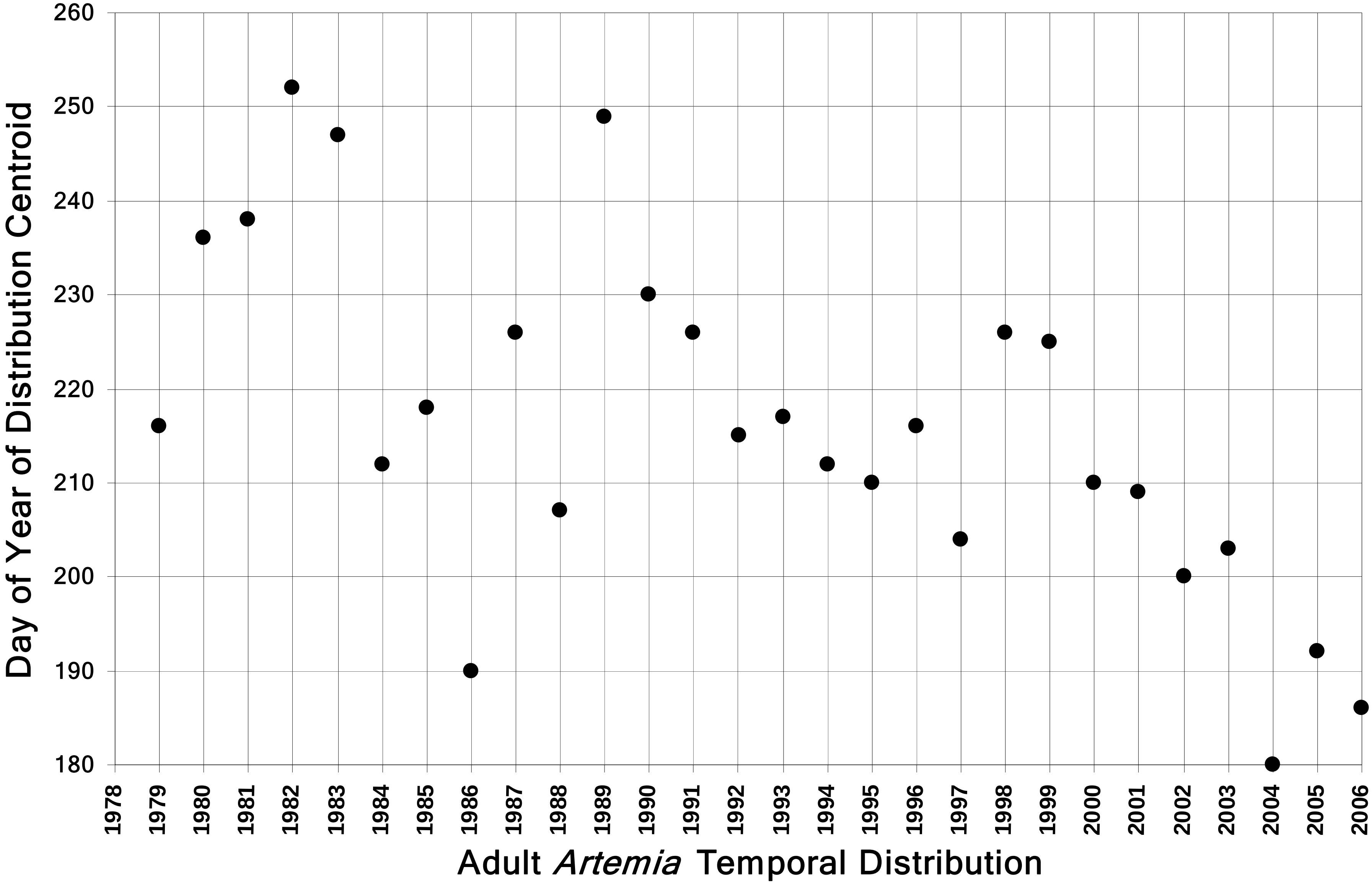
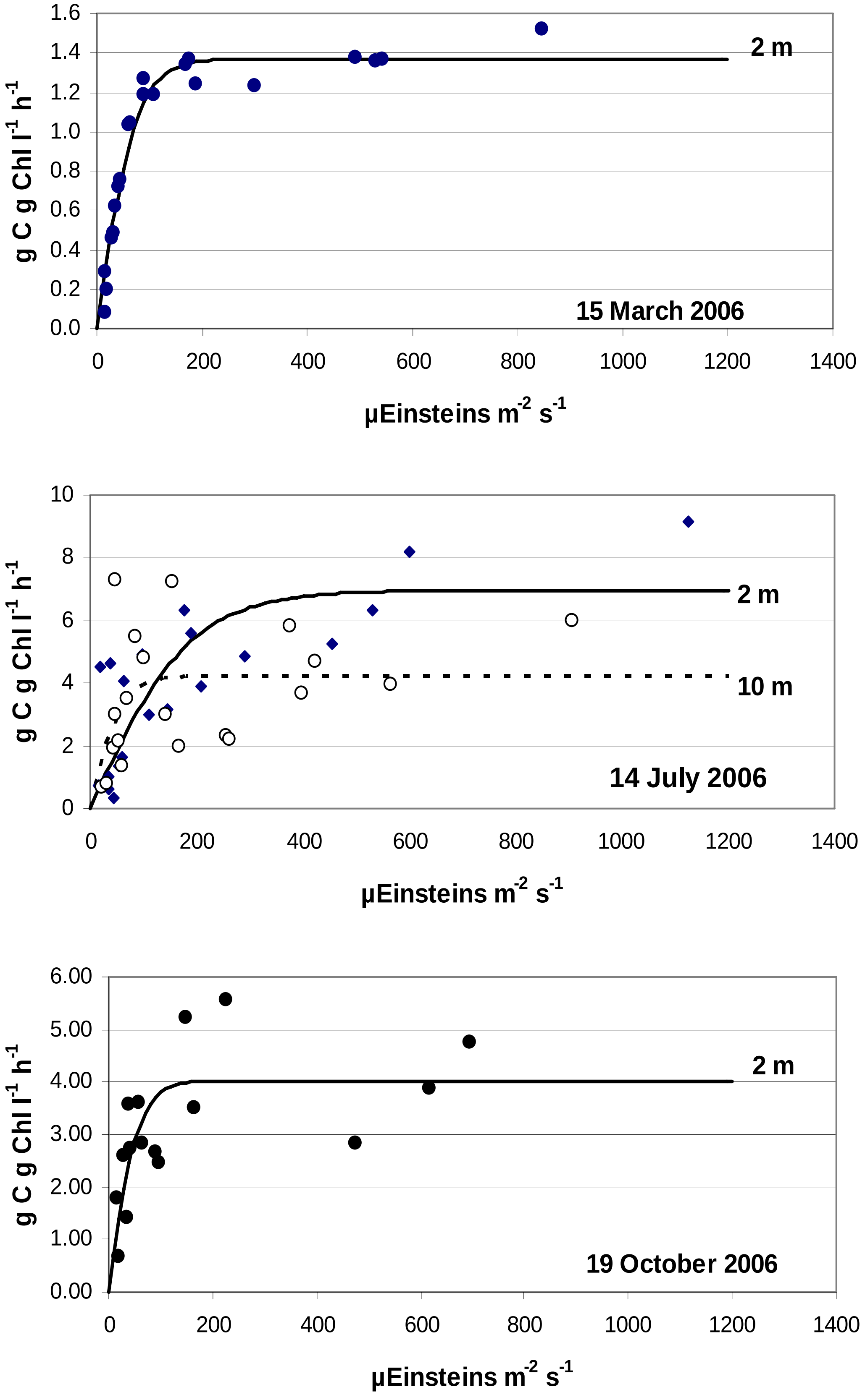

Day of Year of Distribution Centroid
260
250
240
230
220
210
200
190
180
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Adult *Artemia* Temporal Distribution

Figure 24

Figure 25


1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
g C g Chl l^{-1} h^{-1}
2 m
15 March 2006
0
200
400
600
800
1000
1200
1400
µEinsteins m^{-2} s^{-1}
10
8
6
4
2
0
g C g Chl l^{-1} h^{-1}
2 m
10 m
14 July 2006
0
200
400
600
800
1000
1200
1400
µEinsteins m^{-2} s^{-1}
6.00
5.00
4.00
3.00
2.00
1.00
0.00
g C g Chl l^{-1} h^{-1}
2 m
19 October 2006
0
200
400
600
800
1000
1200
1400
µEinsteins m^{-2} s^{-1}

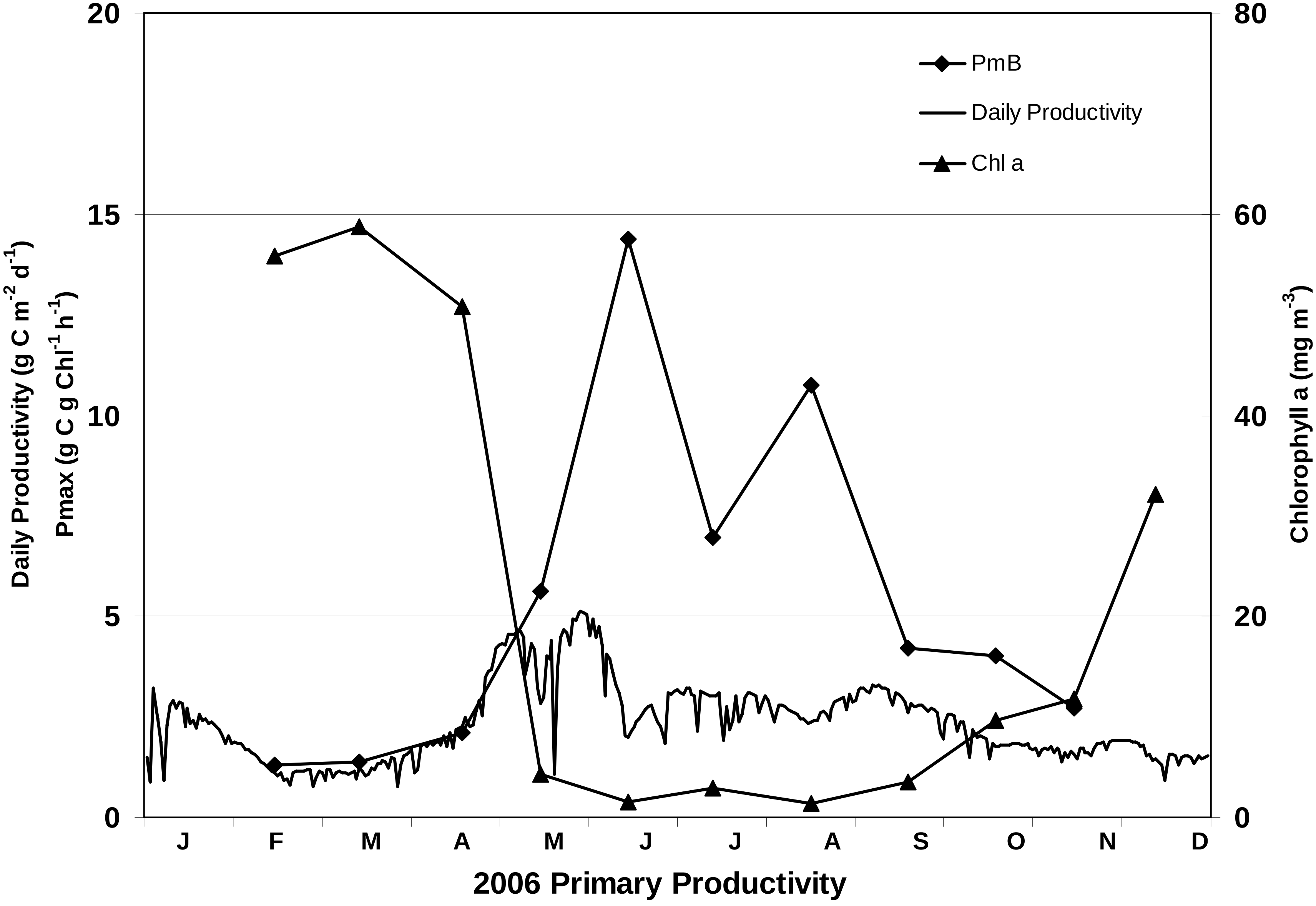
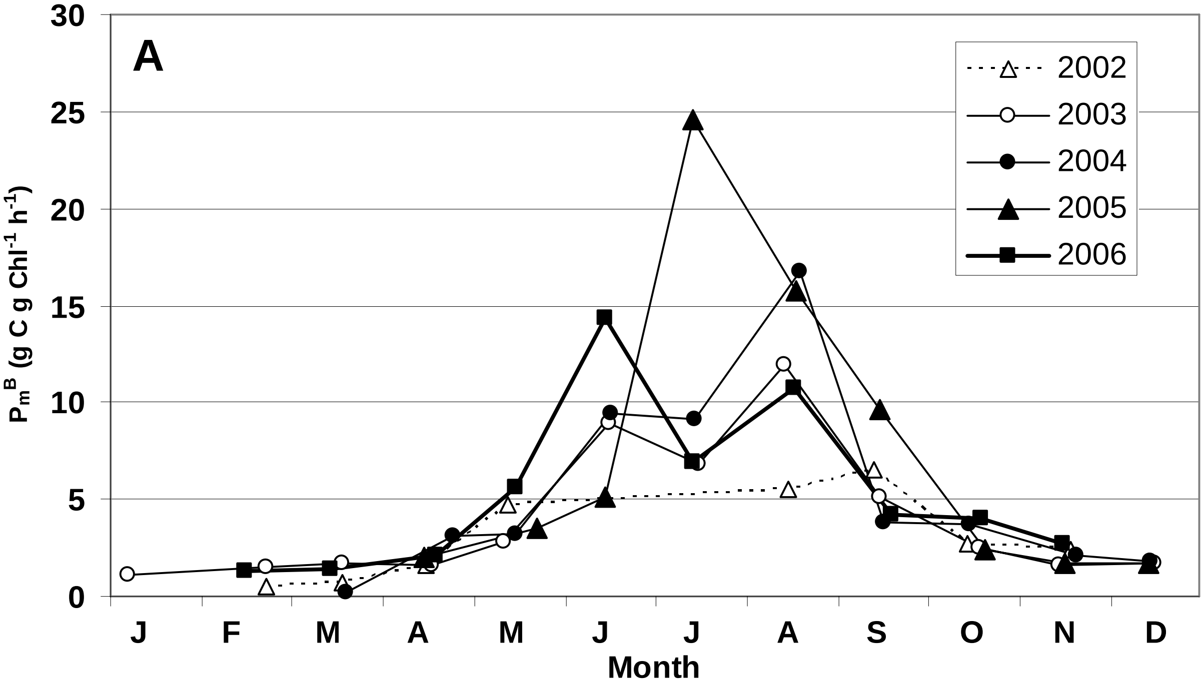

20
15
10
5
0
80
60
40
20
0
Daily Productivity (g C m^{-2} d^{-1})
Pmax (g C g Chl^{-1} h^{-1})
Chlorophyll a (mg m^{-3})
PmB
Daily Productivity
Chl a
J
F
M
A
M
J
J
A
S
O
N
D
2006 Primary Productivity

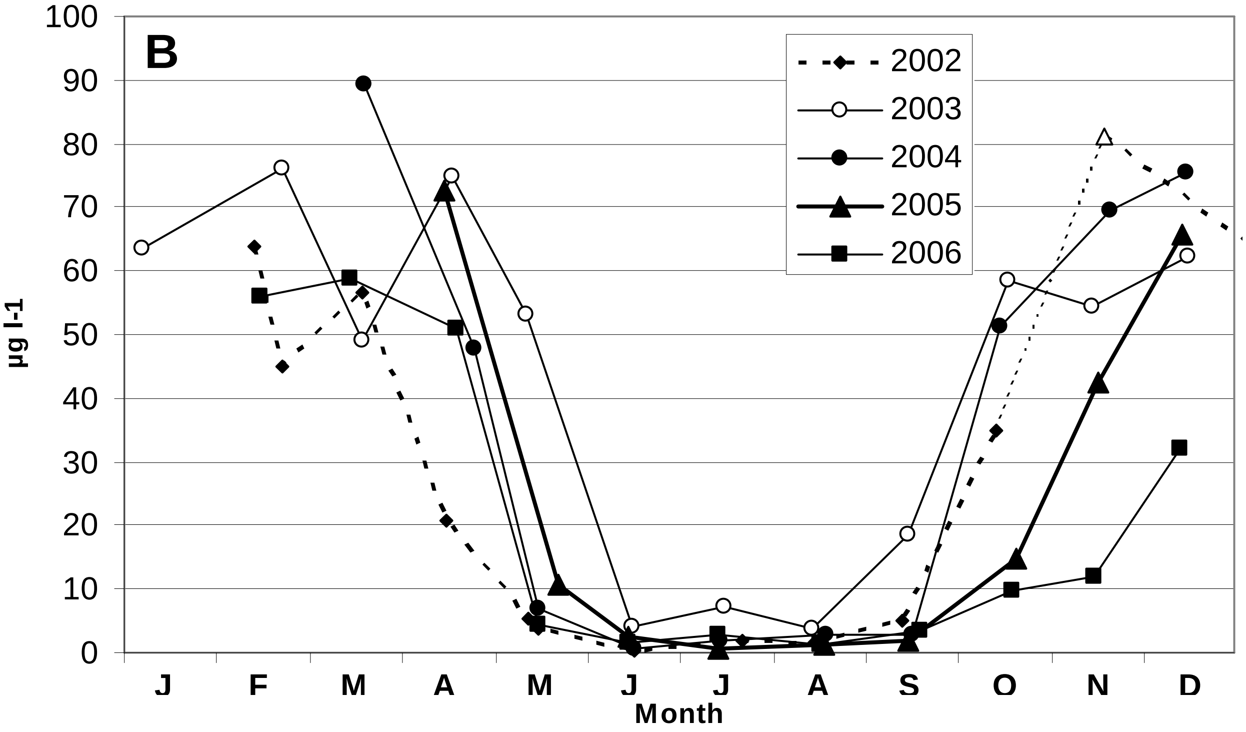
Figure 26

Figure 27

Mixed-layer P_m^B (2 m depth)



Mixed-layer Chlorophyll (2 m depth)



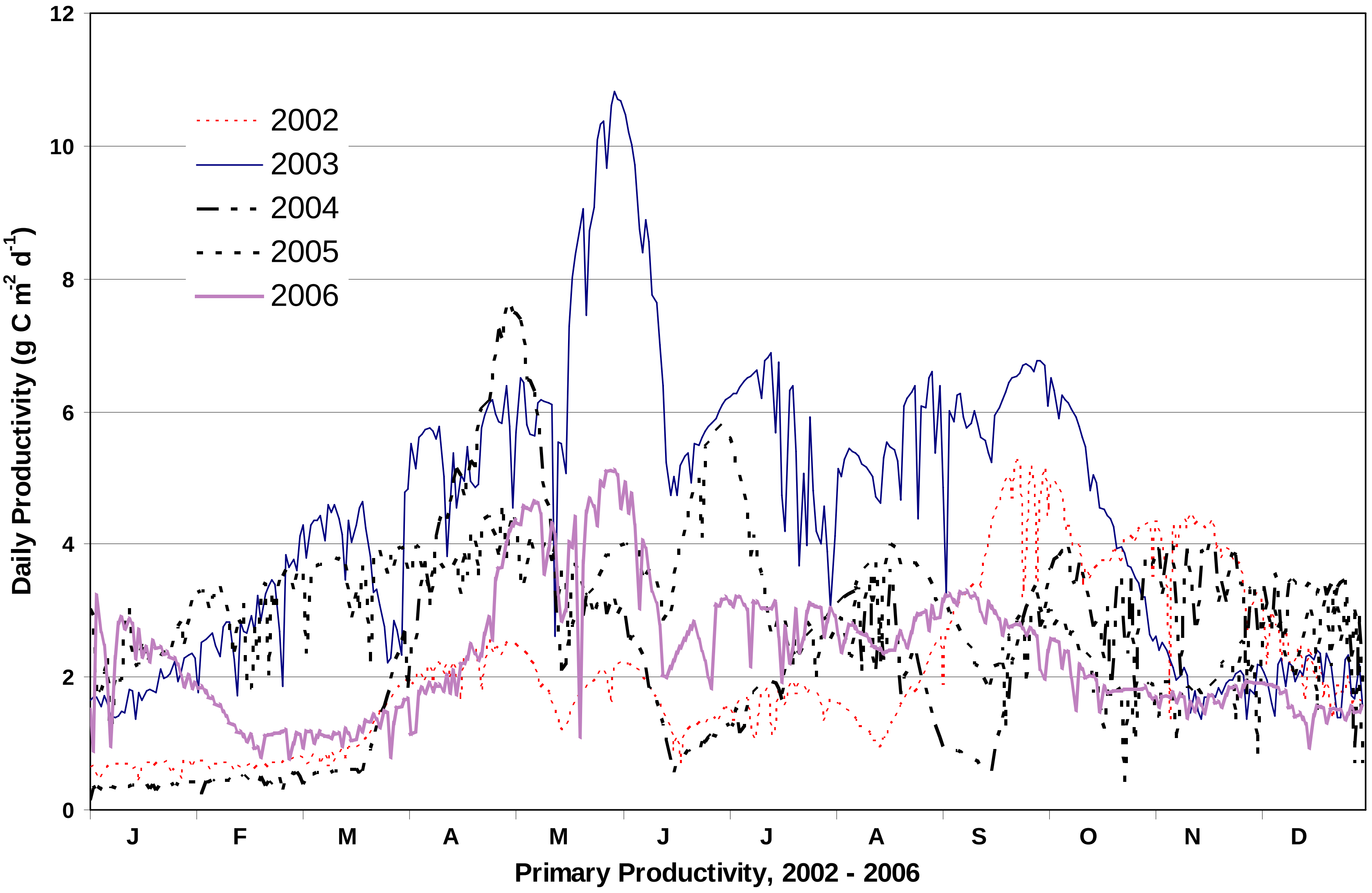

12
10
8
6
4
2
0
Daily Productivity (g C m^{-2} d^{-1})
2002
2003
2004
2005
2006
J
F
M
A
M
J
J
A
S
O
N
D
Primary Productivity, 2002 - 2006

Figure 28

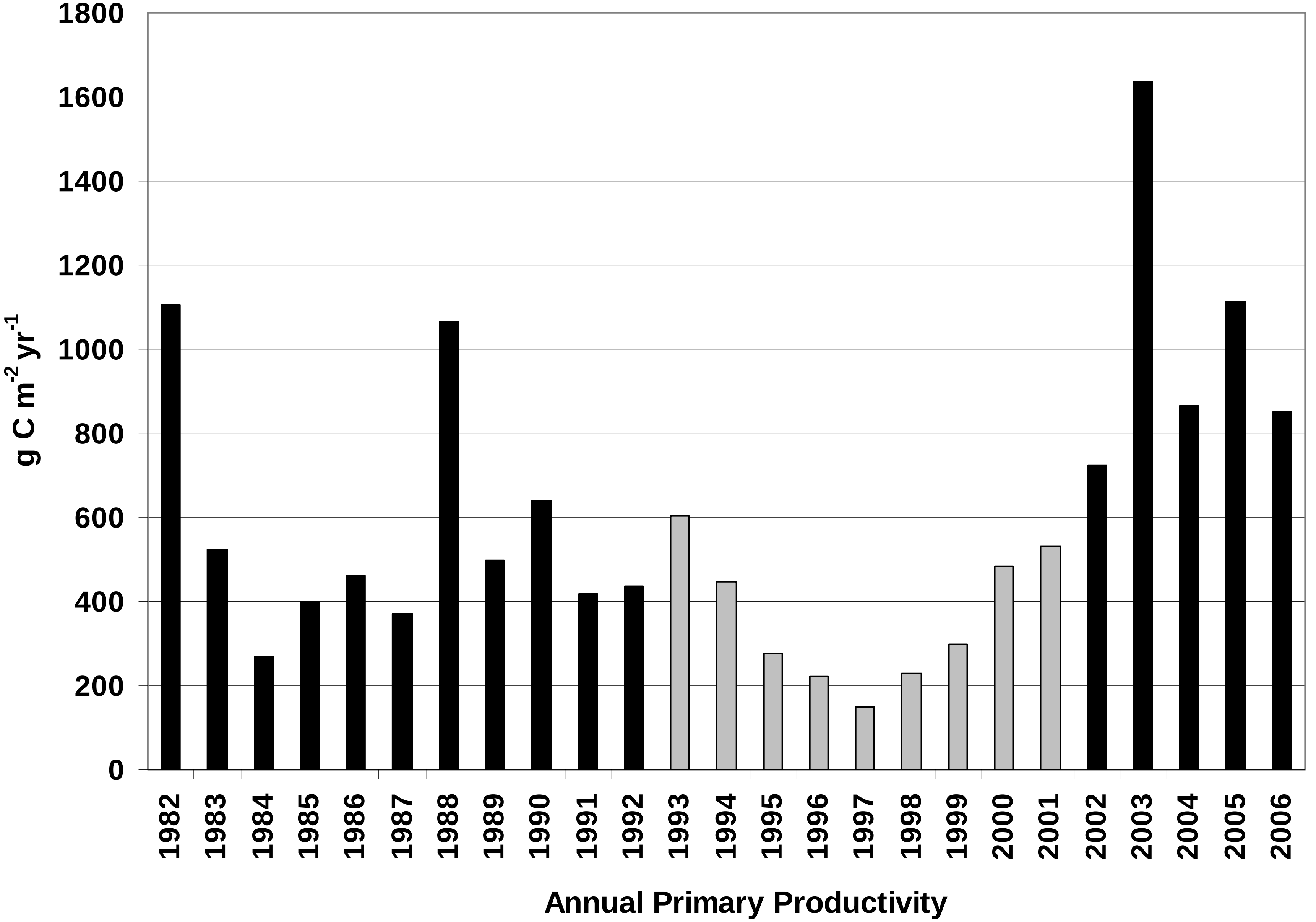

1800
1600
1400
1200
1000
800
600
400
200
0
g C m-2 yr-1
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Annual Primary Productivity

Figure 29

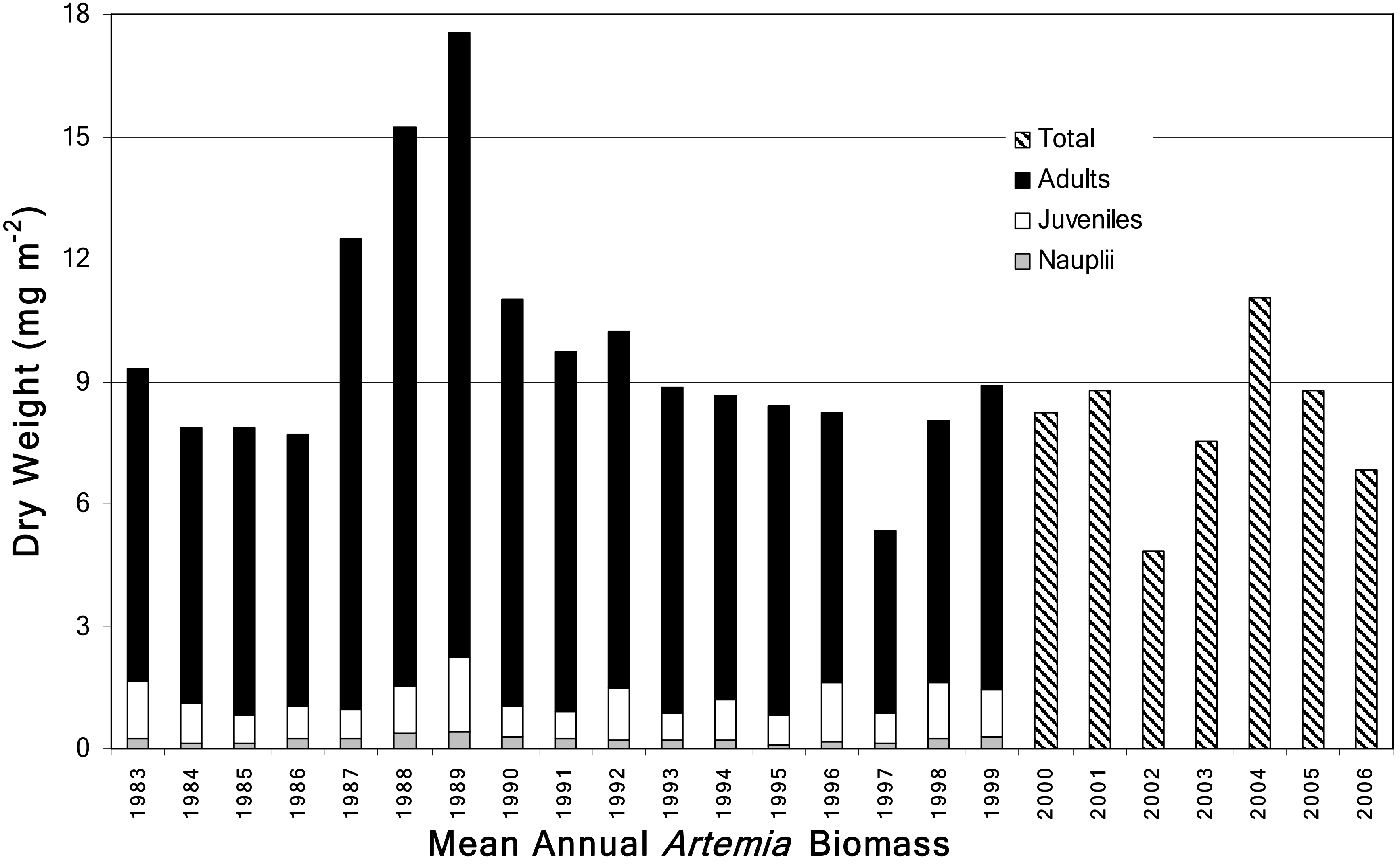

Dry Weight (mg m^{-2})
18
15
12
9
6
3
0
▧ Total
■ Adults
☐ Juveniles
▩ Nauplii
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Mean Annual *Artemia* Biomass

Figure 30

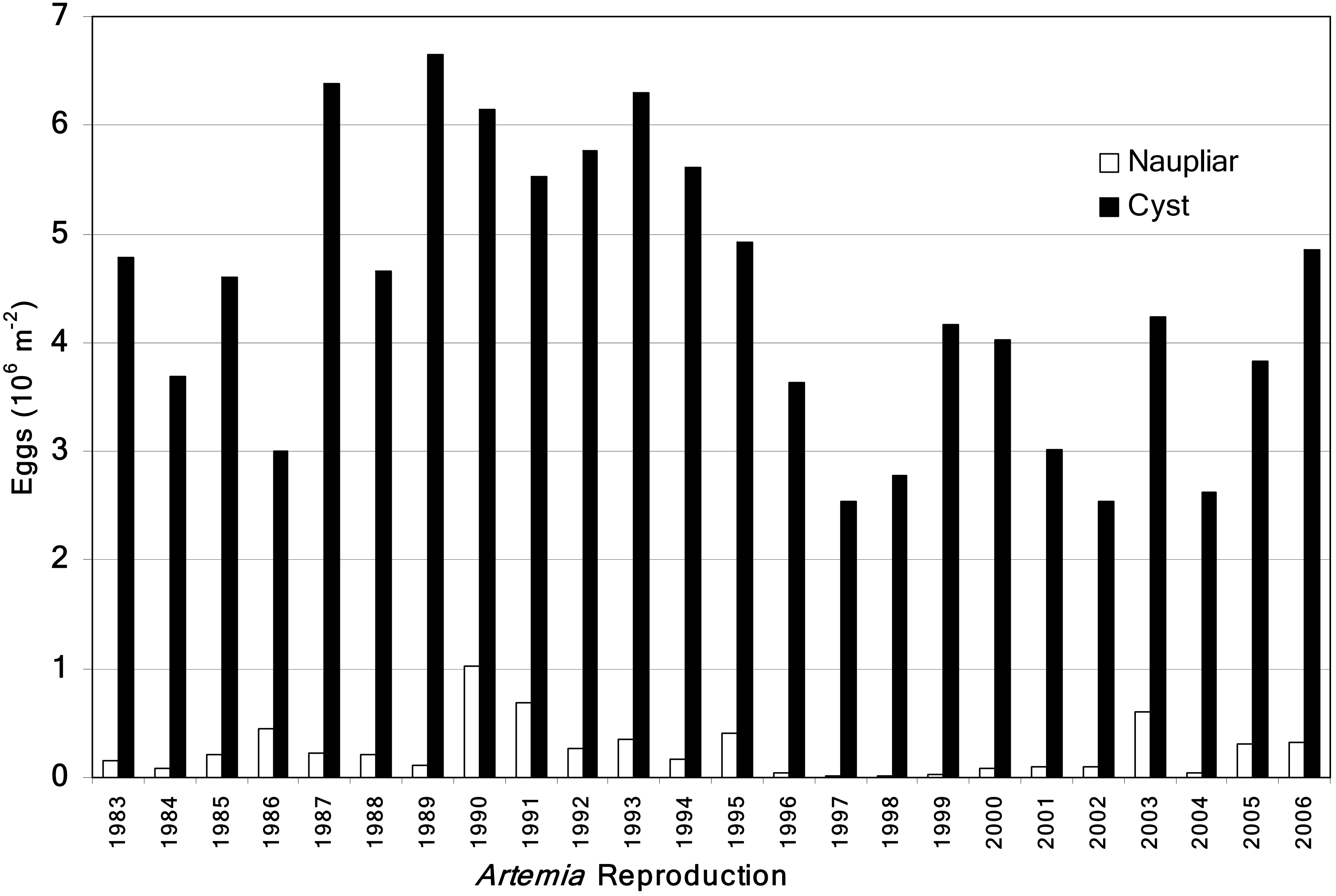

7
6
5
4
3
2
1
0
Eggs (10^6 m^{-2})
☐ Naupliar
■ Cyst
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Artemia Reproduction

Figure 31

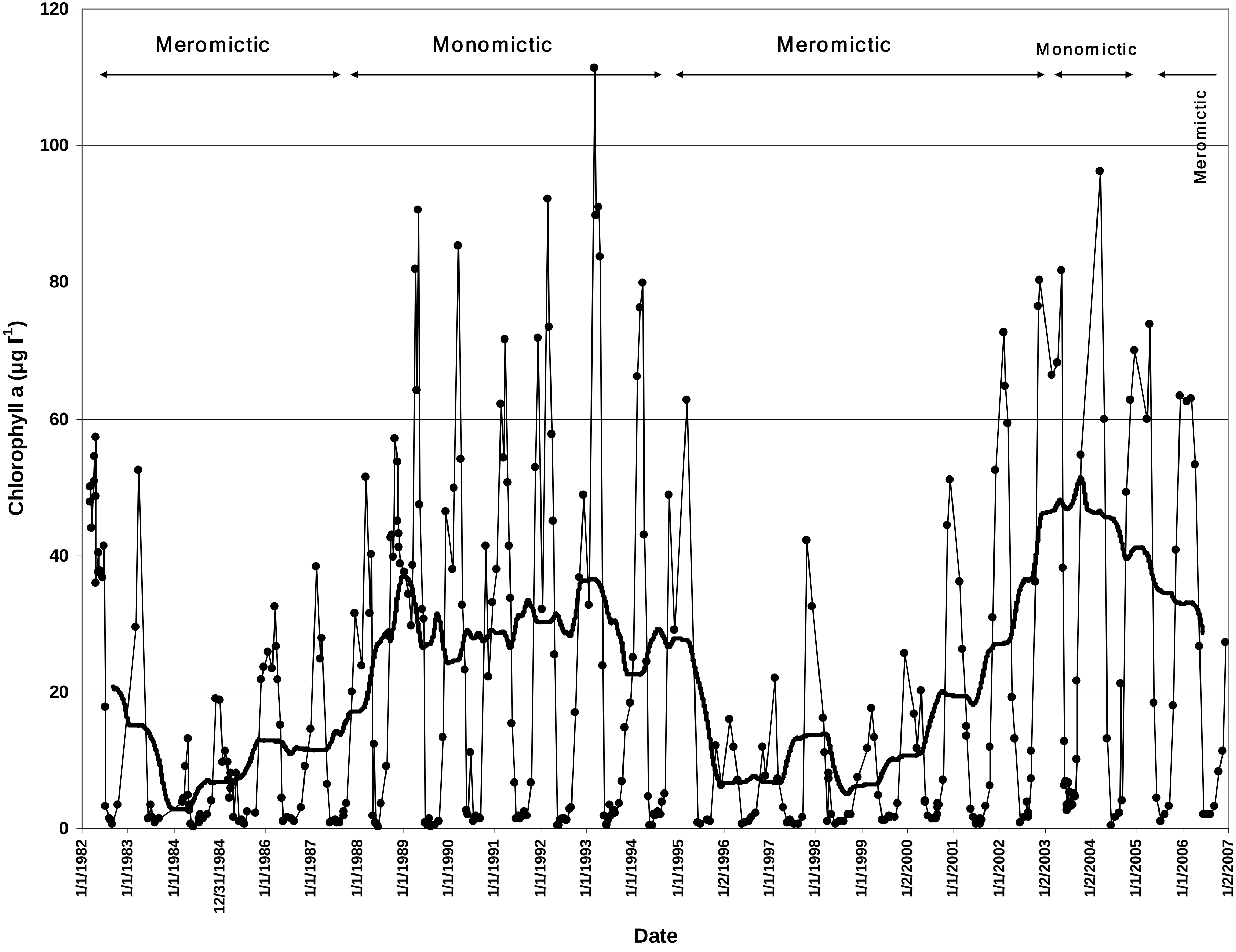

Meromictic
Monomictic
Meromictic
Monomictic
Meromictic
Chlorophyll a (µg l-1)
120
100
80
60
40
20
0
1/1/1982
1/1/1983
1/1/1984
12/31/1984
1/1/1986
1/1/1987
1/1/1988
1/1/1989
1/1/1990
1/1/1991
1/1/1992
1/1/1993
1/1/1994
1/1/1995
1/2/1996
1/1/1997
1/1/1998
1/1/1999
1/2/2000
1/1/2001
1/1/2002
1/2/2003
1/2/2004
1/1/2005
1/1/2006
1/2/2007
Date

Figure 32

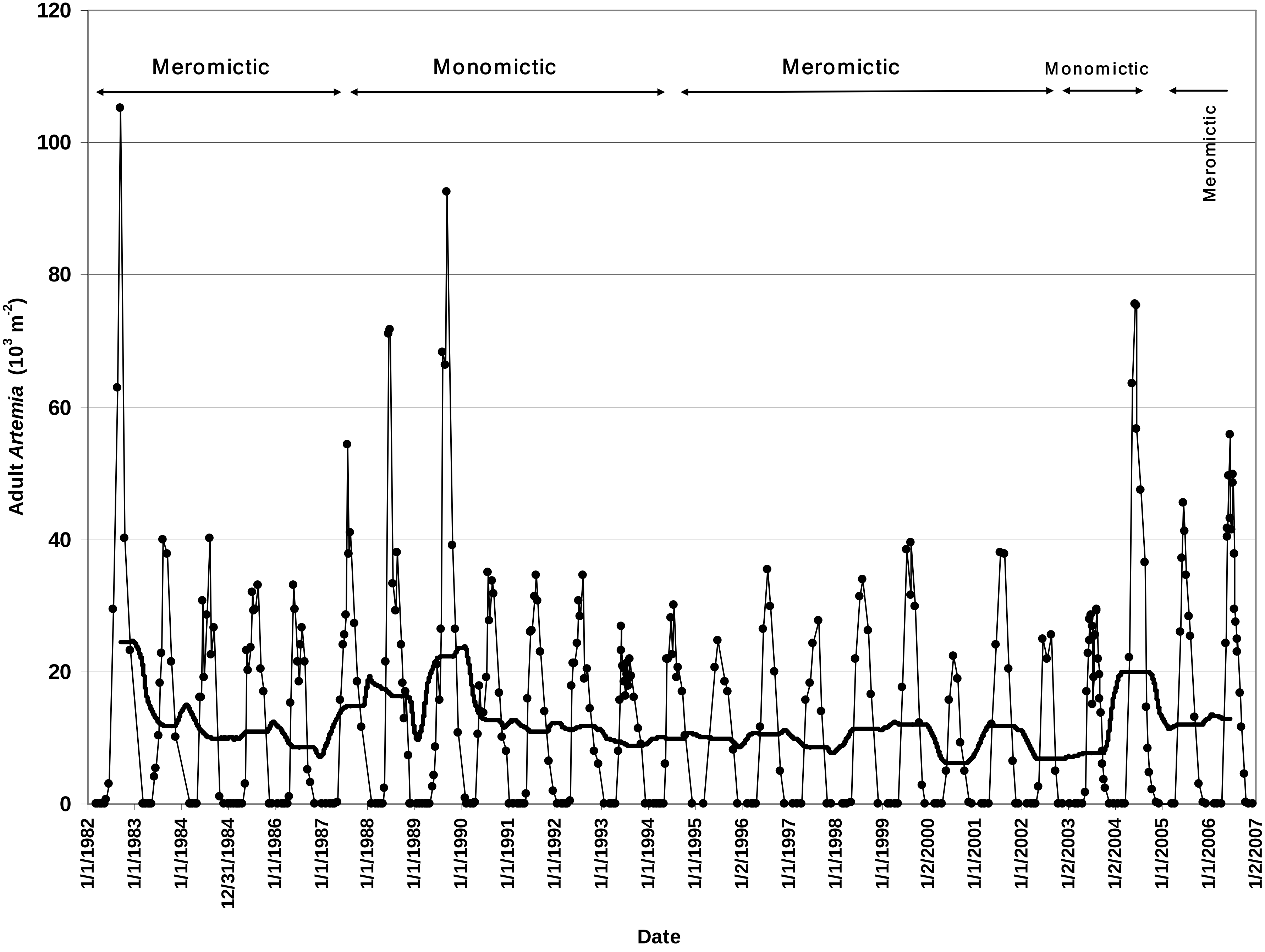

120
100
80
60
40
20
0
Adult *Artemia* (10^3 m^{-2})
Meromictic
Monomictic
Meromictic
Monomictic
Meromictic
1/1/1982
1/1/1983
1/1/1984
12/31/1984
1/1/1986
1/1/1987
1/1/1988
1/1/1989
1/1/1990
1/1/1991
1/1/1992
1/1/1993
1/1/1994
1/1/1995
1/2/1996
1/1/1997
1/1/1998
1/1/1999
1/2/2000
1/1/2001
1/1/2002
1/2/2003
1/2/2004
1/1/2005
1/1/2006
1/2/2007
Date

Figure 33

APPENDIX 2

Orinthology

MONO LAKE WATERFOWL POPULATION MONITORING

2006 Annual Report

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
WATERSHED RESOURCES SPECIALIST
BISHOP, CA 93514
April 2007

TABLE OF CONTENTS

EXECUTIVE SUMMARY .... **iii**

WATERFOWL MONITORING COMPLIANCE .... **v**

LIST OF TABLES .... **vi**

LIST OF FIGURES .... **vii**

INTRODUCTION **1**

METHODS **2**

SUMMER GROUND SURVEYS 2

FALL AERIAL SURVEYS 4

OVERVIEW OF METHODOLOGY 4
Mono Lake Aerial Surveys *5*
Bridgeport Reservoir Aerial Surveys *6*
Crowley Reservoir Aerial Surveys *6*
Ground Verification Counts *7*

STATISTICAL ANALYSIS 7
Summer Ground Counts – Waterfowl Distribution; Shorebird Distribution and Species Richness ... *7*
Summer Ground Counts - Habitat Use *7*
Fall Counts – Data Summary and Analysis *8*
Trend Analysis *8*

PHOTO DOCUMENTATION 9

DATA SUMMARY **9**

2006 CONDITIONS 9

MONO LAKE 9
South Shoreline Areas (South Tufa, South Shore Lagoons, and Sammann's Spring) *9*
Warm Springs and Northeast Shore 10
Black Point to Bridgeport Creek 11
Northwest Shore (DeChambeau Creek, Mill Creek, and Wilson Creek) 11
Rush Creek 12
Lee Vining Creek 12

BRIDGEPORT RESERVOIR 12

CROWLEY RESERVOIR 12

FALL AERIAL SURVEY WEATHER CONDITIONS 12

SUMMER GROUND COUNTS 13

WATERFOWL 13

WATERFOWL HABITAT USE 13

SHOREBIRDS 14

SHOREBIRD HABITAT USE 15

FALL AERIAL SURVEYS 16

MONO LAKE 16

BRIDGEPORT RESERVOIR 17

CROWLEY RESERVOIR 18

COMPARISON OF MONO LAKE WITH BRIDGEPORT AND CROWLEY RESERVOIRS 18

ANALYSIS OF TREND – MONO LAKE 19
DISCUSSION 19
REFERENCES 22
APPENDICES 72
APPENDIX 1. 2006 GROUND COUNT SURVEYS - DATES AND TIMES 72
APPENDIX 2. COMMON, SCIENTIFIC NAMES AND CODES FOR SPECIES NAMES 74
APPENDIX 3. HABITAT CATEGORIES. 75
MARSH 75
WET MEADOW 75
ALKALINE WET MEADOW 75
DRY MEADOW/FORB 75
RIPARIAN AND WETLAND SCRUB 75
GREAT BASIN SCRUB 75
RIPARIAN FOREST AND WOODLAND 76
FRESHWATER-STREAM 76
FRESHWATER-RIA 76
FRESHWATER-POND 76
EPHEMERAL BRACKISH LAGOON 76
EPHEMERAL HYPERSALINE LAGOON 76
UNVEGETATED 76
APPENDIX 4. 2006 FALL AERIAL SURVEY DATES 77
APPENDIX 5. LAKESHORE SEGMENT BOUNDARIES 77
APPENDIX 6. CROSS-LAKE TRANSECT POSITIONS FOR MONO LAKE 78

EXECUTIVE SUMMARY

Waterfowl populations were monitored in 2006 at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, in compliance with State Water Resources Control Board Order 98-05. At Mono Lake, three summer ground surveys and six fall aerial surveys for waterfowl were conducted. In order to determine whether or not long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, fall aerial surveys were also conducted at Bridgeport and Crowley Reservoirs.

A total of ten waterfowl species were encountered at Mono Lake while conducting summer surveys. The six species that used the Mono Lake shoreline habitats and Restoration Ponds (DeChambeau and County Ponds) for brooding were Gadwall, Canada Goose, Mallard, Cinnamon Teal, Northern Pintail and Green-winged Teal. Gadwall was the most abundant waterfowl species breeding at Mono Lake. This species also had the greatest spatial distribution of all waterfowl that use Mono Lake shoreline habitats for breeding.

There was an increase in the number of broods detected at Mono Lake in 2006. A minimum of 89 unique broods were observed using Mono Lake shoreline habitats and Restoration Ponds in the summer. This is the most broods documented since counts started in 2000. The brood count included 67 Gadwall, 11 Canada Goose, seven Mallard, two Northern Pintail, one Cinnamon Teal and one Green-winged Teal brood. There was an increased use of the South Shore Lagoons area by breeding waterfowl and more broods were detected in this area than any other shoreline segment.

A total of 19 shorebird species were encountered during the summer surveys. The total detections of shorebird species that typically summer and occasionally breed at Mono Lake was the lowest since 2002. Shorebird species for which evidence of breeding was detected included: Wilson’s Phalarope, Killdeer, Spotted Sandpiper, and Snowy Plover. The Warm Springs, Sammann’s Springs and South Shore Lagoons areas of Mono Lake attracted the greatest number of shorebird species throughout the summer season.

A total of fourteen waterfowl species were recorded at Mono Lake during fall aerial surveys. The total number of detections and peak one-day count was similar to that seen in 2005. In terms of total waterfowl detections, 22,198 individuals were detected on the lake during these surveys, while 297 individuals were detected at the Restoration Ponds. The peak number of

waterfowl detected on any one survey at Mono Lake in 2006 was 6,605, which occurred on the October 3 survey.

A total of 17 waterfowl species were recorded at Bridgeport Reservoir during the fall 2006 aerial surveys. The peak number of waterfowl detected at Bridgeport Reservoir was 15,238 individuals, and occurred during the September 21st survey. A total of 43,670 waterfowl were detected during the six surveys at Bridgeport Reservoir during the fall season. The most abundant species were Northern Shoveler, Gadwall, and Northern Pintail. The primary area of waterfowl concentration was the West Bay area.

A total of 18 waterfowl species were recorded at Crowley Reservoir during the 2006 fall aerial surveys. The peak number detected at Crowley Reservoir was 7,878 which occurred during the November 15th survey. A total of 25,471 waterfowl were detected at Crowley Reservoir over the six fall season surveys. The most abundant species were Northern Pintail, Mallard and Green-winged Teal. The primary areas of waterfowl concentration were McGee Bay, Layton Springs and the Upper Owens River.

Comparison counts conducted at Bridgeport Reservoir and Crowley Reservoir indicate a large disparity between Mono Lake and the other two bodies of water with regard to the dominant species present. The data indicate that utilization by Ruddy Ducks and Northern Shovelers was proportionally higher at Mono Lake than either the Bridgeport or Crowley Reservoirs. Conversely, utilization by Mallards, Gadwalls, and Northern Pintails, Green-winged Teals was proportionally higher at both Bridgeport Reservoir and Crowley Reservoir than at Mono Lake.

An analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl detected at Mono Lake since 1996.

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 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 2006. Six comparative fall aerial counts were completed at Bridgeport and Crowley Reservoirs. Photos of shoreline habitats and the restoration ponds were taken from a helicopter on September 25, 2006.

LIST OF TABLES

TABLE 1. SUMMER GROUND DATA, SURVEY 1 - JUNE 5-7, 2006 23
TABLE 2. SUMMER GROUND DATA, SURVEY 2 - JUNE 26-28, 2006 24
TABLE 3. SUMMER GROUND DATA, SURVEY 3 - JULY 17-20, 2006 25
TABLE 4. SUMMARY OF GROUND COUNT DATA FOR MONO LAKE, 2006 26
TABLE 5. NUMBER OF BROODS OF SPECIES DETECTED PER VISIT IN EACH SUMMER SURVEY 27
TABLE 6. CHI SQUARE GOODNESS-OF-FIT RESULTS FOR WATERFOWL HABITAT USE DATA. 28
TABLE 7. DETECTIONS OF SUMMERING SHOREBIRD SPECIES AT MONO LAKE, 2002-2006 29
TABLE 8. CHI SQUARE GOODNESS-OF FIT-RESULTS FOR SHOREBIRD FORAGING HABITAT USE DATA. 30
TABLE 9. SUMMARY OF FALL AERIAL SURVEY COUNTS FOR 2006, MONO LAKE 31
TABLE 10. MONO LAKE - FALL AERIAL SURVEY, SEPTEMBER 6, 2006 32
TABLE 11. MONO LAKE - FALL AERIAL SURVEY, SEPTEMBER 21, 2006 33
TABLE 12. MONO LAKE - FALL AERIAL SURVEY, OCTOBER 3, 2006 34
TABLE 13. MONO LAKE - FALL AERIAL SURVEY, OCTOBER 17, 2006 35
TABLE 14. MONO LAKE - FALL AERIAL SURVEY, OCTOBER 31, 2006 36
TABLE 15. MONO LAKE - FALL AERIAL SURVEY, NOVEMBER 15, 2006 37
TABLE 16. MONO LAKE RESTORATION PONDS - AERIAL WATERFOWL COUNTS - 2006 38
TABLE 17. SUMMARY OF SHOREBIRD/WATERBIRD COUNTS AT MONO LAKE DURING FALL AERIAL SURVEY 39
TABLE 18. SUMMARY OF 2006 FALL AERIAL SURVEY COUNTS - BRIDGEPORT RESERVOIR 40
TABLE 19. BRIDGEPORT RESERVOIR FALL SURVEY, SEPTEMBER 6, 2006 41
TABLE 20. BRIDGEPORT RESERVOIR FALL AERIAL SURVEY, SEPTEMBER 21, 2006 41
TABLE 21. BRIDGEPORT RESERVOIR FALL AERIAL SURVEY , OCTOBER 3, 2006 41
TABLE 22. BRIDGEPORT RESERVOIR FALL AERIAL SURVEY, OCTOBER 17, 2006 42
TABLE 23. BRIDGEPORT RESERVOIR FALL AERIAL SURVEY, OCTOBER 31, 2006 42
TABLE 24. BRIDGEPORT RESERVOIR FALL AERIAL SURVEY, NOVEMBER 15, 2006 42
TABLE 25. SUMMARY OF 2006 FALL AERIAL SURVEY COUNTS - CROWLEY RESERVOIR 43
TABLE 26. CROWLEY RESERVOIR FALL AERIAL SURVEY, SEPTEMBER 6, 2006 44
TABLE 27. CROWLEY RESERVOIR FALL AERIAL SURVEY, SEPTEMBER 21, 2006 44
TABLE 28. CROWLEY RESERVOIR FALL AERIAL SURVEY, OCTOBER 3, 2006 45
TABLE 29. CROWLEY RESERVOIR FALL AERIAL SURVEY, OCTOBER 17, 2006 45
TABLE 30. CROWLEY RESERVOIR FALL AERIAL SURVEY, OCTOBER 31, 2006 46
TABLE 31. CROWLEY RESERVOIR FALL AERIAL SURVEY, NOVEMBER 15, 2006 46

LIST OF FIGURES

FIGURE 1. SUMMER GROUND COUNT SURVEY AREAS 47
FIGURE 2. LAKESHORE SEGMENT , SEGMENT BOUNDARIES, AND CROSS-LAKE TRANSECTS OF MONO LAKE 48
FIGURE 3. LAKESHORE SEGMENTS AND SEGMENT BOUNDARIES OF BRIDGEPORT RESERVOIR 49
FIGURE 4. LAKESHORE SEGMENTS AND SEGMENT BOUNDARIES OF CROWLEY RESERVOIR 50
FIGURE 5. EAST SHORE OF SOUTH TUFA AREA SHOWING THE NEW LAGOON PRESENT IN 2006 51
FIGURE 6. EAST END OF SOUTH TUFA AREA SHOWING THE NEW AND EXPANDED LAGOON PRESENT IN 2006. 51
FIGURE 7. PHOTO TAKEN IN THE SAMMANN'S SPRING AREA 52
FIGURE 8. PHOTO TAKEN IN THE SAMMAN'S SPRING AREA SHOWING INFLUENCE OF OLD LITTORAL BARS 52
FIGURE 9. SHORELINE CONDITIONS IN THE GOOSE SPRINGS AREA OF THE SOUTH SHORE LAGOONS IN 2005. 53
FIGURE 10. SHORELINE CONDITIONS IN THE GOOSE SPRINGS AREA OF THE SOUTH SHORE LAGOON 53
FIGURE 11. FLOCKS OF MIGRATING WILSON'S PHALAROPES AT SAMMANN'S SPRINGS 54
FIGURE 12. SHORELINE CONDITIONS AT WARM SPRINGS 55
FIGURE 13. SHORELINE CONDITIONS IN THE NORTHEAST SHORE AREA 55
FIGURE 14. BLACK POINT SHORELINE AREA 56
FIGURE 15. DIE OFF OF SALIX EXIGUA IN THE DECHAMBEAU-CREEK AREA 57
FIGURE 16. WILSON CREEK DELTA AREA. 57
FIGURE 17. DECHAMBEAU CREEK SHORELINE AREA. 58
FIGURE 18. MILL CREEK DELTA AREA. 58
FIGURE 19. WILSON CREEK AREA. 59
FIGURE 20. RUSH CREEK DELTA. 60
FIGURE 21. LEE VINING CREEK DELTA. 60
FIGURE 22. PHOTO OF BRIDGEPORT RESERVOIR. TAKEN FROM A HELICOPTER ON SEPTEMBER 25, 2006. 61
FIGURE 23. ELEVATED WATER LEVELS AT CROWLEY RESERVOIR 62
FIGURE 24. PHOTO SHOWING THE CONDITION OF THE WATER AT CROWLEY RESERVOIR IN FALL 2006. 62
FIGURE 25. MOUTH OF THE OWENS RIVER, CROWLEY RESERVOIR 62
FIGURE 26. BROOD LOCATIONS 63
FIGURE 27. HABITAT USE BY THE DOMINANT SUMMER RESIDENT WATERFOWL SPECIES. THE NUMBERS IN 64
FIGURE 28. FORAGING HABITAT USED BY THE DOMINANT SHOREBIRD SPECIES 65
FIGURE 29. WATERFOWL DETECTED AT EACH WATERBODY DURING FALL AERIAL SURVEYS, 2006. 66
FIGURE 30. DETECTIONS OF DOMINANT SPECIES AT MONO LAKE 67
FIGURE 31. DETECTIONS OF DOMINANT SPECIES AT BRIDGEPORT RESERVOIR 68
FIGURE 32. DETECTIONS OF DOMINANT SPECIES AT CROWLEY RESERVOIR 69
FIGURE 33. TOTAL FALL DETECTIONS OF THE DOMINANT SPECIES AT ALL THREE BODIES OF WATER. 70
FIGURE 34. TREND IN PEAK WATERFOWL NUMBERS AT MONO LAKE, 1996-2006. 71

2006 Mono Lake Waterfowl Population Monitoring
Los Angeles Department of Water and Power
Prepared by Debbie House
Watershed Resources Specialist
Bishop, CA

INTRODUCTION

In order to evaluate the response of waterfowl populations to restoration efforts in the Mono Basin watershed, waterfowl population monitoring is being conducted on an annual basis at Mono Lake [State Water Resources Control Board Orders 98-05 and 98-07]. 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). Restoration activities in the Mono Basin that are expected to influence waterfowl use include the rewatering of Mono Lake tributaries, an increase in the lake level leading to increased surface area of open-water habitats, a subsequent decrease in the salinity of the lake, changes to lake-fringing wetlands, and the creation of freshwater pond habitat. With the exception of the creation and maintenance of freshwater pond habitat at the DeChambeau and County Pond complexes, the majority of the changes in waterfowl habitats will come through proper flow and land management in the tributaries designed to achieve healthy, functional riparian systems, and a rise in lake elevation from reduced water diversions.

Summer ground surveys are conducted in order to document summer use by waterfowl and shorebird species of the Mono Lake shoreline, selected tributaries, and the freshwater restoration ponds. Fall aerial surveys are conducted to provide an index to the number of waterfowl using Mono Lake in the fall. In order to determine whether long-term trends observed at Mono Lake are being mirrored at other Eastern Sierra water bodies, or are specific to Mono Lake and any changes which may be occurring there, fall waterfowl surveys are also conducted at Bridgeport and Crowley Reservoirs.

All summer surveys were conducted by the author. Dr. Mark Hanna, LADWP Eastern Sierra Environmental Issues, participated in the July 18 survey. Fall surveys were conducted by the author with assistance from Allison Miller, 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. These were conducted as either transect surveys, or by making observations from a stationary point. Three days were required to complete each ground survey of Mono Lake, with the exception of the third survey conducted the third week of July, which required four days to complete. The date and time of day that surveys were done in each area around Mono Lake during 2006 have been provided in Appendix 1.

The locations surveyed were those identified in the Waterfowl Restoration Plan (LADWP 1996) as current or historic waterfowl concentration areas, 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 bottomlands and delta (RUCR), Lee Vining Creek bottomlands and delta (LVCR), DeChambeau Ponds (DEPO), and County Ponds (COPO). Areas surveyed during summer ground counts are shown in Figure 1.

Transect surveys along the shoreline were conducted at South Tufa, South Shore Lagoons, Sammann's Spring, Warm Springs, DeChambeau Creek, Wilson Creek, and Mill Creek. Transect surveys were conducted by walking at an average rate of approximately 1.5 km/hr, depending on conditions, and recording waterfowl and shorebird species as they were encountered. Due to the fact that waterfowl are easily flushed, and females with broods are especially wary, the shoreline was scanned well ahead of the observer in order to increase the probability of detecting broods.

Transect surveys were also conducted in lower Rush and Lee Vining Creeks, from the County Road down to the deltas. Surveys along lower Rush Creek were conducted by walking along the southern bluff above the creek. This route offered a good view of the creek while limiting wildlife disturbance and the 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. In both areas, birds observed within 100 meters on either side of the deltas were also recorded.

At the DeChambeau Pond complex, observations were taken from a single stationary point at each of the five ponds. The observation points were selected so as to provide a full view of each pond. However, at the County Ponds, observations were taken from a single location that allowed full viewing of both ponds simultaneously. At all observation points at the DeChambeau and County ponds, a minimum of 5 minutes was spent at each observation point.

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. The total survey time was recorded for each area.

For all waterfowl and shorebird species, the following data were recorded when the individual or group was first detected: the time of the observation, the habitat type the individual or group was using, 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". The common name, scientific name, and 4-letter code for each species mentioned in the document can be found in Appendix 2.

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 broods to an age class 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 lagoon, hypersaline lagoon, and unvegetated. 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 and shorebirds. 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 last 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 hrs. Mono Lake was surveyed in approximately one and one-half hours. Bridgeport Reservoir was surveyed next, and Crowley Reservoir was surveyed last. All three surveys were completed in a single flight by 1200 hrs on the day of the survey. One flight was delayed by two days due to inclement weather.

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 flights, and counted shorebirds and waterbirds. During the cross-lake transect counts, the second observer sat on the opposite side of the plane and censused Ruddy Ducks. At Bridgeport and Crowley, the second observer sat on the opposite side of the plane during the entire survey, and counted all waterfowl.

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.

Eight parallel cross-lake transects were conducted over the open water at Mono Lake. The eight transects are spaced at one-minute (1/60 of a degree, approximately 1 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 (see 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 Ruddy Ducks offshore. Since the survey aircraft's airspeed was carefully controlled, and the approximate length of each subsection was known, it was possible to use a stopwatch to determine the beginning and ending points of each subsection when over open water.

LADWP contracted with Black Mountain Air Service to conduct fixed-winged aerial counts. Black Mountain Air Service 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 at approximately 250 meters from the shoreline. When conducting aerial surveys, the perimeter of the lake was flown first 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. The reservoir was circumnavigated twice during each survey due to the small size of the reservoir and the presence of large concentrations of waterfowl. The second pass around the reservoir allowed for the confirmation of both the number of birds counted and the species composition.

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. The reservoir was circumnavigated twice during each survey, due to presence of large concentrations of waterfowl. The second pass allowed for the confirmation of both the number of birds counted and the species composition.

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.

Statistical Analysis

Summer Ground Counts – Waterfowl Distribution; Shorebird Distribution and Species Richness

Two-way Analysis of Variance (ANOVA) was used to evaluate the variation in the breeding population of waterfowl since 2002. Single-factor Repeated Measures (RM) ANOVA was used to determine if the mean total waterfowl detections differed between lakeshore segments. (Detections at the Restoration Ponds were not included in this analysis; as the water levels of these ponds are managed, and therefore do not accurately reflect water levels, shoreline changes, or waterfowl responses to these factors at Mono Lake.) For shorebirds, single-factor RM ANOVAs were used to determine if either the mean total detections or mean species richness differed among lakeshore segments. The Tukey test (Zar 1996) was used whenever the ANOVA test found a significant difference among sites in the mean number of waterfowl or shorebirds detected. The Tukey Test is a multiple comparison test that identifies which lakeshore segments differ significantly from one another.

Summer Ground Counts - Habitat Use

Chi-square goodness-of-fit analysis was used to determine if individual waterfowl and shorebird 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. For waterfowl, all observations (foraging, resting, brooding, etc.) except those of flyovers were included in this analysis. The waterfowl species for which habitat use data were analyzed were Gadwall, Mallard, Cinnamon Teal, and Canada Goose. 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.

Shorebird habitat use was analyzed in the same manner, except that analysis was confined to foraging observations only. Analysis was done for American Avocet, Killdeer, Least Sandpiper, Red-necked Phalarope and Wilson's Phalarope.

Fall Counts – Data Summary and Analysis

Waterfowl counts were summed over all six fall counts to determine the total detections of each species and total detections for all waterfowl species. The total detections of all waterfowl or of individual waterfowl species provides an index as to the overall use. The fall aerial survey data was also summed by lakeshore segment for each body of water. Single-factor RM ANOVA was used to determine if the mean waterfowl detections for the entire fall season differed between lakeshore segments at each site. The Tukey test (Zar 1996) was used to determine which lakeshore segments differed from one another whenever the ANOVA test found a significant difference in the mean number of waterfowl detected.

The counts of waterfowl detections at Bridgeport and Crowley were compared with counts of waterfowl at Mono for the all comparison counts conducted from 2002 through 2006. Single-factor RM ANOVA was used to evaluate whether the mean number of waterfowl detected differed between the three bodies of water.

Trend Analysis

Simple linear regression analysis was used to evaluate the trend in the number of broods detected since 2000, and in peak one-day waterfowl counts at Mono Lake since 1996. The analysis of peak one-day counts was done excluding Ruddy Duck numbers due to the difference in survey methods employed for this species from 1996-2001 versus 2002 to present. The regression equations were then tested using ANOVA to determine the significance of the regression, i.e. "Is the slope significantly different from zero?" (Zar 1996).

Photo Documentation

As required by the Order 98-05, photo documentation of lake-fringing waterfowl habitats was completed in 2006. Photos were taken from a helicopter at all bodies of water on September 25, 2006. These photos are described under Data Summary below.

The photos of Mono Lake were geo-referenced using the 2002 digital aerial photos of Mono Lake. The extent of the shoreline included in each digital photo taken from the helicopter was determined using the aerial photos. The coordinates for the shoreline area depicted in each photo were then generated from the 2002 aerial photos, and are shown on each shoreline photo. The general shoreline area depicted in each photo is also indicated on an outline diagram of Mono Lake that has been provided along with the photos.

For Bridgeport Reservoir and Crowley Reservoir, the general shoreline area depicted in each photo is indicated on an outline diagram of the reservoirs.

Data Summary

2006 Conditions

Mono Lake

The 2005-2006 water year in the Mono Basin was “Wet” or one in which runoff during 2006 was predicted to be over 136.5% of normal. As a result, during the summer survey period of 2006, the level of Mono Lake was between 1.8 feet and 2.4 feet higher than during the same period in 2005, and increased between the first summer survey and final summer survey. The lake reached its maximum level in August (elevation 6385.1 feet), and then dropped up to 0.6 feet during the fall census period. The increased lake elevation resulted in qualitative differences in lake-fringing habitats during the 2006 monitoring period, some of which are discussed below.

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

The increased lake level flooded lake-fringing wetland vegetation, created new brackish lagoons as a result of the increased groundwater table, and resulted in salt water intrusion into existing brackish lagoons and spring outflow areas. By September when photos of shoreline habitats were taken, the lake had dropped slightly, making some of the shoreline changes observed in summer less evident.

In the South Tufa area, lake-fringing wetland vegetation was inundated, and there was little exposed shoreline. New lagoons formed at the east end of the South Tufa area (see Figure 5).

A series of isolated lagoons were present along the length of the South Shore Lagoons area (see Figure 6). Some of these were not present in 2005, while those that were present in 2005 were larger in 2006. These lagoons attracted breeding and migratory waterfowl in 2006. Shoreline fringing littoral bars were essentially absent, a condition unlike that of the previous four years. Thus, shoreline fringing hypersaline lagoon habitat was extremely limited. The amount of unvegetated shoreline was also further reduced from that present in 2005.

In the Sammann's Spring area, flooding of lake-fringing vegetation was extensive both east and west of the large tufa towers on shore (Figure 7), leaving little exposed shoreline. The influence that old littoral bars have with regard to shoreline habitats was very evident this year in the Sammann's Spring area as the lake elevation increased. For approximately 2 km west of the Sammann's Spring tufa, there is a well-developed, and fairly continuous old littoral bar. Several springs, including Teal, Weary and No Name springs are upstream of this sandbar. Figure 8 shows the contrast in vegetation conditions uphill of the sandbar, as compared to vegetation directly exposed to lake water. The sandbar creates a berm, behind which fresh water spring outflow is isolated from the lakeshore.

The freshwater ponds formed by the outflow of Goose Springs became inundated by lake water. Figures 9 and 10 show the changes in the shoreline in this area as compared to the condition in 2005. These ponds and the spring outflow area at the lake have been an area used by brooding waterfowl, breeding Wilson's Phalaropes, and migrating waterfowl and shorebirds. Unvegetated shoreline and playa was essentially absent in the entire Sammann's Spring shoreline area. Species such as Wilson's Phalaropes appeared willing to rest and feed in shoreline areas with inundated and dying wetland vegetation (Figure 11), but devoid of open shoreline, while American Avocets were absent where shoreline conditions such as this existed.

Warm Springs and Northeast Shore

The rise in lake elevation resulted in the formation of extensive lagoons in the Warm Springs and Northeast Shore areas. Brackish lagoons in the Warm Springs area appeared to be more extensive and, as was the case in other areas, the amount of exposed shoreline decreased as compared to 2005 (see Figure 12). Lake water began intruding on the North Lagoon of the

Warm Springs area in the summer, resulting in an increase in the salinity of the lagoon, as evidenced by salt-stressed and dying vegetation present in the lagoon by late summer. A continuous hypersaline lagoon formed along the shoreline in the Northeast Shore area (Figure 13). Lagoons have been absent in the Northeast Shore area since at least 2002.

Black Point to Bridgeport Creek

Lake elevation changes resulted in the development of additional lake-fringing lagoons along the shoreline from Black Point to Bridgeport Creek. In the Black Point area, several new lagoons formed that were used by waterfowl during fall migration (Figure 14).

Northwest Shore (DeChambeau Creek, Mill Creek, and Wilson Creek)

Qualitative changes were also noted along the northwest shore of the lake, from DeChambeau Creek area to the Wilson Creek area. Due to the rise in lake level, there was little to no exposed shoreline between the wetland vegetation and the lake. Some willow die-off was noted at the edge of the lake in the DeChambeau Creek area (Figure 15) as lake water inundated stands of lake-fringing Coyote Willow (*Salix exigua*). Interestingly, flows from Wilson Creek were of sufficient volume, at least in early summer, that small stands of Coyote Willow inundated by lake water did not show signs of osmotic stress (Figure 16) until later in the summer.

In the DeChambeau Creek area, there was almost no exposed shoreline during summer. At the lakes high point during the summer, the shoreline extended inland to almost the end of the boardwalk. By the end of September, the shoreline had retreated somewhat, resulting in a small amount of exposed shoreline in this area (Figure 17).

The flows in Mill Creek and Wilson Creek were high in 2006. In early June, the majority of the flow in Mill Creek near the delta was captured by a channel to the west, thus seemingly decreasing flows out of a more eastern channel that directs flow into the bay. Figure 18 shows the shoreline condition in the Mill Creek delta area during fall. Lake-fringing vegetation in Wilson Creek and Mill Creek areas was inundated during summer, resulting in little exposed shoreline. East of Wilson Creek and Wilson Creek bay, flooding extended well inland and there was extensive flooding of the meadow vegetation. The large tufa on the east side of Wilson Creek bay, which was connected by a land bridge last year, became isolated from the shoreline as the elevation of the lake increased (Figure 19). Increased waterfowl activity in the flooded area to the east of this tufa was noted in 2006.

Rush Creek

Since the 2005-2006 runoff year was “Wet”, Rush Creek received a peak flow which was of greater magnitude and duration than has been observed since 1998. A change noted in the delta includes an opening up of the creek mouth (Figure 20). Creek flows at the delta were also deflected into the southern park of the bay by a sandbar. Waterfowl were seen using both outflow areas.

Lee Vining Creek

As was the case with Rush Creek, Lee Vining Creek also received high magnitude flows which were greater than have been observed since 2002. The peak flow in Lee Vining Creek of 457 cfs occurred on June 7. Throughout June, water was seen flowing in many small channels which have otherwise remained dry for the last few years. At the delta, the increased lake elevation resulted in additional die-off of *S. exigua* near shore. Figure 21 shows the condition of Lee Vining Creek delta in September.

2006 Conditions – Bridgeport Reservoir

The conditions and water levels at Bridgeport Reservoir appeared similar to those encountered in 2005. Figure 22 shows the condition of Bridgeport Reservoir in late September.

2006 Conditions – Crowley Reservoir

The water level at Crowley Reservoir was extremely elevated throughout the fall survey period. The elevated water levels inundated meadow vegetation in the McGee Bay area (Figure 23). A heavy growth of algae (see Figure 24) was apparent in all parts of the lake except in the immediate vicinity of the freshwater inflows of the Owens River (Figure 25) and McGee Creek. There was no noticeable improvement in the condition of the water at Crowley Reservoir until the mid-November flight.

Fall Aerial Survey Weather Conditions

Relatively mild conditions prevailed throughout the fall survey period. Weak cold fronts passed through the area in early October, but temperatures continued to remain mild.

Summer Ground Counts

Waterfowl

The number of waterfowl detected in each survey area during each visit can be found in Tables 1 through 3. Table 4 provides a summary of the number of detections for each species during each survey. The total number of waterfowl (exclusive of dependent young) detected during summer surveys ranged from 344 to 413 individuals in 2006. Since 2002, there has been no difference in the mean number of waterfowl using Mono Lake in the summer ($p = 0.997$, $F = 0.036$, $df = 4$).

A total of ten waterfowl species were encountered during summer surveys, seven of which were present throughout the summer. Evidence of breeding was documented for six of these species (Gadwall, Canada Goose, Mallard, Northern Pintail, Cinnamon Teal, and Green-Winged Teal). Breeding was suspected but not confirmed for Ruddy Duck. As in previous years, Gadwall was the most abundant and widespread species during the summer.

A total of 115 broods were detected during summer counts, with 89 of those categorized as "unique". Table 5 shows the number of unique broods detected per species in each of the summer survey areas. Figure 26 shows the locations of all of the broods detected in 2006. The number of unique broods represents the minimum number of broods observed using the lake and restoration ponds. The number of unique broods was determined by eliminating broods of age Class II or older that may have been detected during a previous survey. This is the most broods ever recorded since broods counts started in 2000. There was an increased use of the South Shore Lagoons area by breeding waterfowl in 2006. The greatest number of broods (33) were detected in the South Shore Lagoon area. This is the most broods detected in the South Shore Lagoon area, both in terms of number and percent of total broods. Wilson Creek supported 21 broods while 12 broods were detected at DeChambeau Creek. No broods were seen at South Tufa or Warm Springs.

Waterfowl Habitat Use

All four waterfowl species analyzed showed a disproportionate use of the various shoreline habitats in 2006. Table 6 provides the tabulated habitat use data, the chi-squared goodness-of-fit results, and the Bonferonni test results for Gadwall, Mallard, Cinnamon Teal and Canada Goose. Figure 27 is a bar graph depicting the proportional use of habitats by each of these species.

In 2006, Gadwall were seen using ria, brackish lagoons, open-water habitats close to shore (<50 meters) and unvegetated areas significantly more than expected (Bonferonni test, $p < 0.05$). All other habitats were used less than expected.

Use of various habitat types by Mallards was not proportional. Mallards use of brackish lagoons was proportionally greater than the other habitat types (Bonferonni test, $p < 0.05$). Use of ria and unvegetated areas was in proportion to other habitat types, while meadow, freshwater ponds and streams, and open-water habitat areas were not used more or less than expected.

Cinnamon Teal were observed using brackish lagoons proportionally more than other habitat types. Open water areas close to shore, unvegetated areas, and wet meadow habitats were used less than expected. Marsh, freshwater ponds and brackish lagoons were used in proportion to other habitat types.

Canada Geese were observed using wet, alkaline and dry meadows, unvegetated areas, ria, open-water (<50 meters from shore), and brackish lagoons. Wet meadow habitat use was proportionally greater than all other habitats (Bonferonni test, $p < 0.05$). Observations of birds using alkali wet meadow, and brackish lagoons were proportional, while dry meadow habitats, ria and unvegetated habitats were used less than expected.

Shorebirds

A total of 19 shorebird species were encountered at Mono Lake during the summer surveys. The number of shorebirds detected in each survey area during each visit can be found in Tables 1 through 3, while Table 4 provides a summary of the number of detections for each species during each survey. Table 7 provides a summary of the data from 2002-2006 for the four shorebird species that typically summer and occasionally breed at Mono Lake (Wilson's Phalarope was not included). As shown in the table, the total detections of American Avocets, Killdeer, Snowy Plover and Spotted Sandpiper were the lowest since 2002. This decrease was most pronounced for American Avocet and Snowy Plover. The number of American Avocets typically increases through the summer period as early migrants arrive. In 2006, the number of avocets decreased by the end of the summer when only two birds were seen over the three-day survey period.

Phalaropes (including both Wilson's and Red-necked Phalaropes), were the most abundant migrant shorebirds during the summer survey period. The number of phalaropes reported in Tables 1 through 3 represent only individuals seen within 50 meters of shore. Phalarope use of shoreline habitats was primarily along the south shore in the Sammann's Spring and South Shore Lagoons areas, and secondarily in the DeChambeau Creek area. Large rafts of phalaropes could also been seen offshore of Sammann's Spring.

Total shorebird species richness was highest in the Warm Springs area where a total of 13 species were detected in the summer. Other areas of high shorebird species richness include Sammann's Springs (12 species), and South Shore Lagoons (11 species). Mean shorebird species richness differed among sites ($p = 0.001$, $F = 5.745$, $df = 26$), as the mean number of shorebird species detected throughout the summer was highest at Warm Springs, and significantly lower at South Tufa and Wilson, Mill, and Lee Vining Creeks (Tukey test, $p < 0.05$). In terms of shorebird abundance, the majority of shorebird individuals detected were in the Sammann's Spring, South Shore Lagoons, and DeChambeau Creek areas. The mean number of individuals detected among the lakeshore segment areas differed ($p = 0.012$, $F = 3.712$, $df = 26$) as the number of shorebird individuals detected at Sammann's Spring was significantly greater than all sites.

Shorebird Habitat Use

All of the shorebird species showed disproportionate use of the various shoreline habitats. Table 8 provides the tabulated foraging habitat use data, the chi-squared goodness-of-fit results, and the Bonferonni test results for American Avocet, Killdeer, Least Sandpiper, Red-necked Phalarope and Wilson's Phalarope. Figure 28 depicts the proportional use of habitats by each of these species.

American Avocets foraged in open-water habitats close to shore proportionally more than all other habitat types (Bonferonni test $p < 0.05$). The next most frequently-used habitat was brackish lagoons, but use of this habitat type was not greater than expected. The use of hypersaline lagoons was less than expected. American Avocets were not seen using any meadow habitat, vegetated riparian habitat, or ria.

Killdeer foraged primarily on unvegetated areas and used all other habitats less than expected (Bonferonni test, $p < 0.05$). Least Sandpipers used unvegetated areas more than expected

(Bonferonni test, $p < 0.05$). Least Sandpipers were also seen using brackish lagoons, open water areas close to shore and hypersaline lagoons.

Wilson's Phalaropes used open-water areas close to shore proportionally more than expected (Bonferonni test, $p < 0.05$). The next most frequently-used habitats were unvegetated, ria and brackish lagoons, although these were used less than expected, as compared to the use of open-water areas close to shore. Red-necked Phalaropes were only seen foraging in open-water areas close to shore and ria, using open-water areas more than ria.

Fall Aerial Surveys

Mono Lake

A total of fourteen waterfowl species and 22,198 individuals were recorded at Mono Lake during fall aerial surveys (Table 9). The peak number of waterfowl detected at Mono Lake on any single count was 6,605 and occurred on the October 3 survey (Table 9, Figure 29). Compared to the 2005 counts, the total number of detections was essentially the same (22,198 vs. 22,566 in 2005) while the one-day peak count in 2006 was approximately 20% less than that seen in 2005. The peak number of Northern Shoveler occurred on September 21, while the peak number of Ruddy Ducks occurred on October 3. The peak count of 5,726, exclusive of Ruddy Ducks, varied little from the peak count of 6,054 in 2005.

In terms of total detections, Ruddy Ducks and Northern Shovelers were the dominant species during fall migration (Figure 30) with Ruddy Ducks accounting for 31.2% (6,924) of all detections, and Northern Shovelers accounting for 38.4% (8,517) of all detections. There was a 38% decrease in total detections of Northern Shovelers in 2006 as compared to 2005 (13,780). The number of Ruddy Ducks in 2006 was similar to that seen in 2005 (6,515 in 2006 vs. 6,924 in 2005).

Tables 10 through 15 provide the results of each of the six fall surveys in terms of the number of individuals of each species detected in each lakeshore segment. There was a significant difference in the proportional use of the lakeshore segments and offshore areas by waterfowl during the fall period ($p = 0.009$, $F = 2.382$, $df = 89$), however, the ANOVA results explain only 35% of the variation in the data, and the power of the test was low. The mean number of waterfowl detected during fall surveys was highest in offshore areas, and secondarily in Mill Creek, Black Point, and South Shore Lagoons. Waterfowl seemed to be more dispersed around the lake in the fall of 2006 than in previous years, although no analysis was conducted to evaluate this observation statistically. Waterfowl were repeatedly observed using the new and enlarged lagoons that formed in the Black Point and South Shore Lagoons area (see Figures 6 and 14).

A total of ten waterfowl species and 297 individuals (less than 2% of all fall detections) and 1,002 American Coots were detected at the DeChambeau and County Pond complexes during fall surveys (Table 16).

The most abundant shorebirds at Mono Lake during fall were phalaropes and American Avocets (Table 17). The majority of phalaropes were detected either offshore or on shore along the west side of the lake (Mill Creek to Ranch Cove). During fall, the main concentration of American Avocets was along the north shoreline areas (Northeast Shore west to Black Point) (see Tables 10-15).

Bridgeport Reservoir

A total of 17 waterfowl species and 43,670 individuals were recorded at Bridgeport Reservoir during the 2006 fall aerial surveys (Table 18). The peak number of waterfowl detected on any single count at Bridgeport Reservoir was 15,238 individuals, which occurred on September 21 (Table 18, Figure 29). Compared to the 2005 counts, these numbers represent a 48% decrease in total detections and an approximate 36% decrease in the one-day peak count at Bridgeport.

Figure 31 shows the number of each species detected per survey at Bridgeport for the seven most abundant species. The most abundant species (in terms of total detections) were Northern Shoveler followed by Gadwall, Northern Pintail and Mallard. These four species comprised approximately 80% of all waterfowl identified at Bridgeport Reservoir. The total number of Northern Shovelers detected at Bridgeport in 2006 was approximately 10% less than in 2005. Northern Shovelers were proportionally more abundant at Bridgeport this year than in 2005 (~35% of identified birds as compared to ~20%). Tables 19 through 24 provide the results of each of the six fall surveys in terms of the number of each species detected in each lakeshore segment. There was a significant difference in the mean number of waterfowl detected at each of the lakeshore segments ($p = 0.006$, $F = 9.09$, $df = 17$). The greatest proportion of waterfowl were detected in the West Bay area (Tukey test, $p < 0.05$). There was no significant difference in use between the North Arm and East Shore lakeshore segment areas.

Crowley Reservoir

A total of 18 waterfowl species and 25,474 individuals were detected at Crowley Reservoir during the 2006 fall aerial surveys (Table 25). The peak number of waterfowl detected on any single count at Crowley Reservoir was 7,878 individuals and occurred on November 15 (Table 25, Figure 29). These numbers represent a 56% decrease in total detections and a 57% decrease in the one-day peak count at Crowley as compared to 2005. The total waterfowl detections at Crowley were generally lower than usual early in the fall, and the peak count for Crowley, which did not occur until the November 15 count, is the latest that the peak count has occurred since regular surveys began in the fall of 2002.

The most abundant species, in terms of total detections, were Northern Pintail, Mallard and Green-winged Teal. Figure 32 shows the number of each species detected per survey at Crowley for the six most abundant species.

Tables 26 through 31 provide the results of each of the six fall surveys in terms of number of each species detected by lakeshore segment. The mean proportion of waterfowl detection differed among lakeshore segments ($p < 0.001$, $F = 10.33$, $df = 41$). The proportion of waterfowl detected at McGee Bay was greater than all other lakeshore segments (Tukey test, $p < 0.05$). There was no significant difference among the other lakeshore segments.

Comparison of Mono Lake with Bridgeport and Crowley Reservoirs

In terms of total fall detections, Mono Lake received less use by waterfowl than Bridgeport Reservoir in the fall of 2006. The total fall detections at Mono Lake and Crowley Reservoir were similar in 2006. Based on an analysis of all comparison count data from 2002-2006, the mean number of waterfowl detected at Crowley Reservoir is significantly higher than Mono Lake, but the same has not been true when comparing Bridgeport Reservoir to Mono Lake, due to the annual and seasonal variability in waterfowl use of Bridgeport Reservoir.

Mono Lake was used primarily by Northern Shovelers and Ruddy Ducks during fall migration. These two species accounted for approximately 70% of all waterfowl detected at Mono Lake in

2006, whereas these two species accounted for 35% of all detections at Bridgeport Reservoir and 11% of detections at Crowley Reservoir.

The absolute abundance of waterfowl species also differed between Mono Lake and the two reservoirs. Figure 33 depicts the total detections of the most abundant species for Mono, Bridgeport and Crowley over the entire fall season. These graphs illustrate a noticeable disparity between the two reservoirs and Mono Lake in terms of total detections for several species. The total detections of Northern Shovelers in 2006 was higher at Bridgeport Reservoir than either Mono Lake or Crowley Reservoir. More Ruddy Ducks were detected at Mono Lake than either Bridgeport or Crowley Reservoir. The other dabbling duck species that are dominant at the reservoirs, namely Gadwall, Green-winged Teal, Northern Pintail, and Mallard, were only encountered in relatively small numbers at Mono Lake.

Analysis of Trend – Mono Lake

There has been no significant change in the breeding population of waterfowl at Mono Lake since 2002 in terms of the number of waterfowl using the lake. Although the number of broods detected in 2006 was the highest since 2000, there has been enough variation in the last seven year that no significant trend was detected ($p = 0.09$).

There has been a significant positive trend in the peak number of waterfowl at Mono Lake during fall. Figure 34 illustrates the trend in the peak number of waterfowl detected at Mono Lake from 1996-2006. The regression coefficient ($r = 0.628$) indicates that there is a positive relationship between the peak number of waterfowl and the year. Analysis of variance indicates that this relationship is statistically significant ($p = 0.038$, $F = 5.865$, $df = 1,9$).

Discussion

As has been the case in previous years, use of Mono Lake shoreline habitats in the summer was concentrated along the northwest shore, and along the south shoreline in the South Shore Lagoon area. Although the total number of waterfowl using the lake during summer has not changed since 2002, the total number of waterfowl broods was almost twice that recorded in 2005, and the highest since 2000. This suggests an increase in the reproductive success of breeding waterfowl over previous years. Factors that influence reproductive success in waterfowl include the spatial heterogeneity of habitats, which influences predator search efficiency (Bowman and Harris 1980 in Baldassarre and Bolen 1994), weather events that influence habitat condition before and during the nesting period (Greenwood et al 1995), and predation.

There was a substantial increase in the use of South Shore Lagoons by breeding waterfowl, and this area produced the most broods in 2006, and the most ever detected in this area. This may be related to changes noted in the lake-fringing habitats – notably the increase in the number and extent of lagoons. Duck pairs and then brooding females were well-spaced along the length of the shoreline in this area, occupying many of these lagoons. The habitat conditions may have been favorable for brood production by influencing cover, food availability or predator success in this shoreline area.

There was a decrease in the numbers of American Avocets, Snowy Plovers, Killdeer and Spotted Sandpipers detected during summer surveys, with the decrease being most pronounced for American Avocets and Snowy Plovers. American Avocets typically use hypersaline lagoons or forage along the shoreline in unvegetated areas. Due to the increase in lake elevation, there was little exposed shoreline, and few hypersaline lagoons. Changes in habitat quality and quantity on a regional scale should also be considered as a possible reason for the decrease in use of Mono Lake by American Avocets. Snowy Plovers forage almost exclusively in unvegetated areas, and are typically seen on the playa areas east of Sammann's Springs tufa to Warm Springs during summer surveys. The increase in lake elevation resulted in the flooding of all but a very small amount of the playa in this area. Snowy Plovers appeared confined to these small patches of exposed playa on the east side of the lake. Thus, it is likely that the decrease in the number of Snowy Plovers in 2006 as compared to previous years is related to the reduction in exposed playa as the lake level increased during the summer of 2006.

The use of Mono Lake in the fall by migratory waterfowl was similar to that seen in 2005 in terms of total numbers and the peak one-day count. Dabbling duck species appeared to respond to the changes in lake-fringing habitats associated with the increase in lake elevation by making use of new and enlarged lake-fringing lagoons in the areas of Black Point and South Shore Lagoons.

Decreases in total detections and peak one-day counts were seen at both Bridgeport and Crowley Reservoirs as compared to 2005. There was no obvious change in local conditions at Bridgeport Reservoir. Changes noted at Crowley Reservoir included a very elevated lake level and eutrophication as evidenced by the heavy growth of algae throughout the fall. It is unknown if local conditions at Crowley can explain the noticeable decrease in use this year. Weather and habitat conditions throughout the flyway should also be considered when evaluating annual variations such as this.

The comparison count data provided insight regarding the relative use of Mono Lake, Bridgeport Reservoir, and Crowley Reservoir by waterfowl during fall migration. The large disparity in total detections of Mallard, Gadwall, Green-winged Teal and Northern Pintail between Mono Lake and the two reservoirs indicates that either a comparable number of individuals of these species are not stopping at Mono Lake, or that the turnover rate of individuals at Mono Lake is high, or both. The low use by species other than Northern Shoveler and Ruddy Duck may relate to a lack of physiological adaptations to saline and alkaline conditions at Mono Lake or a lack of suitable food resources.

The analysis of the trend in peak waterfowl numbers indicates a continued significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996. The variable nature of population data necessitates caution in the interpretation of this relative short-term trend.

References

Bowman, G. B. and L. D. Harris. 1980. Effect of spatial heterogeneity on ground-nesting depredation. *In* Waterfowl ecology and management. G. Baldassarre and E. Bolen. 1994. John Wiley and Sons, Inc. U.S.A.

Boyd, W. S. and J. R. Jehl, Jr. 1998. Estimating the abundance of Eared Grebes on Mono Lake, California by Aerial Photography. Colonial Waterbirds 21(2): 236-241.

Gollop, J. B. and W. H. Marshall. 1954. A guide to aging duck broods in the field. Mississippi Flyway Council Technical Section. 14 pp. Northern Prairie Wildlife Research Center Home Page.

Greenwood, Raymond J., Alan B. Sargeant, Douglas H. Johnson, Lewis M. Cowardin, and Terry L. Shaffer. 1995. Factors associated with duck nest success in the Prairie Pothole Region of Canada. Wildlife Monographs 128:1-57. Jamestown, ND: Northern Prairie Wildlife Research Center Online http://www.npwrc.usgs.gov/resource/birds/nestsucc/index.htm (Version 02JUN99).

Jehl, J. R. Jr. 2002. Waterfowl populations at Mono Lake, California, 2001. Hubbs-Sea World Research Institute. Technical Report 2002-330.

Los Angeles Department of Water and Power (LADWP). 1996. Mono Basin waterfowl habitat restoration plan. Prepared for the State Water Resources Control Board. In response to Mono Lake Basin Water Right Decision 1631.

Los Angeles Department of Water and Power (LADWP). 2000a. Mono Basin Implementation Plan. To comply with State Water Resources Control Board Decision 1631 and Order No. 98-05 and 98-07.

Los Angeles Department of Water and Power (LADWP). 2000b. 1999 Mono Basin Vegetation and Habitat Mapping.

Zar, J. 1996. Biostatistical analysis. Third Edition. Prentice Hall. New Jersey.

Table 1. Summer Ground Data, Survey 1 - June 5-7, 2006

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Canada Goose			15							4	12	**31**
Cinnamon Teal		2		5	2	8	6	5		2		**30**
Gadwall	9	4	19	4	4	7	12	20	17	63	21	**180**
Green-winged Teal		4			1		7	1		2		**15**
Mallard	6	2				7	43	11		1	4	**74**
Northern Pintail				2	1		6			1		**10**
Ruddy Duck					5		2					**7**
Total waterfowl by area	**15**	**12**	**34**	**11**	**13**	**22**	**76**	**37**	**17**	**73**	**37**	**347**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet						16	18	2	4			**40**
Black-necked Stilt						1						**1**
Killdeer	3	3	6	2		1	6	5	2	4	3	**35**
Long-billed Curlew								8				**8**
Red-necked Phalarope							4					**4**
Snowy Plover						14	6					**20**
Spotted Sandpiper	7	3	1							4		**15**
White-faced Ibis											1	**1**
Willet									4			**4**
Wilson's Phalarope		1	2			6	108	5			11	**133**
Wilson's Snipe			3									**3**
Total shorebirds by area	**10**	**7**	**12**	**2**	**0**	**38**	**142**	**20**	**10**	**8**	**15**	**264**

Table 2. Summer Ground Data, Survey 2 - June 26-28, 2006

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Canada Goose			46								8	**54**
Cinnamon Teal		4		2	7	8	1				5	**27**
Gadwall	6	14	17	7	2	4	10	50	2	119	41	**272**
Green-winged Teal		3					2					**5**
Mallard		2	1			10	14	2		14	2	**45**
Northern Pintail		2						4				**6**
Northern Shoveler								1				**1**
Ruddy Duck				1	2							**3**
Total waterfowl by area	**6**	**25**	**64**	**10**	**11**	**22**	**27**	**57**	**2**	**133**	**56**	**413**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet						15	33	2				**50**
Killdeer	2	3	7	1		1	3	6		6		**29**
Long-billed Curlew						1	4	5				**10**
Marbled Godwit							1					**1**
Snowy Plover						4	3					**7**
Spotted Sandpiper	4	5								2		**11**
Willet						2						**2**
Wilson's Phalarope		4	18			18	8090	333		45	2	**8510**
Wilson's Snipe			2								1	**3**
Total shorebirds by area	**6**	**12**	**27**	**1**	**0**	**41**	**8134**	**346**	**0**	**53**	**3**	**8623**

Table 3. Summer Ground Data, Survey 3 - July 17-20, 2006

Waterfowl Species	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal				1								**1**
Canada Goose			16					32	12		7	**67**
Cinnamon Teal				1			12		2			**15**
Gadwall	1		14	7	2		2	27		2	146	**201**
Green-winged Teal			1									**1**
Mallard	6	3	2					16		3	14	**44**
Northern Pintail								4				**4**
Redhead											7	**7**
Ruddy Duck					4							**4**
Total waterfowl by area	**7**	**3**	**33**	**9**	**6**	**0**	**14**	**79**	**14**	**5**	**174**	**344**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet						2						**2**
Black-necked Stilt						1						**1**
Greater Yellowlegs						1	1	5				**7**
Killdeer	2	5	11	1		5	1	6	11	2		**44**
Least Sandpiper		9	11			24	54	9	3			**110**
Long-billed Curlew						1						**1**
Marbled Godwit							3					**3**
Red-necked Phalarope							922	2099				**3021**
Semipalmated Plover						5		3				**8**
Short-billed Dowitcher						11						**11**
Snowy Plover						12						**12**
Spotted Sandpiper	9	3	2				3	1	2	1		**21**
Western Sandpiper						11	73					**84**
White-faced Ibis						35	2	1				**38**
Willet						3		7				**10**
Wilson's Phalarope	45	6	2567				5538	261			9	**8426**
Wilson's Snipe			1								3	**4**
Phalaropus spp.							3280	615				**3895**
Total shorebirds by area	**56**	**23**	**2592**	**1**	**0**	**111**	**9877**	**3007**	**16**	**3**	**12**	**15698**

Table 4. Summary of Ground Count Data for Mono Lake, 2006

Waterfowl	Survey 1	Survey 2	Survey 3	**Total Detections**
Blue-winged Teal			1	1
Canada Goose	31	54	67	152
Cinnamon Teal	30	27	15	72
Gadwall	180	272	201	653
Green-winged Teal	15	5	1	21
Mallard	74	45	44	163
Northern Pintail	10	6	4	20
Northern Shoveler		1		1
Redhead			7	7
Ruddy Duck	7	3	4	14
Total Waterfowl	347	413	344	1104

Shorebirds	Survey 1	Survey 2	Survey 3	**Total Detections**
American Avocet	40	50	2	92
Black-necked Stilt	1		1	2
Greater Yellowlegs			7	7
Killdeer	35	29	44	108
Least Sandpiper			110	110
Long-billed Curlew	8	10	1	19
Marbled Godwit		1	3	4
Red-necked Phalarope	4		3021	3025
Semipalmated Plover			8	8
Short-billed Dowitcher			11	11
Snowy Plover	20	7	12	39
Spotted Sandpiper	15	11	21	47
Western Sandpiper			84	84
White-faced Ibis	1		38	39
Willet	4	2	10	16
Wilson's Phalarope	133	8510	8426	17069
Wilson's Snipe	3	3	4	10
Phalaropus spp.			3895	3895
Total Shorebirds	264	8623	15698	24585

Table 5. Number of Broods of Species Detected Per Visit in Each Summer Survey

	Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total broods
Survey 1	CAGO			3							2	6	11
	CITE												0
	GADW			1				1	1			1	4
	GWTE												0
	MALL							1	1			1	3
	NOPI												0
	Total broods	0	0	4	0	0	0	2	2	0	2	8	18
Survey 2													
	CAGO												0
	CITE											1	1
	GADW		4		1	1			14		3	3	26
	GWTE												0
	MALL		1								2		3
	NOPI												0
	Total broods	0	5	0	1	1	0	0	14	0	5	4	30
Survey 3													
	CAGO												0
	CITE												0
	GADW	1		7	3	1		2	14			9	37
	GWTE			1									1
	MALL								1				1
	NOPI								2				2
	Total broods	1	0	8	3	1	0	2	17	0	0	9	41
Total broods per area		1	5	12	4	2	0	4	33	0	7	21	89

Table 6. 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.

	GADW				MALL				CITE				CAGO			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh	7	62.7	49.5	-	2	15.7	12.0	-	6	10.3	1.8	NS				
Wet Meadow	4	62.7	55.0	-	7	15.7	4.8	-					46	21.714	27.2	+
Alkaline Wet Meadow	5	62.7	53.1	-	2	15.7	12.0	-	2	10.3	6.7	-	30	21.714	3.2	NS
Dry Meadow/Forb													10	21.714	6.3	-
Riparian Scrub	1	62.7	60.7	-	1	15.7	13.8	-								
Great Basin Scrub																
Riparian Forest																
Freshwater Stream					3	15.7	10.3	-								
Ria	194	62.7	275.0	+	18	15.7	0.3	NS	6	10.3	1.8	NS	2	21.714	17.9	-
Freshwater Pond	27	62.7	20.3	NS	5	15.7	7.3	-	15	10.3	2.2	NS				
Brackish Lagoon	124	62.7	59.9	+	94	15.7	390.5	+	39	10.3	80.2	+	32	21.714	4.9	NS
Hypersaline Lagoon	6	62.7	51.3	-												
Unvegetated	94	62.7	15.6	+	14	15.7	0.2	NS	2	10.3	6.7	-	10	21.714	6.3	-
Open Water <50m	165	62.7	166.9	+	11	15.7	1.4	-	2	10.3	6.7	-	22	21.714	0.0	NS
Total	627		807.3		157		452.5		72		105.9		152		65.7	

Table 7. Detections of Summering Shorebird Species at Mono Lake, 2002-2006

SPECIES	YEAR	SURVEY1	SURVEY2	SURVEY3	TOTAL
American Avocet	2002	301	453	1083	1837
	2003	497	438	568	1503
	2004	286	399	2998	3683
	2005	60	224	628	912
	2006	40	50	2	92
Killdeer	2002	47	37	78	162
	2003	46	64	86	196
	2004	59	49	60	168
	2005	46	48	48	142
	2006	35	29	44	108
Snowy Plover	2002	5	58	11	74
	2003	34	60	24	118
	2004	31	22	29	82
	2005	22	55	71	148
	2006	20	7	12	39
Spotted Sandpiper	2002	13	33	24	70
	2003	19	18	40	77
	2004	25	17	13	55
	2005	18	11	25	54
	2006	15	11	21	47

Table 8. Chi Square Goodness-of-Fit Results for Shorebird Foraging 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.

	AMAV				KILL				LESA				RNPH				WIPH			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh																	3	779.8	773.8	-
Wet Meadow																				
Alkaline Wet Meadow					4	11.5	4.9	-												
Dry Meadow/Forb					3	11.5	6.3	-									1	779.8	777.8	-
Riparian Scrub																				
Great Basin Scrub																				
Riparian Forest																				
Freshwater Stream																				
Ria													30	719	660.3	-	199	779.8	432.5	-
Freshwater Pond																	28	779.8	724.8	-
Brackish Lagoon	34	27.7	1.4	NS	4	11.5	4.9	-	15	15.5	0.0	NS					302	779.8	292.7	-
Hypersaline Lagoon	1	27.7	25.7	-					2	15.5	11.8	-					1	779.8	777.8	-
Unvegetated					35	11.5	48.0	+	33	15.5	19.8	+					391	779.8	193.8	-
Open Water <50m	48	27.7	14.9	+					12	15.5	0.8	NS	1408	719	660.3	+	5313	779.8	26355.1	+
Total	83		42.1		46		64.1		62		32.3		1438		1320.5		6238		30328.1	

Table 9. Summary of Fall Aerial Survey Counts for 2006, Mono Lake

Species	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	Total Detections	%Total
American Wigeon			4		21		25	0.11
Bufflehead		2				1	3	0.01
Canada Goose				14	80	60	154	0.69
Cinnamon Teal	255	42	21				318	1.43
Gadwall	89	45	47	14	10	10	215	0.97
Green-winged Teal		112	298	234	266	260	1170	5.27
Lesser Scaup					3	10	13	0.06
Mallard	68	224	251	247	167	458	1415	6.37
Northern Pintail	50	86	119	10	188	266	719	3.24
Northern Shoveler	1838	4873	1142	204	245	215	8517	38.37
Redhead				20	10	2	32	0.14
Ring-necked Duck						1	1	0.00
Ruddy Duck	105	448	3876	1148	841	506	6924	31.19
Snow Goose						7	7	0.03
Unidentified *Anas*	442	342	847	248	640	161	2680	12.07
Unidentified Diving Duck					5		5	0.02
Total waterfowl	2847	6174	6605	2139	2476	1957	**22198**	

Table 10. Mono Lake - Fall Aerial Survey, September 6, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Cinnamon Teal					255											255	255
Gadwall	40									28	20	1				89	89
Mallard			38		30											68	68
Northern Pintail					50											50	50
Northern Shoveler					212				576	350	700					1838	1838
Ruddy Duck							6	1			3					10	105
Unidentified *Anas* spp.			140		300							2				442	442
Total Waterfowl	40	0	178	0	847	0	6	1	576	378	723	3	0	0	0	2752	2847

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet		1		27	186	1628	45	37	2000							3924	3924
American Coot																0	19
Black-necked Stilt							2									2	2
Great Blue Heron													2			2	2
Long-billed Curlew									1	6						7	7
White-faced Ibis			82	35				4	3	1						125	125
Willet									3							3	3
Calidris spp.					20	4										24	24
Phalaropus spp.										300	5800	4060	7580	465	1170	19375	21311
Total Waterbirds	0	1	82	62	206	1632	47	41	2007	307	5800	4060	7582	465	1170	23462	25417

Table 11. Mono Lake - Fall Aerial Survey, September 21, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Bufflehead	2															2	2
Cinnamon Teal	2				20				20							42	42
Gadwall			30	10								5				45	45
Green-winged Teal	50			60					2							112	112
Mallard			25	115	80									4		224	224
Northern Pintail	5		20	50					10			1				86	86
Northern Shoveler	90		600	300	45		202	39	1200	820	1500	32		43		4871	4873
Ruddy Duck		5				85			4	10	20					124	448
Unidentified			220	55	66								1			342	342
Total Waterfowl	149	5	895	590	211	85	202	39	1236	830	1520	38	1	47	0	**5848**	**6174**

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet					160	19	1161	221	80	25						1666	1718
American Coot	8															8	58
Killdeer	5															5	5
White-faced Ibis				30												30	30
Calidris spp.									12							12	12
Phalaropus spp.			30		26			15					25	357		453	2439
Total Waterbirds	13	0	30	30	186	19	1161	236	92	25	0	0	25	357	0	2174	4262

Table 12. Mono Lake - Fall Aerial Survey, October 3, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR*	WESH	LVCR	RACO		
American Wigeon								4								4	4
Cinnamon Teal			2	4	10				5							21	21
Gadwall			4	3				20		20						47	47
Green-winged Teal	200		32	36	30											298	298
Mallard		10	77	12	111			30				5		6		251	251
Northern Pintail					20			52	25	20	2					119	119
Northern Shoveler	150	5	105	199		3	6	132	141	296	75	30				1142	1142
Ruddy Duck				80	7		46					80	65		60	338	3876
Unidentified	225	25	249	65	55					8	30	190				847	847
Total Waterfowl	575	40	469	399	233	3	52	238	171	344	107	305	65	6	60	3067	6605

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet			38	136	345	22	590	70	80	40						1321	1367
American Coot	5		200	120				5		6				3	30	369	425
Great Blue Heron	2															2	2
Calidris spp.					43											43	43
Marbled Godwit									1							1	1
Phalaropus spp.					15	10		10		20						55	1994
Spotted Sandpiper	2															2	2
Total Waterbirds	9	0	238	256	403	32	590	85	81	66	0	0	0	3	30	1793	3834

Table 13. Mono Lake - Fall Aerial Survey, October 17, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose								14								14	14
Gadwall			4	2					8							14	14
Green-winged Teal	140		17	18	40		5	10							4	234	234
Mallard	5		57	63	67			32	23							247	247
Northern Pintail					5				5							10	10
Northern Shoveler	5	12		8			78	20	23	13		45				204	204
Redhead					20											20	20
Ruddy Duck	102	14		15	3		5	26	160		20	120	68	32	44	609	1148
Unidentified	60	5	73		78			20	10		2					248	248
Total Waterfowl	312	31	151	106	213	0	88	122	229	13	22	165	68	32	48	1600	2139

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet				8	9	21	32	64	18	5						157	157
American Coot			30		30				37	10						107	167
Great Egret				1												1	1
Red-necked Phalarope																0	60
Chalidris spp.									1							1	1
Total Waterbirds	0	0	30	9	39	21	32	64	56	15	0	0	0	0	0	266	386

Table 14. Mono Lake - Fall Aerial Survey, October 31, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon				10			2	5		3						20	21
Canada Goose			37	3				40								80	80
Gadwall								5							5	10	10
Green-winged Teal	35		38	30	5		7	45	20	44		10		20	12	266	266
Lesser Scaup																0	3
Mallard			40	45	15		5	32							30	167	167
Northern Pintail			35	40	50			38		20		5				188	188
Northern Shoveler			50	5	3	4	47	41	40	40	5	5		2		242	245
Redhead																0	10
Ruddy Duck	9	12		5				6	31	24	76	42		17	17	239	841
Unidentified *Anas*	95	12	106	90	15				5	40		18	182	18	25	606	640
Unidentified Diving Ducks																0	5
Total Waterfowl	139	24	306	228	88	4	61	212	96	171	81	80	182	57	89	1818	2476

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot			20	300				5			3	20	5	15		368	390
American Avocet			10	5	23	1	50	2								91	91
Western Grebe																0	2
Total Waterbirds	0	0	30	305	23	1	50	7	0	0	3	20	5	15	0	459	483

Table 15. Mono Lake - Fall Aerial Survey, November 15, 2006

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Bufflehead	1															1	1
Canada Goose	5		15					40								60	60
Gadwall				10												10	10
Green-winged Teal	40			140						80						260	260
Lesser Scaup								10								10	10
Mallard		10	94	240			47	54	13							458	458
Northern Pintail			30	40				19		175			2			266	266
Northern Shoveler	140			8			28	30	7				1	1		215	215
Redhead			2													2	2
Ring-necked Duck	1															1	1
Ruddy Duck	13			6					7	2		34	42	41	30	175	506
Snow Goose								7								7	7
Unidentified *Anas*			35	85				20		20			1			161	161
Total Waterfowl	200	10	176	529	0	0	75	180	27	277	0	34	46	42	30	1626	1957

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot	10		134	233			8	40	5			21	1	13	8	473	479
American Avocet							6									6	6
Great Blue Heron	1															1	1
Unidentified shorebirds							5									5	5
Total Waterbirds	11	0	134	233	0	0	19	40	5	0	0	21	1	13	8	485	491

Table 16. Mono Lake Restoration Ponds - Aerial Waterfowl Counts - 2006

DeChambeau Ponds	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	**Total Fall Detections**
American Wigeon				2			2
Blue-winged Teal				1			1
Gadwall				90		2	92
Lesser Scaup					2		2
Mallard			15	31			46
Northern Pintail				1			1
Northern Shoveler				6			6
Redhead				1			1
Ring-necked Duck				1			1
Ruddy Duck				4			4
Anas		47	17		40	10	114
Total Waterfowl	0	47	32	137	42	12	270
American Coot	7	5	22	208	275	405	922

County Ponds	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	**Total Fall Detections**
Northern Shoveler			8				8
Anas		7	5		5		17
Total Waterfowl	0	7	13	0	5	0	25
American Coot	0	6	35	0	30	9	80

Table 17. Summary of Shorebird/Waterbird Counts at Mono Lake During Fall Aerial Survey

Survey Date	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	**Total Fall Detections**
American Avocet	3924	1718	1367	157	91		7257
American Coot	19	58	425	167	390		1059
Black-necked Stilt	2						2
Great Blue Heron	2		2				4
Great Egret				1			1
Killdeer		5					5
Long-billed Curlew	7						7
Marbled Godwit			1				1
Spotted Sandpiper			2				2
Western Grebe					2		2
White-faced Ibis	125	30					155
Willet	3						3
Phalaropus spp.	21311	2439	1994	60			25804
Calidris spp.	24	12	43	1			80
Total Waterbirds	25417	4262	3834	386	483	0	34382

Table 18. Summary of 2006 Fall Aerial Survey Counts - Bridgeport Reservoir

Species	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	Total Detections	%Total
American Wigeon				40			40	0.09
Bufflehead	1		3	6	22	51	83	0.19
Canada Goose	325	180	33	26	232	340	1136	2.60
Cinnamon Teal	155	200	30				385	0.88
Common Merganser	29	6	10				45	0.10
Gadwall	1200	4266	1848	200	209	85	7808	17.88
Green-winged Teal		1355	1320	310	128	326	3439	7.87
Lesser Scaup				50		5	55	0.13
Mallard	200	605	1247	1100	524	622	4298	9.84
Northern Pintail	500	2600	2872	750	630	268	7620	17.45
Northern Shoveler	8115	5876	1225	100	100	10	15426	35.32
Redhead		5	10	70		10	95	0.22
Red-breasted Merganser					1		1	0.00
Ring-necked Duck				20	23	5	48	0.11
Ruddy Duck			50		46	11	107	0.25
Snow Goose						3	3	0.01
Tundra Swan						11	11	0.03
Unidentified *Anas* spp.	1600	145	100	290	720	215	3070	7.03
Total Waterfowl	12125	15238	8748	2962	2635	1962	43670	

Table 19. Bridgeport Reservoir Fall Survey, September 6, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead	1			1
Canada Goose		325		325
Cinnamon Teal	5	150		155
Common Merganser	29			29
Gadwall		1200		1200
Mallard		200		200
Northern Pintail		500		500
Northern Shoveler		8115		8115
Unidentified		1600		1600
Total waterfowl	35	12090	0	12125

Table 20. Bridgeport Reservoir Fall Aerial Survey, September 21, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Canada Goose		180		180
Cinnamon Teal		100	100	200
Common Merganser	6			6
Gadwall	366	3900		4266
Green-winged Teal	55	1300		1355
Mallard		600	5	605
Northern Pintail		2600		2600
Northern Shoveler	26	5850		5876
Redhead		5		5
Unidentified	145			145
Total waterfowl	598	14535	105	15238

Table 21. Bridgeport Reservoir Fall Aerial Survey , October 3, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead		3		3
Canada Goose		33		33
Cinnamon Teal		30		30
Common Merganser	10			10
Gadwall	143	1600	105	1848
Green-winged Teal	120	1200		1320
Mallard	47	1200		1247
Northern Pintail	72	2800		2872
Northern Shoveler	5	1200	20	1225
Redhead		10		10
Ruddy Ducks		40	10	50
Unidentified	100			100
Total waterfowl	497	8116	135	8748

Table 22. Bridgeport Reservoir Fall Aerial Survey, October 17, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
American Wigeon		40		40
Bufflehead		6		6
Canada Goose		26		26
Gadwall		200		200
Green-winged Teal	24	280	6	310
Lesser Scaup	42	8		50
Mallard		1100		1100
Northern Pintail		750		750
Northern Shoveler		100		100
Redhead		70		70
Ring-necked Duck		20		20
Unidentified	20	200	70	290
Total waterfowl	86	2800	76	2962

Table 23. Bridgeport Reservoir Fall Aerial Survey, October 31, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead		19	3	22
Canada Goose		232		232
Gadwall	4	200	5	209
Green-winged Teal	8	120		128
Mallard	10	500	14	524
Northern Pintail		625	5	630
Northern Shoveler		100		100
Red-breasted Merganser	1			1
Ring-necked Duck	3	20		23
Ruddy Duck		40	6	46
Unidentified	20	680	20	720
Total waterfowl	46	2536	53	2635

Table 24. Bridgeport Reservoir Fall Aerial Survey, November 15, 2006

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead	2	16	33	51
Canada Goose	325	15		340
Gadwall		80	5	85
Green-winged Teal		265	61	326
Lesser Scaup			5	5
Mallard		580	42	622
Northern Pintail		268		268
Northern Shoveler		10		10
Redhead		10		10
Ring-necked Duck		5		5
Ruddy Duck	1	5	5	11
Snow Goose		3		3
Tundra Swan		11		11
Unidentified		185	30	215
Total waterfowl	328	1453	181	1962

Table 25. Summary of 2006 Fall Aerial Survey Counts - Crowley Reservoir

Species	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov	**Total Detections**	**%Total**
American Wigeon		1	2	20		58	81	0.32
Bufflehead		2	18	38	128	121	307	1.21
Canada Goose	140	101	21	10	82	45	399	1.57
Canvasback						2	2	0.01
Cinnamon Teal	38	6	2				46	0.18
Common Merganser				5			5	0.02
Gadwall	862	243	287	165	162	185	1904	7.47
Green-winged Teal	105	150	220	772	1521	790	3558	13.97
Greater White-fronted Goose			10				10	0.04
Lesser Scaup		5		20	29	15	69	0.27
Mallard	93	162	159	618	989	2167	4188	16.44
Northern Pintail	552	229	420	745	1530	2830	6306	24.75
Northern Shoveler	4	210	222	137	73	67	713	2.80
Red-breasted Merganser						1	1	0.00
Redhead		15	10	10	15	5	55	0.22
Ring-necked Duck			5	5	20	7	37	0.15
Ruddy Duck	34	145	344	683	806	141	2153	8.45
Tundra Swan					2	17	19	0.07
Unidentified *Anas* spp.	512	810	620	814	1438	1427	5621	22.07
Total Waterfowl	2340	2079	2340	4042	6795	7878	25474	

Table 26. Crowley Reservoir Fall Aerial Survey, September 6, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
Canada Goose			15				125	140
Cinnamon Teal	5			30			3	38
Gadwall		2		700	20	20	120	862
Green-winged Teal				20			85	105
Mallard	3			82	7		1	93
Northern Pintail	1		1	400			150	552
Northern Shoveler	4							4
Ruddy Duck	2			2			30	34
Unidentified	15	10		234	3	15	235	512
Total waterfowl	30	12	16	1468	30	35	749	2340

Table 27. Crowley Reservoir Fall Aerial Survey, September 21, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	1							1
Bufflehead							2	2
Canada Goose	83			18				101
Cinnamon Teal	5						1	6
Gadwall	150						93	243
Green-winged Teal	25			120			5	150
Lesser Scaup							5	5
Mallard	12			40	3		107	162
Northern Pintail	60			160			9	229
Northern Shoveler	14		2	100			94	210
Redhead							15	15
Ruddy Duck	1		8	35			101	145
Unidentified	100	10	150	250	120		180	810
Total waterfowl	451	10	160	723	123	0	612	2079

Table 28. Crowley Reservoir Fall Aerial Survey, October 3, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon							2	2
Bufflehead	18							18
Canada Goose					21			21
Cinnamon Teal					2			2
Gadwall	15	5	5	130			132	287
Greater White-fronted Goose	10							10
Green-winged Teal				175	40		5	220
Mallard				82	20	2	55	159
Northern Pintail	95			305			20	420
Northern Shoveler	152		5	60			5	222
Redhead				10				10
Ring-necked Duck				5				5
Ruddy Duck	20	50	80	70		2	122	344
Unidentified	110			300	20		190	620
Total waterfowl	420	55	90	1137	103	4	531	2340

Table 29. Crowley Reservoir Fall Aerial Survey, October 17, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	20							20
Bufflehead			12	20			6	38
Canada Goose	10							10
Common Merganser							5	5
Gadwall	30			60		4	71	165
Green-winged Teal	50		6	480	90		146	772
Lesser Scaup				20				20
Mallard	30	30	6	290	130		132	618
Northern Pintail	70			580			95	745
Northern Shoveler	10		2	110			15	137
Redhead	10							10
Ring-necked Duck				5				5
Ruddy Duck	144	8	47	280			204	683
Unidentified		20		660	52	2	80	814
Total waterfowl	374	58	73	2505	272	6	754	4042

Table 30. Crowley Reservoir Fall Aerial Survey, October 31, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
Bufflehead	20	4	9	51	12	11	21	128
Canada Goose				32	50			82
Gadwall		10		90		32	30	162
Green-winged Teal	20	4	10	1415	30	30	12	1521
Lesser Scaup		5		20			4	29
Mallard	100	4	6	620	20	185	54	989
Northern Pintail	480			1000			50	1530
Northern Shoveler		4	24	25			20	73
Redhead				15				15
Ring-necked Duck	3			15			2	20
Ruddy Duck	80	129	4	360	59	10	164	806
Tundra Swan			2					2
Unidentified	337	4	10	950	30	44	63	1438
Total waterfowl	1040	164	65	4593	201	312	420	6795

Table 31. Crowley Reservoir Fall Aerial Survey, November 15, 2006

Species	Lakeshore segment							Total
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	20						38	58
Bufflehead	20	7	23	41	3	10	17	121
Canada Goose						15	30	45
Canvasback							2	2
Gadwall	89			80		1	15	185
Green-winged Teal				450	270		70	790
Lesser Scaup	5					10		15
Mallard	50		56	1125	210	360	366	2167
Northern Pintail	270			2475	30	20	35	2830
Northern Shoveler	10			55		2		67
Red-breasted Mergenser							1	1
Redhead				5				5
Ring-necked Duck				7				7
Ruddy Duck	19	44	7		27	4	40	141
Tundra Swan				15			2	17
Unidentified	10	5	2	975	60	45	330	1427
Total waterfowl	493	56	88	5228	600	467	946	7878

Figure 1. Summer Ground Count Survey Areas

Figure 2. Lakeshore Segment , Segment Boundaries, and Cross-Lake Transects for Fall Aerial Surveys of Mono Lake

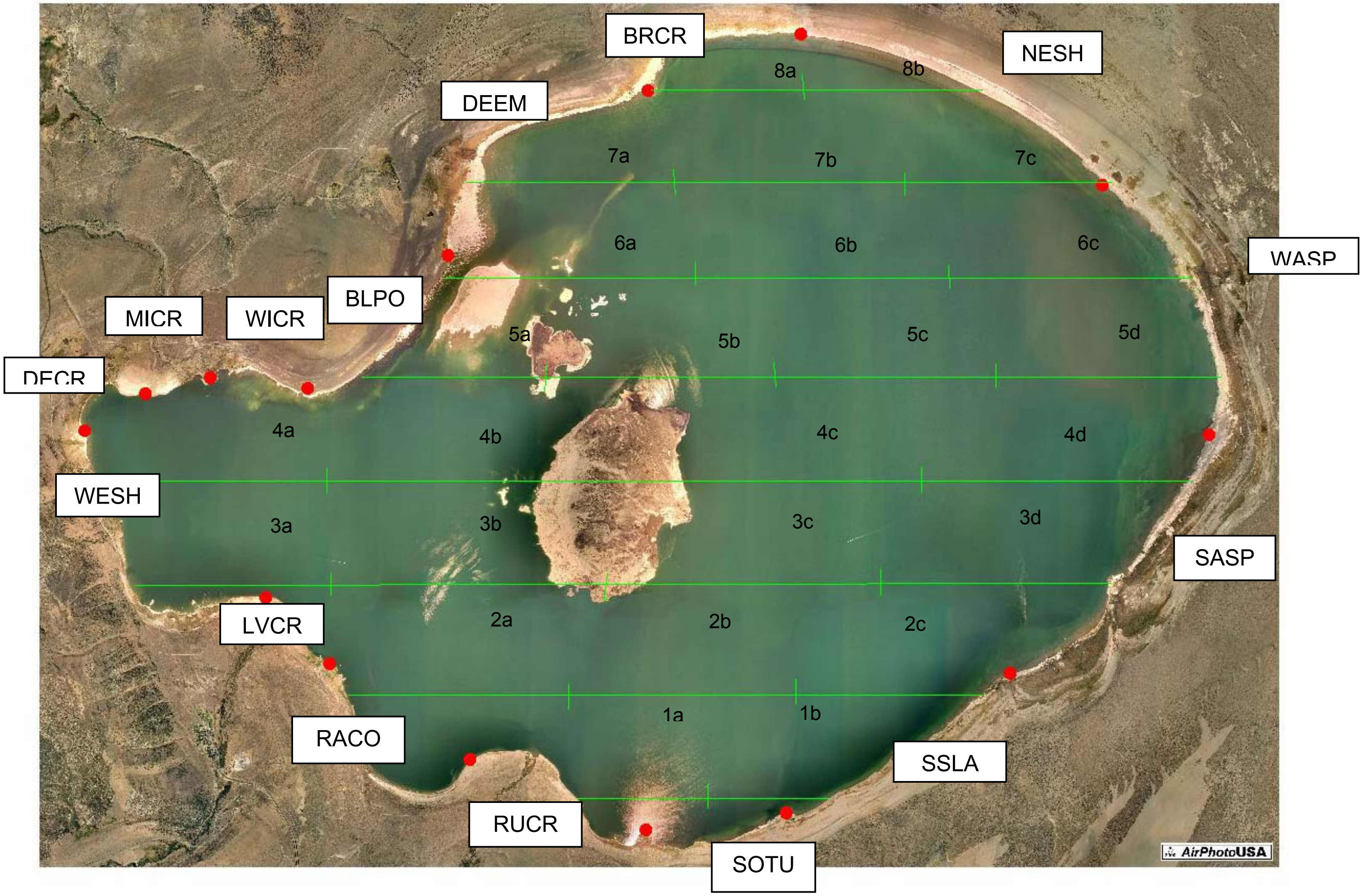


Figure 3. **Lakeshore Segments and Segment Boundaries used for Fall Ariel Surveys of Bridgeport Reservoir**

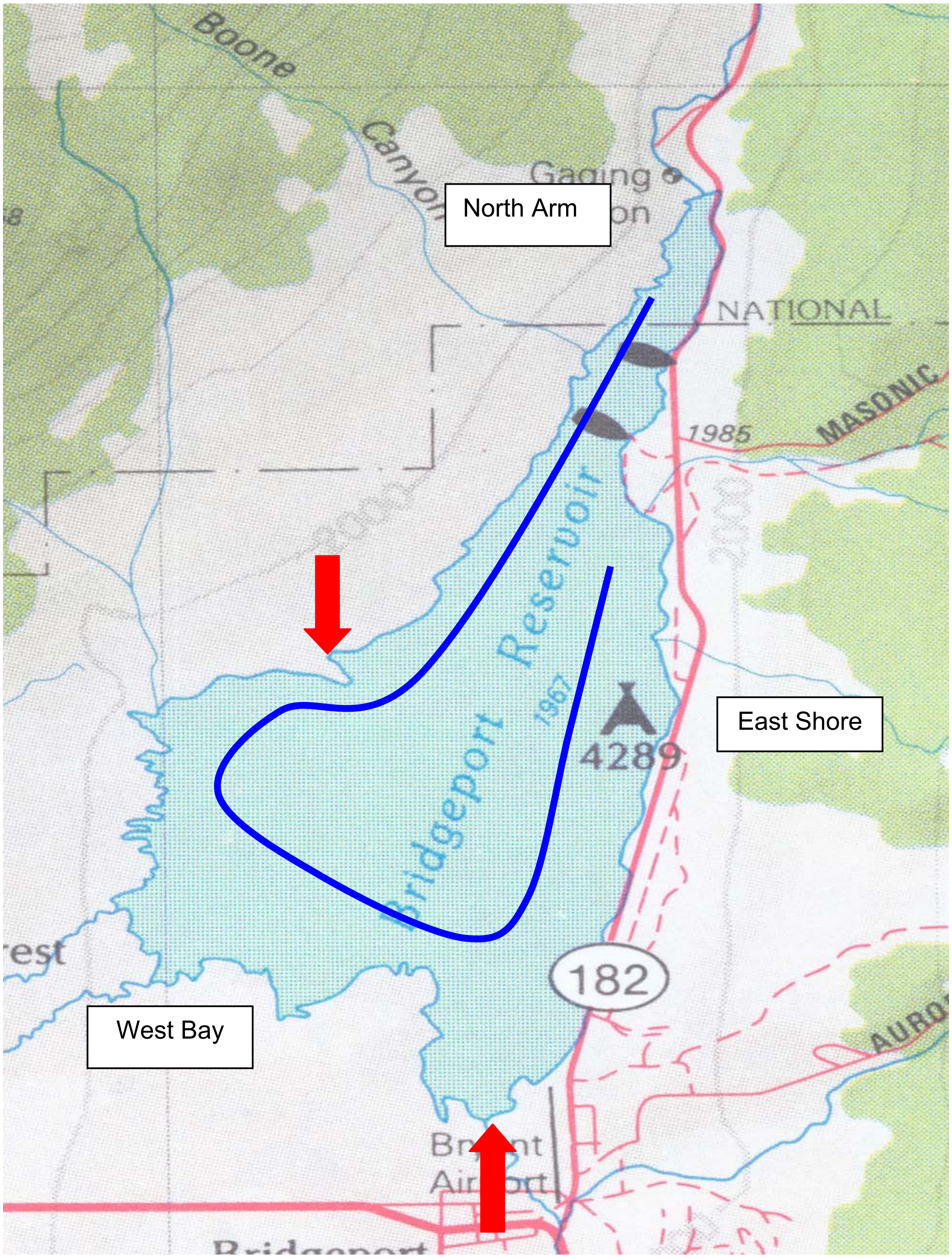


Figure 4. Lakeshore Segments and Segment Boundaries used for Aerial Surveys of Crowley Reservoir

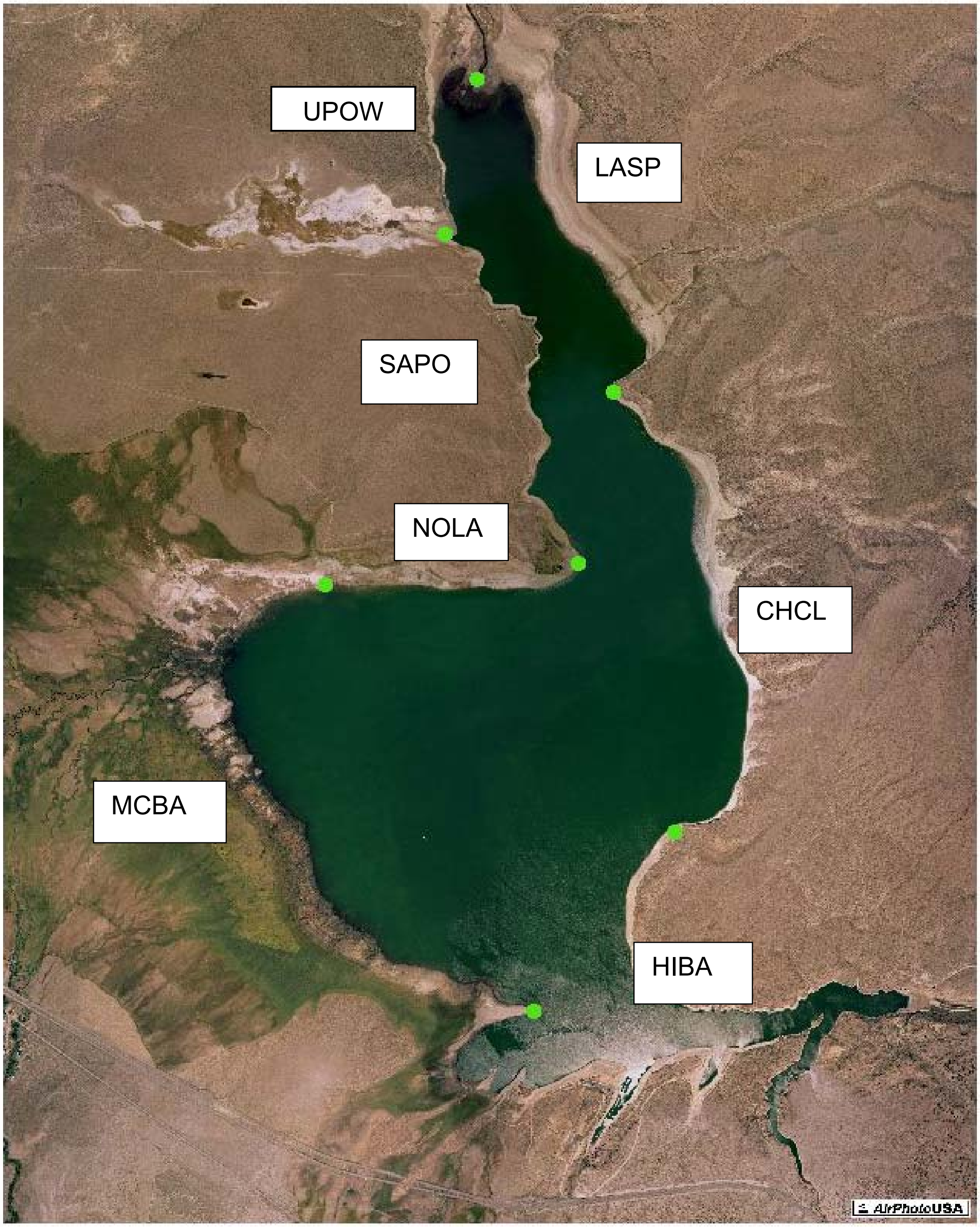


Figure 5. East Shore of South Tufa Area Showing the New Lagoon Present in 2006

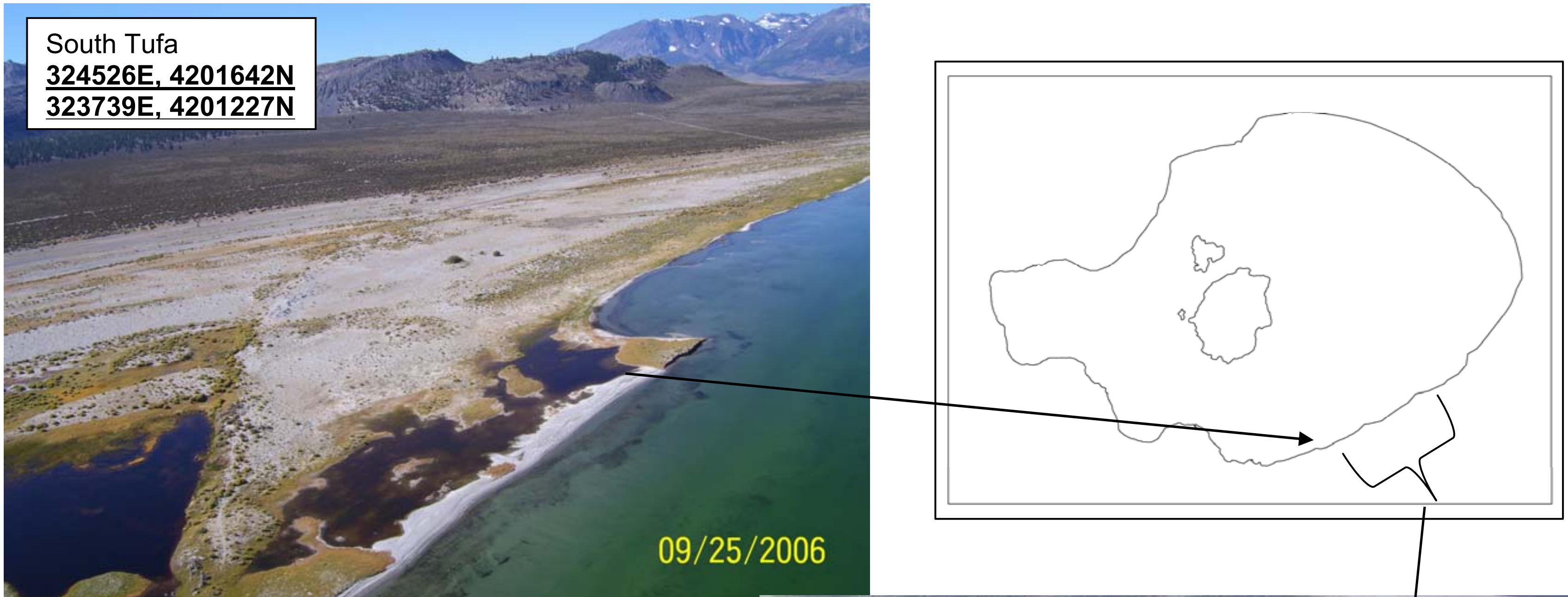


Figure 6. East End of South Tufa Area Showing the New and Expanded Lagoon Present in 2006. These lagoons attracted breeding and migratory waterfowl.

07/19/2006

Figure 7. Photo Taken in the Sammann's Spring Area showing extensive flooding of lake-fringing wetlands due to the increase in lake elevation during 2006.

07/19/2006

Figure 8. Photo Taken in the Samman's Spring Area Showing Influence of Old Littoral Bars on Lake-Fringing Wetland Habitats. Lake-fringing wetland vegetation to the right of the littoral bar is being inundated by lake water and dying off, while the littoral bar is serving to isolate spring-supported wetland vegetation on the left from lake water.

Figure 9. Condition of the Shoreline in the Goose Springs Area of the South Shore Lagoons in 2005. The Goose Springs outflow formed a series of freshwater ponds used by breeding waterfowl and Wilson's Phalaropes, and migratory waterfowl. The red arrow points to a tufa that can be used as a reference point. The same tufa is indicated by a red arrow in Figure 10.

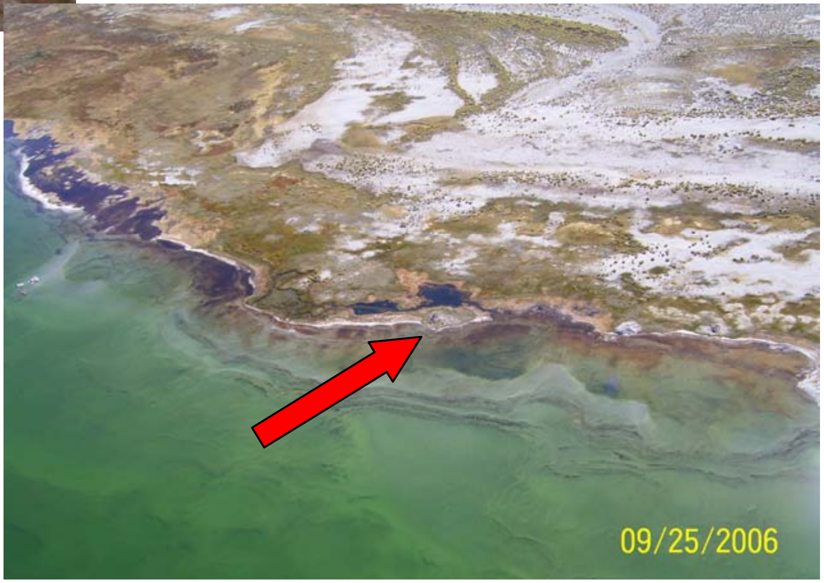


Figure 10. Condition of the Shoreline in the Goose Springs Area of the South Shore Lagoons in 2006. The freshwater ponds formed by the outflow of Goose Springs were inundated by lake water due to the increase in lake elevation in 2006. The lagoon near the tip of the arrow was a freshwater pond, but by the fall of 2006, was brackish due to saltwater intrusion.

Figure 11. Flocks of Migrating Wilson's Phalaropes at Sammann's Springs. Wilson's Phalaropes readily rested and foraged in shoreline areas such as this where wetland vegetation was dying due to inundation by lake water.

Figure 12. Shoreline Conditions at Warm Springs. As compared to 2005, the lagoons at Warm Springs appeared to be larger, while the amount of exposed shoreline had decreased.

Warm Springs – North Lagoon
<u>**331546E, 4212167N**</u>
<u>**332307E, 4210731N**</u>

Figure 13. Shoreline Conditions in the Northeast Shore Area. A continuous hypersaline lagoon formed along the shoreline between Warm Springs and Bridgeport Creek.

Northeast Shore
<u>**327579E, 4215131N**</u>
<u>**331120E, 4212640N**</u>

09/25/2006

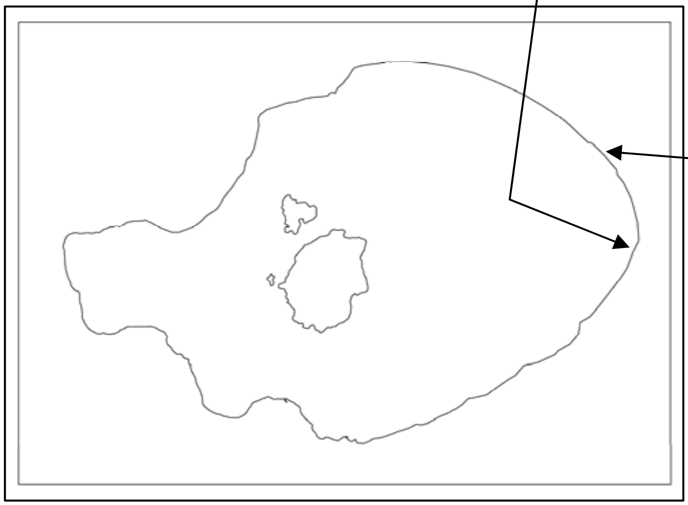


Figure 14. Black Point Shoreline Area. New shoreline lagoons were present in the Black Point area in 2006. These lagoons were used by migrating waterfowl in the fall.

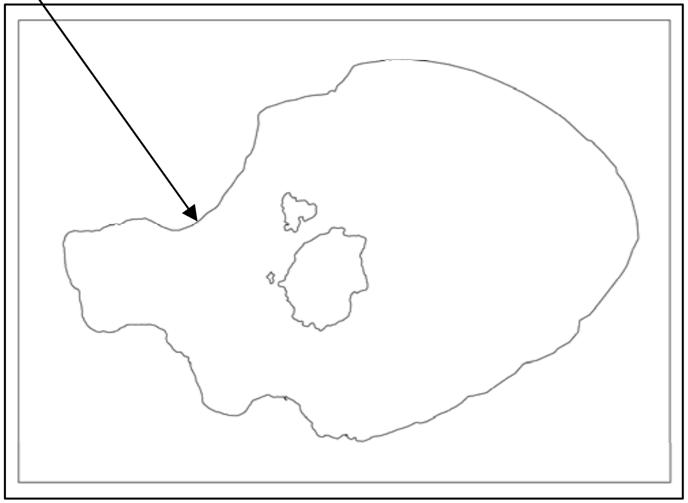


Figure 15. Die Off of Salix exigua in the DeChambeau-Creek Area in response to inundation by lake water.

Figure 16. Wilson Creek Delta Area. The increase in lake elevation resulted in inundation of *S. exigua* at the mouth of Wilson Creek. Due to the high flows in Wilson Creek at this time, these willows did not yet show signs of osmotic stress.

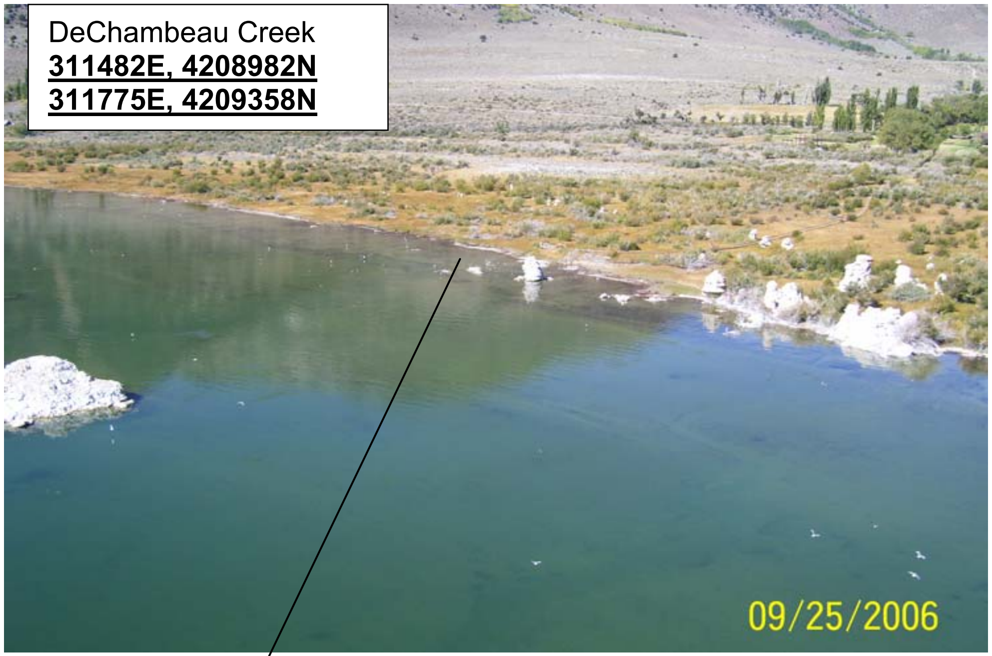


Figure 17. DeChambeau Creek Shoreline Area.

Figure 18. Mill Creek Delta Area.

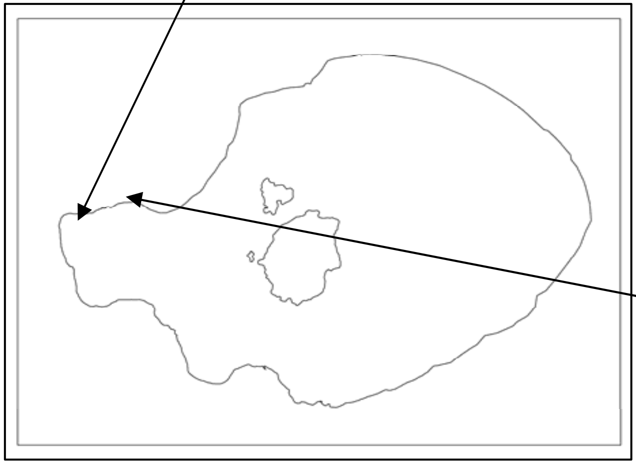
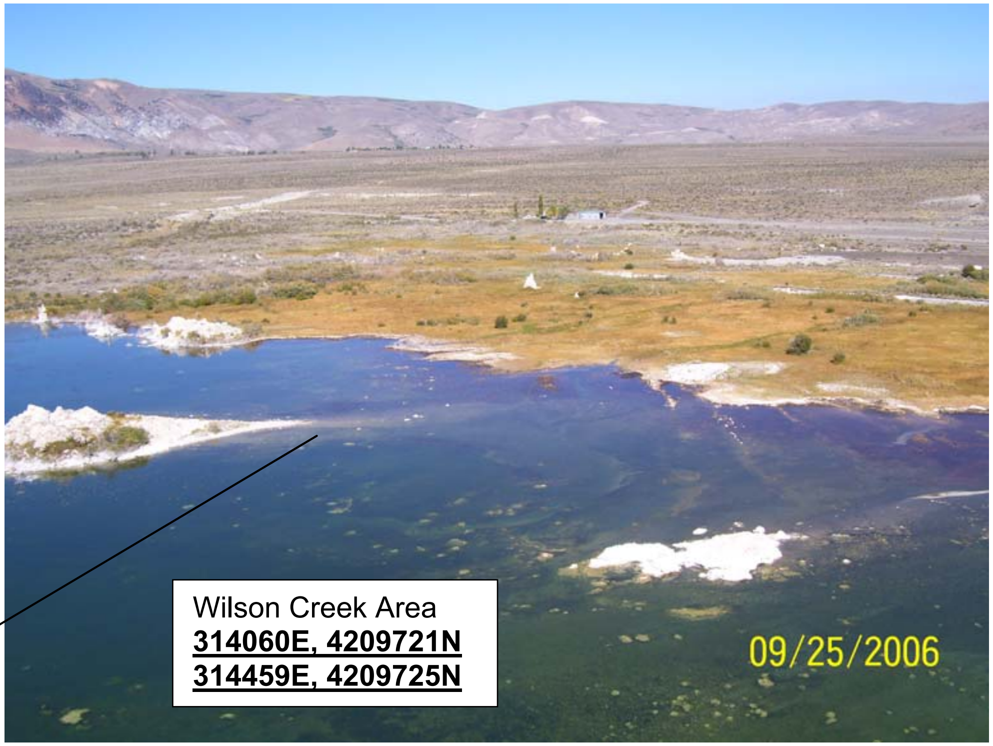
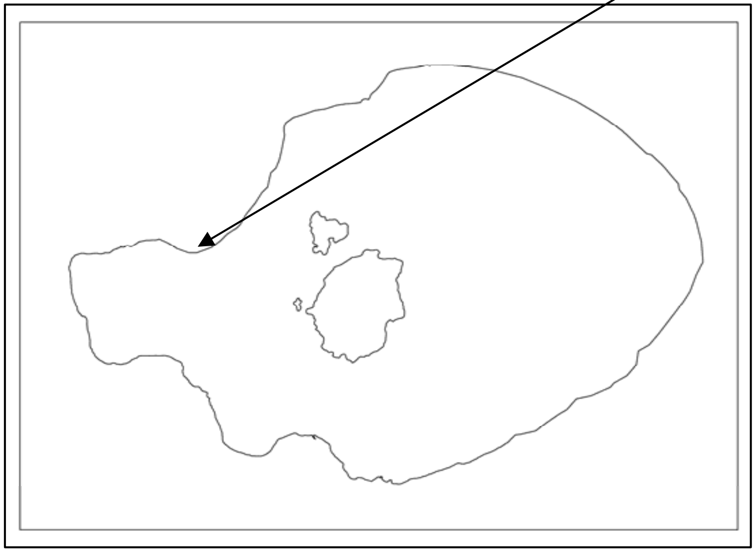
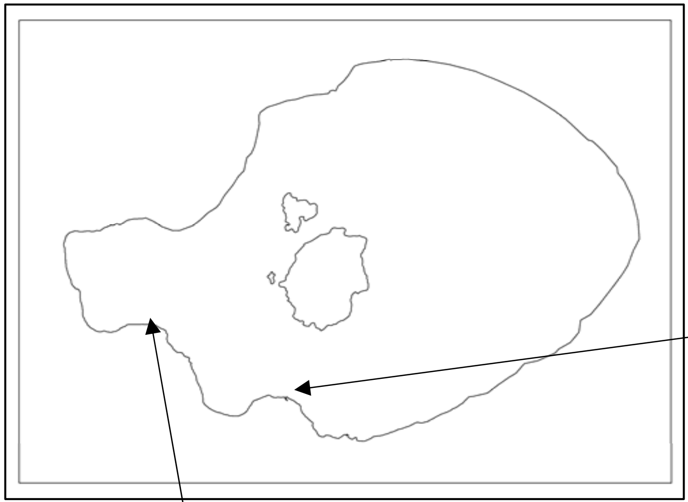
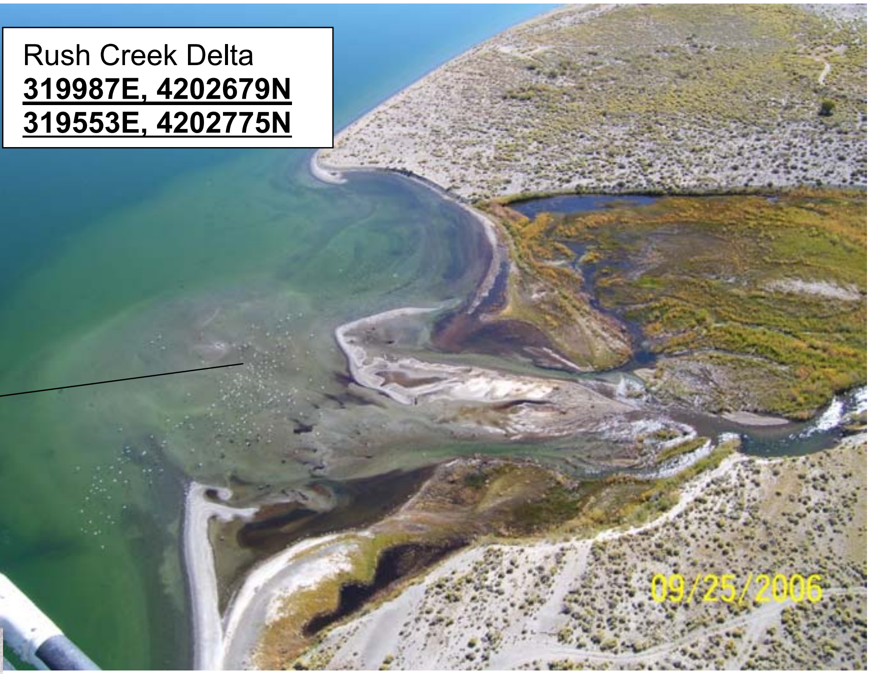


Figure 19. Wilson Creek Area. The tufa island on the left hand side of the photo was connected by a land by a land bridge in 2005. In 2006, there was extensive flooding of the meadows east of this tufa. There was increased in use of the area east of this tufa in 2006 by waterfowl as compared to the last several years.





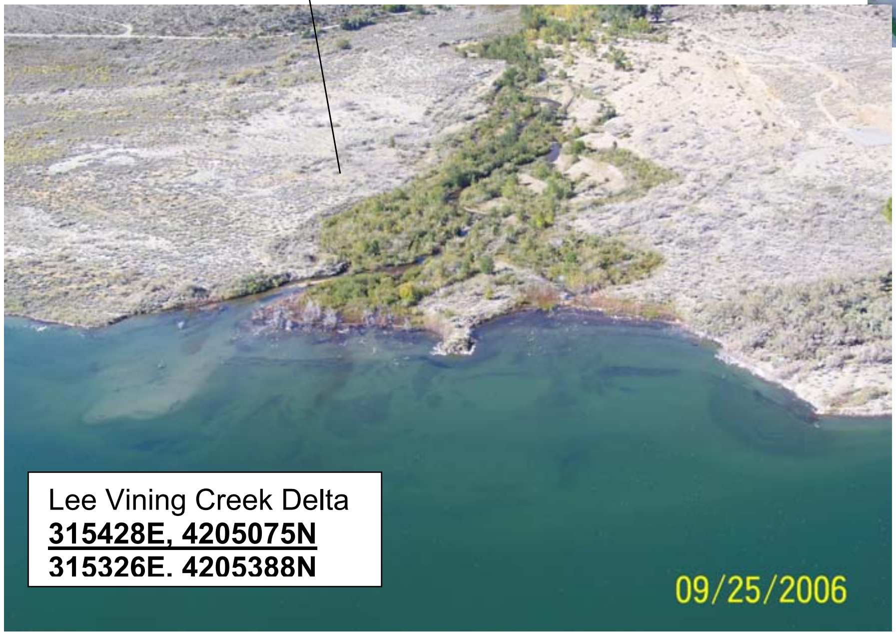




Rush Creek Delta
319987E, 4202679N
319553E, 4202775N

09/25/2006

Figure 20. Rush Creek Delta. Flocks of ducks and gulls can be seen in flight after being flushed from the delta.



Lee Vining Creek Delta
315428E, 4205075N
315326E. 4205388N

09/25/2006

Figure 21. Lee Vining Creek Delta.

Figure 22. Photo of Bridgeport Reservoir. Taken from a helicopter on September 25, 2006.

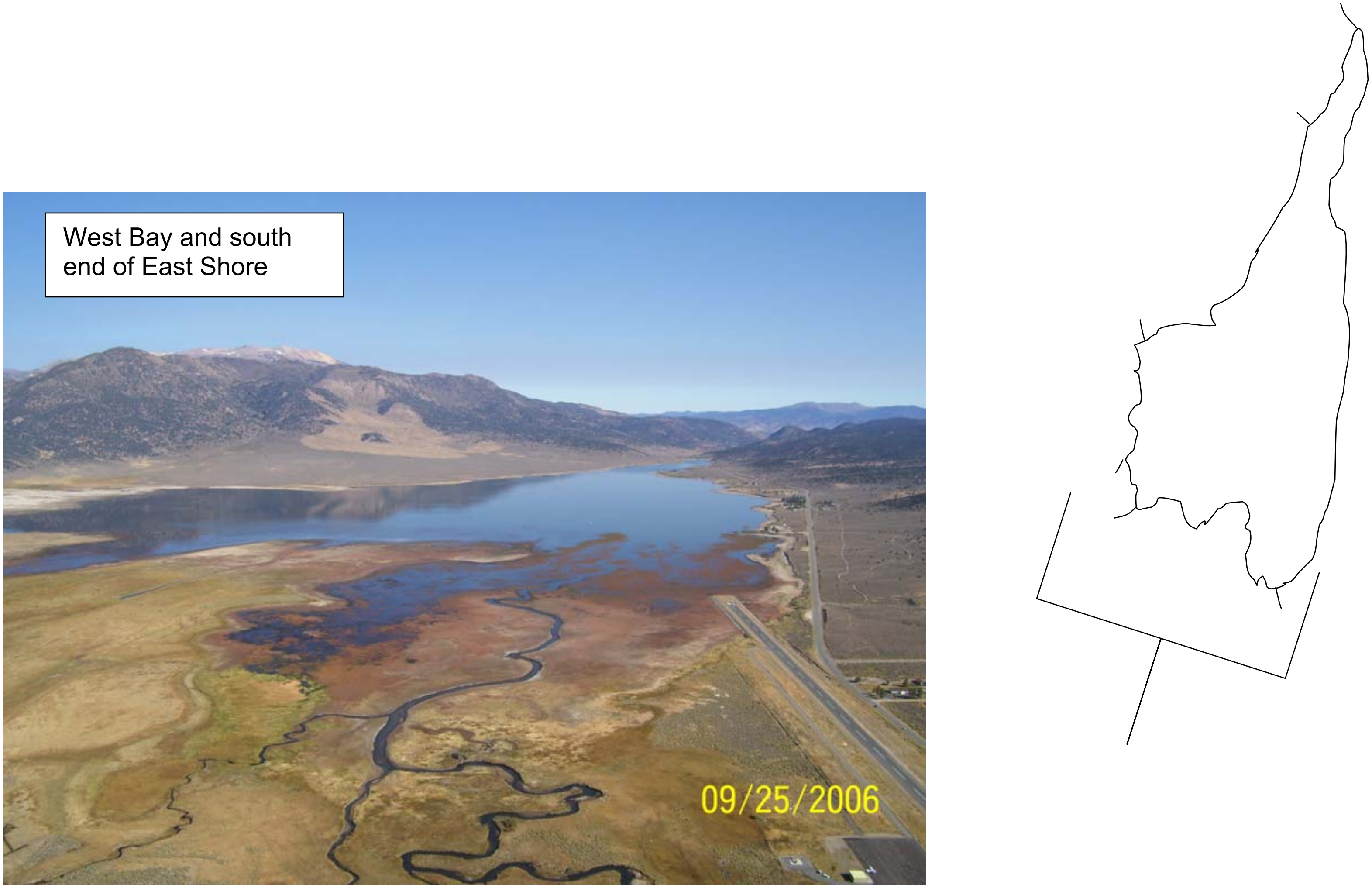


Figure 23. Elevated Water Levels at Crowley Reservoir resulted in flooding of meadow vegetation in McGee Bay.

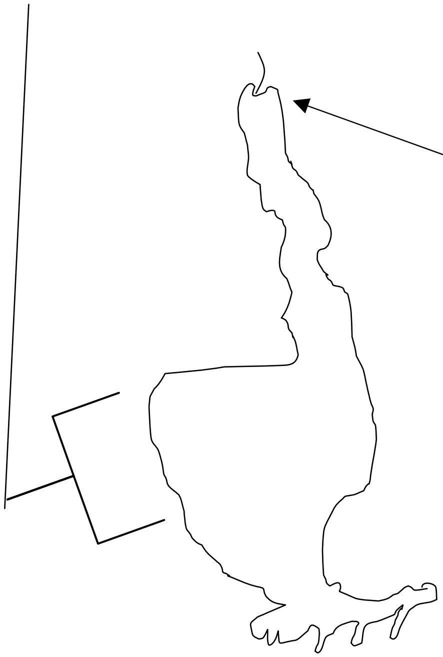


Figure 24. Photo Showing the Condition of the Water at Crowley Reservoir in Fall 2006.

Figure 25. Mouth of the Owens River, Crowley Reservoir. The water was very green in all parts of the lake except in freshwater inflow areas such as this.

Figure 26. Brood Locations. The number in parentheses indicates the minimum number of broods of each species found in the indicated lakeshore segment or restoration pond complex.

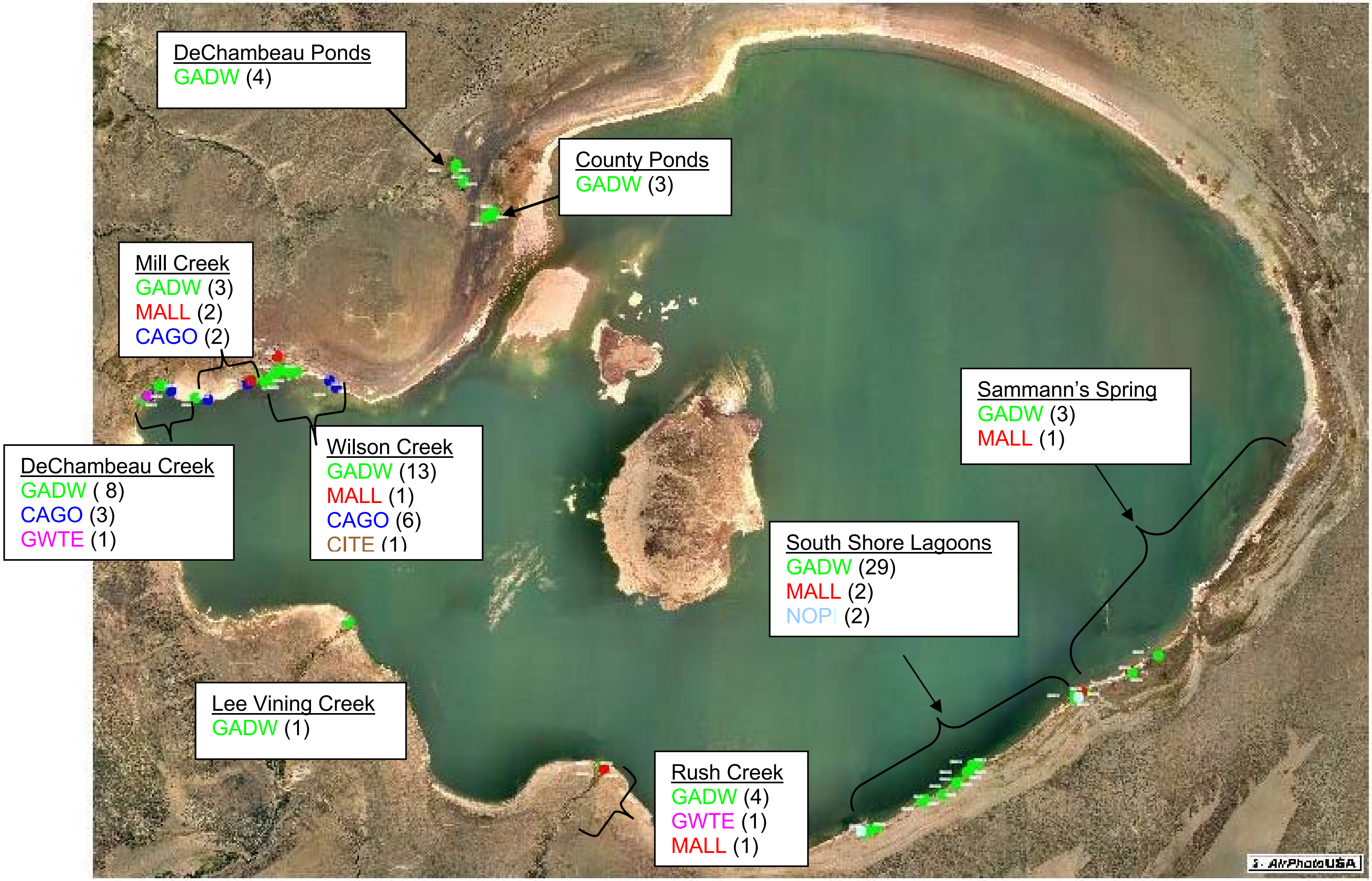


Figure 27. Habitat Use by the Dominant Summer Resident Waterfowl Species. The numbers in **parentheses indicate the sample size. The bars represent the percent of total observations.**

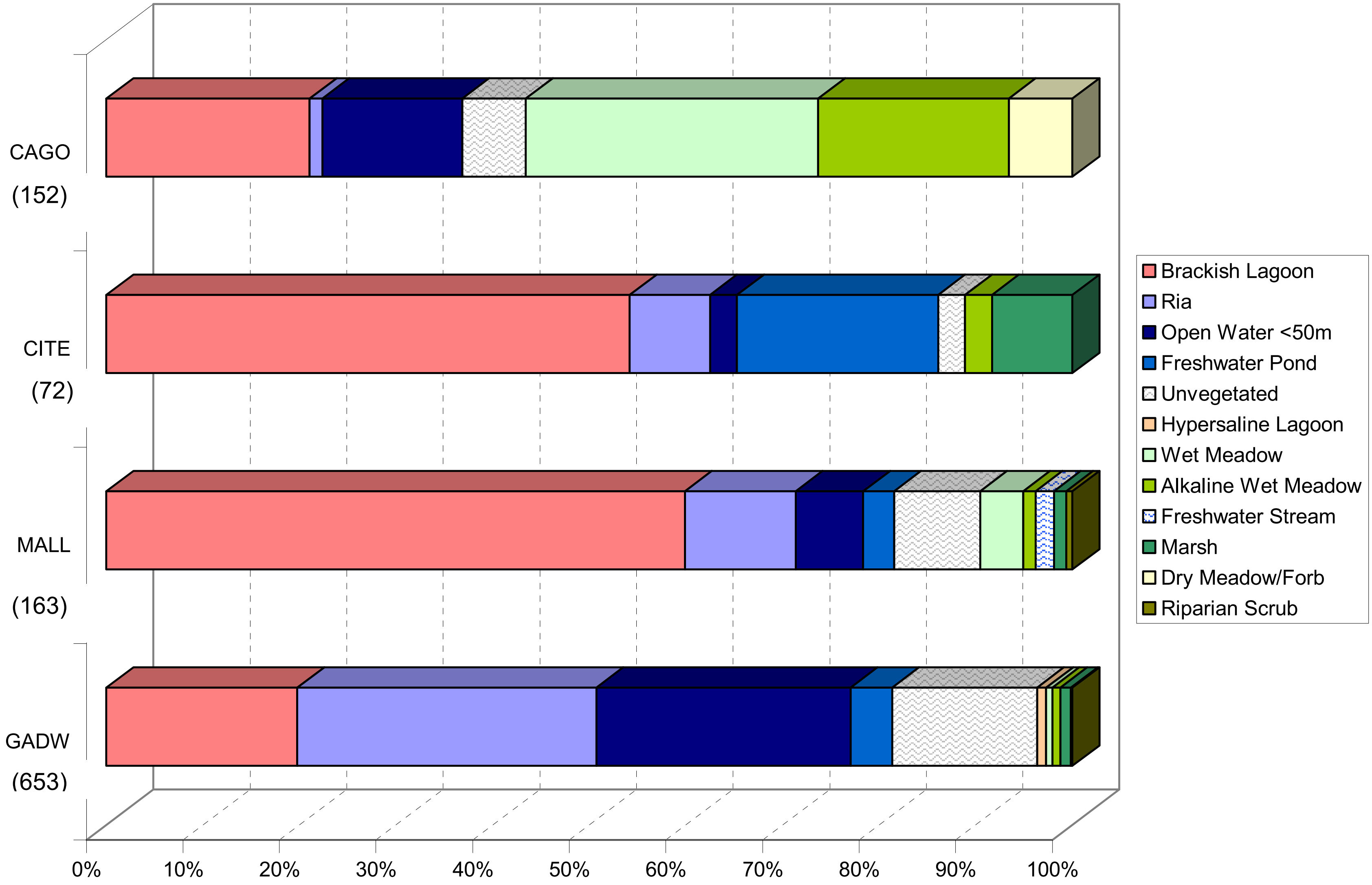


Figure 28. Foraging Habitat Used by the Dominant Shorebird Species. The numbers in parentheses **indicate the sample size. The bars represent the percent of total observations.**

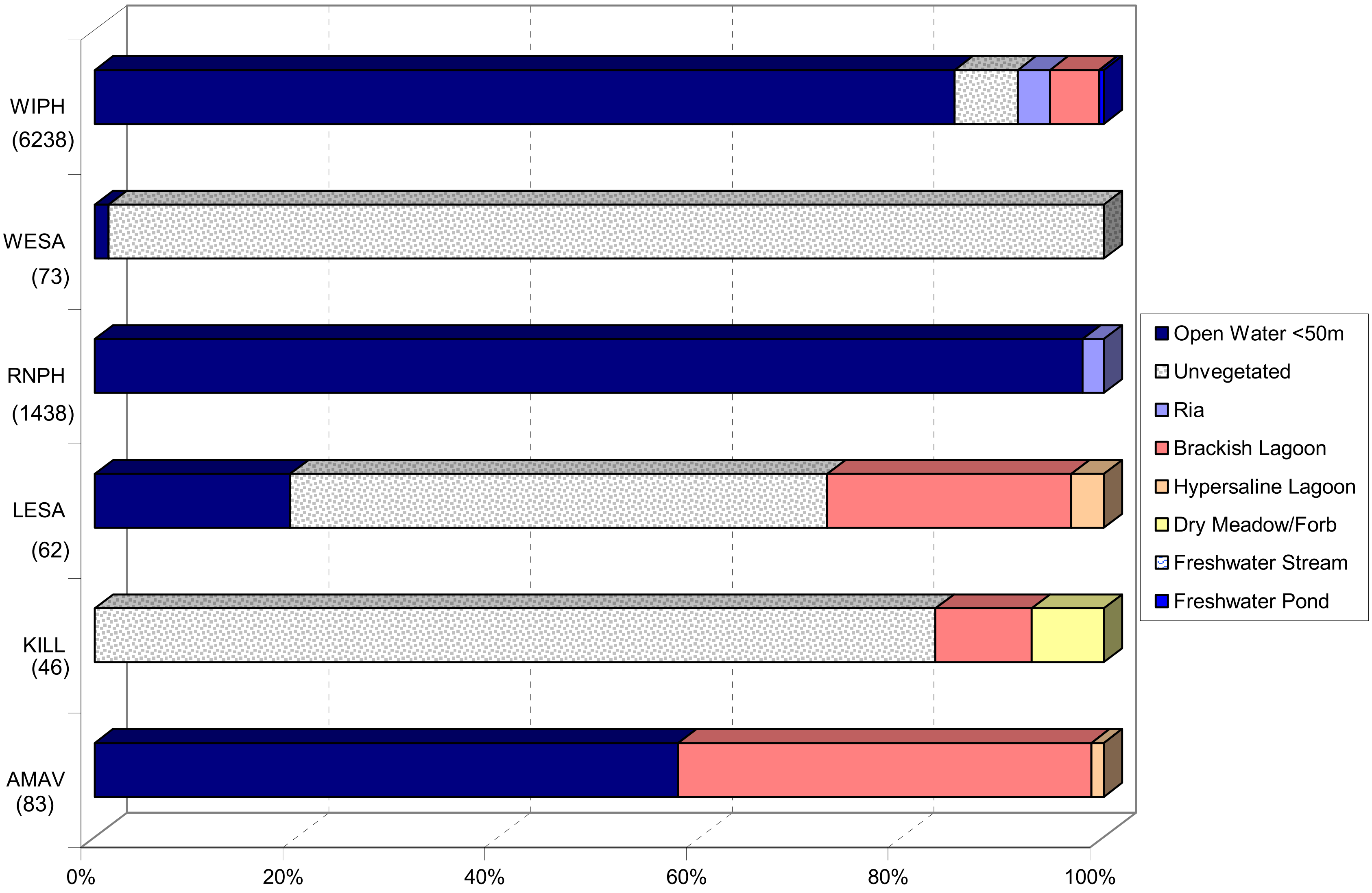


Figure 29. Total Waterfowl Detected at each Waterbody During Fall Aerial Surveys, 2006.

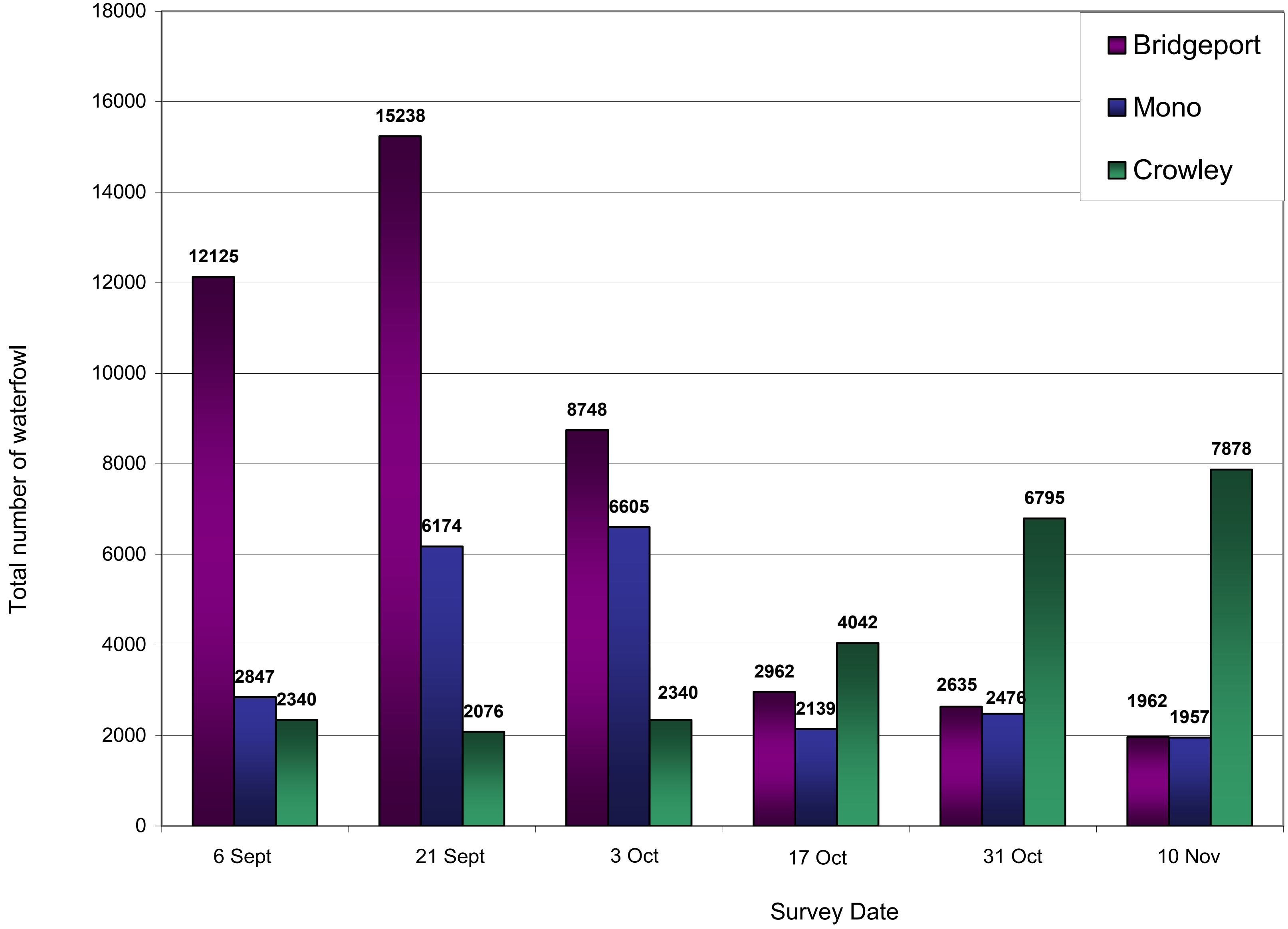
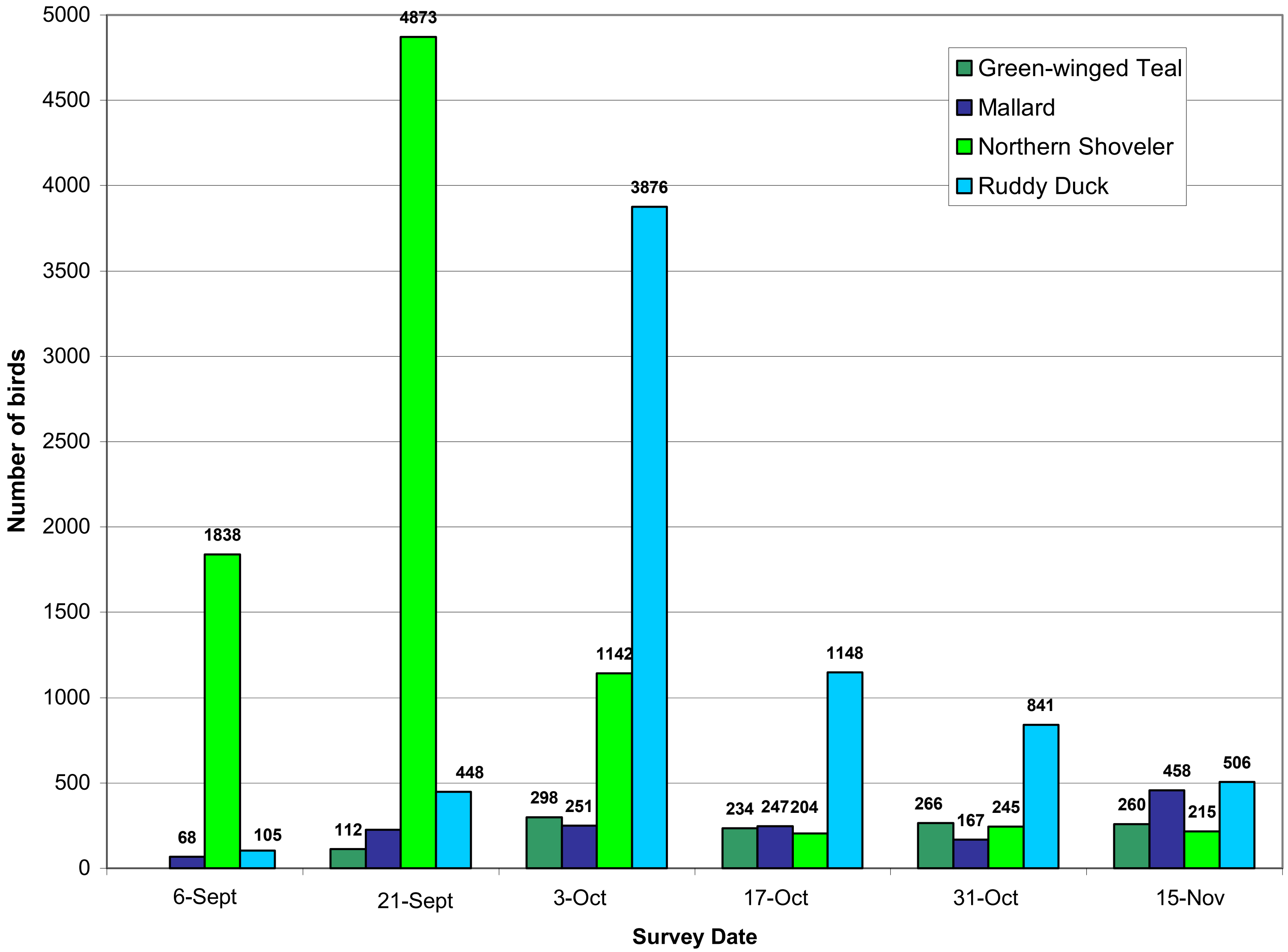


Figure 30. Total Detections of Dominant Species at Mono Lake During Fall Aerial Surveys, 2006.



djhouse4/9/06

Figure 31. Total Detections of Dominant Species at Bridgeport Reservoir During Fall Aerial Surveys.

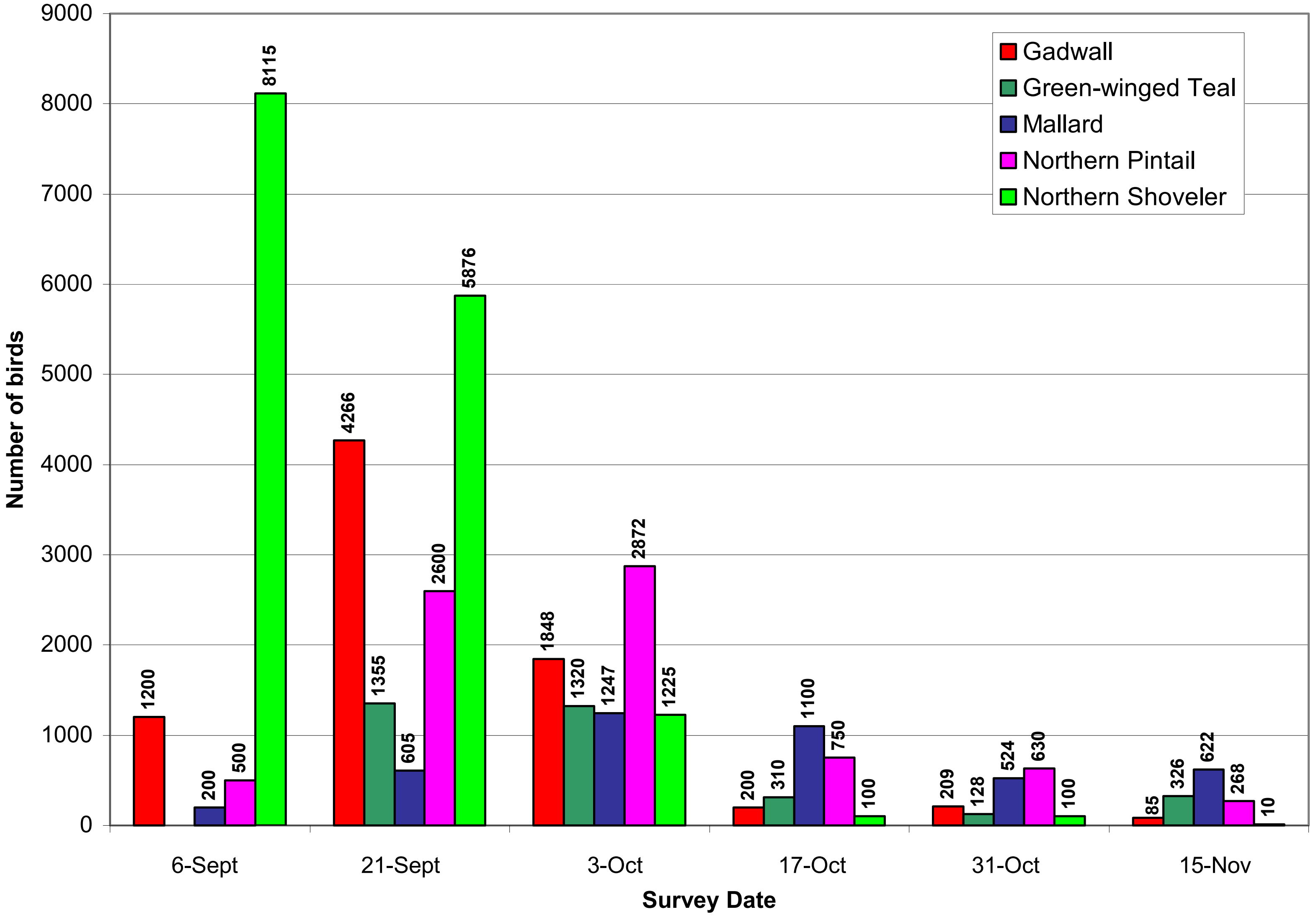


Figure 32. Total Detections of Dominant Species at Crowley Reservoir During Fall Aerial Surveys.

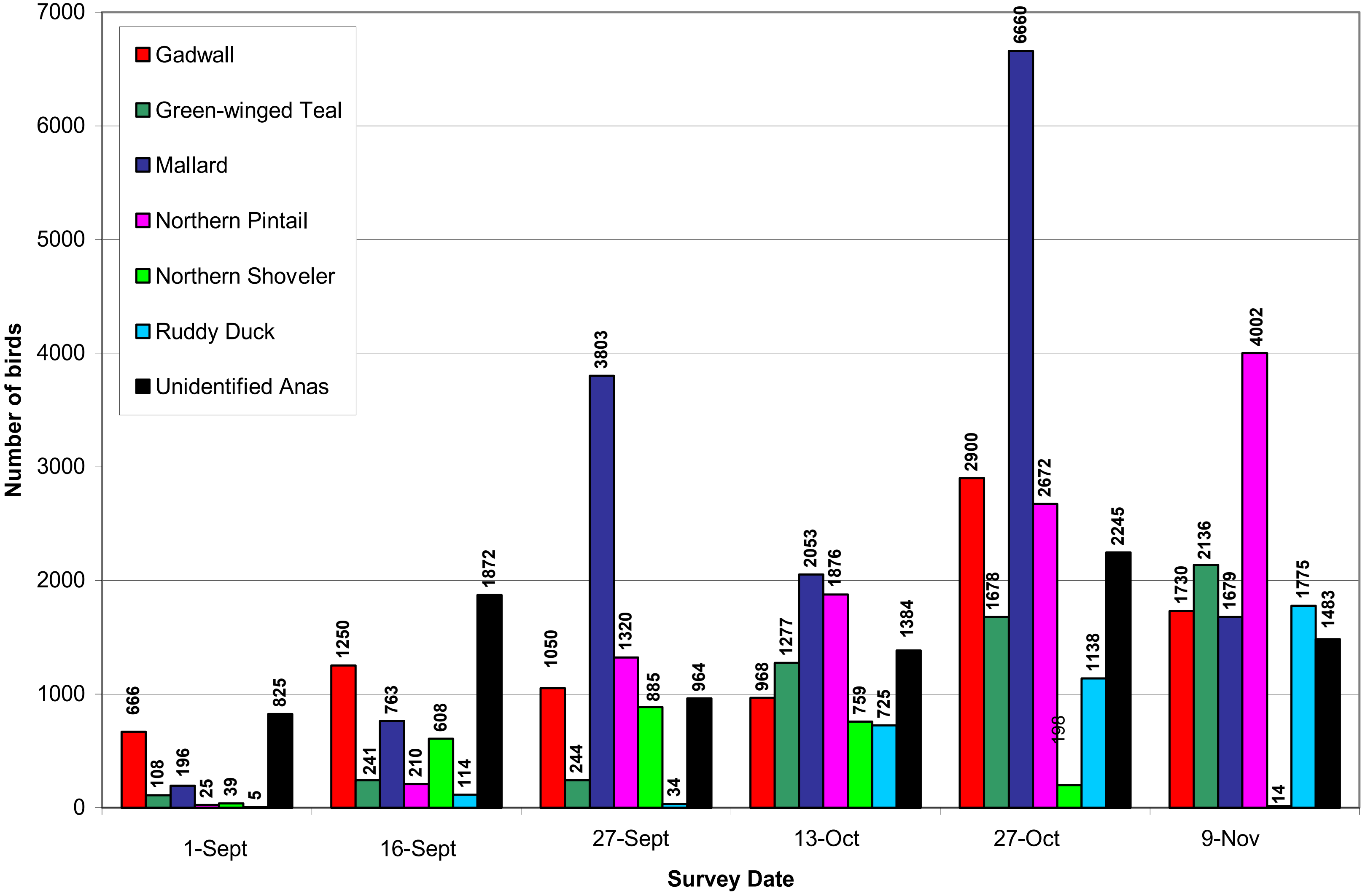


Figure 33. Total Fall Detections of the Dominant Species at all Three Bodies of Water.

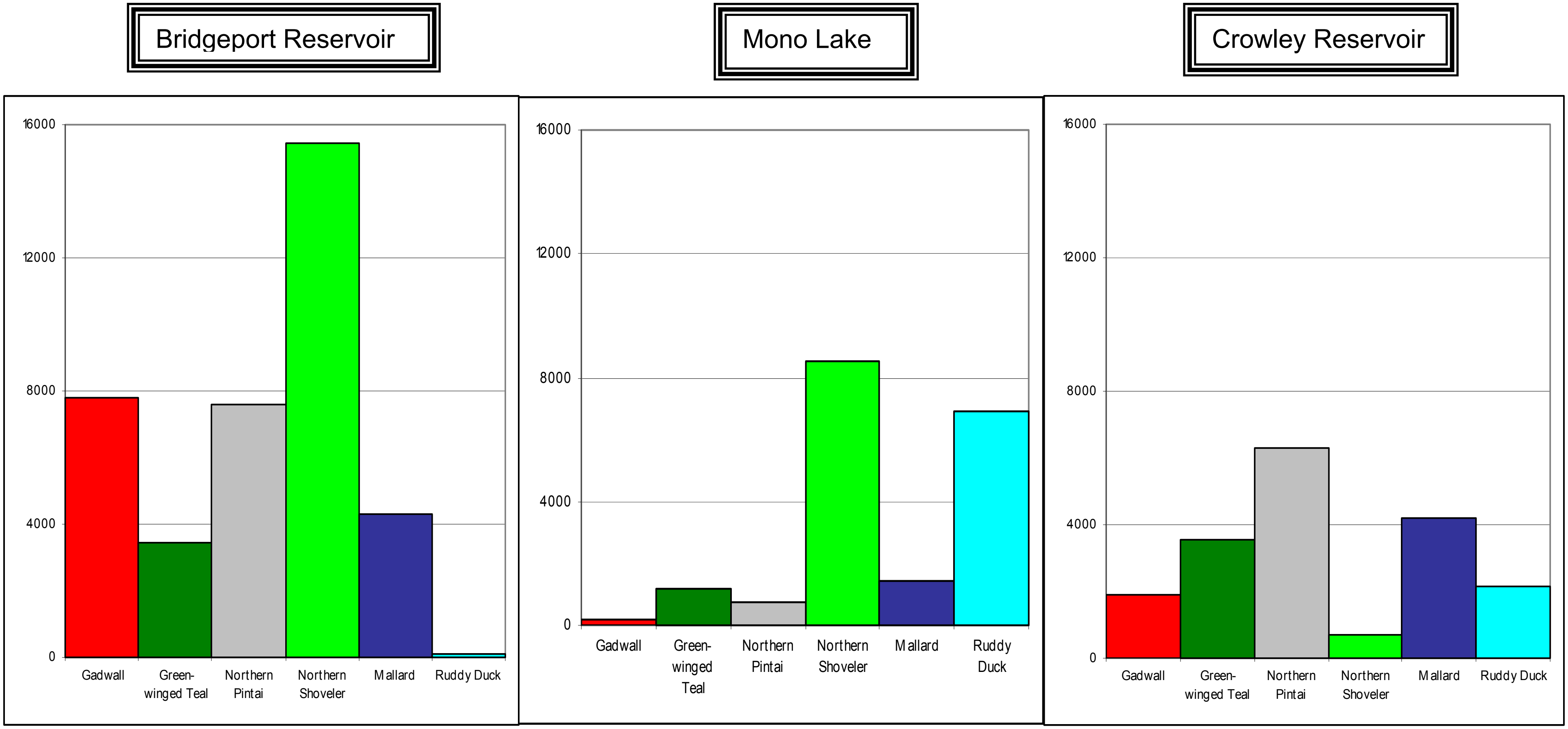
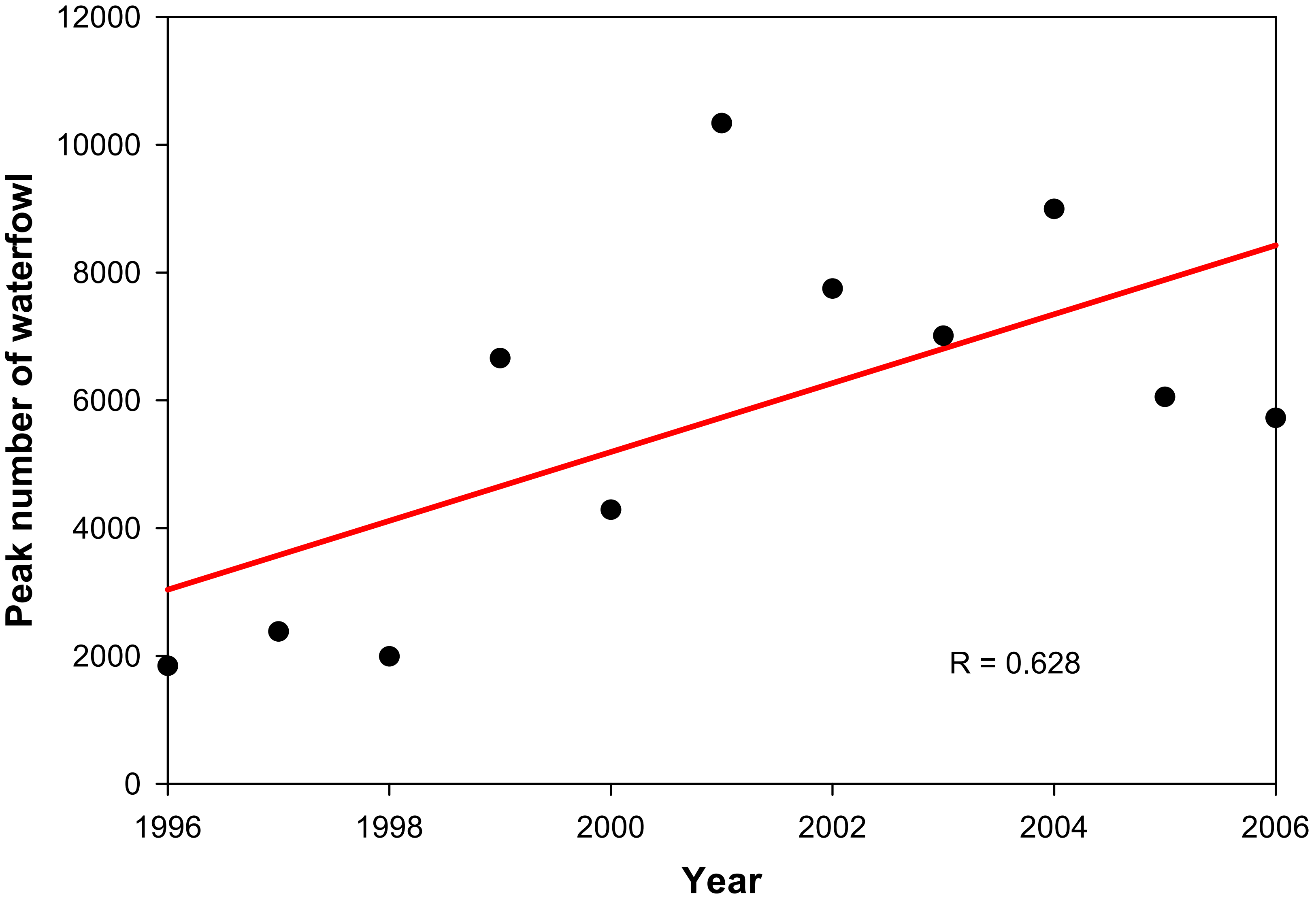


Figure 34. Trend in Peak Waterfowl Numbers (not including Ruddy Ducks) at Mono Lake, 1996-2006.



APPENDICES

Appendix 1. 2006 Ground Count Surveys - Dates and times that surveys were conducted at each summer survey area.

Survey 1

Survey area	Survey Date and Time		
	June 5	June 6	June 7
RUCR	1214-1312 hrs		
SOTU	0542-0650 hrs		
SSLA	0651-0932 hrs		
SASP			0539-0924 hrs
WASP			0925-1100 hrs
WICR		0837-0952 hrs	
MICR		0711-0836 hrs	
DECR		0532-0705 hrs	
LVCR		1125-1217 hrs	
DEPO		1310-1335 hrs	
COPO		1343-1400 hrs	

Survey 2

Survey area	Survey Date and Time		
	June 26	June 27	June 28
RUCR	0540-0700 hrs		
SOTU	0734-0832 hrs		
SSLA	0832-1200 hrs		
SASP			0804-1128 hrs
WASP			0622-0804 hrs
WICR		0849-0945 hrs	
MICR		0720-0843 hrs	
DECR		0550-0720 hrs	
LVCR		1232-1307 hrs	
DEPO		1110-1145 hrs	
COPO		1152-1205 hrs	

Appendix 1. Continued

Survey 3

Survey area	Survey Date and Time			
	July 17	July 18	July 19	July 20
RUCR				0615-0724 hrs
SOTU	0540-0650 hrs			0813-0929 hrs
SSLA	0650-1107 hrs			
SASP			0540-0955 hrs	
WASP			0955-1142 hrs	
WICR		0820-0928 hrs		
MICR		0730-0820 hrs		
DECR		0544-0730 hrs		
LVCR		1233-1311 hrs		
DEPO		1035-1110 hrs		
COPO		1120-1140 hrs		

Appendix 2. Common, Scientific Names and Codes for species names occurring in the document.

Common Name	Scientific Name	Code
American Avocet	*Recurvirostra americana*	AMAV
American Coot	*Fulica americana*	AMCO
American Wigeon	*Anas americanus*	AMWI
Black-necked Stilt	*Himantopus mexicanus*	BNST
Blue-winged Teal	*Anas discors*	BWTE
Bufflehead	*Bucephala albeola*	BUFF
Canada Goose	*Branta canadensis*	CAGO
Canvasback	*Aythya valisineria*	CANV
Cinnamon Teal	*Anas cyanoptera*	CITE
Common Merganser	*Mergus merganser*	COME
Great Blue Heron	*Ardea herodias*	GBHE
Great Egret	*Ardea alba*	GREG
Greater Yellowlegs	*Tringa melanoleuca*	GRYE
Killdeer	*Charadrius vociferous*	KILL
Lesser Scaup	*Aythya affinis*	LESC
Least Sandpiper	*Calidris minutilla*	LESA
Long-billed Curlew	*Numenius americanus*	LBCU
Gadwall	*Anas strepera*	GADW
Greater White-fronted Goose	*Anser albifrons*	GWFG
Green-winged Teal	*Anas crecca*	GWTE
Mallard	*Anas platyrhynchos*	MALL
Marbled Godwit	*Limosa fedoa*	MAGO
Northern Pintail	*Anas acuta*	NOPI
Northern Shoveler	*Anas clypeata*	NSHO
Redhead	*Aythya americana*	REDH
Red-breasted Merganser	*Mergus serrator*	RBME
Red-necked Phalarope	*Phalaropus lobatus*	RNPH
Ring-necked Duck	*Aythya collaris*	RNDU
Ruddy Duck	*Oxyura jamaicensis*	RUDU
Semipalmated Plover	Charadrius semipalmatus	SEPL
Short-billed Dowitcher	*Limnodromus griseus*	SBDO
Snow Goose	*Chen caerulescens*	SNGO
Snowy Plover	*Charadrius alexandrinus*	SNPL
Spotted Sandpiper	*Actitis macularia*	SPSA
Tundra Swan	*Cygnus columbianus*	TUSW
Western Grebe	*Aechmorphorus occidentalis*	WEGR
Western Sandpiper	*Calidris mauri*	WESA
White-faced Ibis	*Plegadis chihi*	WFIB
Willet	*Catoptrophorus semipalmatus*	WILL
Wilson's Phalarope	*Phalaropus tricolor*	WIPH
Wilson's Snipe	*Gallinago delicata*	WISN
Anas spp.	Unidentified *Anas* species	UNTE
Calidris spp	Unidentified *Calidris* species	CALX
Phalaropus spp.	Unidentified *Phalaropus* species	PHAX

Appendix 3. Habitat Categories Used for Documenting use by Waterfowl and Shorebird 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 lagoon

Lagoons 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 lagoons. In some cases, lagoons 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 lagoon

Lagoons 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 lagoons. 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. 2006 Fall Aerial Survey Dates

Survey Number	1	2	3	4	5	6
Mono Lake	6 Sept	21 Sept	3 Oct	17 Oct	31 Oct	15 Nov
Bridgeport Reservoir	6 Sept	21 Sept	3 Oct	17 Oct	31 Oct	15 Nov
Crowley Reservoir	6 Sept	21 Sept	3 Oct	17 Oct	31 Oct	15 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. Cross-Lake Transect Positions for Mono Lake

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”

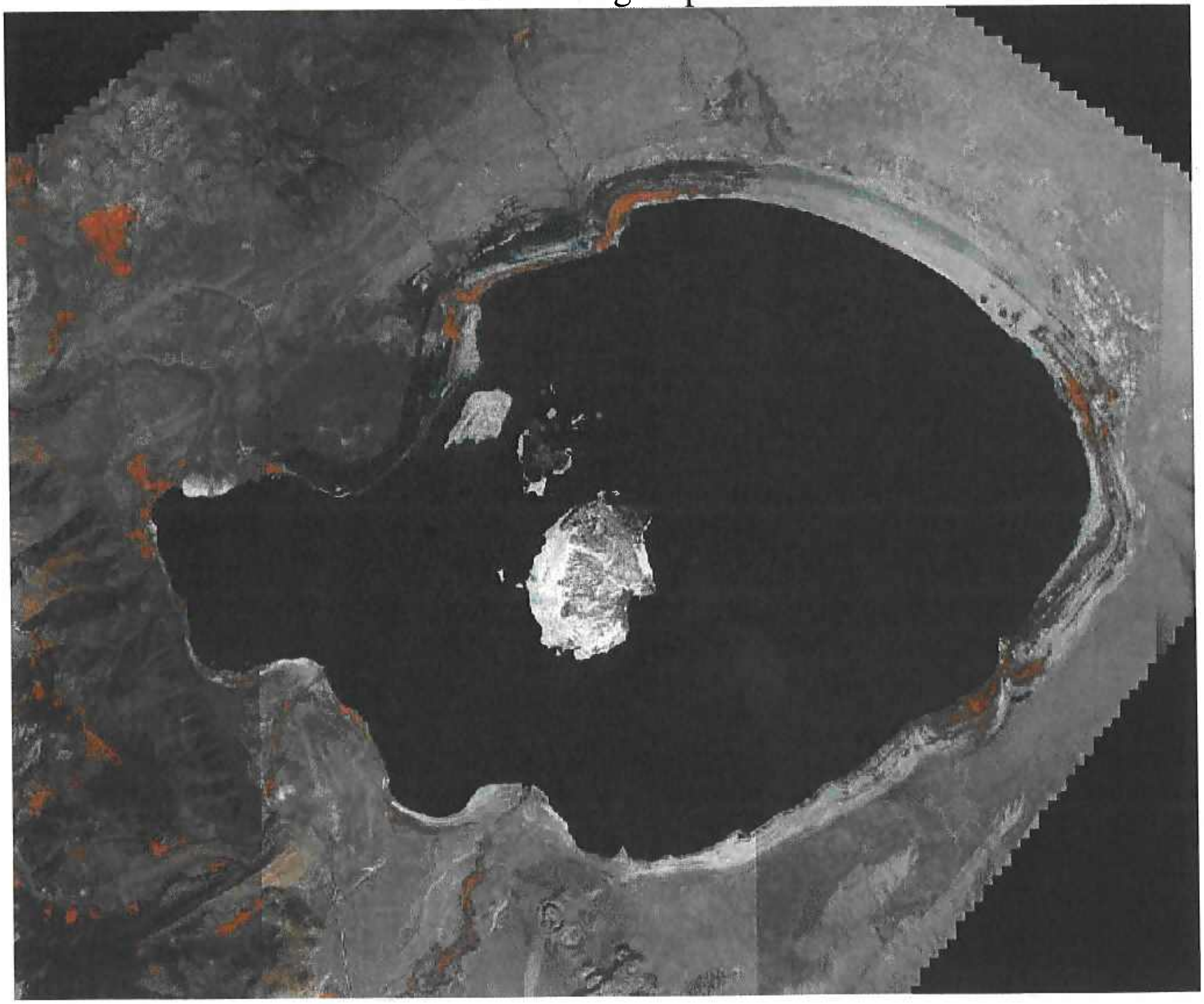
APPENDIX 3

Vegetation

2006

Mono Lake Vegetation

Monitoring Report



Prepared by

David W. Martin, Ph.D.
Watershed Resource Specialist
Los Angeles Department of Water and Power
300 Mandich Street Bishop, CA

Lake Fringing Wetland Vegetation Mapping

Introduction

The Los Angeles Department of Water and Power (LADWP) conducted vegetation-mapping activities in lake fringing wetlands surrounding Mono Lake and in tributary stream deltas during the 2006 growing season. These efforts were undertaken to fulfill State Water Resources Control Board obligations as directed in Decision 1631 and Order No. 98-05. The objective of these monitoring efforts is to determine changes that occur in the lake fringing wetlands as lake levels rise and how those changes may relate to waterfowl activity in the region.

Monitoring protocol was developed working closely with the waterfowl monitoring consultants, Don Paul and David Chapin in 1999. The aerial photography and examination of vegetation mapping of Mono Basin waterfowl habitat was comprised of three separate steps. Methods of each step were fully described in the 1999 Mono Basin Vegetation and Habitat Mapping Report (LADWP 1999).

Methods

In 1999, a GIS database was developed from the 1999 imagery using ESRI ArcView software. A series of tiles from the composite digital image that covered the entire Mono Lake shoreline area were exported using PhotoMapper and then imported into the GIS database. Using these imported images as a backdrop, cover class polygons were delineated on the computer screen as ArcView shape files (often referred to as "heads-up digitizing"). Polygons were mapped by subarea, which roughly correspond to the set of subareas used by Debbie House during her waterfowl surveys (Figure 5).

For the 2005-06 mapping effort, satellite imagery was utilized in place of the aerial imagery utilized in 1999. The satellite imagery was obtained between July 10 and August 20 2005. Space Imaging acquired satellite imagery from their IKONOS platform at a resolution of 0.8 meters in true color as a single 4-band (red, green, blue, near infra-red). These four bands were collected simultaneously with identical look angles, and were precisely registered. The scale of the photography was 1:24000 or 1" = 2000'.

ESRI's new ARCMAP software was used to compare vegetation and waterfowl habitat conditions between the 1999 and 2005 imagery. The two years of aerial photography were layered 2005 over 1999. When the images are layered in this fashion, the view can be toggled back and forth between the two. The vegetation cover class polygons developed from the 1999 imagery were then layered on the 2005 imagery. The edges of the polygons were examined to determine if there was a match between the image and the polygon. If there were any questionable edges, the polygon was viewed over the 1999 imagery to determine if the differences were due to differences in the imagery or vegetation change. If differences were detected, new polygons were created. This effort was repeated for all of the polygons generated during the 1999 mapping effort. Figures 1 through 4 illustrate the different combinations that are used to determine discrepancies between the years for the Rush Creek Delta area. In some cases, the edge of a polygon did not appear to line up with a visible vegetation boundary and new polygons were developed.

A number of large discrepancies were apparent between 1999 and 2005. A number of these were in the lake fringing areas and are not surprising considering the changes that had occurred in lake elevation between the two imagery sampling periods. Additional discrepancies resulted from the fact that the satellite imagery had much better resolution than the aerial image utilized in 1999. Because of this, the edge of different vegetation types was easier to delineate. Further, improvements in both the ARCMAP software and computer speed have made the process of "heads up digitization" much easier.

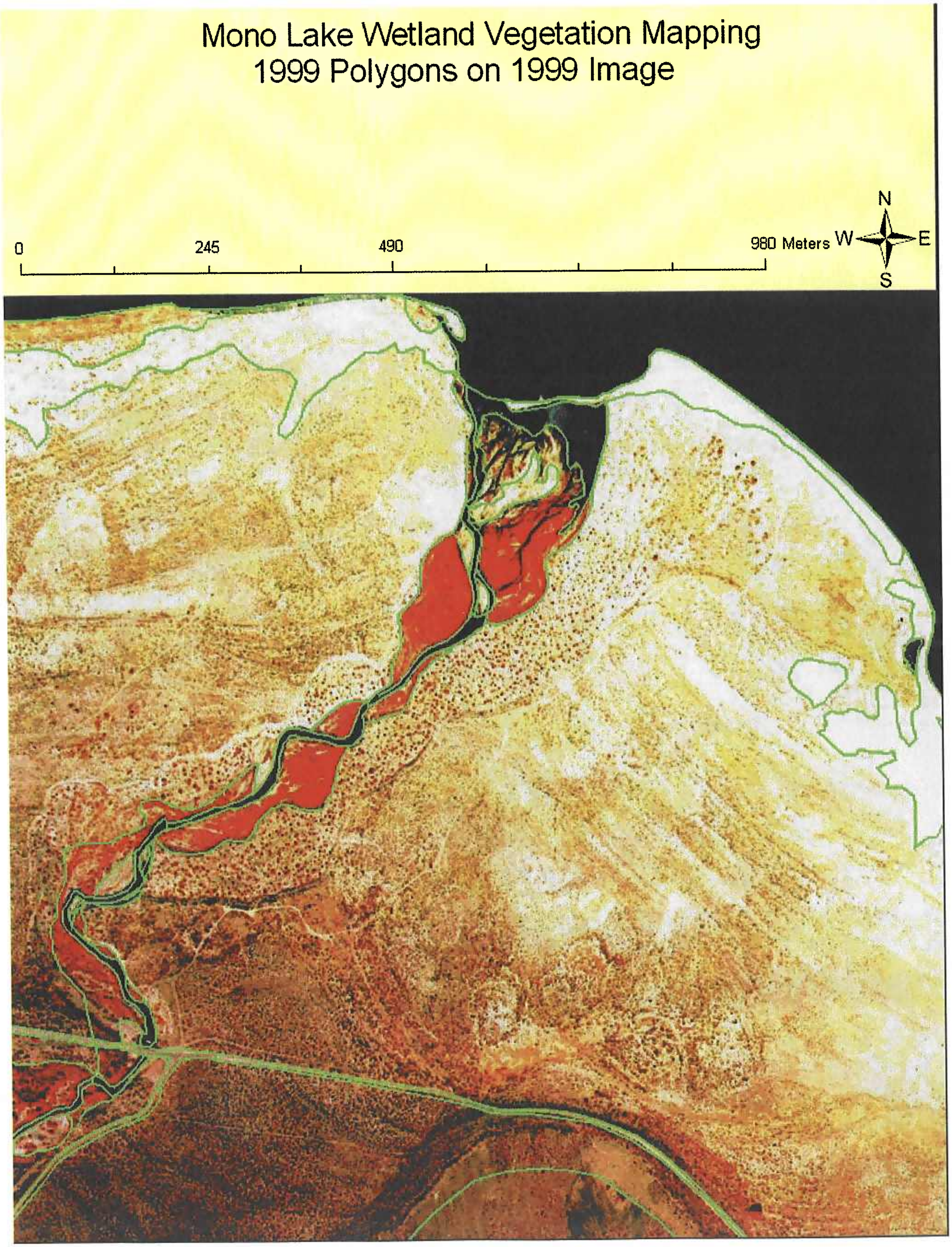

Mono Lake Wetland Vegetation Mapping
1999 Polygons on 1999 Image
0
245
490
980 Meters
N
W
E
S

Figure 1.

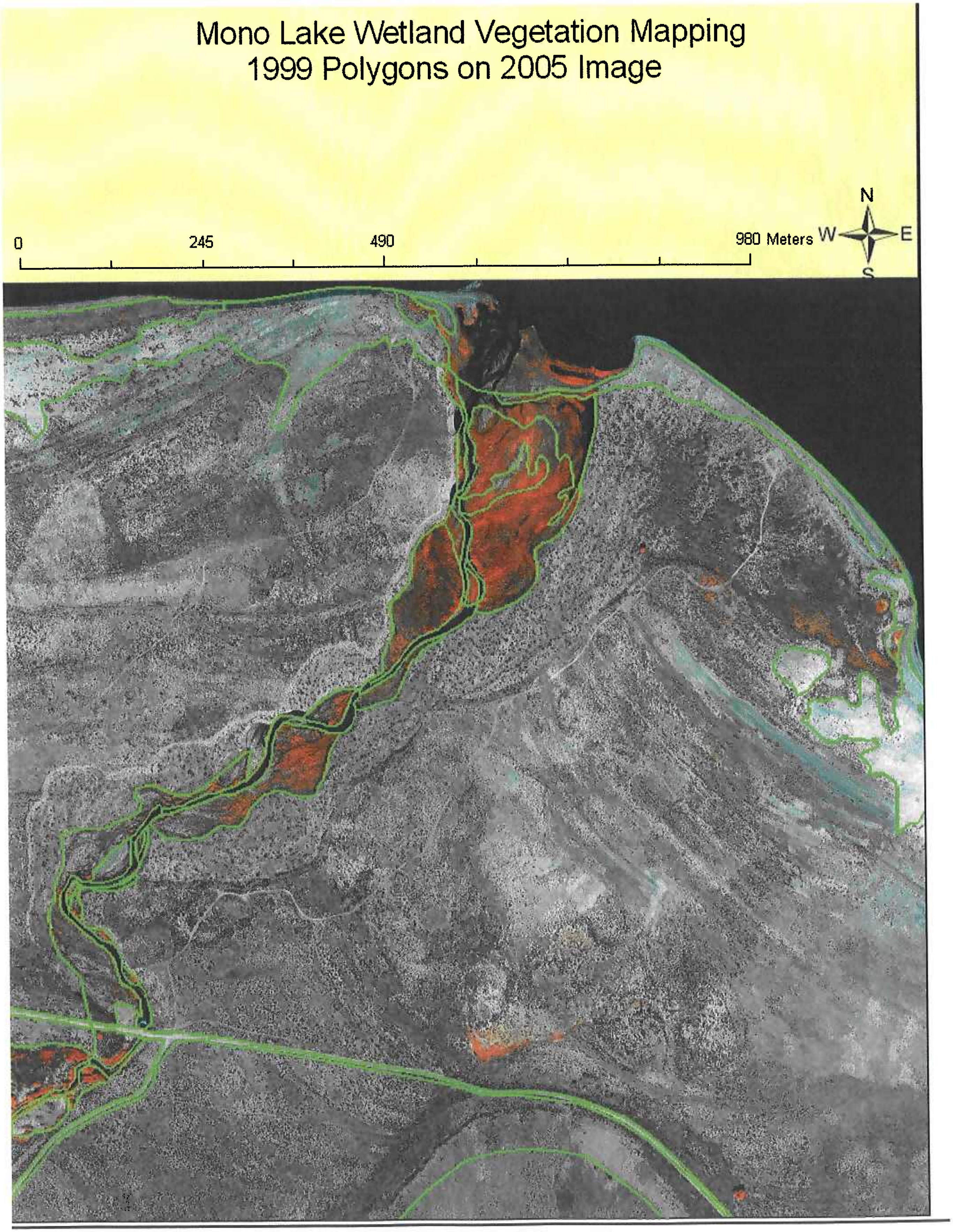

Mono Lake Wetland Vegetation Mapping
1999 Polygons on 2005 Image
0
245
490
980 Meters
N
W
E
S

Figure 2.

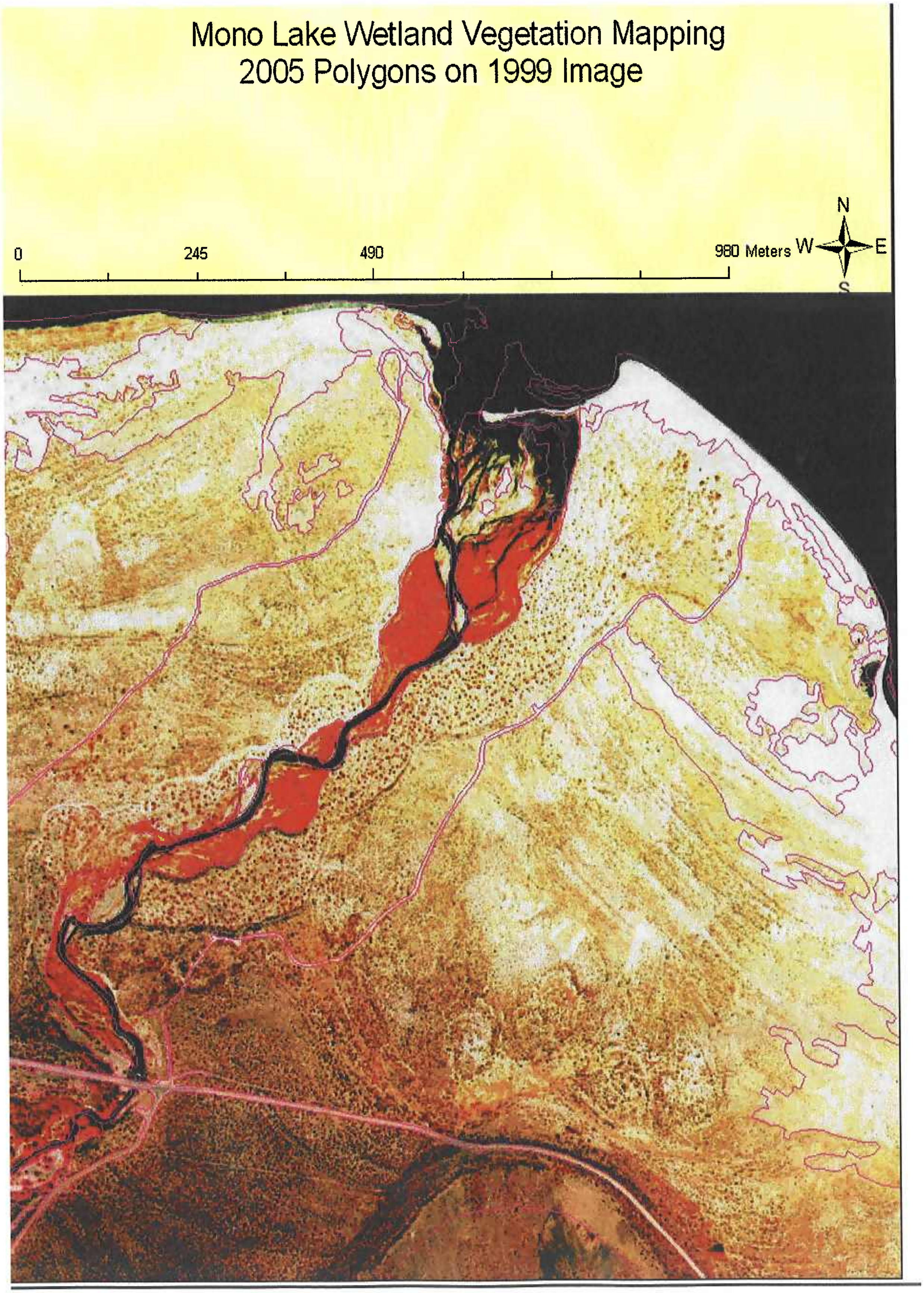

Mono Lake Wetland Vegetation Mapping
2005 Polygons on 1999 Image
0
245
490
980 Meters
N
W
E
S

Figure 3.

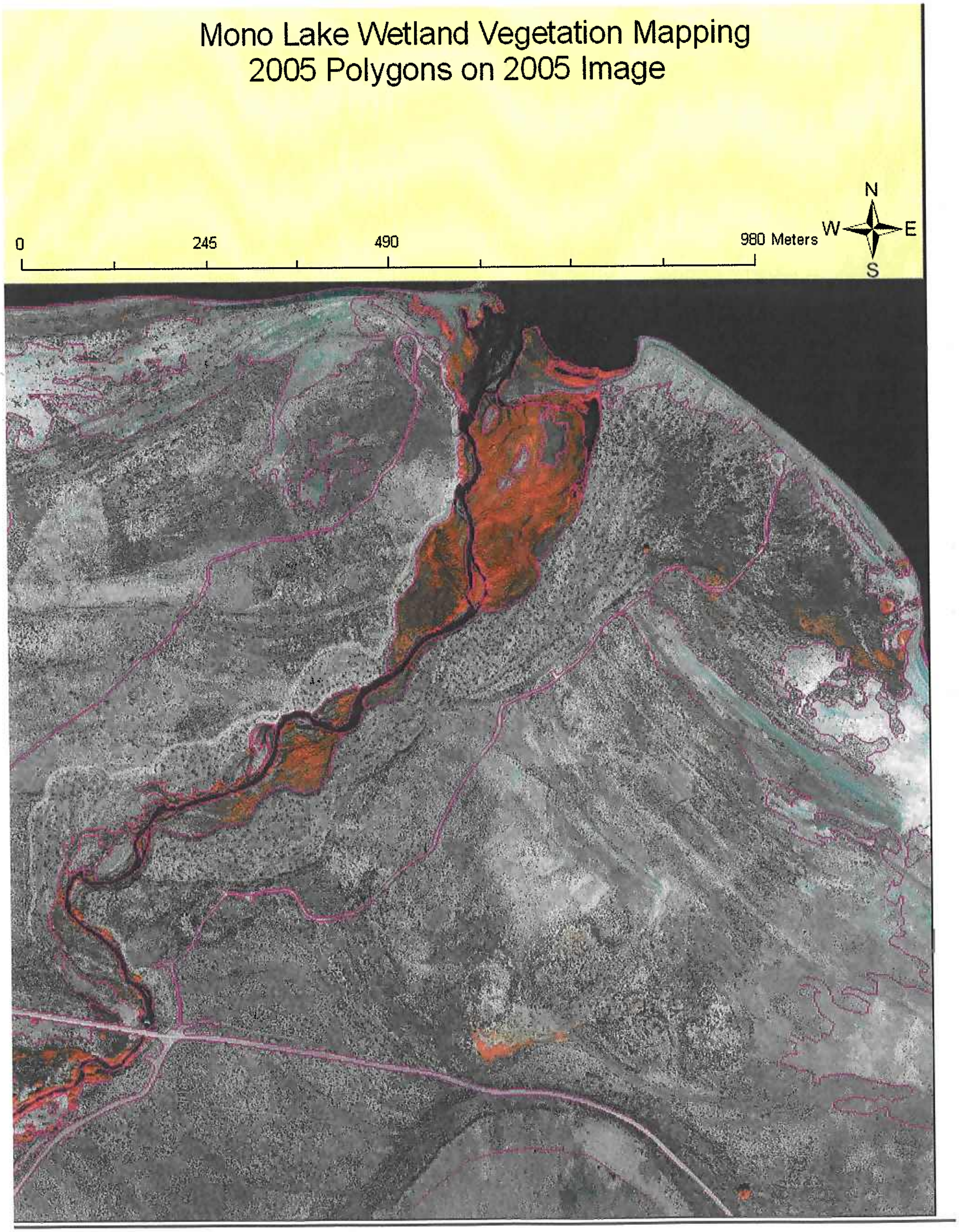

Mono Lake Wetland Vegetation Mapping
2005 Polygons on 2005 Image
0
245
490
980 Meters
N
W
E
S

Figure 4.

Classification

The selection of a vegetation classification for the 1999 habitat mapping and monitoring was based on three basic criteria. First, the classification used for monitoring should be compatible with previous vegetation mapping. Secondly, the cover classes needed to distinguish structurally different habitat types utilized differently by waterfowl. Thirdly, the cover classes used for monitoring habitat changes needed to be individually discriminated using the 1999 CIR aerial photography and digital image. The classes used in the mapping and a brief description of each of the classes is as follows:

Marsh

Areas with surface water usually present all year and dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typha 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

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. Distinction between alkaline wet meadow and dry meadow was not always clear, in classifying polygons in both the 1999 and 2005 mapping

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*).

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 (*Artemesia 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 lake shore 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

This class included the channels of streams that had flowing water at the time of the aerial photography. Generally, a channel had to be > 10 feet wide to be mapped.

Freshwater- ria

Surface water at the mouths of streams that likely had some salt/fresh water stratification were mapped as ria. Since the distance to which rias extended up the stream channel was difficult to determine from the aerial photography, the boundary between ria and stream was subjectively interpreted.

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 lagoon

If an extensive area of marsh or wet meadow indicating the presence of springs was present landward, lagoons along the shoreline created by the formation of littoral bars were mapped as ephemeral brackish lagoons. In some cases, lagoons 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 lagoon

If an extensive area of marsh or wet meadow was not present landward, lagoons along the shoreline created by the formation of littoral bars were mapped as ephemeral hypersaline lagoons. These areas contain concentrated brine due to evaporation.

Unvegetated

Barren to sparsely vegetated (< 15 percent cover) areas were classified as unvegetated. This class included sandy areas, alkaline flats, tufa, and delta outwash deposits.

Man-made

Areas classified as man-made included buildings, parking areas, larger roads, farm houses, and compounds. Stands of horticulturally established tree species (e.g. black locust, Siberian elm) usually growing near houses or farms were also classified as man-made.

Results and Discussion

The classification and mapping of vegetation and other cover classes presented here documents areas of different waterfowl habitat types at Mono Lake in 2005 and the differences between these habitat types as originally mapped in 1999 and the 2005 conditions.

Accuracy of Cover Type Classification

To evaluate the accuracy of polygon classification, vegetation data were collected on the ground at 70 locations around the entire lake shoreline. Data from these locations were compared to the vegetation type classified at the same location, using the GPS coordinates for the sample point to identify the sample point location on the vegetation GIS data layer. At each location, a classification type was determined from plant cover and composition of the general area. These classifications were compared to those mapped in the vegetation data layer. Of the 70 points used in the verification process, 59 (84 percent) were correct. There are a number of reasons for the misclassification. One was that several of the points fell on the border between polygons. An additional source of misidentification was that the ground truthing occurred in 2006, which was significantly wetter than 2005. The reason the ground truthing was not done in 2005 was that the imagery was captured late in 2005 and by the time it was processed and delivered, it was too late in the year to complete any field work.

Figure 1 illustrates the sub areas that were utilized for the mapping effort. Nomenclature follows that used by Debbie House for her Waterfowl Monitoring Report. The specific areas are; Sammon Springs (SASP), Sammon Springs East(SASP East), Warm Springs (WASP), Northeast Shore (NESH), Bridgeport Creek Delta (BRCR), Dechambeau Embayment (DEEM), Black Point (BLPT), Mill/Wilson Delta (MICR/WICR), Dechambeau Creek Delta (DECR), West Shore/Lee Vining Creek Delta (WESH/LVCR), Ranch Cove (RACO), Rush Creek Delta (RUCR), South Tufa (SOTU), and South Shore Lagoons (SSLA).

Observed Change

Table 1 illustrates the acreage of each habitat type for 1999 and 2005. Also presented are the percentages of the total acreage that each habitat makes up.

Table 1. Acreage of each habitat type for both 1999 and 2005

Habitat Type	1999		2005	
	Acreage	% total area	Acreage	% total area
Ria	2.9	<0.1	5.5	<0.1
Freshwater	10.3	0.1	8.5	0.1
Freshwater Pond	8.6	0.1	12.1	0.1
Brackish Lagoon	109.3	0.9	17.9	0.1
Riparian Forest	8.3	0.1	21.4	0.2
Wet Meadow	83.0	0.7	29.4	0.2
Hypersaline Lagoon	110.7	0.9	38.4	0.3
Man Made	56.3	0.5	126.4	1.0
Riparian Shrub	333.5	2.7	204.4	1.6
Marsh	300.2	2.4	408.9	3.1
Wet Meadow-Alkaline	582.3	4.7	1293.2	9.8
Dry Meadow	1944.3	15.7	1377.7	10.5
Great Basin Shrub	3819.3	30.9	3662.2	27.8
Bare Ground	5000.2	40.4	5955.4	45.2

Table 2 illustrates the differences between the two sampling periods for all of the sub areas and the total differences. For the entire map area, there was an increase of nearly 792 acres in the mapping area between 1999 and 2005. This is a direct result of the decline in lake level that occurred during this same time period. Field observations indicate that a great deal of this acreage was again flooded in 2006. Therefore some of the changes that are depicted in the mapping and the table no longer exist.

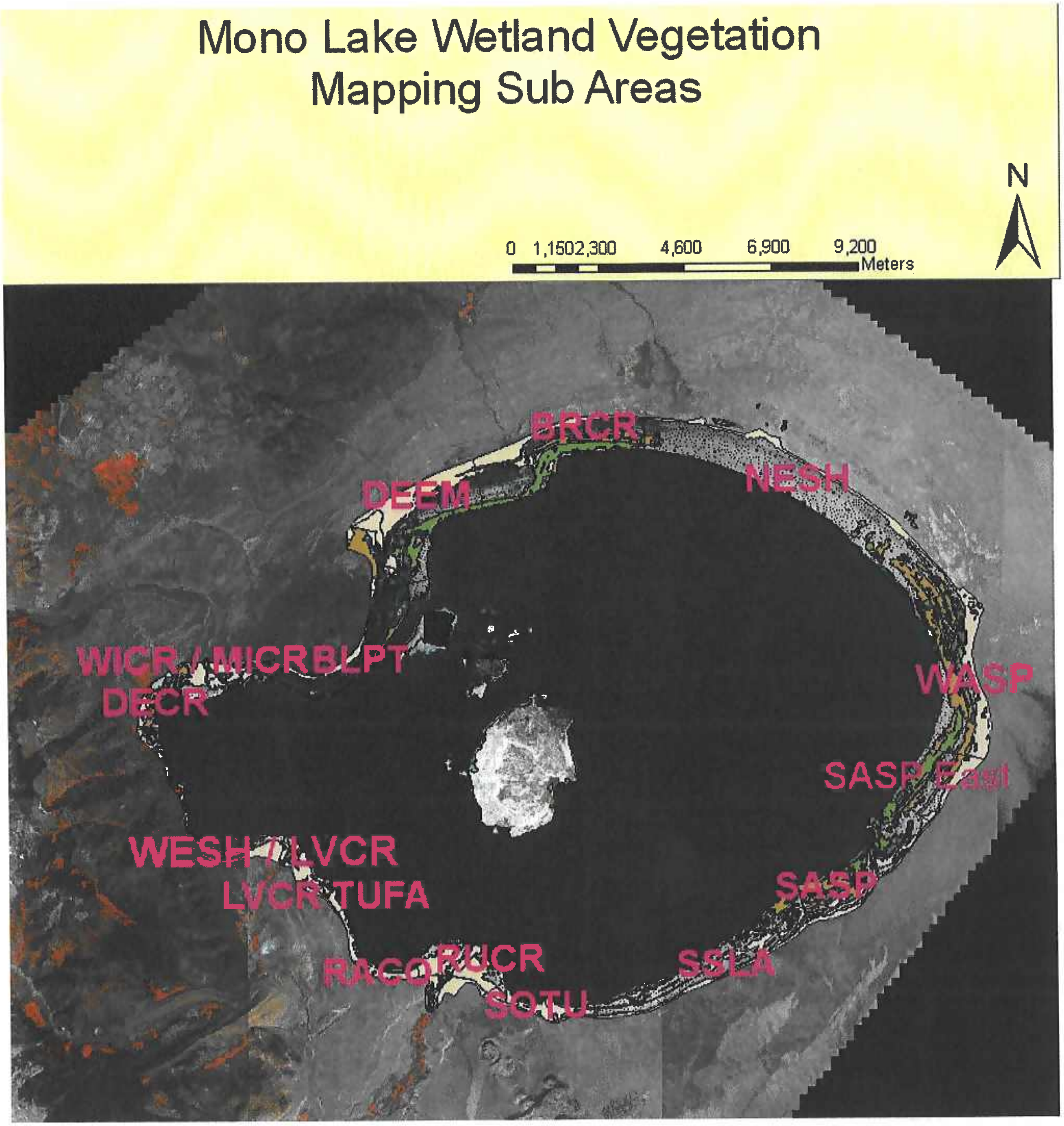


Figure 5. Mapping subarea, nomenclature follows that used by Debbie House in her waterfowl monitoring efforts.

Table 2. Comparison of vegetation acreage by habitat type for sampling years 1999 and 2005.

Habitat Type	**Sammon Springs**			**Sammon Springs East**			**Warm Srpings**			**Northeast Shore**		
	1999	**2005**	**Change**	**1999**	**2005**	**Change**	**1999**	**2005**	**Change**	**1999**	**2005**	**Change**
Marsh	165.6	134.4	-31.2	15.2	13.3	-1.9	66.0	85.8	19.7	1.2	2.5	1.3
Wet Meadow-Alkaline	179.2	223.1	43.9	106.1	128.6	22.5	233.0	174.0	-59.0	20.4	32.2	11.8
Dry Meadow	267.1	183.0	-84.1	120.8	108.1	-12.7	394.0	365.1	-28.9	190.1	210.3	20.2
Riparian Shrub	1.7	17.8	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great Basin Shrub	261.4	241.6	-19.9	135.8	118.5	-17.3	359.7	362.4	2.7	205.7	208.5	2.8
Riparian Forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare Ground	151.4	312.1	160.7	160.1	233.0	72.9	191.6	413.0	221.4	1829.7	1970.2	140.5
Man Made	0.0	4.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Freshwater	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brackish Lagoon	8.8	0.1	-8.7	3.4	0.0	-3.4	29.6	5.5	-24.2	21.6	6.1	-15.5
Hypersaline Lagoon	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	0.0	-105.5
Wet Meadow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Freshwater Pond	0.5	0.8	0.3	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0
Total Acres	**1035.9**	**1118.5**	**82.6**	**541.4**	**601.5**	**60.1**	**1274.3**	**1406.2**	**131.9**	**2374.1**	**2429.7**	**55.6**

Habitat Type	**Bridgeport Creek Delta**			**Dechambeau Embayment**			**Black Point**			**Mill/Wilson Delta**		
	1999	**2005**	**Change**	**1999**	**2005**	**Change**	**1999**	**2005**	**Change**	**1999**	**2005**	**Change**
Marsh	9.1	2.0	-7.0	25.2	80.5	55.3	0.9	5.7	4.9	0.0	12.1	12.1
Wet Meadow-Alkaline	0.0	260.1	260.1	0.0	224.3	224.3	9.7	82.1	72.4	0.4	18.6	18.3
Dry Meadow	291.9	122.7	-169.2	227.1	107.7	-119.4	32.1	1.4	-30.8	24.4	23.9	-0.5
Riparian Shrub	0.0	0.0	0.0	7.0	0.1	-6.9	0.0	0.0	0.0	70.3	10.6	-59.7
Great Basin Shrub	276.9	282.8	5.9	650.0	557.2	-92.8	145.2	91.5	-53.7	192.7	212.3	19.6
Riparian Forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	4.7	2.6
Bare Ground	650.8	677.4	26.6	482.7	545.2	62.5	543.2	645.2	102.0	135.3	129.9	-5.4
Man Made	0.0	0.0	0.0	0.0	9.2	9.2	0.0	2.2	2.2	29.7	42.3	12.6
Ria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2
Freshwater	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.1	-2.5
Brackish Lagoon	12.1	2.1	-10.0	1.0	0.1	-0.8	5.5	0.6	-4.9	2.0	0.0	-1.9
Hypersaline Lagoon	1.6	0.0	-1.6	0.0	0.5	0.5	3.6	0.0	-3.6	0.0	34.6	34.6
Wet Meadow	0.0	0.0	0.0	18.3	0.0	-18.3	0.0	0.0	0.0	20.6	0.0	-20.6
Freshwater Pond	0.0	0.0	0.0	7.3	10.7	3.4	0.4	0.1	-0.2	0.1	0.0	-0.1
Total Acres	**1242.4**	**1347.2**	**104.8**	**1418.6**	**1535.5**	**116.9**	**740.6**	**828.8**	**88.2**	**480.1**	**493.2**	**13.1**

Table 2 continued.

Habitat Type	Ranch Cove			Rush Creek Delta			South Shore Lagoon			South Tufa		
	1999	2005	Change	1999	2005	Change	1999	2005	Change	1999	2005	Change
Marsh	0.0	0.0	0.0	0.0	8.4	8.4	0.0	14.2	14.2	1.9	2.6	0.7
Wet Meadow-Alkaline	0.0	13.7	13.7	0.0	18.1	18.1	7.7	71.2	63.6	0.0	7.2	7.2
Dry Meadow	0.0	0.0	0.0	0.0	8.5	8.5	239.8	116.0	-123.7	0.0	18.8	18.8
Riparian Shrub	49.3	21.7	-27.7	44.9	29.4	-15.5	2.6	0.3	-2.3	0.0	0.0	0.0
Great Basin Shrub	123.8	148.1	24.3	517.3	450.8	-66.5	267.7	348.0	80.3	246.0	220.6	-25.3
Riparian Forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare Ground	31.4	24.8	-6.6	81.1	131.4	50.2	627.0	678.8	51.7	44.5	51.2	6.8
Man Made	0.0	1.0	1.0	3.7	9.6	6.0	3.4	11.0	7.6	6.4	10.4	4.0
Ria	0.0	0.0	0.0	2.4	1.3	-1.1	0.0	0.0	0.0	0.0	0.0	0.0
Freshwater	0.0	0.0	0.0	5.9	6.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Brackish Lagoon	0.8	0.0	-0.8	0.2	0.1	-0.1	23.6	2.4	-21.2	0.0	0.2	0.2
Hypersaline Lagoon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3	0.0	0.0	0.0
Wet Meadow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
Freshwater Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Acres	**205.3**	**209.3**	**4.0**	**655.5**	**664.2**	**8.8**	**1171.8**	**1244.5**	**72.7**	**298.7**	**311.1**	**12.3**

Habitat Type	Lee Vining Creek Tufa			Dechambeau Creek Delta			South East Shore			All Sub Areas		
	1999	2005	Change	1999	2005	Change	1999	2005	Change	1999	2005	Change
Marsh	4.2	4.6	0.4	0.0	3.9	3.9	10.7	38.8	28.1	300.2	408.9	108.7
Wet Meadow-Alkaline	1.5	0.0	-1.5	0.0	0.0	0.0	24.4	39.9	15.6	582.3	1293.2	710.9
Dry Meadow	5.2	8.6	3.4	28.2	50.1	21.9	101.0	31.0	-70.0	1944.3	1377.7	-566.6
Riparian Shrub	16.6	16.3	-0.3	61.8	46.5	-15.3	79.4	61.7	-17.6	333.5	204.4	-129.2
Great Basin Shrub	79.0	77.6	-1.4	41.5	39.6	-1.9	316.7	302.6	-14.1	3819.3	3662.2	-157.1
Riparian Forest	0.0	0.0	0.0	1.2	0.0	-1.2	5.1	16.6	11.6	8.3	21.4	13.0
Bare Ground	4.9	4.6	-0.2	7.6	9.1	1.5	52.0	122.7	70.7	5000.2	5955.4	955.3
Man Made	0.0	1.5	1.5	6.6	22.2	15.6	6.5	12.4	5.8	56.3	126.4	70.1
Ria	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	-0.5	2.9	5.5	2.6
Freshwater	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.9	0.2	10.3	8.5	-1.8
Brackish Lagoon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.3	17.9	-91.4
Hypersaline Lagoon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.7	38.4	-72.4
Wet Meadow	0.0	0.0	0.0	44.1	29.1	-15.0	0.0	0.0	0.0	83.0	29.4	-53.6
Freshwater Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	12.1	3.4
Total Acres	**111.4**	**113.2**	**1.8**	**191.0**	**200.5**	**9.5**	**598.0**	**627.7**	**29.7**	**12369.3**	**13161.2**	**791.9**

The difference in acreage for each sub area between the two mapping efforts ranged from 1.8 acres for the Lee Vining Tufa area to 131.9 acres for the Warm Springs Area (Table 3). All of these differences represent 0.1 percent difference or less compared to the total acreage mapped in 2005.

Table 3. Acreage of each of the mapping sub areas and the differences between 1999 and 2005.

Sub Area	1999	2005	diff
Lee Vining Creek Tufa	111.4	113.2	1.8
Ranch Cove	205.3	209.3	4.0
Rush Creek Delta	655.5	664.2	8.8
Dechambeau Creek Delta	191.0	200.5	9.5
South Tufa	298.7	311.1	12.3
Mill/Wilson Delta	480.1	493.2	13.1
South East Shore	598.0	627.7	29.7
Northeast Shore	2374.1	2429.7	55.6
Sammon Springs East	541.4	601.5	60.1
South Shore Lagoon	1171.8	1244.5	72.7
Sammon Springs	1035.9	1118.5	82.6
Black Point	740.6	828.8	88.2
Bridgeport Creek Delta	1242.4	1347.2	104.8
Dechambeau Embayment	1418.6	1535.5	116.9
Warm Srpings	1274.3	1406.2	131.9
All Sub Areas	**12369.3**	**13161.2**	**791.9**

Overall, the greatest increase in habitat type was observed in Bare Ground (Table 4). The increase in the acreage can be directly related to the decrease in lake elevation between the two mapping periods.

Table 4. Acreage change for each habitat type.

Habitat Type	**All Sub Areas**		
	1999	**2005**	**Change**
Dry Meadow	1944.3	1377.7	-566.6
Great Basin Shrub	3819.3	3662.2	-157.1
Riparian Shrub	333.5	204.4	-129.2
Brackish Lagoon	109.3	17.9	-91.4
Hypersaline Lagoon	110.7	38.4	-72.4
Wet Meadow	83.0	29.4	-53.6
Freshwater	10.3	8.5	-1.8
Ria	2.9	5.5	2.6
Freshwater Pond	8.6	12.1	3.4
Riparian Forest	8.3	21.4	13.0
Man Made	56.3	126.4	70.1
Marsh	300.2	408.9	108.7
Wet Meadow-Alkaline	582.3	1293.2	710.9
Bare Ground	5000.2	5955.4	955.3
Total Acres	**12369.3**	**13161.2**	**791.9**

The lake elevation was 6384.2 ft above mean sea level (msl) in September 1999 and 6381.8 ft above msl in September of 2005. The approximately 2.4 ft change in lake level exposed as much as 295 feet of lakeshore. This change is best illustrated in the Warm Springs area which had the largest increase of bare ground (221 acres). When the polygons developed in 1999 are superimposed on the 2005 image, the change is easily observed (Figure 6). On the figure (5), the total area mapped in 1999 is shown in the mint green color. The areas that are not covered by the 1999 polygons are newly mapped barren areas or dry meadows (red areas) that were underwater. During the 2006 ground truthing, much of this area was again covered by water in 2006 when the lake elevation was 6384.4 ft above msl.

The decreases observed in the areas mapped as Brackish Lagoon (-91.4 acres) and Hypersaline Lagoon (-72.4 acres) also likely resulted in the lowering of the lake elevation.

The second greatest increase in habitat type was in the Wet Alkali Meadow which increased by 710 acres (Figure 6). Two areas, Bridgeport Creek Delta, and Dechambeau Embayment accounted for more than half (485 acres) of this change. Sammon Springs and the South Shore Lagoons subarea accounted for most of the rest of the increase. These increases in Wet Alkali Meadow in the subareas were mostly the result of areas previously mapped as the Dry Meadow habitat type being reclassified as Wet Alkali Meadow (Figure 7). This is likely due to two factors; the quality of the imagery made it easier to determine differences in wet vs dry meadows and the ground truthing for the mapping was conducted in 2006, an above average precipitation year, and many area that had no standing water in previous years had standing water.

All of the increase of the Fresh Water Pond type was observed at the Dechambeau Embayment area. The 3.4 acre increase results from the filling of the northeast county pond and pond 5 of the Dechambeau Ponds.

The increase in acreage of man-made features (70.1 acres) is completely a result of improved mapping. A number of roads that were included in the Great Basin Shrub type, were remapped as man made feature. This is evident in Figures 7 and 8. In Figure 7 which shows the polygons from the 1999 mapping, none of the roads that are apparent on Figure 8 were delineated. This improvement in mapping also accounts for about half of the decrease in the Great Basin Shrub type. The remaining acres of Great Basin shrub were likely “lost” because the polygons boundaries were drawn much tighter to the edge of the habitat.

Figure 6. Warm Springs Area vegetation. The 1999 polygons have been superimposed on the 2005 polygons and image.

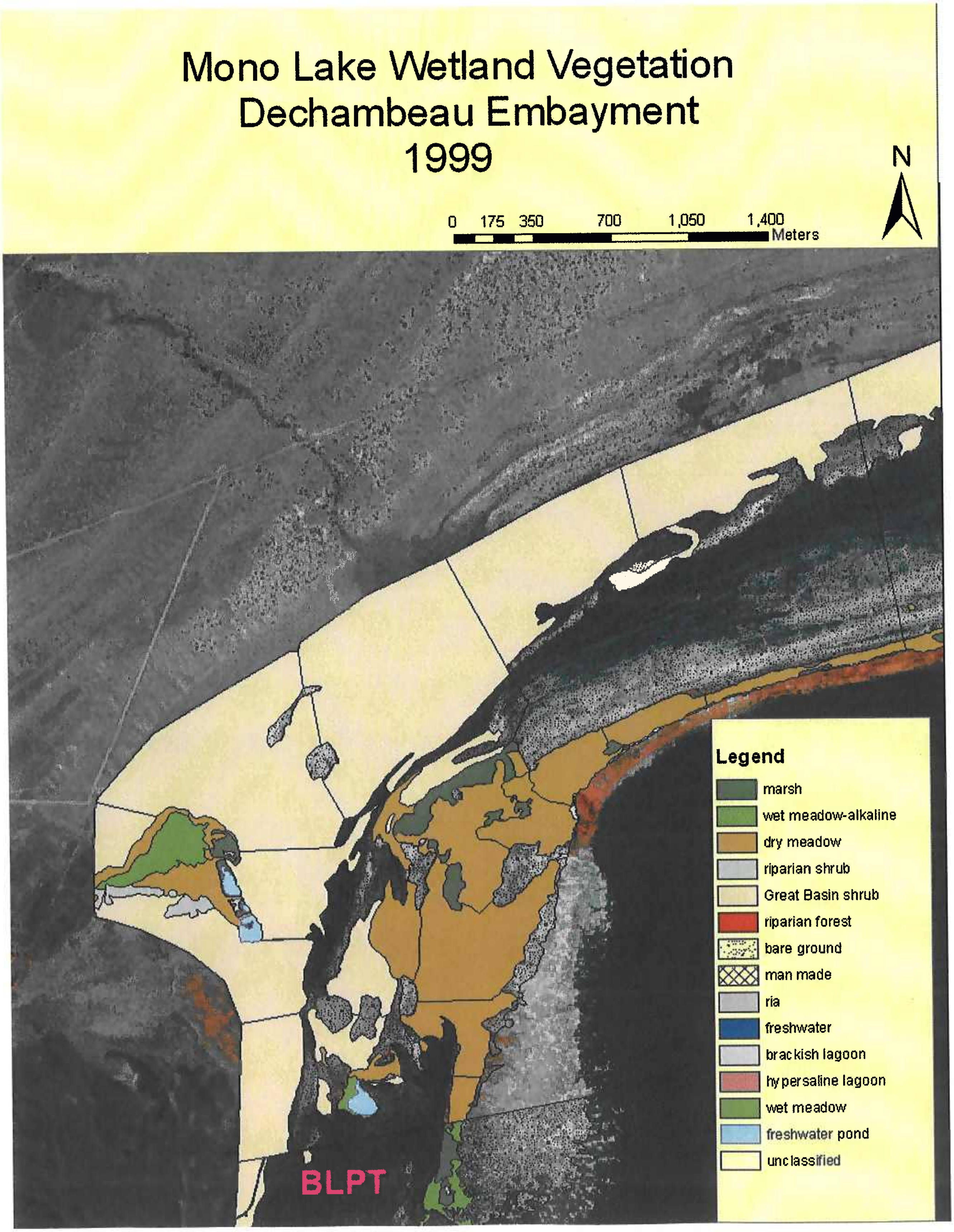


Figure 7. Vegetation mapping from Dechambeau Embayment in 1999.

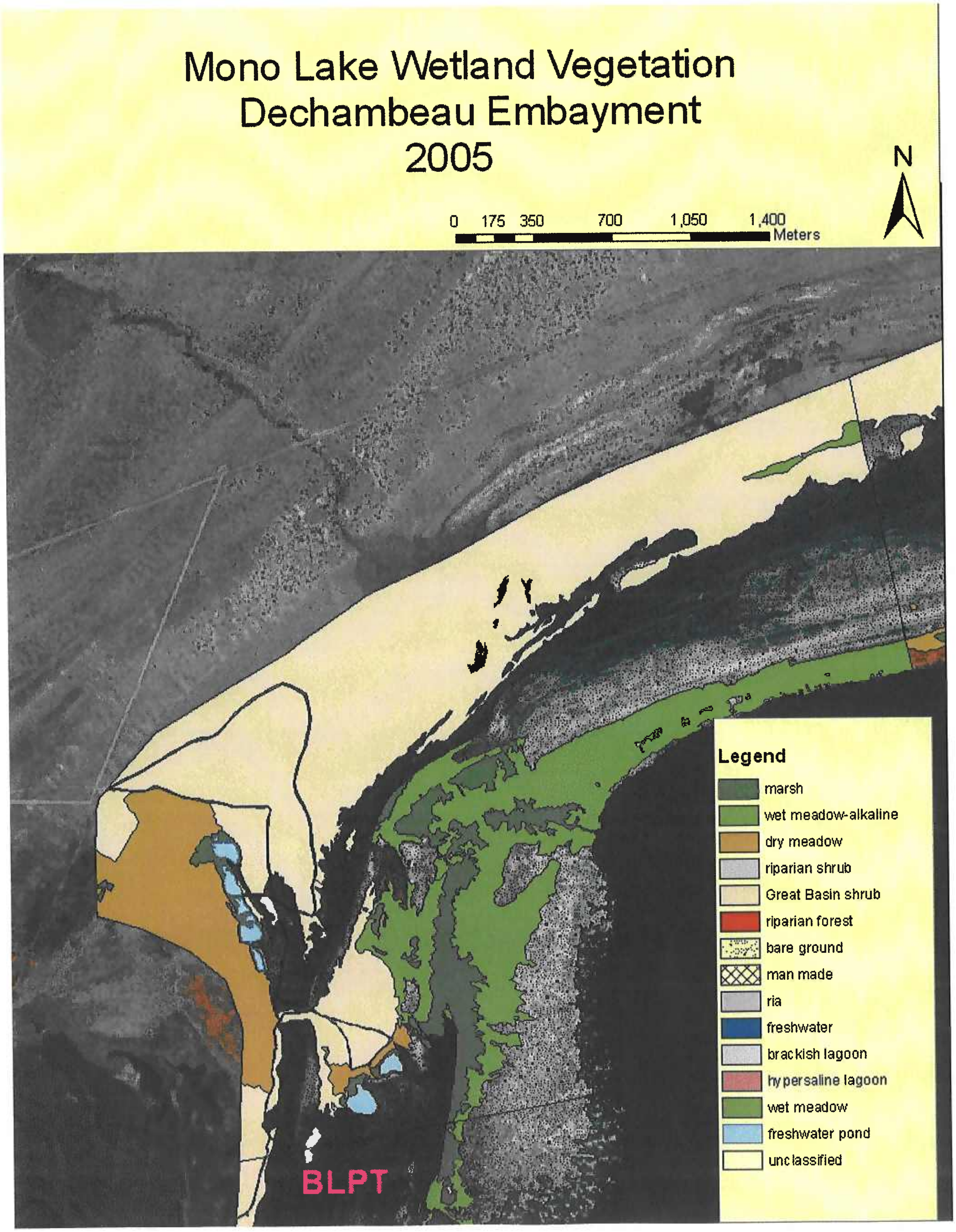


Figure 8. Vegetation mapping from Dechambeau Embayment in 2005.

Additional Monitoring

This year was an off year for most of the other vegetation monitoring in the Basin. Staff from LADWP continued to place large woody debris in both Rush and Lee Vining Creeks on an opportunistic basis.

Salt Cedar Control

Annual surveys for salt cedar have continued in the lake fringing wetlands and the riparian areas along all of the tributaries to Mono Lake. There were no salt cedar plants detected or treated by LADWP in 2005. There were also none identified or treated by members of the Mono Lake Committee or their volunteers (Reis pers. comm..).

APPENDIX 4

Spring Survey

Mono Lake Spring Survey, October 2004

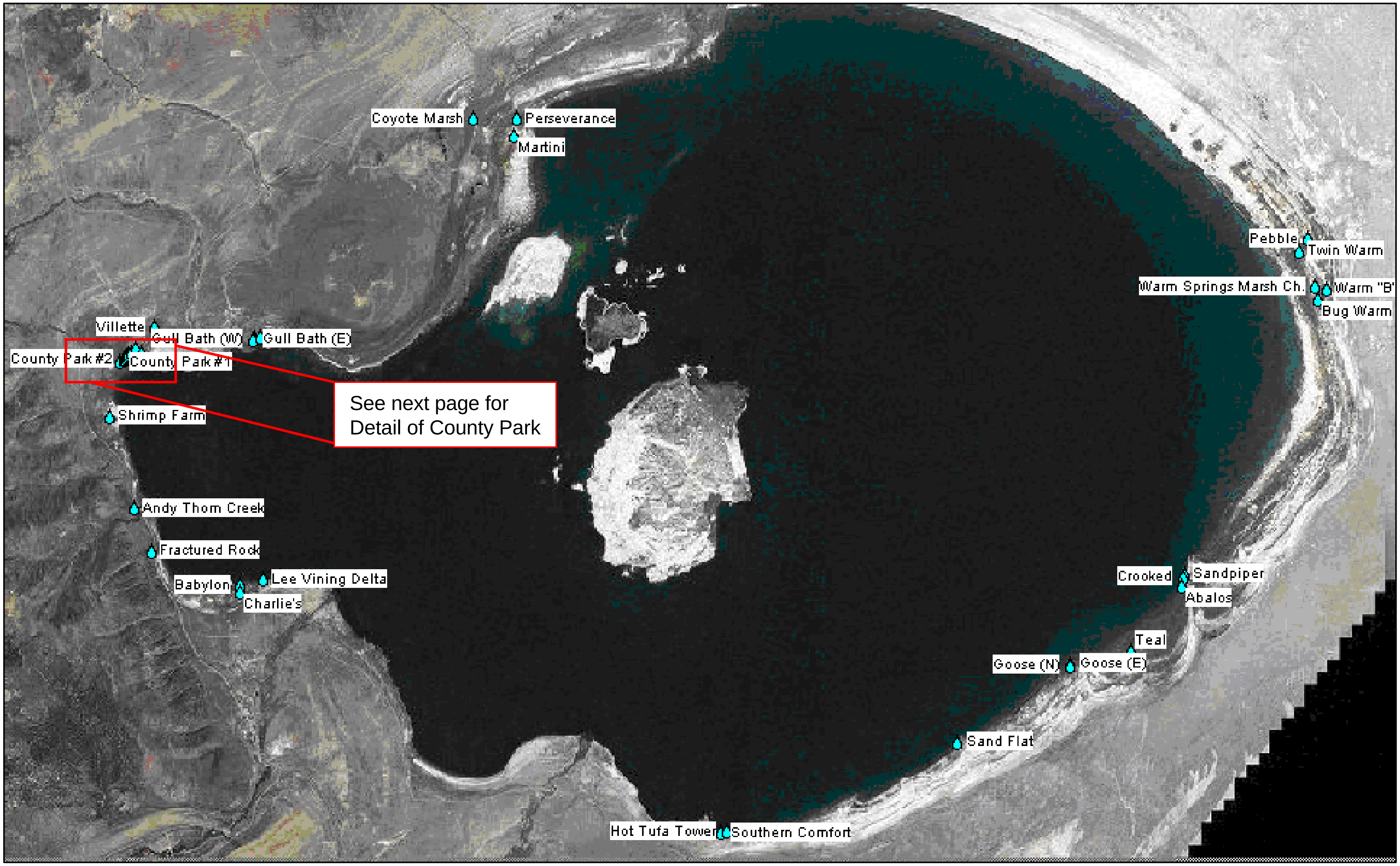
The Mono Lake Spring Survey was conducted October 12 and 13, 2004 by Mark Hanna, Robert Prendergast, and Chuck Mauer of the Los Angeles Department of Water & Power (LADWP). The survey was performed to comply with the terms and conditions of LADWP water right Licenses Nos. 10191 and 10192 as set forth in the State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07.

The spring locations are shown in Figure 1. The spring data are listed in Table 1. Photographs from the spring survey are included in Figure 2. The total flowrate estimated from all the springs that were measured is approximately 8,650 acre-feet. Many of the spring areas were choked with dense vegetation, making it extremely difficult to access and locate the spring source, as can be seen in the photos in figure 2. Due to the rapid changes occurring at the lake and the difficulty in locating many of the springs, all of the accessible sites were surveyed using a hand held Global Positioning System (GPS). For each site, longitude and latitude coordinates were recorded.

The lake elevation during the survey was 6380.8 (USGS Datum), 3.8 feet lower than the 1999 spring survey, and 6.7 feet higher than the 1992 spring survey. Visual observations made during this survey indicate that many of the spring sites visited this year will also be inundated with a slight rise in the lake elevation of one to two feet. Most of the springs are expected to be inundated when the lake reaches an average elevation of 6392 feet. However, others further up the exposed lakebed may begin flowing again.

The next survey is scheduled for the Fall of 2009.

Mono Basin Spring Survey, October 2004
Approximate Spring Locations, Mono Lake



See next page for Detail of County Park

Figure 1

Mono Basin Spring Survey, October 2004
Approximate Spring Locations, County Park

Figure 1 (cont)

Mono Basin Spring Survey, October 2004
Table 1

Spring	Flow (cfs)	Measuring Device	Temp. (deg F)	Elec. Cond. (uS/cm)	Sulfur Strands	H_2S Gas	Tufa Tower	Clarity	Photo	UTM Coordinates Latitude	
Northwest Shore											
Gull Bath (E)	2.23	velocimeter	51	140	N	N	Y	clear	39	N 38° 01.075"	W 119° 07.131"
Gull Bath (W)	0.65	velocimeter	50	155	N	N	Y	clear	40, 41	N 38° 01.073"	W 119° 07.160"
Villette	trace	not measurable	46	100	N	N	Y	clear	1, 2	N 38° 01.164"	W 119° 08.346"
County Park #1	0.1	estimate	50	190	N	N	Y	clear	22	N 38° 00.827"	W 119° 08.748"
County Park #2	0.1	estimate	52	120	N	N	Y	clear	23	N 38° 00.846"	W 119° 08.708"
County Park #3	0.1	estimate	50	190	N	N	Y	clear	24	N 38° 00.852"	W 119° 08.707"
County Park #4	0.72	velocimeter	51	185	N	N	Y	clear	25	N 38° 00.875"	W 119° 08.681"
County Park #5	0.05	estimate	52	140	N	N	Y	clear	26	N 38° 00.889"	W 119° 08.663"
County Park #6	0.15	estimate	52	140	N	N	Y	clear	27	N 38° 00.899"	W 119° 08.652"
County Park #7	0.29	velocimeter	52	130	N	N	Y	clear	28	N 38° 00.917"	W 119° 08.618"
County Park #8	1.04	velocimeter	52	140	N	N	Y	clear	29	N 38° 00.953"	W 119° 08.574"
County Park #9	1.12	velocimeter	52	120	N	N	N	clear	30, 31	N 38° 00.914"	W 119° 08.487"
Black Point Seep (Scoria Tufa?)	0.6	velocimeter	53	160	N	N	N	clear	38	N 38° 01.093"	W 119° 07.062"

Mono Basin Spring Survey, October 2004
Table 1 (continued)

Spring	Flow (cfs)	Measuring Device	Temp. (deg F)	Elec. Cond. (uS/cm)	Sulfur Strands	H_2S Gas	Tufa Tower	Clarity	Photo	UTM Coordinates Latitude	
West Shore											
Shrimp Farm	0.49	velocimeter	54	175	N	N	N	algae, clear	34	N 38° 00.304"	W 119° 08.859"
Fractured Rock	0.48	velocimeter	64	310	N	N	N	clear	32	N 37° 59.031"	W 119° 08.314"
Andy Thom Creek	0.47	weir estimate	44	42	N	N	N	clear	33	N 37° 59.432"	W 119° 08.535"
Southwest Shore											
Lee Vining Delta	0.3	1 ft CIP weir	51	240	N	N	Y	clear	37	N 37° 58.783"	W 119° 06.962"
Babylon	0.17	velocimeter	53	140	N	N	Y	clear	36	N 37° 58.727"	W 119° 07.245"
Charlie’s	trace	estimate	50	90	N	N	Y	clear	35	N 37° 58.661"	W 119° 07.241"
South Shore											
Southern Comfort	0.1	estimate, no direct flow to lake	92	2200	N	N	Y	clear	3	N 37° 56.465"	W 119° 01.375"
Hot Tufa Tower	underwater						Y		4	N 37° 56.481"	W 119° 01.321"

Mono Basin Spring Survey, October 2004
Table 1 (continued)

Spring	Flow (cfs)	Measuring Device	Temp. (deg F)	Elec. Cond. (uS/cm)	Sulfur Strands	H_2S Gas	Tufa Tower	Clarity	Photo	UTM Coordinates Latitude	
Southeast Shore											
Sand Flat	trace	vegetated, flow seeping to lake	n/a	n/a	N	N	Y	algae	5	N 37° 57.376"	W 118° 58.555"
Sandpiper	0.35	velocimeter, flow to lake	44	540	N	N	N	clear	8, 9	N37 59.024”	W118 55.861”
Goose (E)	1.16	velocimeter, flow to lake	54	440	N	N	Y	clear	6	N 37° 58.145"	W 118° 57.214"
Teal	0.2	estimate	54	360	N	N	Y	algae on top	7	N 37° 58.273"	W 118° 56.491"
Crooked	0.1	estimate, flowing to lake	44	480	N	N	N	clear	10	N 37° 58.996"	W 118° 55.887"
Abalos	0.05	estimate, flowing to lake	56	380	N	N	N	clear	11	N 37° 58.912"	W 118° 55.905"
East Shore											
Warm “B”	0.7	90° V-notch, 50' west of spring	84	2200	N	N	N	clear	12, 13	N 38° 01.772"	W 118° 54.224"
Warm Springs Marsh Ch.	0.11	velocimeter	60	3300	N	N	N	clear	15	N 38° 01.792"	W 118° 54.366"
Twin Warm	0.15	estimate	92	2400	N	N	N	clear	16	N 38° 02.131"	W 118° 54.568"
Pebble	vegetated		62	1500	N	N	N	clear	17	N 38° 02.249"	W 118° 54.457"
Bug Warm	trace		91	2700	N	Y	N	clear	14	N 38° 01.668	W 118° 54.328"
North Shore											
Perseverance	trace flows to lake,		48	1100	n/a	n/a	N	clear	20	N 38° 03.232"	W 119° 04.034"
Coyote Marsh	trace, vegetated		70	480	N	N	N	clear	18	N 38° 03.222"	W 119° 04.550"
Martini	trace		60	2000	Y	Y	N	clear	19	N 38° 03.069"	W 119° 04.072"

Mono Basin Spring Survey, October 2004
Photos

see table 1 for photo locations

Photo # 1

Photo # 2

Photo # 3

Photo # 4

Figure 2

Mono Basin Spring Survey, October 2004
Photos (continued)

see table 1 for photo locations

Photo # 5

Photo # 6

Photo # 7

Photo # 8

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)
see table 1 for photo locations

Photo # 9

Photo # 10

Photo # 11

Photo # 12

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)
see table 1 for photo locations

Photo # 13

Photo # 14

Photo # 15

Photo # 16

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)

see table 1 for photo locations

Photo # 17

Photo # 18

Photo # 19

Photo # 20

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)
see table 1 for photo locations

Photo # 22*

Photo # 23

Photo # 24

Photo # 25

Figure 2 (cont)

* Photo 21 intentionally omitted

Mono Basin Spring Survey, October 2004
Photos (continued)
see table 1 for photo locations

Photo # 26

Photo # 27

Photo # 28

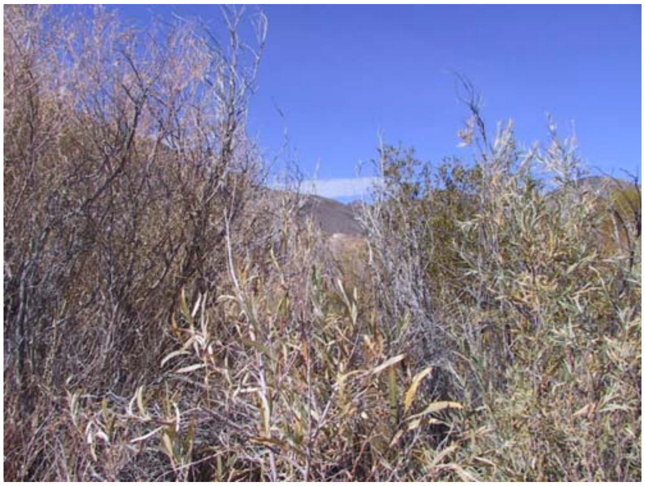


Photo # 29

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)

see table 1 for photo locations

Photo # 30

Photo # 31

Photo # 32

Photo # 33

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)
see table 1 for photo locations

Photo # 34

Photo # 35

Photo # 36

Photo # 37

Figure 2 (cont)

Mono Basin Spring Survey, October 2004
Photos (continued)

see table 1 for photo locations

Photo # 38

Photo # 39

Photo # 40

Photo # 41

Figure 2 (cont)