In Response to the State Water Resources Control Board Order Nos. 98-05 and 98-07

COMPLIANCE REPORTING

STREAM MONITORING

FISH MONITORING

WATERFOWL MONITORING

RUNOFF FORECAST AND OPERATIONS

May, 2003

Los Angeles Department of Water and Power

May 15, 2003

Mr. Harry Schueller
Chief Deputy Director
State Water Resources Control Board
P. O. Box 100
Sacramento, California 95812-0100

Dear Mr. Schueller:

Subject: Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07

Pursuant to the State Water Resources Control Board (SWRCB) Decision 1631 and Order Nos. 98-05 and 98-07 (Orders), and in accordance with the terms and conditions of the Los Angeles Department of Water and Power (LADWP) Mono Basin Water Right License Nos. 10191 and 10192, enclosed is a submittal entitled "Compliance Reporting", which contains the four reports required by the Orders. The reports are as follows:

- Mono Basin Operations for Runoff Year (RY) 2003-2004
- Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks 2002
- Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks – Monitoring Results and Analysis for Runoff Season 2002-03
- Mono Basin Waterfowl Habitat and Population Monitoring 2002-2003

In addition to the four reports, the binder also includes a report entitled "Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07". This report summarizes LADWP's restoration and monitoring activities performed during RY 2002 and the restoration and monitoring activities proposed for RY 2003.

The filing of the reports and the restoration and monitoring performed by LADWP in the Mono Basin fulfills LADWP's requirements for RY 2002 as set forth in Decision 1631 and Order Nos. 98-05 and 98-07. Electronic copies of the report on compact disc have been provided to the interested parties.

If you have any questions, please contact Mr. Peter Kavounas, of my staff, at (213) 367-1032.

Sincerely,

ORIGINAL SIGNED BY:
THOMAS M. ERB

Thomas M. Erb
Director of Water Resources

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Section 1

Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07

Compliance with State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07

May, 2003

Los Angeles Department of Water and Power

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Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1361 and Order Nos. 98-05 and 98-07 (Orders), the Los Angeles Department of Water and Power (LADWP) is to undertake certain activities in the Mono Basin to be in compliance with the terms and conditions of its water right licenses 10191 and 10192. In particular, the Orders state that LADWP is to undertake activities to restore and monitor the fisheries, stream channels, and waterfowl habitat. This summary provides an overview of all of the activities LADWP and its consultants completed during Runoff Year (RY) 2002 for compliance. This summary also provides a list of planned work/activities for RY 2003.

RY 2002 was the fourth full field season after the adoption of the Orders. As such, LADWP is continuing the implementation of its revised Stream and Stream Channel Restoration Plan, revised Grant Lake Operation and Management Plan, and revised Waterfowl Habitat Restoration Plan. This required, among other things, scheduling field crews and other resources, coordinating with various other agencies, and preparing work plans. LADWP completed most of the planned work/activities for compliance.

Please see **Figure 1** for an aerial image of Mono Basin, showing major streams and LADWP facilities.

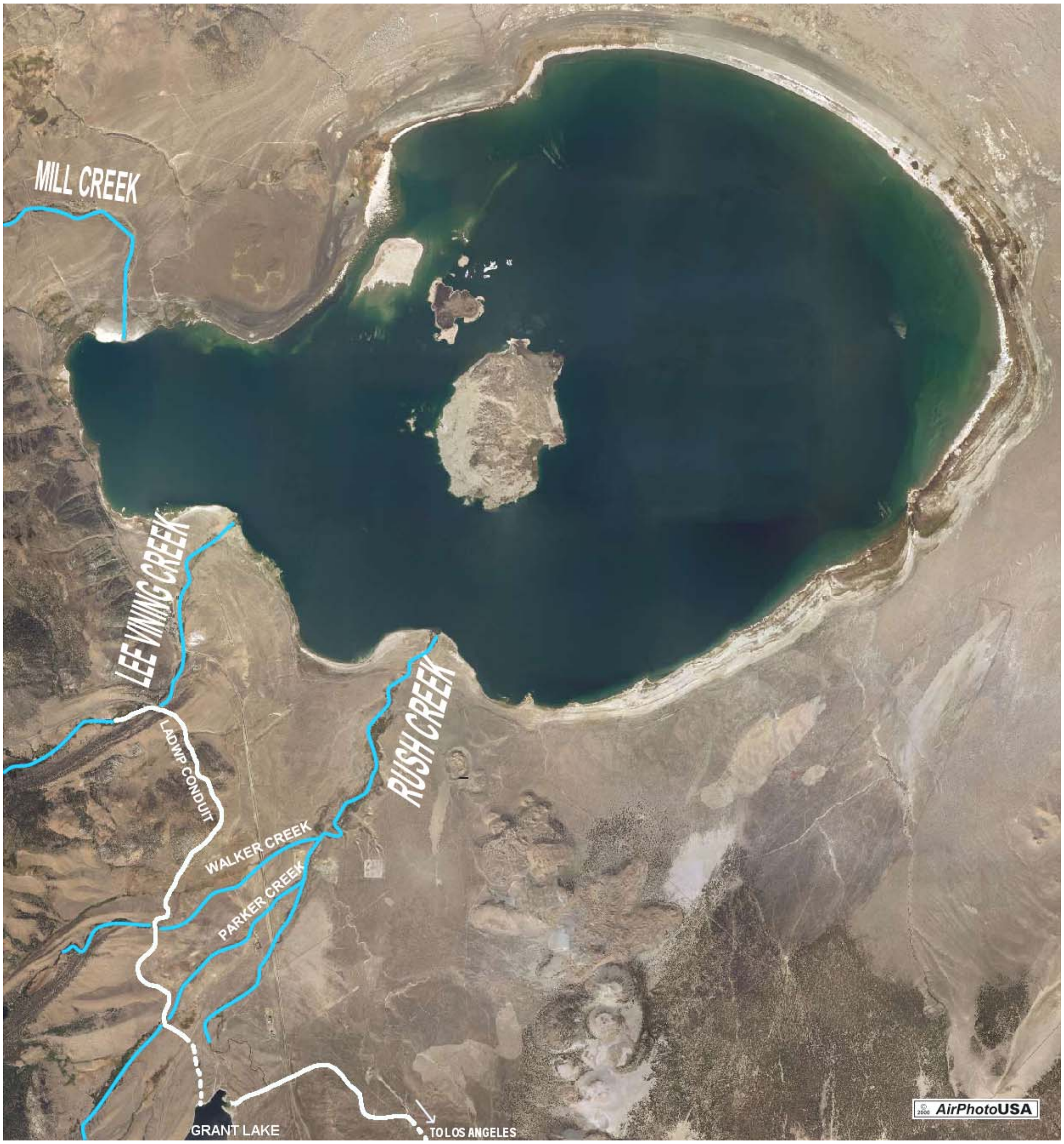


Figure 1: Aerial Photograph of Mono Basin

Work Performed During Runoff Year 2002

Restoration Activities

Streams

In 2002, LADWP undertook and completed several measures that were outlined in the Mono Basin Stream and Stream Channel Restoration Plan (1996). These included:

- Restoration of the Mono Gate One Return Ditch was completed;
- All construction for the Rush Creek 3D Floodplain Restoration Project was completed;
- 8-Channel invert excavation to remove sediment plug at the channel entrance was completed;
- Rush Creek Narrows pilot revegetation project was initiated;
- Continued with the grazing moratorium;
- All bags of gravel have been opened;
- Remaining roads closures near Rush Creek were completed;
- Sediment bypass strategies have been developed for Lee Vining Creek

Mono Gate One Return Ditch

Restoration of the Mono Gate One Return Ditch (MGORD) has been completed. The work performed included dredging the accumulated sediment from the ditch, removing obstructions, stabilizing the sideslopes susceptible to seepage and erosion, and armoring banks at their bends. Minor improvements after observation of high flows may still be performed. These high flows were anticipated to take place during RY 2003, but if stream restoration flows are not released, the minor improvements may be postponed for wetter conditions.

3D Floodplain Restoration Project

The 3D Floodplain Restoration Project was completed in RY 2002, and consisted of lowering the right bank floodplain 4-6 feet, placement of large woody debris and large boulders, and creation of overflow channels for topographic diversity and to encourage the natural establishment of floodplain vegetation. The objectives of this project are to allow floodplain inundation in moderate flow events (250 cfs and greater), raise the groundwater table across the floodplain, and reduce channel confinement along the main channel. The location of this project site is shown in **Figure 2**.

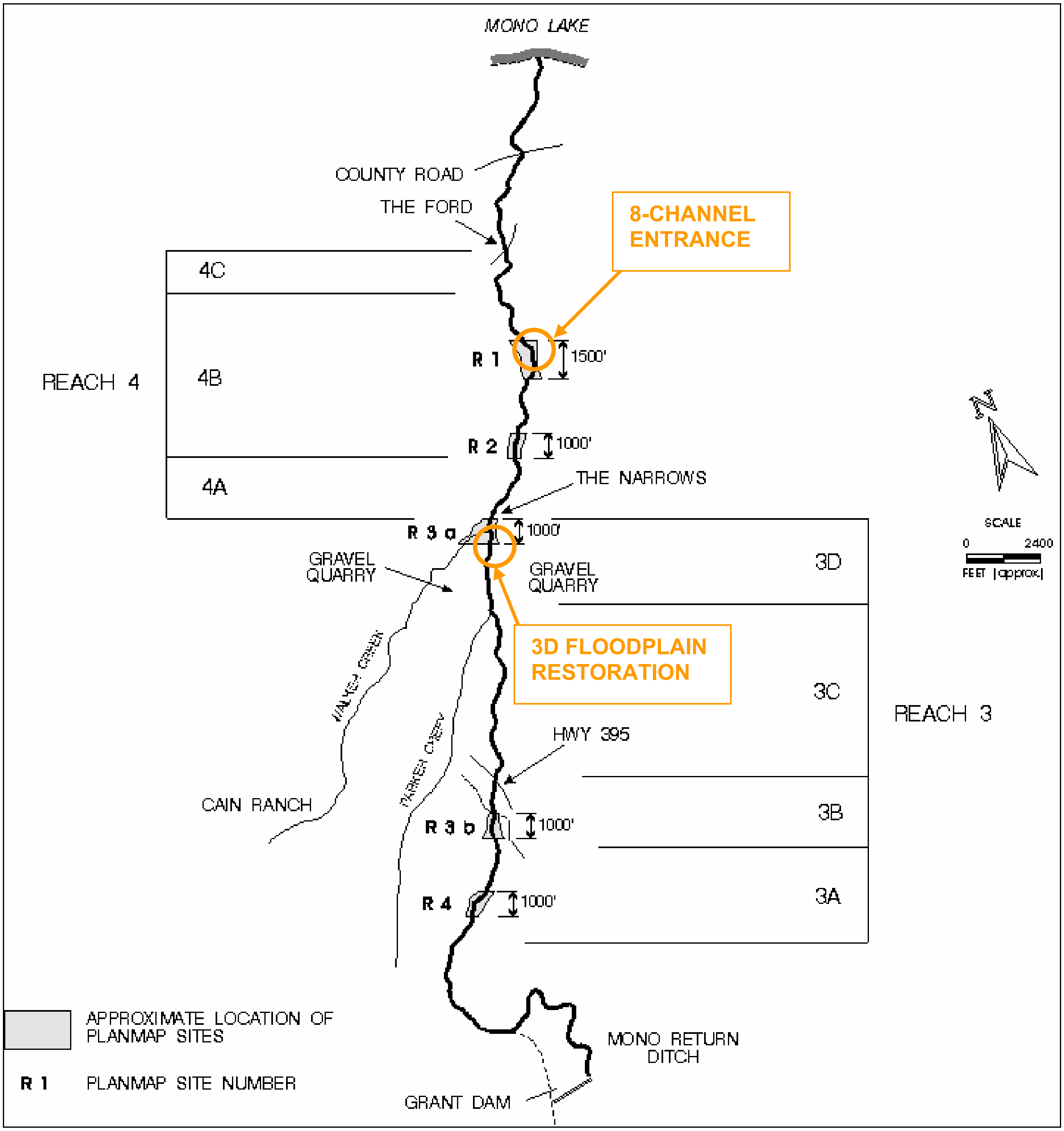


Figure 2: Mono Basin Project Locations

Photos of the restoration project may be seen in **Figure 3** through **Figure 6**. **Figure 3** and **Figure 4** are taken from the Narrows, looking toward the floodplain restoration site. **Figure 5** is taken from the south side of the 3D valley wall. **Figure 6** is taken from the upstream end of the floodplain and shows the side channel flowing with approximately 2 cfs of flow.

Figure 3: 3D Floodplain Restoration Site: Pre-Excavation

Figure 4: 3D Floodplain Restoration Site: Excavation Completed

Figure 5: 3D Floodplain Restoration Site

Figure 6: 3D Floodplain Restoration Site and Side Channel

8-Channel Rewatering

The sediment plug at the Rush Creek 8-Channel entrance was removed, and the 8-Channel was widened at the upstream end. The excavated areas were rehabilitated by spreading woody debris and transplanting willows along the newly created banks that were removed from the channel construction area. As a result of this project, the 8-Channel is expected to be inundated at least once every two years, and this will ultimately transform the riparian vegetation from the current Black Cottonwood and Wood's Rose patch into a Black Cottonwood patch. The location of this project site is shown in **Figure 2**. **Figure 7** and **Figure 8** show the 8-Channel Entrance Site.

Figure 7: Rush Creek 8-Channel Entrance Site, Looking Downstream

Figure 8: Rush Creek 8-Channel Entrance Site, Looking Upstream

Revegetation

The Rush Creek Narrows Pilot Revegation Project was initiated. 54 Jeffrey Pines were planted below the Rush Creek Narrows using three different irrigation treatments: 1) Driwater, 2) Terrasorb water polymers, and 3) none – the control group. It was determined that the Driwater irrigation treatment produced the most survivors, or three times more than the Terrasorb water polymer, which produced the same number of survivors as the control treatment. A total of 11 trees survived. The Terrasorb water polymer was applied as a hydrated crystalline material to the backfill. The Driwater method, applied in paper quart containers, is shown in **Figure 9**.

Figure 9: Driwater Planting Method for Revegetation

Grazing Moratorium

There was no grazing on LADWP's land in the Mono Basin during RY 2002. The grazing moratorium is still in effect for all lands in the Mono Basin and will be continued for a total of at least 10 years, per the Mono Basin Stream & Stream Channel Restoration Plan (LADWP, 1996).

Gravel Bags

All bags of spawning gravel have been opened (either by DWP and team or by natural disintegration), and the gravel has been distributed throughout the stream.

Road Closures

Remaining unimproved access roads in the valley bottomlands of Rush Creek were closed during RY 2002. Access roads to Lee Vining Creek were closed in prior years, and the work done in RY 2002 completes all planned road closures in the Mono Basin.

Sediment Bypass
LADWP originally planned to have completed the following items in RY 2002:

- Complete concept designs of three sediment bypass alternatives for the diversion on Lee Vining Creek,
- Collect and respond to comments on these alternatives,
- Complete detailed design specifications for the selected alternative in time for construction to take place in RY 2003.

The sediment bypass alternatives were developed and comments have been collected regarding those strategies. Detailed design specifications will be completed upon final selection of the sediment bypass alternative. Construction of the bypass in the fall of 2003 is still desirable.

Waterfowl

In RY 2002, LADWP continued its waterfowl habitat monitoring and restoration program. The following is a summary of activities:

- Monitored Mono Lake hydrology;
- Monitored lake ornithology;
- Revised waterfowl census methodology;
- Selected expert to provide peer review of waterfowl surveys;
- Monitored lake limnology

Mono Lake Hydrology
The elevation of Mono Lake was monitored on a weekly basis. The lake elevation ranged from 6382.5 on April 1, 2002 to 6382.0 on March 31, 2003. The average surface area during RY 2002, based on the Pelagos Corp. 1986 bathymetric study, was approximately 70.5 square miles, or 45,107 acres. The lake was meromictic during RY 2002, but this state is weakening due to evaporative concentration of the upper mixed layer accompanying a slight (~0.5-feet) decline in surface elevation.

LakeOrnithology
Ms. Deborah House, Range and Wildlife Biologist with LADWP, conducted three summer waterfowl ground counts and six fall aerial surveys. The next regularly scheduled vegetation surveys are set for 2005. Aerial photography of the Mono Basin was conducted on September 17, 2002.

Waterfowl Census Methodology
A revision of the waterfowl survey protocol proposed by LADWP was negotiated with the Mono Lake Committee and peer reviewed. The new protocol is described in Section 5 of the Compliance Report.

Expert for Peer Review
Robert McKernan, director of the San Bernardino County Museum, was selected to provide peer review of the waterfowl survey results every five years, starting in 2003.

Mono Lake Limnology
Limnology was monitored by UC Santa Barbara. Algal biomass was within normal ranges. Total brine shrimp biomass was the lowest on record, which was the result of a very large first generation followed by a very small second generation.

Monitoring

Stream Channel

Monitoring and Reporting
During RY 2002, McBain and Trush continued their monitoring program developed in 1997 and 1998 following the White and Blue book principles. Three monitoring reaches have been established on Rush Creek, two reaches on Lee Vining Creek, and one reach on each of Parker and Walker creeks, totaling 55 cross-sections. In addition, the Lower Rush Creek Gaging Station was completed and is in operation. Detailed descriptions of McBain and Trush's monitoring of reaches, water temperature, and channel dynamics are found in their report titled "Monitoring Results and Analyses for Runoff Season 2002-03 – Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks". This report is also included in Section 4 of the Compliance Report.

Fishery

Monitoring and Reporting
Mr. Hunter continued the monitoring program originally developed in RY 1997 and 1998 according to the White and Blue book principles. This plan was altered during the course of its implementation to rely more heavily on electrofishing for population estimates in place of snorkeling, as electrofishing proved to be more accurate in the beginning monitoring seasons. Pool habitats were evaluated using snorkeling surveys and pools were classified by their habitat quality rating (Class 5 being highest quality). Three planmap sections in Rush Creek (Country Road, Upper, and Lower), two planmap sections on Lee Vining Creek (Upper and Lower), and one planmap section on each of Walker and Parker creeks were studied. Mr. Hunter's detailed methods and findings are described in his report titled "Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker creeks – 2002", located in Section 3 of Compliance Reporting.

Waterfowl

Oversight of the Monitoring Program
During RY 2002, Dr. White oversaw the Waterfowl Habitat Restoration Program in the Mono Basin. He facilitated outside review and documentation of a revised waterfowl monitoring plan and reviewed the annual reports on lake limnology and waterfowl distribution and abundance. He also made a helicopter inspection of the Mono Lake shoreline and Crowley Lake.

During RY 2002, LADWP contracted with IK Curtis and AirPhoto USA to provide GIS-compatible aerial photography for the Mono Basin with a scale of 1:2400 or 1 inch = 200 feet.

LADWP personnel collected hydrology data for the four streams and Mono Lake.

Informational Meetings

The LADWP sponsored two meetings during the RY 2002 for the experts and interested persons to present and discuss restoration and monitoring activities, hydrology, and other issues related to the Mono Basin. The meetings were held on April 23, 2002 and December 3, 2002 in Sacramento.

April Meeting: This meeting, held on April 23, 2002, provided an opportunity for the stream monitoring experts to present the findings of their RY 2001 monitoring activities and discuss their proposed RY 2002 scope of work. Chris Hunter and his team requested data, including stream temperatures, Cain Ranch (50-yr data set), and recent aerial photos. He also suggested hiring a graduate student to perform a fish movement study and otolith sampling to determine ages of fish. He indicated that rainbow trout seem to be increasing, brown trout numbers are steady, and most fish are in good condition. Bill Trush discussed the ramping options, and indicated that a 5-10% ramping rate would be closer to natural than 20%. He mentioned that ramping rates are difficult to correlate to ecological benefits. He discussed projects, including the 8-Channel Entrance, 3D Floodplain Restoration, and studying the groundwater influence. He said that at the end of 2003, he will provide a complete write-up on progress toward termination criteria, and will incorporate historic data. Ken Anderson requested that LADWP support the seasonal closure of the Mono Lake islands to recreation.

In addition, the preliminary RY 2002 runoff forecast and operations were discussed. The preliminary runoff forecast indicated a “dry normal II” year.

Attendees included those shown in **Table 1**.

Table 1
Mono Basin April Meeting Attendees

Name	Agency/Affiliation
Bill Trush	McBain & Trush
Chris Hunter	Hunter
Ken Knudson	Hunter
Heidi Hopkins	MLC
Peter Vorster	MLC
Steve Parmenter	DFG
Greg Reis	MLC
Janet Goldsmith	SMC
Ken Anderson	State Parks
Dan Meister	Mono County
Dave Martin	LADWP – Bishop
Debbie House	LADWP – Bishop
Brian White	LADWP
Bob Prendergast	LADWP
Peter Kavounas	LADWP
Steve McBain	LADWP

November Meeting: This meeting, held on December 3, 2002, provided an opportunity for the stream monitoring experts and waterfowl experts to present and discuss their RY 2002 activities. Darren Mierau of McBain & Trush outlined their efforts in 1) mapping of 1929 aerial photos, 2) installation of a gaging station along Rush Creek, 3) designs for the 8-channel entrance project and the 3D floodplain project, and 4) experimental plantings of Jeffrey pines downstream of the Rush Creek Narrows. Chris Hunter reviewed his progress with the fish monitoring. He discussed the conditions of the stream (relatively high temperatures, presence of cladophora) and some of the things he would like to accomplish, including determining whether the current fish sampling sites are representative of the whole system, beginning a fish movement study, and using otoliths to age fish. Dave Martin reviewed construction projects, including the 8-channel entrance and the 3D floodplain project. Brian White reviewed the lake limnology studies and protocol for conducting waterfowl monitoring. The status of the burn program was discussed and the SWRCB has been asked to relieve the LADWP of the requirement to conduct burns. An overview of the runoff recap was also presented at this meeting.

Attendees included those shown in **Table 2**.

Table 2
Mono Basin December Meeting Attendees

Name	Agency/Affiliation
Bill Trush	McBain & Trush
Darren Mierau	McBain & Trush
Chris Hunter	Hunter
Peter Vorster	MLC
Greg Reis	MLC
Lisa Cutting	MLC
Ken Anderson	State Parks
Debbie House	LADWP – Bishop
David Martin	LADWP – Bishop
Brian White	LADWP
Peter Kavounas	LADWP
Bob Prendergast	LADWP

Activities Planned for Runoff Year 2003

Restoration Activities

Streams

Sediment Bypass at Lee Vining Intake
Design and construction of the sediment bypass at the Lee Vining Intake may be completed in the fall of 2003.

Mono Gate One
A retrofit of Mono Gate One will be evaluated during RY 2003 to ensure that it can operate as needed to comply with Order 98-05. The retrofit of this facility would provide capability for remote operation and precise flow measurement.

Peak Flows and Ramping Study
Peak flows and ramping rates for Rush and Lee Vining creeks were set forth by Order 98-05 and need to be reevaluated based on a study of data collected during the first eight to ten years of the full implementation of the Order. This study will focus on integrating the physical processes, riparian plant dynamics, and fish habitat into regulated hydrographs that address the range of water year types.

Addition to the Stream Restoration Team
Roy McDonald, of MWH, will be augmenting the current Mono Basin stream restoration effort. His expertise in the field of fluvial geomorphology will provide additional resources and perspective on this critical matter.

Waterfowl

Prescribed Burn Program
In August 2002, LADWP requested that the SWRCB relieve them of the requirement to conduct the prescribed burn program. This issue was discussed during the November meeting. Per verbal communications with the SWRCB in December 2002, LADWP considers the prescribed burn program to be on hold until the year 2014 or until the lake level reaches 6,391 feet, whichever comes first.

Channel Rewatering:
There are currently no plans to rewater the channels described in the waterfowl plan.

Monitoring

Streams

Dr. Trush will continue the stream channel monitoring program on Rush, Lee Vining, Parker, and Walker creeks. The following specific items will be included in the RY 2002 monitoring:

Post-Transition Flows

Data collection for the determination of post-transition flows and ramping will continue if stream restoration flows are released from Grant Lake. These data support the study that will focus on integrating the physical processes, riparian plant dynamics, and fish habitat into regulated hydrographs that address the range of water year types.

Evaluate Groundwater Dynamics

Baseline groundwater elevations that don't result from high flow releases will be studied during RY 2003, so that in subsequent years' monitoring, higher groundwater elevations would be attributable to the 3D floodplain construction and side-channel re-opening.

Aerial Photography

Aerial photographs will be acquired for geomorphic and riparian monitoring at a scale of 1"=20' with 0.12' pixel scale. Specifically, the work will include establishing local survey-grade ground control along the stream corridors of Rush, Lee Vining, Parker, and Walker Creeks, with survey control permanently monumented with rebar, and contracting acquiring low-altitude aerial photo flight (scale 1:2,400) to produce a new set of digital orthophotos and surface model to be used in the orthorectification process.

Riparian Planting Experiments

Monitoring of plant survival at the Narrows Pilot project will continue, and conditions that favor natural riparian plant recruitment at the 3D Floodplain site and the 8-Channel site will be evaluated.

Temperature Monitoring

Temperature monitoring will be continued for the six thermographs in the system: three along Rush Creek, and one each on Parker, Walker, and Lee Vining Creek.

Fishery

Fish Monitoring

Chris Hunter and his fish monitoring team will utilize the same monitoring sites and methods for Rush, Lee Vining, Parker and Walker creeks that were used during the years 2000, 2001 and 2002. Collection of scale and otolith samples will be added to better estimate ages of brown and rainbow trout in Rush and Lee Vining creeks.

Fish Movement Study
A fish movement study will be conducted by a graduate student and guided by Chris Hunter for the purpose of determining:

1. Whether young fish move into the MGORD from Rush Creek and remain there growing to larger sizes than they would attain in main Rush Creek;
2. Whether larger fish move out of the stream into the MGORD seeking better habitat conditions;
3. Whether mature fish from Rush Creek move into Parker and Walker creeks to spawn, or whether these streams are dependent upon resident spawners to sustain their brown trout populations;
4. Whether fish hatched in Parker and Walker usually recruit to the Rush Creek fishery.

Instream Flow Studies
The monitoring team will retain the services of an instream flow expert to determine future flow regimes that are suitable for the trout fishery.

Fish Habitat
Habitat surveys will be conducted using snorkeling and some long-term monitoring at selected pools.

Waterfowl

Dr. White will continue to oversee the waterfowl monitoring program. This program consists of the following components:

- Limnology: Dr. Jellison and Dr. Melack will continue limnological monitoring in the Mono Basin.
- Waterfowl Population Surveys: Deborah House will perform the waterfowl population surveys in the Mono Basin.
- Aerial Photography: LADWP will conduct aerial photography of the Mono Basin in a GIS-compatible format.
- Hydrology: LADWP will continue to monitor the elevation of Mono Lake and collect hydrologic data in the Mono Basin.

Informational Meetings

LADWP will host two meetings with the researchers and interested parties to discuss restoration and monitoring activities in the Mono Basin. As in previous years, the meetings will be held prior to and after the field season. The first meeting has been scheduled for April 25, 2003. The second meeting will be held in November, 2003.

Physical Projects Remaining

Streams

Intake Facilities on Walker and Parker Creeks
The control facilities on Walker and Parker creeks will be reconfigured to allow control of the amount of flow being released to the creeks. These facilities need to be designed and constructed. The designs and construction are expected to be completed within five years.

Lee Vining – Grant Lake Conduit Siphon
A retrofit of the Lee Vining – Grant Lake Conduit Siphon will be evaluated to ensure that it can operate as needed to comply with Order 98-05.

Waterfowl

Channel Rewatering on Rush Creek
No construction activities are planned for the channels on lower Rush Creek.

Table 3
List of Abbreviations

Los Angeles Department of Water and Power	LADWP
Mono Gate One Return Ditch	MGORD
Runoff Year	RY
State Water Resources Control Board	SWRCB

Section 2

Mono Basin Operations for Runoff Year 2002-2003

Mono Basin Operations for Runoff Year 2003-2004

The May 1 Mono Basin Runoff Forecast for the 2003-04 Runoff Year is 90,800 acre-feet, or 74% of normal (using the 1941-1990 average of 122,124 acre-feet). The May 1 forecast is substantially the same as the April 1 forecast, and the April 23^{rd}, 2003 plan titled "Preliminary Mono Basin Operations for Runoff Year 2003-04"”(attached) remains essentially unchanged.

In light of discussion held during the April 25^{th}, 2003 meeting LADWP will be delaying the start of ramping of Rush Creek flows from the stated date of May 15^{th} to May 27^{th} . DWP will also delay the ramping of Lee Vining Creek flows from the stated May 15^{th} to May 19^{th}. This is to reflect a suggestion that in light of the cooler temperatures experienced in April and early May the peak flows in the Mono Basin Creeks may come later than predicted by the forecasting models.

April 23, 2003

Mr. Harry Schueller
Chief Deputy Director
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812-0100

Dear Mr. Schueller:

Subject: Preliminary Mono Basin Operations for Runoff Year 2003-04

The April 1, 2003 Mono Basin runoff forecast for the 2003-04 runoff year is 88,700 acre-feet, or 73 percent of normal (using the 1941-1990 average of 122,124 acre-feet). This year is classified as a "Dry Normal" according to the provisions of the State Water Resources Control Board (SWRCB) Order 98-05. The operations plan based on the April 1 forecast is preliminary, and will be finalized once the May 1, 2003 forecast has been developed. Unless there is substantial difference, the Los Angeles Department of Water and Power (LADWP) will not submit a revised operations plan.

To meet the SWRCB requirements, LADWP intends to follow the guidelines shown in Attachment 1, with two modifications: [1] changing the ramping rate on Rush Creek from the 10 percent required by Decision 1631, to 25 cfs increments, in order to calibrate two measuring stations in Rush Creek (this change requires authorization by the SWRCB); and [2] Mono Basin exports will be allocated over the October-to-March period, instead of the entire year.

Attachment 2 titled "Grant Lake Operations Model-Statistical Summaries" presents a summary of the "educated guess" of flows in the Mono Basin streams and LADWP facilities for the 2003-04 runoff year. This simulation is based on the runoff pattern experienced in 1989, a year of similar runoff volume to the forecasted 2003-04 runoff. The simulated flows do not represent minimum or maximum flows, or targets of any kind. They merely provide a possible scenario of flow distribution in the basin. The scenario presented in Attachment 2 assumes that flows are controlled with precision, and is based on historical information which incorporates past temperature and precipitation patterns throughout the runoff year and reflects operational practices by Southern California Edison (SCE) in Mono Basin. The actual flows will likely be different, since facility control is not precise, weather is not likely to mimic the past, and SCE may have changed their method of operation.

Grant Lake Storage: On April 1, storage in the Grant Lake Reservoir was approximately 18,550 acre-feet, less than half of the total reservoir capacity of 47,500 acre-feet. This level and the projected fluctuation of the reservoir are lower than necessary for the safe operation of the Grant Lake Marina for recreational purposes. As addressed below, operational decisions on diversions from Lee Vining Creek and the pattern of Mono Basin exports are influenced by this condition and are intended to assist in raising the storage in Grant Lake during the April-to-September period. Figure 1 shows the forecasted inflow, outflow, and storage for the Grant Lake Reservoir through the 2003-04 runoff year.

Rush Creek: SWRCB Order 98-05 further subdivides the "Dry Normal" classification in two categories specifically for Rush Creek. Based on this, the forecasted runoff for 2003-04 suggests that the required Stream Restoration Flows (SRF) for Rush Creek are 200 cfs for seven days. LADWP would like the opportunity to calibrate two measuring stations on Rush Creek, namely the measuring station on the Mono Gate One Return Ditch and the station below the County Road crossing. To achieve this, it is preferred that ramping up to the 200 cfs peak flow is done in 25 cfs increments instead of the 10 percent required by the order.

Decision 1631 provides base flow requirements for Rush Creek, as shown in Attachment 1. LADWP intends to abide by those requirements, including the provision that "...the instream flow requirements shall be the (dry year flow requirement) or the inflow into Grant Lake from Rush Creek, whichever is less." (Decision 1631, page 198). It is expected that on certain days instream flows may be lower than the inflow to Grant Lake; every effort will be made to adjust flows daily to minimize this occurrence. Figure 2 shows an illustration of possible Rush Creek flows.

Lee Vining Creek: SWRCB Decision 1631 and Order 98-05 provide base flow and SRF requirements for Lee Vining Creek. LADWP intends to abide by those requirements, and operate as shown in Attachment 1. The operation includes diversion of flows in excess of the 54 cfs base flow requirement. LADWP will use its facilities to effect this diversion and will make every effort to maintain the required flow (LADWP intends to modify its Lee Vining diversion facility in the future to gain greater control of the releases into Lee Vining Creek). At this time, releases to Lee Vining Creek from the facility cannot be controlled reliably, and the diversion of water this year may result in a short-term flow of less than the required 54 cfs. LADWP will review Lee Vining Creek flow information daily and make adjustments as necessary to minimize the occasions and duration of releases below 54 cfs.

The diversion from Lee Vining Creek will be undertaken to maximize the amount of stored water in Grant Lake, for reasons discussed earlier. Figure 3 shows an illustration of possible Lee Vining Creek flows.

Walker and Parker Creeks: Walker and Parker Creeks will be managed as shown in Attachment 1, in accordance with SWRCB Decision 1631 and Order 98-05.

Mono Lake Elevation: On April 1, 2003, Mono Lake's water surface elevation measured approximately 6,382.5 ft amsl (US Geological Survey datum). Given the most current forecast and the proposed operations, the elevation of Mono Lake is projected to be approximately 6382.0 ft amsl at the end of the runoff year. This is graphically shown in Figure 4 titled "Mono Lake Elevation and Transition Period Exports". The estimate is derived from modeling and includes a number of assumptions such as normal precipitation conditions for the remainder of the year. The projected lake elevation is to be used as a general indicator only.

Mono Basin Exports: In accordance with Decision 1631, LADWP is permitted to divert up to 16,000 acre-feet during the runoff year. LADWP plans to export the allowed 16,000 acre-feet during the October-March period. In the long term, LADWP plans to divert the allowed amount in an even, year-round pattern. The operations this year reflect the Grant Lake considerations discussed earlier.

Peak Flows: The values of expected magnitude and timing of the peak flows in Lee Vining, Walker, and Parker Creeks were generated by a predictive model and are shown below:

MAGNITUDE AND TIMING OF PEAK FLOWS IN LEE VINING, WALKER, AND PARKER CREEKS		
Creek	**Magnitude**	**Timing**
Lee Vining	178 cfs	June 3rd, 2003
Walker	26 cfs	June 14th, 2003
Parker	40 cfs	June 18th, 2003

The model uses regression analysis of historical data to predict future events. Since the actual values depend heavily on ambient temperatures that are difficult to predict with any degree of certainty, it is more than likely that the values in the above table are not accurate. It is intended that they be used as an indicator of magnitude and timing of the peak flows. These predictions are based on the April 1, 2003 forecast and assume average precipitation for the following six months.

If you have any questions, please contact Mr. Peter Kavounas at (213) 367-1032.

Sincerely,

Original signed by
Thomas M. Erb

Thomas M. Erb
Director of Water Resources

PK:ctc

Enclosures

c: Mr. Jim Edmondson, California Trout, Inc.
Mr. Bill Bramlette, U.S. Forest Service, Inyo National Forest
Mr. James Barry, California Department of Parks and Recreation
Mr. Joe Bellomo, People for Mono Basin Preservation
Dr. William Trush, McBain & Trush
Mr. Ken Anderson, Department of Parks and Recreation
Mr. Marshall S. Rudolph, Mono County Counsel
Mr. Jim Canaday, Division of Water Rights, State Water Resources Control Board
Mr. Gary Smith, Department of Fish and Game
Ms. Lisa Cutting, Mono Lake Committee
Mr. Chris Hunter
Mr. Steve Parmenter
Mr. Roger Porter
Mr. Peter Kavounas

bc: Thomas M. Erb
Gene L. Coufal
Clarence Martin
Charlotte Rodrigues
Terry Williams
Steve Keef
Robert Prendergast
Steven McBain

MONO BASIN OPERATIONS - PLANNING GUIDELINE B

Hydrologic Year Type: Dry-Normal I
Forecasted Volume of Runoff (acre-feet): 83,655 < - ≤ 92,207

LOWER RUSH CREEK

Instream Flows:

	Apr-Sept	Oct-Mar
Flow (cfs)	47	44

Minimum base flows are those specified above or the inflow to Grant Lake reservoir, whichever is less. However, if the inflow is less than the dry year instream flow requirements, then dry year base flow requirements apply (Refer to Schedule A).

Stream Restoration Flows: 200 cfs for 7 days

- Begin ramping stream restoration flows on May 15.
- Ramping rate: 10% change ascending and descending, or 10-cfs incremental change, whichever is greater.

LEE VINING CREEK

Instream Flows:

	Apr-Sept	Oct-Mar
Flow (cfs)	54	40

Minimum base flows are those specified above or the stream flow at the point of diversion, whichever is less.

Stream Restoration Flows: Allow peak flow to pass point of diversion

- Begin ramping for stream restoration flows on May 15.
- Ramping rate: 20% change ascending and 15% change descending, or 10 cfs incremental change, whichever is greater.

Lee Vining Conduit Diversions:

- Divert flows in excess of base flows until May 15.
- Diversions may resume 7 days after the peak flow.

WALKER AND PARKER CREEKS

Instream Flows:

	Apr-Sept	Oct-Mar
Parker Creek (cfs)	9	6
Walker Creek (cfs)	6	4.5

Minimum base flows are those specified above or the stream flow at the point of diversion, whichever is less.

Stream Restoration Flows: Allow peak flow to pass point of diversion

Lee Vining Conduit Diversions: None

MONO BASIN EXPORTS Maintain 22 cfs throughout the year.

Grant Lake Operations Model - Statistical Summaries

2003 Runoff Year: Dry-Normal

	Lee Vin. Creek Above Intake	Walker Creek Above Conduit	Parker Creek Above Conduit	Rush Creek @ Damsite	Lee Vin. Creek Release	Lee Vin. Conduit Diver.	Lower Walker Parker Flow	Lower Rush Cr. Release	Rush C. Bottom land Flow	Grant Lake Storage	Grant Lake Outflow	Grant Lake Spill	Mono Basin Export	Owens River Abv. E. Portal	Owens River Blw. E. Portal
Daily Flows															
	cubic feet/second									ac-ft	cubic feet/second				
Start										18,551					
Min	16	1	2	17	16	0	5	17	22	12,770	17	0	0	39	56
Ave	51	5	6	58	46	5	11	50	62	20,220	72	0	22	44	83
Max	197	22	34	115	197	97	55	200	217	24,800	200	0	44	60	106
End										13,300					
Monthly Average Flows															
cubic feet/second										1st of Month					
Apr	73	2	5	87	63	9	7	47	54	18,551	47	0	0	48	65
May	101	8	6	88	73	28	14	82	96	21,640	82	0	0	50	67
Jun	132	16	19	94	129	3	35	102	137	23,670	102	0	0	46	63
Jul	65	8	13	64	52	13	20	54	75	23,180	47	0	0	41	58
Aug	31	4	7	39	31	0	12	38	50	24,520	38	0	0	44	61
Sep	30	3	6	34	30	0	8	34	42	24,230	35	0	1	42	60
Oct	29	4	5	40	29	0	8	39	48	23,890	84	0	44	44	105
Nov	25	7	3	44	25	0	10	42	53	21,150	87	0	44	43	104
Dec	22	3	3	36	22	0	6	33	39	18,920	77	0	44	44	105
Jan	35	3	3	52	34	1	5	44	49	16,670	88	0	44	43	105
Feb	44	2	3	52	40	5	5	44	49	14,940	88	0	44	43	104
Mar	28	3	3	74	28	0	6	44	50	13,640	88	0	44	43	104
Monthly Total Flows															
acre-feet										Average					
Apr	4,322	122	299	5,173	3,768	554	421	2,797	3,218	19,782	2,797	0	0	2,829	3,841
May	6,203	475	384	5,412	4,488	1,715	859	5,053	5,912	23,729	5,053	0	0	3,077	4,123
Jun	7,875	927	1,149	5,570	7,700	175	2,076	6,068	8,145	22,443	6,068	0	0	2,765	3,776
Jul	4,008	464	775	3,929	3,223	785	1,239	3,347	4,586	24,091	2,890	0	0	2,544	3,590
Aug	1,905	269	449	2,371	1,898	8	718	2,361	3,079	24,387	2,361	0	0	2,684	3,729
Sep	1,789	164	338	2,020	1,789	0	502	2,020	2,522	24,085	2,064	0	44	2,510	3,565
Oct	1,764	234	279	2,448	1,764	0	512	2,427	2,940	22,546	5,145	0	2,718	2,688	6,451
Nov	1,496	418	184	2,622	1,486	9	601	2,524	3,126	20,118	5,154	0	2,630	2,540	6,182
Dec	1,331	166	214	2,186	1,331	0	380	2,017	2,397	17,760	4,735	0	2,718	2,700	6,463
Jan	2,160	156	171	3,203	2,094	66	326	2,705	3,032	15,828	5,423	0	2,718	2,666	6,429
Feb	2,471	137	150	2,861	2,216	255	288	2,426	2,714	14,316	4,881	0	2,455	2,370	5,769
Mar	1,703	160	214	4,545	1,700	3	374	2,675	3,049	13,125	5,393	0	2,718	2,641	6,404
Apr-Sep	26,102	2,422	3,394	24,476	22,866	3,236	5,816	21,646	27,462		21,233	0	44	16,409	22,624
Oct-Mar	10,924	1,270	1,212	17,866	10,592	333	2,482	14,776	17,257		30,732	0	15,956	15,605	37,698
Annual Total	37,027	3,692	4,606	42,341	33,458	3,569	8,297	36,421	44,719		51,964	0	16,000	32,015	60,322

Table 1

Forecasted Grant Lake Reservoir - Daily Inflow, Outflow, & Storage

Dry Normal Runoff Year Illustration

for RY 2003-04

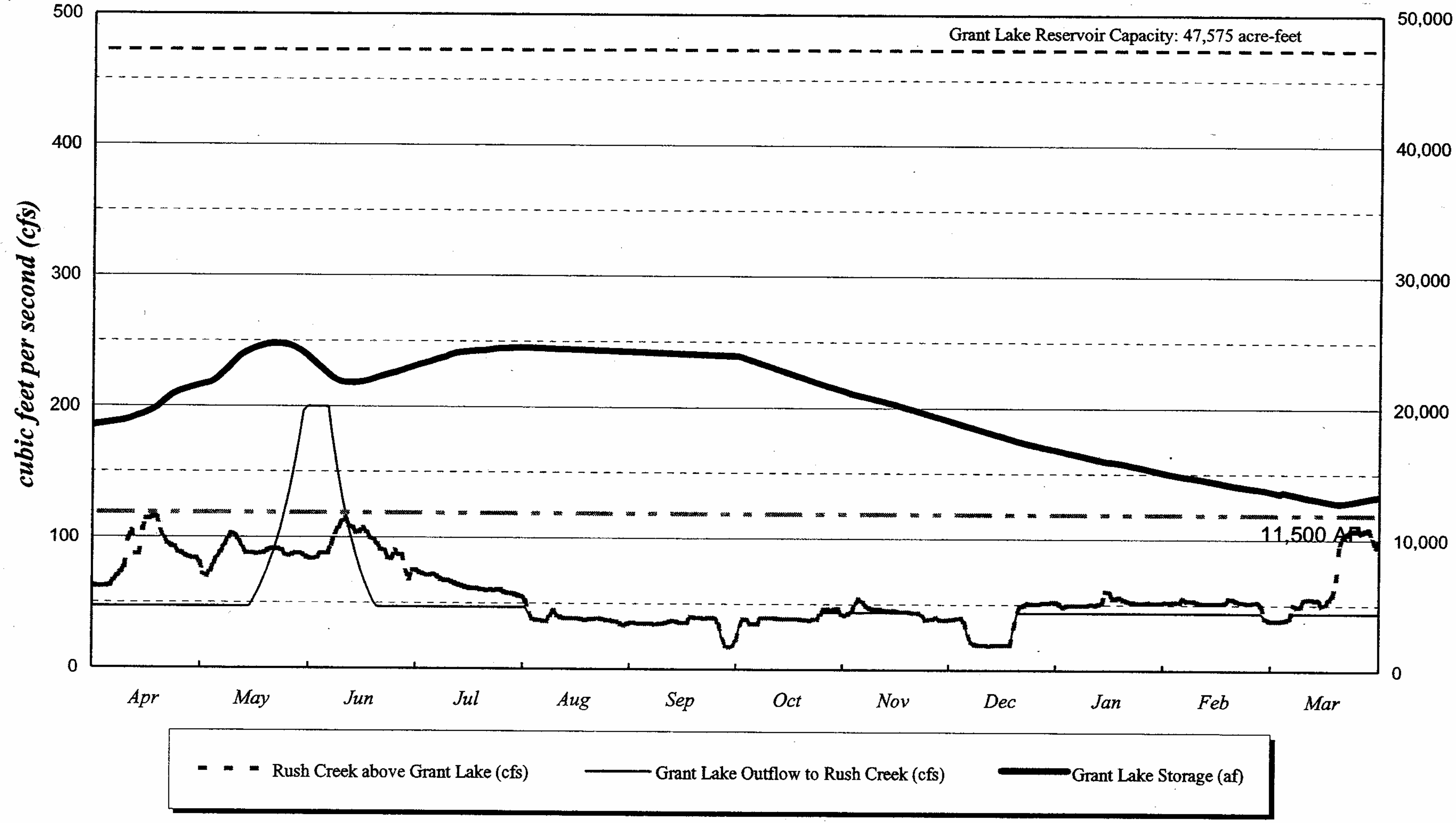
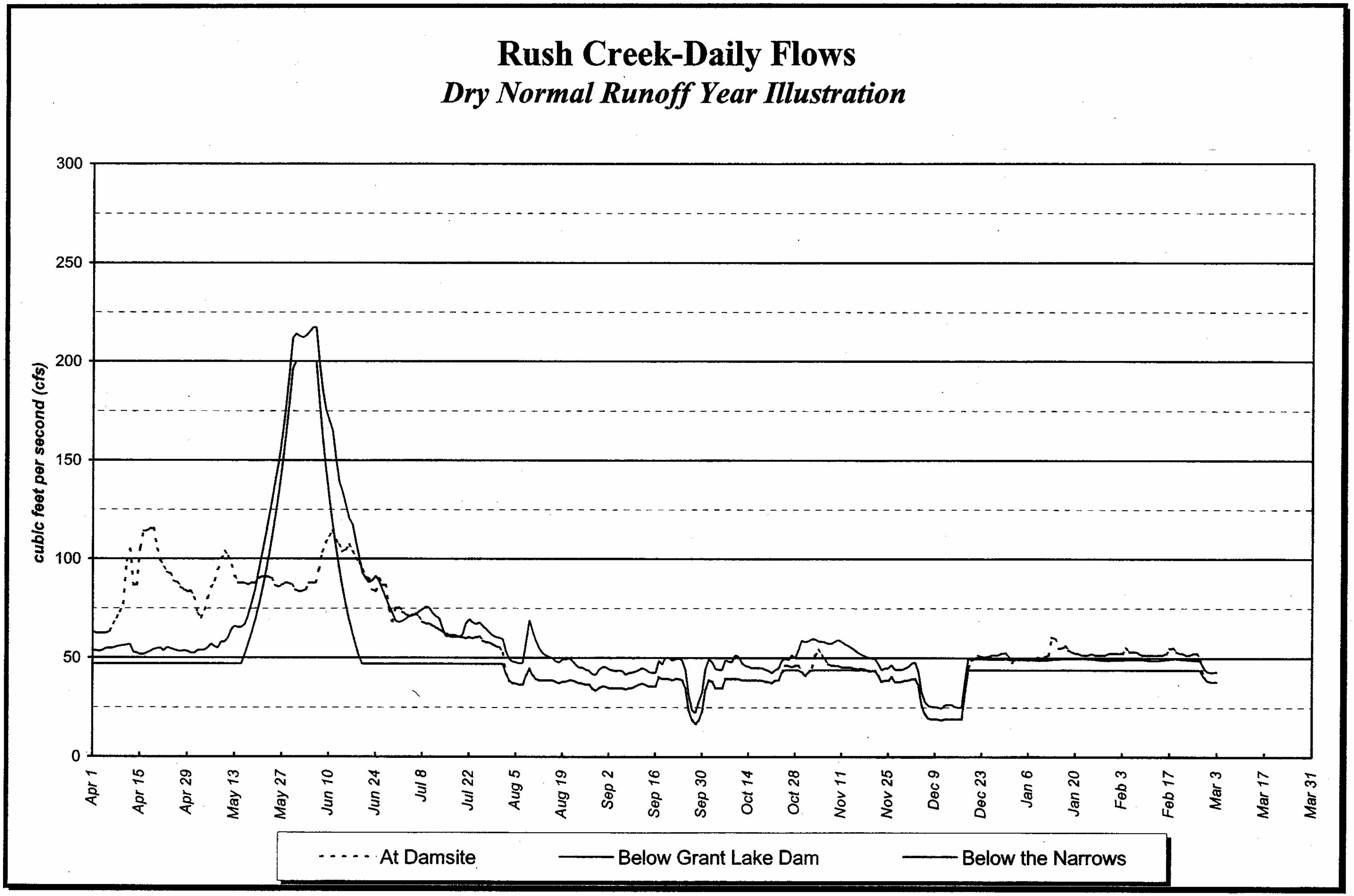


FIGURE 1

FIGURE 2



Rush Creek-Daily Flows
Dry Normal Runoff Year Illustration
cubic feet per second (cfs)
300
250
200
150
100
50
0
Apr 1
Apr 15
Apr 29
May 13
May 27
Jun 10
Jun 24
Jul 8
Jul 22
Aug 5
Aug 19
Sep 2
Sep 16
Sep 30
Oct 14
Oct 28
Nov 11
Nov 25
Dec 9
Dec 23
Jan 6
Jan 20
Feb 3
Feb 17
Mar 3
Mar 17
Mar 31
At Damsite
Below Grant Lake Dam
Below the Narrows

FIGURE 3

Lee Vining Creek-Daily Flows

Dry Normal Runoff Year Illustration

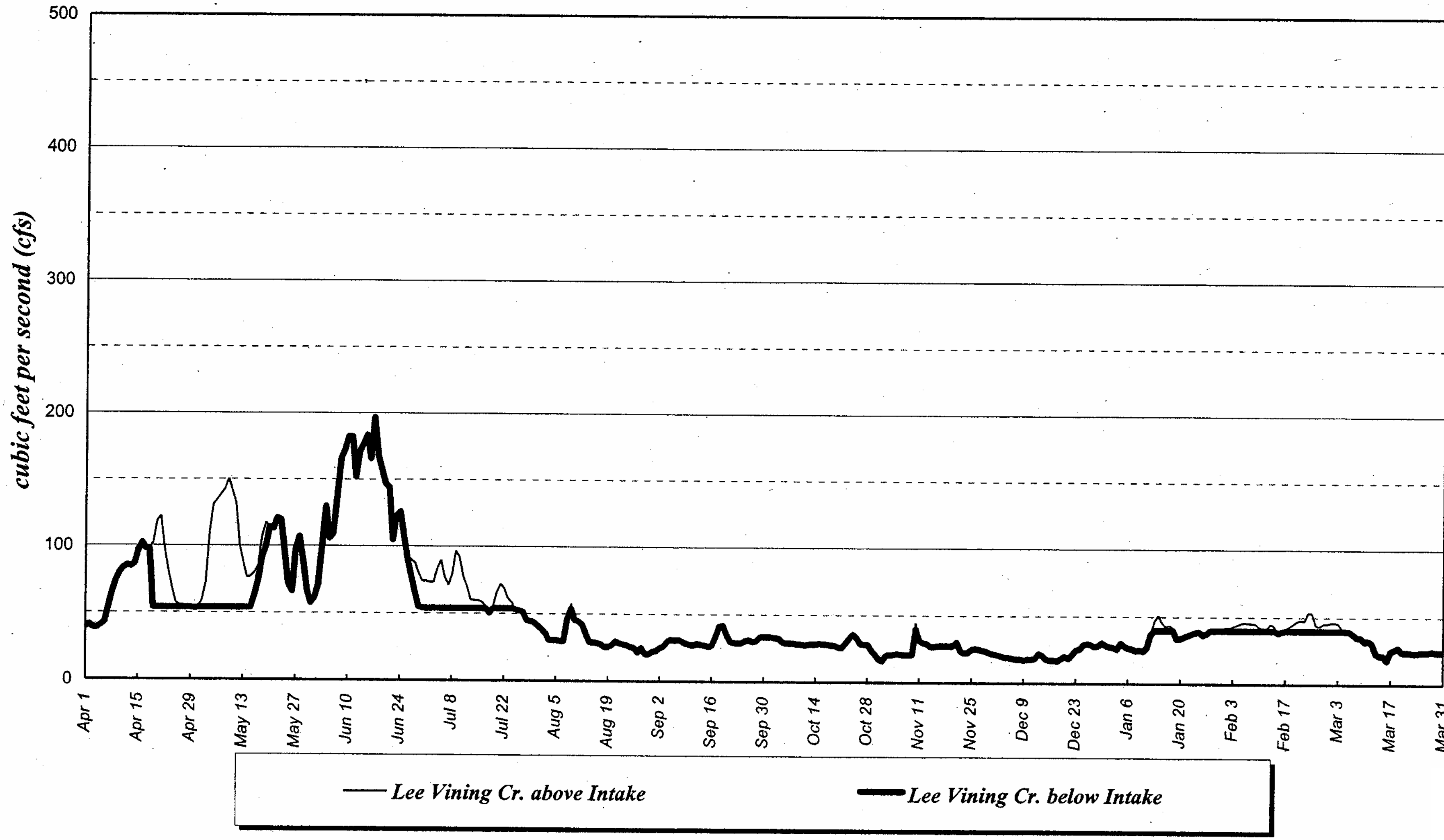
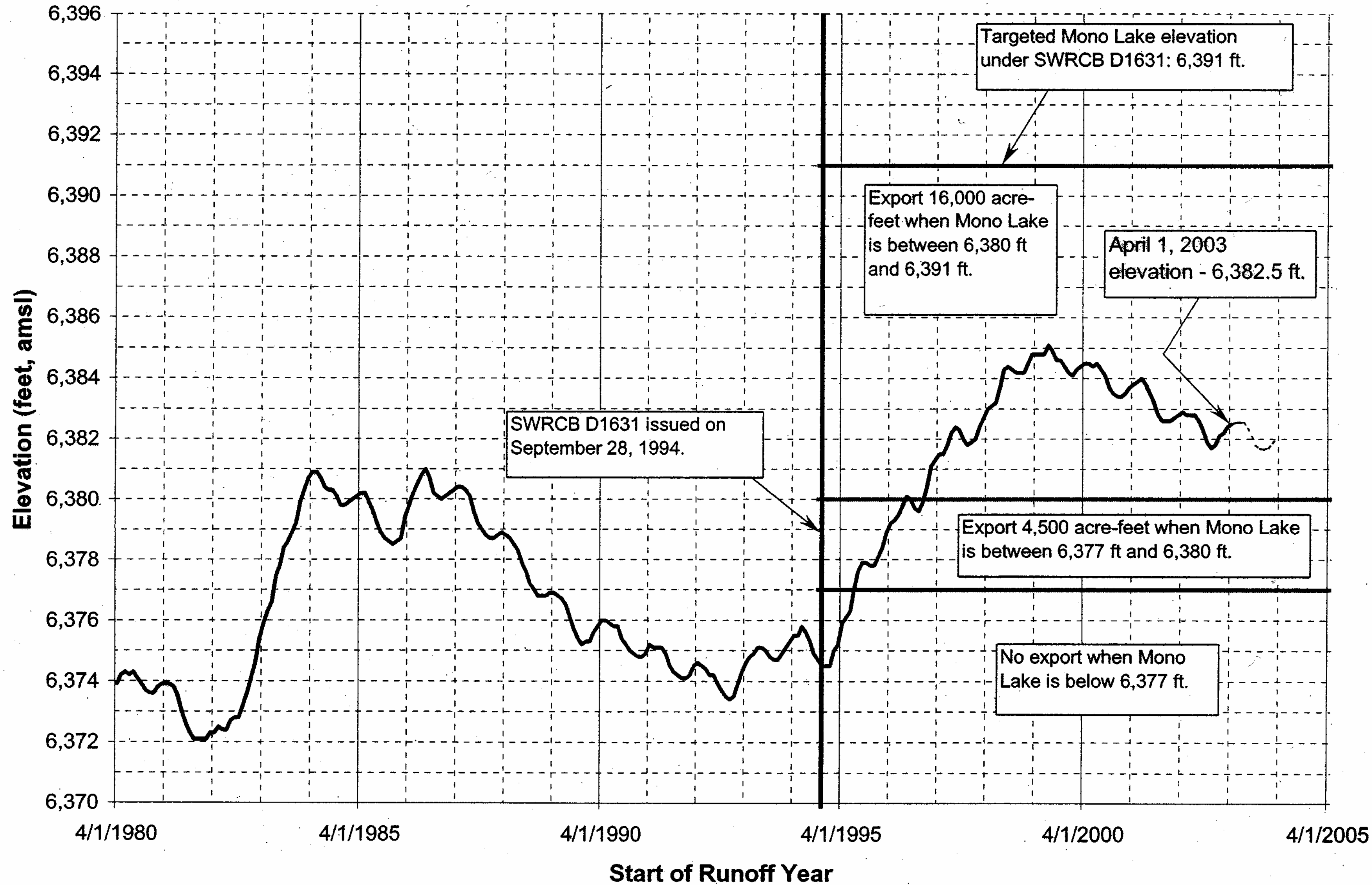


FIGURE 4

Mono Lake Elevation and Transition Period Exports

April 1980 - April 2005



Note: The time until the Mono Lake elevation reaches 6,391 ft is called the "Transition Period". Export rules change at the end of that interval.
*Based on Runoff Forecast Model developed in 1993.

4/17/2003 by Paul Scantlin
Mono Lake Elev, data-chart 2003-04

Section 3

Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks 2002

Fisheries Monitoring Report For Rush, Lee Vining, Parker and Walker creeks 2002

Prepared by: Chris Hunter
Brad Shepard
Ken Knudson
Ross Taylor
Matt Sloat

Prepared for: Los Angeles Department of Water and Power

Date: May 2003

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Executive Summary

This report presents the results of the fourth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) WR 98-07. We used mark-recapture electrofishing techniques to estimate trout populations in four sections of Rush Creek and two main stem sections of Lee Vining Creek. Fish population estimates for two Lee Vining Creek side channels and Parker and Walker creeks were made using electrofishing depletion methods. We surveyed Rush Creek from the outlet of the Mono Gate Outflow Return Ditch (MGORD) down to the upper end of the County Road sample section to document the abundance and distribution of high quality pool habitats by quality class. We tagged trout in Rush Creek that were 225 mm and longer in all our sample sections and below the County Road to further assess trout movement in Rush Creek.

Densities (number per hectare) of age 1 and older brown trout were higher in 2002 than in any previous year in all sections of Lee Vining Creek, but were lower in all sections of Rush Creek. Densities in 2002 were similar as previous years in Walker Creek and similar to 2001, but higher than 1999 and 2000, in Parker Creek. Densities of age 1 and older rainbow trout were higher in 2002 in the lower portion of Lee Vining Creek, but similar to past years in the upper portion. Densities of age 1 and older rainbow trout were slightly lower in all Rush Creek sections.

Estimates of trout standing crops (kg/hectare) were similar in Lower and Upper Rush Creek between 2002 and 2001, but lower than in 1999 and 2000. Standing crops were much lower in the County Road section of Rush Creek in 2002 than in previous years. Estimated trout standing crops were higher in 2002 in all Lee Vining Creek sections, except the main channel portion of the Upper section. Standing crops in 2002 were the highest yet estimated in both the Walker and Parker creek sections.

While young-of-the-year (y-o-y) brown trout remain extremely abundant in all sampled sections, their abundance has declined from previous years. We believe that spawning habitat is probably adequate to fully seed these streams with trout, but the lower estimated numbers of brown trout y-o-y might result in lower numbers of age 1 and older brown trout in subsequent years.

Pool habitats surveys located a total of 45 high quality pools (20 Class 5 and 25 Class 4 pools) in the 10.7 km portion of Rush Creek from the MGORD down to the top end of the County Road Rush Creek sampling section. Most of these high quality pools were located in two distinct reaches: 1) from the MGORD down through our Upper Rush sample section; and 2) from the Narrows down through our Lower Rush sample section. A total of 157 brown trout were observed via snorkeling in ten of these pools in June 2002 and only one brown trout longer than 350 mm was seen. That 350 mm fish was observed during a night dive.

We compared the estimated fish population data for Rush and Lee Vining creeks to the termination criteria adopted by the SWRCB. The termination criteria are:

1. Lee Vining sustained catchable brown trout averaging 8-10 inches in length.
2. Rush Creek fairly consistently produced brown trout weighing ¾ to 2 pounds. Trout averaging 13 to 14 inches were also regularly observed.

In 2002 we estimated that Lee Vining Creek supported 46 to 52 trout per 100 m of channel length or 485 to 780 trout per hectare that were 200 mm (~8 inches) and longer. About 60-80% of these larger fish were brown trout. We believe Lee Vining Creek is approaching termination criteria for fish 8.0 inches and longer. However, only two trout (both were rainbows) longer than 330 mm (~13 inches) were captured in Lee Vining Creek during 2002.

In Rush Creek we only captured six trout (all were brown trout) that were longer than 330 mm (~13 inches) and only five of these trout weighed more than 340 grams (0.75 pound) during 2002. The pool survey information collected thus far support our sample section findings that, except for the MGORD, Rush Creek supports few larger trout. At this time we do not believe that Rush Creek has met the termination criteria. However, the MGORD supports the highest densities of larger trout we have observed, probably due to its "tail water" spring creek characteristics of a relatively stable flow and thermal regime, abundant cover for fish provided by deep water and elodea, and what appears to be ample food production.

The SWRCB requires us to recommend additional quantitative termination criteria for Rush and Lee Vining creeks as well as quantitative termination criteria for Parker and Walker creeks. The lack of historical fish population data makes it very difficult to recommend reasonable quantitative termination criteria with confidence. We recommend that data collection be continued for a few more years so we can develop termination criteria that are more defensible and scientifically based than existing criteria. Additional data collection will also allow us to explore relationships between trout abundance and physical parameters, such as stream flows, water temperatures, and stream channel characteristics, and to better determine the movement patterns and age-class structure of trout. These additional data will help in determining seasonal use of habitats in the system and estimate mortality rates by age and season to better assess termination criteria. We are considering a termination criteria based upon standing crop (biomass per area) as a criteria that would be more stable, quantifiable, and could potentially be adjusted as habitat conditions improve.

Study Area

The same three population estimate sample sections in Rush Creek (County Road, Lower, and Upper) and two (Lower and Upper) in Lee Vining Creek sampled during previous years were again sampled from September 1 to 13, 2002 (Hunter et al. 2001 and 2002; Table 1 and Figure 1). While we expressed previous concerns (Hunter et al. 2001) about the dynamic nature of the stream channels, particularly in Rush Creek, making sample sections dynamic, it was agreed we would maintain existing sample sections after a site visit with representatives from Los Angeles Department of Water and Power (LADWP) in 2001. These sample sections have been changing slightly each year and in some cases we have had to slightly modify our sections to include or exclude newly formed or abandoned side channels. These modifications have resulted in slightly different lengths and areas of wetted channel that have been sampled each year. We continued to sample the middle channel in the upper portion of the Lower Rush Creek sample section and made more detailed length and width measurements of this channel in 2002. This channel was 49 m long and averaged 3.7 m wide. In 2002 we sampled the same length of the side channel associated with the Lower Lee Vining Creek section as we had in all prior years except 2001, when we sampled about 70 addition meters of channel length. We did not make an estimate in the Mono Gate One Return Ditch (MGORD) in 2002 due to LADWP's channel maintenance and reconstruction project.

Table 1. Total length (m), average wetted width (m), and total surface area of sample sections in Rush, Lee Vining, Parker, and Walker creeks sampled from September 1 to September 13, 2002.

Section	Length (m)	Width (m)	Area (m^2)
Rush – County Road	813	8.0	6504
Rush - Lower	405	6.9	2794
Rush – Upper	430	7.4	3182
Lee Vining – Lower	155	4.8	744
Lee Vining - Lower-B1	195	4.8	936
Lee Vining - Upper-main	330	5.8	1914
Lee Vining - Upper-A4	201	4.2	844
Parker	98	2.2	216
Walker	100	1.8	180

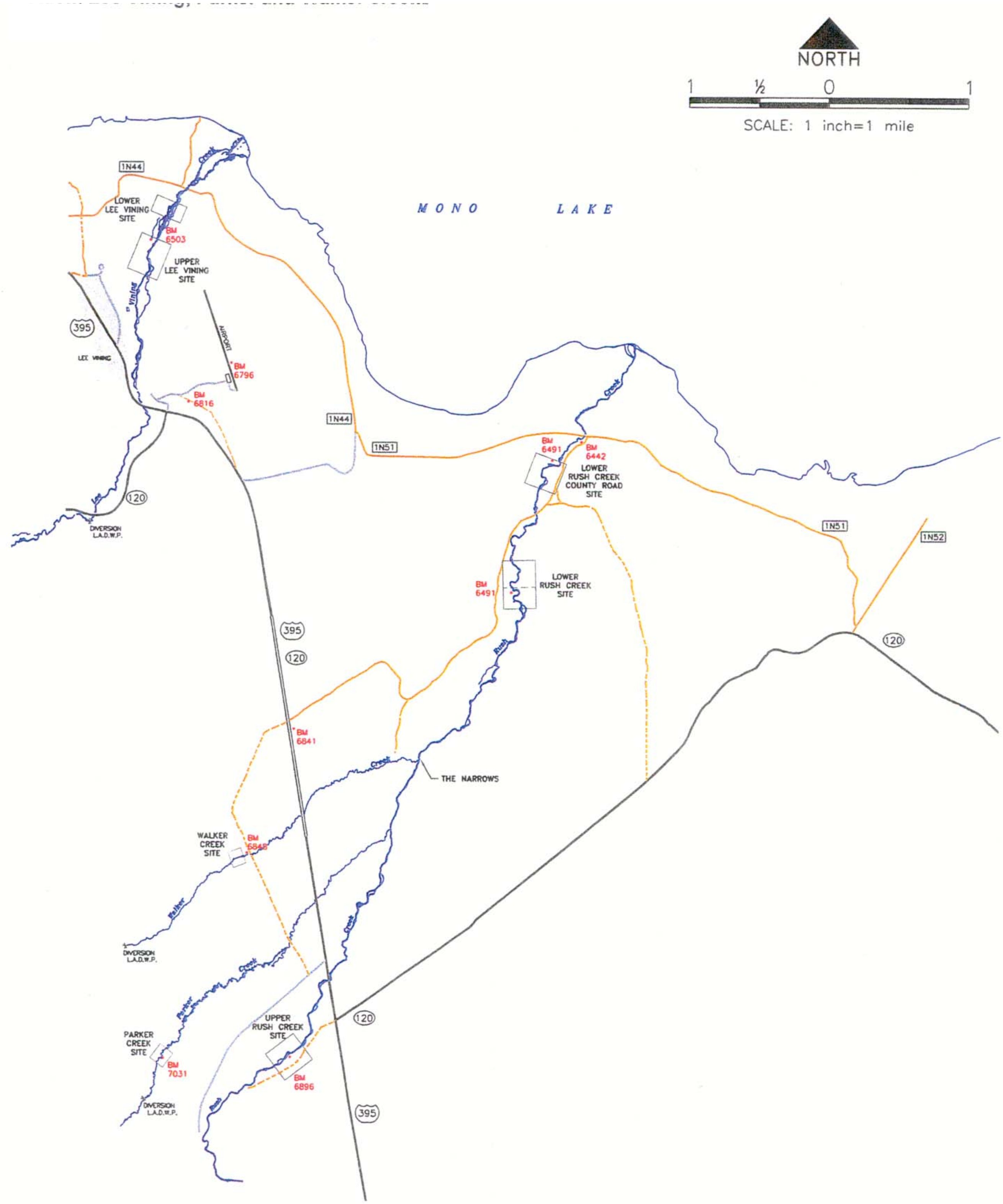


Figure 1. Map of Mono Basin study area with fish sampling sites displayed (from McBain and Trush 2000).

In addition to late summer sampling, we counted and mapped the distribution of pools within Rush Creek from the MGORD downstream through our Lower Rush sample section in June of 2002 and continued this survey downstream to the upper end of the County Road sample section in mid-September 2002. All pool locations were referenced by distance (in km) downstream from the lower end of the MGORD. We used this upstream reference point because with the filling of Mono Lake, the mouth of Rush Creek at Mono Lake does not represent a stable reference point. Stream flows and water temperature data are on file with LADWP and McBain and Trush consultants.

Methods

Fish Population Estimates

During the late summer (September 1 to 12, 2002) mark-recapture estimates were made in the County Road, Lower, and Upper sections of Rush Creek, and the main channels of the Lower and Upper sections in Lee Vining Creek. For all mark-recapture estimate sections fish were captured using a Smith-Root® 2.5 GPP electrofishing system that consisted of a Honda® generator powering a variable voltage pulsator (VVP) that had a rated maximum output of 2,500 watts. This unit was set at 30 or less pulses per second to reduce risk of injury to fish and voltages were set to allow for capture of fish without harming fish. Obtaining this desired response in fish usually resulted in voltages ranging from 300 to 500 and amperes from 0.3 to 1.5. Depletion estimates were made in one sample section within each of Parker and Walker creeks and in the two side-channels of Lee Vining Creek associated with the Lower and Upper sections. For depletion estimates Smith-Root® BP backpack electrofishers (Models 12B and LR-24) were used to capture fish.

During mark-recapture electrofishing, the generator and VVP unit were transported downstream in a small barge. An insulated tub with two battery-powered aerators was carried in the barge to transport captured fish. A person operating a mobile anode and a dip netter fished each half of the stream in a downstream direction (total of two anode operators and two dip netters). All netted fish were placed in the insulated tub within the barge shortly after capture.

Two backpack shockers were used in the two Lee Vining Creek side-channels, while a single backpack shocker was used in each of the Walker and Parker creek sections. At least one dip-netter per electrofisher netted fish stunned by that shocker. Another crew member served as a backup dip-netter and carried a live bucket equipped with an aerator in which all captured fish were placed immediately after capture, except in Walker Creek where one person both netted fish and transported the live bucket.

To meet the assumption of closed populations for sampling purposes, all sample sections, except the County Road Section, were blocked at both ends prior to sampling. Block fences were not placed at the boundaries of the County Road section; however, this section was long enough (813 m) that effects of movements at the ends of the sample section should have been low in proportion to the entire section. In the Upper and Lower Rush Creek sections and main channels of the Upper and Lower Lee Vining Creek sections, 12 mm mesh hardware cloth fences were installed at the upper and lower boundaries of the sections. These hardware cloth fences were installed by driving fence posts at approximately two-meter intervals through the bottom portion of the hardware cloth approximately 15 cm from its bottom edge. Rope was then strung across the top of each fence post and anchored to willows, fence posts, or trees on each bank. The hardware cloth was held vertically by wiring the top of the cloth to this rope with baling wire. These fences were installed prior to the marking run and maintained in place until after the recapture effort was completed. Fences were cleaned and checked at least once daily, and usually twice daily, to ensure they remained in place and for any possible dead fish between mark and recapture sampling. Several storms came through the area between our mark and recapture fishing events. These storms, and the wind associated with these storms, raised stream flows and dramatically increased the amount of leaf and litter debris moving down the stream channels causing most of our block fences to fail at least once. Therefore, the assumption of population closure during the estimates was not met. We discuss the implications of this assumption violation in the Discussion section. For the side channel portions of the Upper and Lower Lee Vining Creek sections and the sample sections in Parker and Walker creeks 12 mm mesh block seines were placed at sample section boundaries during depletion efforts.

All captured fish were anesthetized, measured to the nearest mm (total length), and most were weighed to the nearest gram. Data were entered onto both data sheets and into a hand-held personal computer (Compaq iPAC®) in the field. The lower caudal fin was clipped to mark fish in the County Road section of Rush Creek and in the Upper Lee Vining Creek sections, the anal fin was clipped in the Lower Rush and Lower Lee Vining sections, and the upper portion of the caudal fin was clipped in the Upper Rush Creek section. When clipping a fin, scissors was used to make a straight vertical cut from the top, or bottom, of the fin approximately 1-3 mm deep at a location about 1-3 mm from the posterior edge of the fin. Trout 225 mm and longer captured in Rush Creek were tagged with numbered tags to assess fish movement. Population and biomass estimates were conducted according to methods presented in last year's report (Hunter et al. 2001).

Length-Weight Regression

Length-weight regressions (Cone 1989) were calculated for brown trout in each section of Rush Creek by year to assess differences in length-weight relationships between sections and years. Log_{10} transformations were made on both length and weight prior to running regressions.

Pool Habitat Reconnaissance in Rush Creek

Following the study plan amendment prepared for the LADWP in May 2002 reconnaissance-level pool habitat and snorkeling surveys were conducted in Rush Creek from June 24 to 28 and September 14, 2002. We surveyed 10.73 kilometers of

Rush Creek, starting at the lower end of the MGORD and proceeding downstream to the upper end of the County Road sample section. All habitats identified as pools (Bisson et al. 1981) were classified into quality class (Platts et al. 1983; Appendix A). All of the highest quality pools (Class 5) were referenced by distance (in km) downstream from the outlet of the MGORD, flagged with plastic flagging, and their locations were determined with a Global Positioning System receiver (datum=NAD 27). We used this km upstream reference point at the MGORD because, with the filling of Mono Lake, the mouth of Rush Creek at Mono Lake does not represent a stable reference point.

Since deep pools tend to be the domain of larger trout (Heggenes 2002) and since browns generally seek deeper water associated with cover as they grow (Blades and Vincent 1969; Heggenes 1988; Kocik and Taylor 1996), habitat measurements and snorkel observations were only made in the highest quality pools (Class 5). The relative abundance of fish cover by type (i.e., overhanging and submerged vegetation, woody debris, undercut banks, large rocks, root wads and bubble curtains) was estimated as proportion of pool wetted surface area covered by each type. Eight to 25 depth and velocity measurements were recorded across one or two transects per pool. Size distributions of streambed substrates were estimated using size classifications recommended by Platts et al. (1983). Vegetation along the stream adjacent to each pool was classified into general categories (grass, shrub, tree, or bare ground). Pools were typed according to procedures in Bisson et al. (1981). Day and night snorkel surveys were made in nine Class 5 pools utilizing standard underwater observation techniques (Thurow 1994). In addition, maximum residual depth (maximum depth of the pool tail riffle subtracted from the maximum pool depth; Lisle 1986 and 1987) and maximum pool diameter were recorded for all pools classified as Class 4 and 5.

Results

Fish Population Abundance

Rush Creek

County Road Section

The majority of the brown trout captured in the County Road Section of Rush Creek were from 70 to 110 mm and the longest brown trout captured was 341 mm (Figure 2). Few rainbow trout were captured and most of these were from 50 to 80 mm with three fish over 250 mm (Figure 3). This section supported an estimated 434 age 1 and older and 1,656 age 0 brown trout (Table 2). Estimates of brown trout were relatively precise with standard deviations ranging from 4 to 7% of the estimates. No estimate could be made for rainbow trout age 1 and older, but the section supported an estimated 21 age 0 rainbow trout; however, this estimate was likely biased due to the low number of recaptures (Table 2).

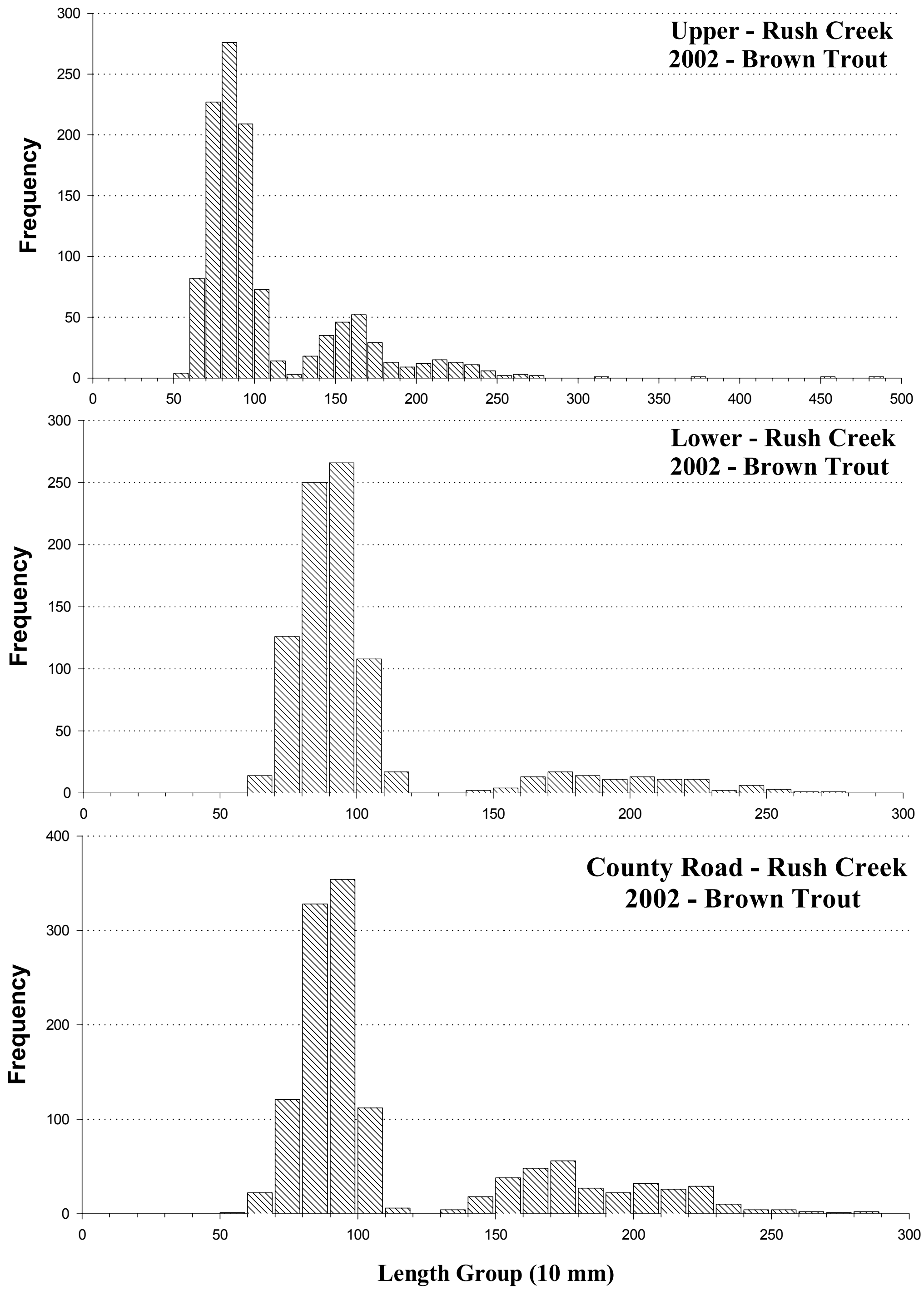


Figure 2. Length frequency histograms of brown trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek from September 1 to September 12, 2002. Note the different scales on both the vertical and horizontal axes between graphs.

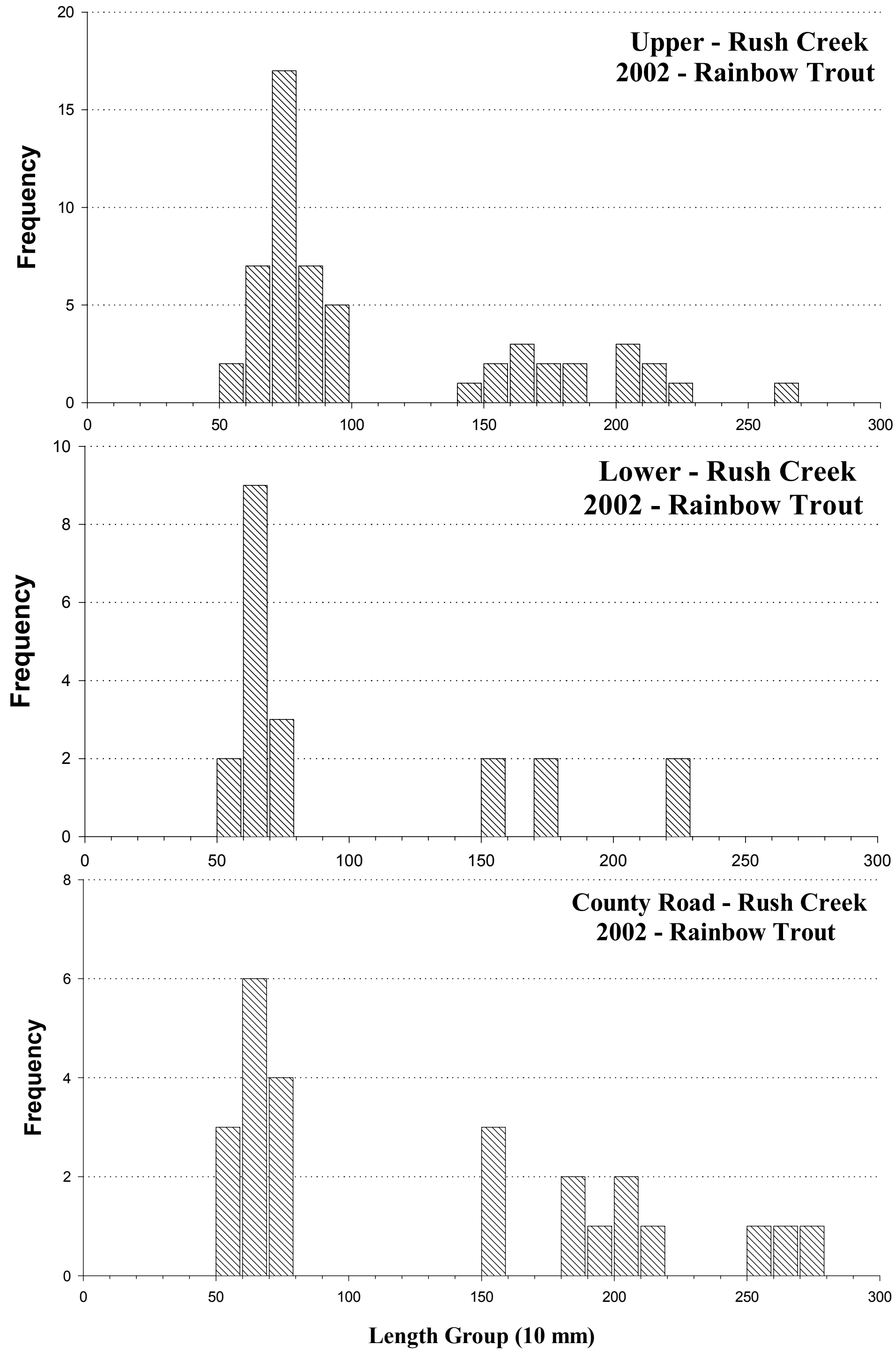


Figure 3. Length frequency histograms for rainbow trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek from September 1 to September 12, 2002. Note the different scales on the vertical axes between graphs.

Table 2. Mark-recapture estimates showing number of fish marked (M), number captured on recapture run (C), number recaptured on recapture run (R), number of mortalities (Morts) between mark and recapture run, estimated number, and standard deviation (S.D.) by stream section, species and length group (YOY = age 0) during September 2001. Estimator method is shown after species (LL=log likelihood; MP=modified Peterson).

Stream (Section)	Mark-Recapture					
Species (Estimator) Length Group	M	C	R	Morts	Estimated[1/] number	S.D.
Rush Creek (County Road Section)						
Brown Trout (MP)						
YOY (< 125 mm)	560	551	186	19	1656	81
125-199 mm	126	146	60	1	303	21
200 + mm	78	79	47	1	131	6
Rainbow Trout (MP)						
YOY (< 125 mm)	5	7	1	2	NP[2/]	-
125 + mm	12	5	5	0	12	0
Rush Creek (Lower Section)						
Brown Trout (LL)						
YOY (< 125 mm)	450	481	179	32	1428	69
125-200 mm	47	45	33	1	92	2
200 + mm	38	33	23	1	71	4
Rainbow Trout (MP)						
YOY (< 125 mm)	10	7	3	0	21	6
125 + mm	4	3	1	0	NP[2/]	-
Rush Creek (Upper Section)						
Brown Trout (MP)						
YOY (< 125 mm)	468	480	71	30	3282	18
125-199 mm	83	103	33	3	256	28
200 + mm	51	51	30	3	89	7
Rainbow Trout (LL)						
YOY (< 125 mm)	11	28	3	0	100	31
150 + mm	12	12	8	0	24	3

Table 2. (Continued).

Stream (Section) Species (Estimator) Length Group	Mark-Recapture M	C	R	Morts	Estimated[1] number	S.D.
Lee Vining Creek (Lower Section – Main Channel)						
Brown Trout (MP)						
YOY (< 125 mm)	16	13	6	2	33	7
125-199 mm	29	29	16	0	52	5
200 + mm	41	35	30	0	48	2
Rainbow Trout (MP)						
YOY (< 125 mm)	0	1	0	0	NP[2/]	-
150 + mm	9	10	7	0	13	1
Lee Vining Creek (Upper Section – Main Channel)						
Brown Trout (LL)						
YOY (< 125 mm)	36	53	14	0	176	30
125-199 mm	46	41	26	0	87	5
200 + mm	29	26	20	0	55	3
Rainbow Trout (LL)						
YOY (< 125 mm)	41	40	9	0	215	35
125-199 mm	21	10	8	0	30	2
200 + mm	21	17	15	0	38	2

1/ To arrive at a complete estimate the mortalities ("Morts") should be added to the "Estimated number".
2/ "NP" denotes that an estimate was not possible for this size group.
3/ The number of recaptured fish for these estimates were below 7, the number recommended for an unbiased modified Peterson estimate.

Lower Section

Length frequencies of brown trout captured in the Lower Section were similar to the distribution observed for the County Road Section (Figure 2). Few rainbow trout longer than 80 mm were captured (Figure 3). This section supported an estimated 163 age 1 and older and 1,428 age 0 brown trout (Table 2). Estimates of all size classes of brown trout were relatively precise with standard deviations ranging from 4 to 6% of the estimates. Again, no estimate could reliably be made for age 1 and older rainbow trout, but this section supported an estimated six age 0 rainbow trout; however, this estimate was likely biased due to the low number of recaptures (Table 2).

Upper Section

Length frequencies of brown trout captured in the Upper Section had a smoother distribution than those observed for the County Road and Lower sections and a few large brown trout, up to 485 mm, were captured (Figure 2). More rainbow trout were captured than in the lower two sections, but the length frequency distribution was similar (Figure 3). The Upper Section of Rush Creek supported an estimated 345 age 1 and older and 3,282 age 0 brown trout (Table 2). This section supported an estimated three age 1 and older and 31 age 0 rainbow trout; however, these rainbow trout estimates were likely biased due to the low number of recaptures.

Lee Vining Creek

Lower Section

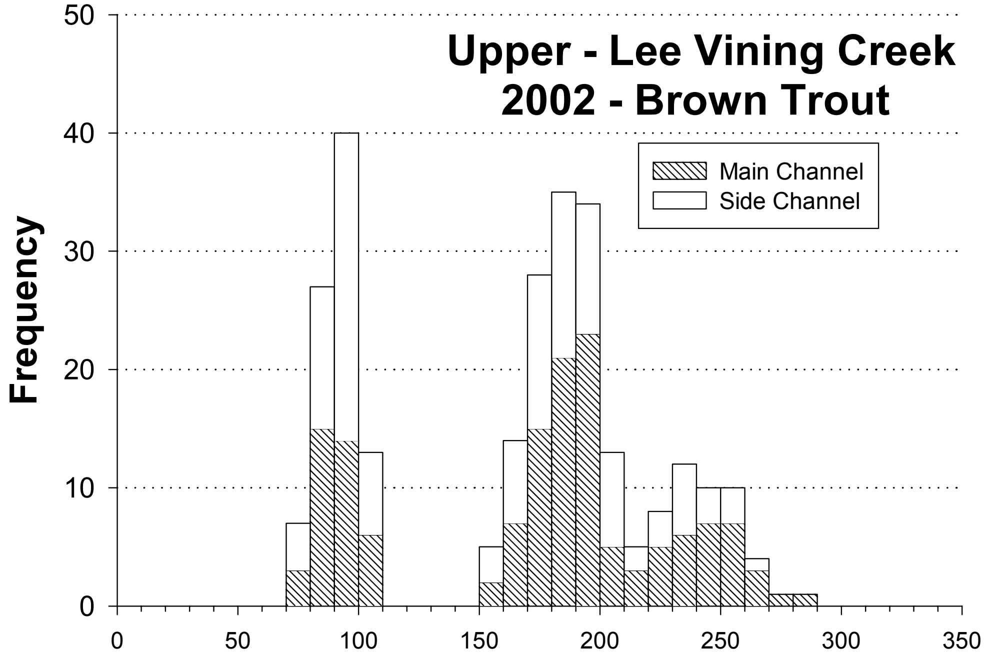
More age 0 brown trout (<125 mm) were captured in the side channel portion than in the main channel portion of the Lower Section of Lee Vining Creek; however, more age 1 and older brown trout were captured in the main channel (Figure 4). Most rainbow trout, especially age 0, were captured in the side channel portion of the Lower Section (Figure 5). The main channel supported an estimated 33 age 0 and 100 age 1 and older brown trout, while the side channel supported an estimated 63 age 0 and 39 age 1 and older brown trout (Tables 2 and 3). No estimate of age 0 rainbow trout could be made for the main channel, but the main channel supported an estimated 13 rainbow trout age 1 and older. The side channel supported an estimated 64 age 0 and 33 age 1 and older rainbow trout.

Upper Section

More age 0 brown trout (< 125 mm) were captured in the side channel than in the main channel of the Upper Section of Lee Vining Creek, while more age 1 and older brown trout were captured in the main channel (Figure 4). More age 0 rainbow trout were captured in the main channel, but more age 1 and older rainbow trout were captured in the side channel (Figure 5). The main channel portion of the Upper Section supported an estimated 176 age 0 and 142 age 1 and older brown trout, and 215 age 0 and 68 age 1 and older rainbow trout (Table 2). The side channel portion supported an estimated 49 age 0 and 74 age 1 and older brown trout, and one age 0 and 33 age 1 and older rainbow trout (Table 3).

Parker Creek

Only brown trout were captured in Parker Creek and most of these were less than 110 mm (Figure 6). Parker Creek supported an estimated 69 age 0 and 23 age 1 and older brown trout (Table 3).



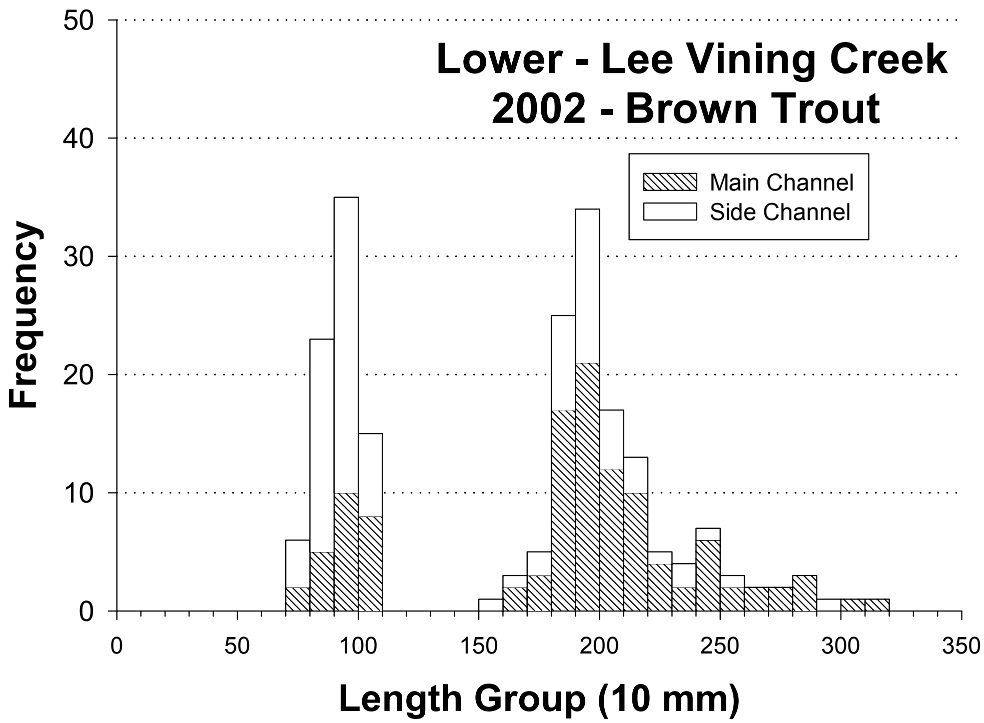


Figure 4. Length frequency histograms for brown trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2002 showing those fish captured in the main channel (cross-hatched bars) and side channel (open bars) portions of each section.

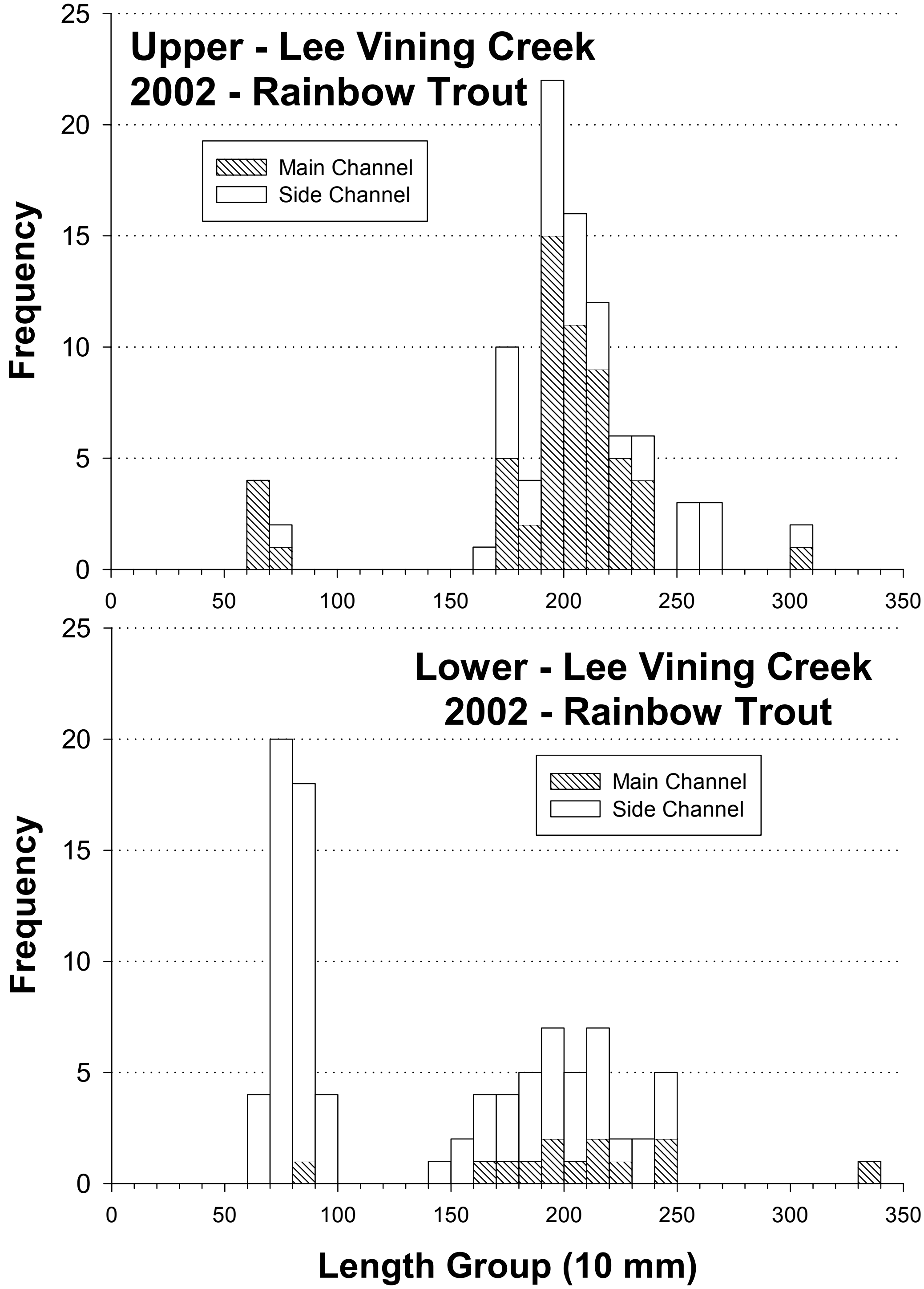


Figure 5. Length frequency histograms for rainbow trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2002 showing those fish captured in the main channel (cross-hatched bars) and side channel (open bars) portions of each section.

Table 3. Depletion population estimates made in the side channel portions of the Lower and Upper sections of Lee Vining Creek and in Parker and Walker creeks during September 2002 showing number of fish captured on each pass, estimated number, and standard deviation (S.D.) by species and length group (YOY = age 0).

Stream (Section) Species Length Group	Number captured per pass 1	2	3	4	Estimated number	S.D.
Lee Vining Creek (Lower Side Channel)						
Brown Trout						
YOY (<125 mm)	38	16	-	-	63	7.5
125-199 mm	20	4	-	-	24	0.9
200 + mm	14	1	-	-	15	0.3
Rainbow Trout						
YOY (<125 mm)	28	17	-	-	64	18.1
125-199 mm	13	3	-	-	16	0.9
200 + mm	16	1	-	-	17	0.3
Lee Vining Creek (Upper Side Channel)						
Brown Trout						
YOY (<125 mm)	43	6	-	-	49	1.0
125-199 mm	44	4	-	-	48	0.6
200 + mm	26	0	-	-	26[1/]	-
Rainbow Trout						
YOY (<125 mm)	1	0	-	-	1[1/]	-
125-199 mm	11	3	-	-	14	1.0
200 + mm	16	3	-	-	19	0.8
Parker Creek						
Brown Trout						
YOY (<125 mm)	31	13	12	6	69	5.2
125-199 mm	5	2	0	1	8	0.5
200 + mm	11	3	1	0	15	0.3
Walker Creek						
Brown Trout						
YOY (<125 mm)	106	42	16	-	173	4.8
125-199 mm	12	4	0	-	16	0.4
200 + mm	7	0	0	-	7[1/]	-

[1/] Maximum likelihood estimate not possible because all fish captured on the first pass. The estimate was considered as the first pass catch.

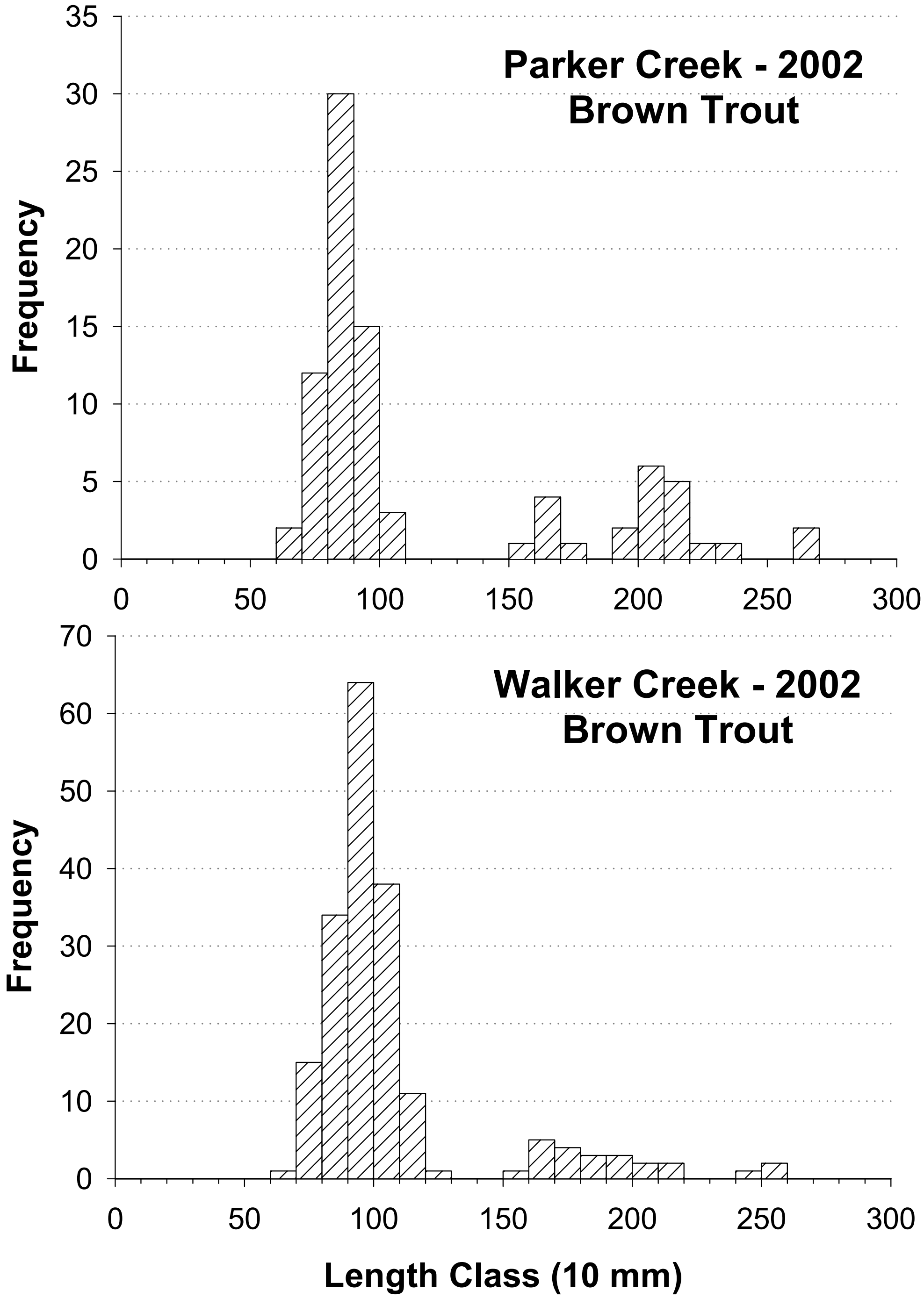


Figure 6. Length frequency histograms for brown trout captured in Parker (upper) and Walker (lower) creeks during September 2002. Note the different scales on the vertical axes.

Walker Creek

Only one rainbow trout (193 mm) was captured in Walker Creek, but 187 brown trout were captured with most being less than 120 mm (Figure 6). Walker Creek supported an estimated 173 age 0 and 23 age 1 and older brown trout (Table 3).

Relative Condition of Brown Trout in Rush Creek

Log_{10} transformed length-weight regressions for brown trout had R^2-values over 0.98 for almost all sample events indicating that weight was strongly correlated to length (Table 4). Length-weight regressions for brown trout from Rush Creek indicated that brown trout captured during 2000 were in better condition (a fish of a certain length weighed more) than those captured during all other years (green lines versus other colors; Figure 7), while fish captured in 2001 were in poorer condition (blue lines versus other colors). Brown trout captured in 2002 were in about average condition compared to the other years.

Table 4. Regression statistics for log_{10} transformed length (L) to weight (WT) for brown trout 100 mm and longer captured in Rush Creek by sample section and year.

Section	Year	N	Equation	R^2	P
County Road	2000	412	$Log_{10}(WT) = 2.936*Log_{10}(L) – 4.827$	0.987	< 0.01
	2001	552	$Log_{10}(WT) = 2.912*Log_{10}(L) – 4.815$	0.979	< 0.01
	2002	476	$Log_{10}(WT) = 2.946*Log_{10}(L) – 4.884$	0.993	< 0.01
Lower	1999	314	$Log_{10}(WT) = 3.027*Log_{10}(L) – 5.078$	0.992	< 0.01
	2000	230	$Log_{10}(WT) = 2.975*Log_{10}(L) – 4.904$	0.985	< 0.01
	2001	350	$Log_{10}(WT) = 2.975*Log_{10}(L) – 4.939$	0.986	< 0.01
	2002	250	$Log_{10}(WT) = 2.907*Log_{10}(L) – 4.784$	0.994	< 0.01
Upper	1999	317	$Log_{10}(WT) = 2.933*Log_{10}(L) – 4.843$	0.981	< 0.01
	2000	309	$Log_{10}(WT) = 3.001*Log_{10}(L) – 4.958$	0.981	< 0.01
	2001	335	$Log_{10}(WT) = 2.987*Log_{10}(L) – 4.958$	0.992	< 0.01
	2002	373	$Log_{10}(WT) = 2.945*Log_{10}(L) – 4.859$	0.989	< 0.01
MGORD	2001	769	$Log_{10}(WT) = 2.873*Log_{10}(L) – 4.719$	0.990	<0.01

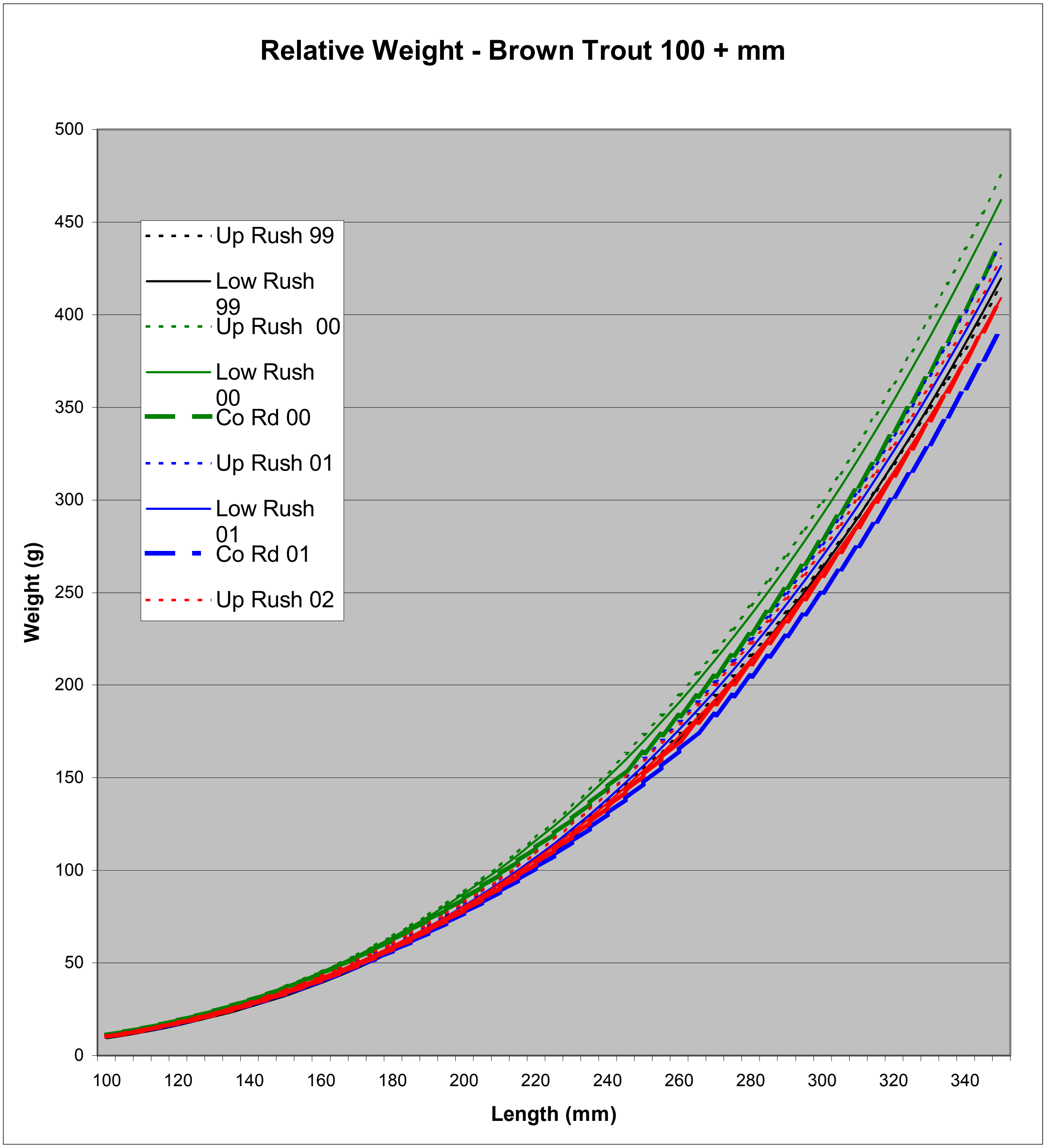


Figure 7. Length-weight regressions for brown trout captured in three sections of Rush Creek during the late summers of 1999, 2000, 2001, and 2002. Legend shows the section (dotted is Upper, solid is Lower, and dashed is County Road) and year (black is 1999, green is 2000, blue is 2001, and red is 2002).

Computation of condition factors for brown trout 150 to 250 mm showed a similar trend as relative weights between years in Rush Creek, where conditions were better during 2000 than other years, but were similar for the other years (Figure 8). Condition factors for the other streams followed a similar pattern, except for Walker Creek. Condition factors were generally 1.0 or higher, indicating an average or slightly better than average condition for brown trout captured in Mono Lake tributaries.

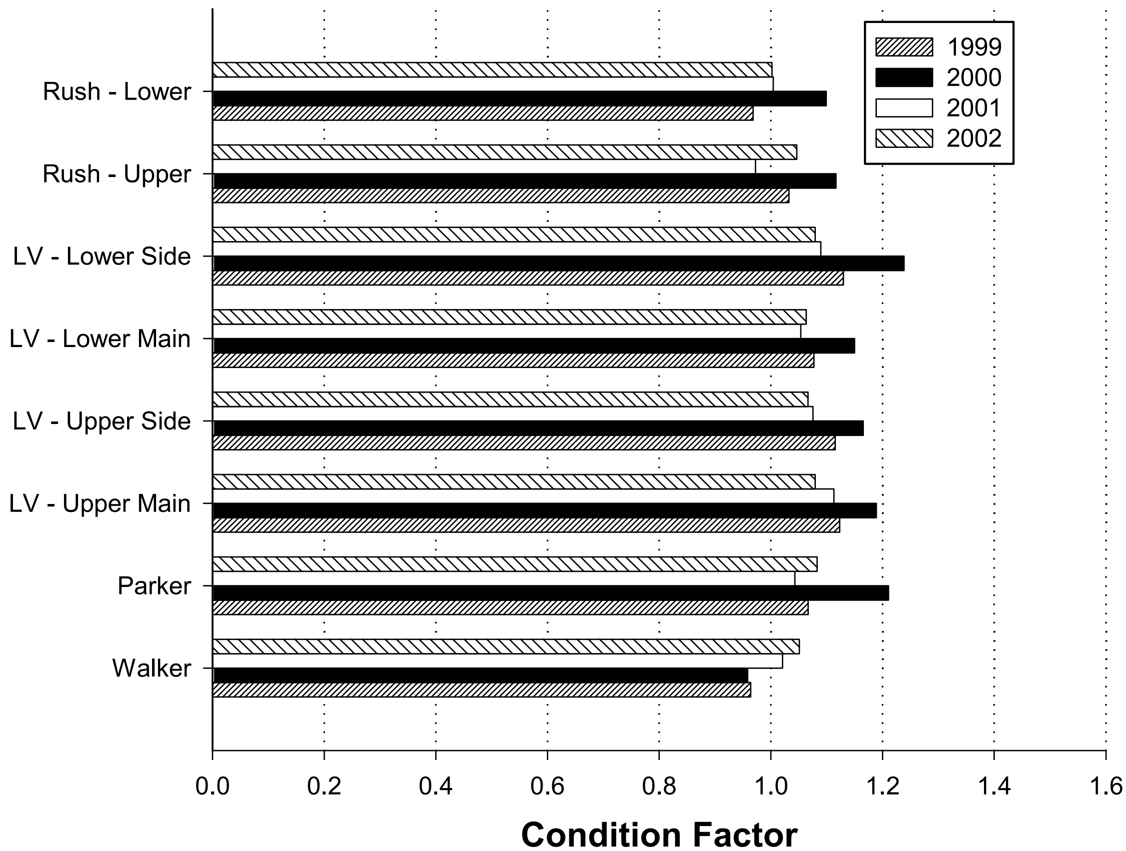


Figure 8. Condition factors for brown trout 150 to 250 mm long in Mono Lake tributaries from 1999 to 2002.

Tags Placed on Fish in Rush Creek Drainage

We tagged 107 brown and rainbow trout within our annual sample sections in the Rush Creek drainage and 22 brown trout below the County Road in Rush Creek (Table 5). All trout that were tagged were 225 mm or longer, except for 14 brown trout tagged in Rush Creek below County Road. We did not recapture any of the 436 fish tagged during March 2001 in Rush Creek during 2002.

Table 5. Number and minimum, maximum, and average lengths of brown and rainbow trout tagged in the Rush Creek drainage during 2002 sampling.

				Length (mm)		
Stream	Section	Species	Number	Min	Max	Average
Rush Creek	Below Co. Rd.	Brown	22	184	279	220.5
Rush Creek	Co. Rd.	Rainbow	3	252	275	263.7
Rush Creek	Co. Rd.	Brown	39	225	341	243.6
Rush Creek	Lower	Brown	19	226	272	241.9
Rush Creek	Upper	Rainbow	1	270	270	270.0
Rush Creek	Upper	Brown	38	225	485	252.2
Parker Creek		Brown	4	229	270	250.8
Walker Creek		Brown	3	241	258	251.7

Pool Habitat Reconnaissance in Rush Creek

Twenty Class 5 and 25 Class 4 pools, the highest quality pools observed, were found in Rush Creek from the MGORD down to the top of the County Road sample section (Table 6; Appendix B). Most of these high quality pools were located in four distinct reaches: 1) immediately below the MGORD; 2) within the Upper Rush sample section; 3) midway between the Narrows down through the Lower Rush sample section; and 4) immediately above the County Road sample section. No decent pools were found within nearly half of the surveyed length (4.7 km), especially from the mouth of Walker Creek down to the Narrows (Appendix B).

Pools located just below the MGORD and within our Upper Rush Section had mean water velocities, as measured across the deepest portions of these pools, ranging from 0.3 to 0.6 meters per second (mps). Mean water velocities in pools from the Narrows down through our Lower Rush sample section were (with one exception) higher than in any other pools where we measured velocities, ranging from 0.5 to 1.0 mps. Lower mean pool water velocities were recorded in pools above the County Road sample section, ranging from 0.2 to 0.5 mps.

Except for the boulder-dominated pools immediately below the MGORD, maximum and residual pool depths generally increased with increasing distance downstream. The shallowest Class 5 pools were within the Upper Rush sample section, where residual pool depths were less than 1.0 m at two of the three pools. The deepest pools were located between the Lower Rush and County Road sample sections, with residual depths exceeding 1.2 m in four of the five pools.

The proportion of cover provided by each cover-type, as well as total cover scores, for the 20 Class 5 pools where cover was assessed indicated that depth, bubble curtains, and boulder were the most common cover types below the MGORD (Table 7). In the

Table 6. Locations of Class-5 pools, as distance below the MGORD, depths, lengths, widths, and water velocities measured within these pools, and number of rainbow and brown trout observed via day and night snorkeling during 2002.

Pool class or stream feature	Distance below MGORD (km)	Max depth (m)	Riffle crest depth (m)	Residual depth (m)	Length (m)	Width (m)	Area (sq. m)	Water velocity (mps)		Number observed				Largest length-class observed (mm)
										Rainbow		Brown		
								Max	Mean	Day	Night	Day	Night	
Class 5 No. 1	0.22	1.6	0.3	1.3	16.5	8.8	477	1.0	0.4	0		5		250-300
Class 5 No. 2	0.39	1.2	0.2	0.9	13.4	7.3	322	1.2	0.6	0		3		200-250
Class 5 No. 3	0.63	1.2	0.2	0.9	13.1	8.8	380	0.8	0.4					
Class 5 No. 4	0.82	1.2	0.3	1.0	13.4	8.2	362	0.8	0.3	0		5		200-250
Top Up. Rush	1.96													
Class 5 No. 5	2.10	0.9	0.2	0.7	21.9	8.5	614	0.8	0.5	0	0	12	7	200-250
Class 5 No. 6	2.23	1.1	0.2	0.9	15.8	9.8	507	0.5	0.3	2	2	20	10	200-250
Class 5 No. 7	2.34	1.2	0.2	1.0	33.8	9.1	1006	0.6	0.3	2	2	28	21	250-300
Bottom Upper Rush	2.37													
Parker Cr.	5.45													
Walker Cr.	6.36													
Class 5 No. 8	7.02	1.2	0.3	0.9	20.7	7.9	539	1.2	0.9					
Class 5 No. 9	7.13	1.2	0.4	0.9	21.3	6.7	469	1.0	0.7	0	0	4	8	350-400
Class 5 No. 10	7.33	1.4	0.4	1.0	13.4	7.3	322	1.0	0.7	0	0	9	4	150-200
Class 5 No. 11	7.35	1.2	0.2	1.0	17.1	7.0	393	0.9	0.5	0	0	9	4	200-250
Class 5 No. 12	7.61	1.1	0.2	0.9	21.9	7.3	527	1.1	0.8					
Class 5 No. 13	7.95	1.4	0.4	1.0	11.3	11.0	406	1.0	0.3					
Class 5 No. 14	8.45	1.4	0.4	1.0	16.5	4.3	230	1.2	1.0					
Top Lower Rush	8.80													
Class 5 No. 15	9.22	1.2	0.2	0.9	13.7	5.2	233	0.9	0.8					
Bottom Lower Rush	9.23													
Class 5 No. 16	9.66	1.6	0.2	1.4	50.6	13.1	2176	0.5	0.2					
Class 5 No. 17	9.81	1.5	0.2	1.2	20.7	6.7	456	0.4	0.4					
Class 5 No. 18	10.01	1.6	0.3	1.3	18.9	7.9	491	0.6	0.5					
Class 5 No. 19	10.13	1.2	0.2	1.0	23.8	5.5	428	0.5	0.3					
Class 5 No. 20	10.53	1.6	0.3	1.3	17.7	11.6	672	0.6	0.3					

Table 7. Proportions of cover types available and total cover scores in Class 5 pools in Rush Creek during 2002.

Cover Type	POOL NUMBER																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Depth	30	15	15	15		10	10	15	25	15	15	10	20	20	10	25	15	20	20	25
Bubble Curtain	20	30	35	55	5			20	20	40	15	15		15		20	10	10		
Boulders	30	20	15	25	5															
Submerged Woody Debris	5	10	5	5	5	5	10	5	20	5	15	10	25	10	15	15	15	25	20	50
Overhanging Vegetation		5			25	5	20	15	25	20	30	50	35	50	25	5	30	30	20	10
Submerged Vegetation	5		5			15	5						20			10	20		10	10
Root Wads					10	15	10													
Undercut Banks			5								5					10				
Total Cover Score	90	80	80	90	50	50	55	55	90	80	80	85	100	95	50	85	90	85	70	115

rest of the study area, overhanging and/or submerged vegetation and depth generally provided most of the fish cover. The lowest total cover scores were found in pools within our sample sections (i.e., Pools 5, 6 and 7 in Upper Rush and Pool 15 in Lower Rush). Three of the nine highest total habitat scores were in pools located within the stream reach between the Lower Rush and County Road sample sections.

Discussion

Reliability of Estimates

As we explained in the Methods, several storms came through the area between our mark and recapture fishing events during 2002. These storms caused block fences in the Lower and Upper Rush Creek and main channel sections of Lower and Upper Lee Vining Creek to fail, at least for short time periods. While we do not believe block fence failures were too significant in most sections, since fences only partially failed in these sections, the block fences at both boundaries of the Upper Rush Creek section went totally down on several occasions and, in some cases, may have been down for several hours. Another factor that contributed to block fence failures in 2002 was the weakened condition of the fencing material after four years of use, thus it is important that new fencing be purchased for sampling in 2003. Our inability to meet the population closure assumption could have resulted in over-estimates of fish populations, especially if marked fish moved out of, or unmarked fish moved into, a sample section.

Estimate and Standing Crop Comparisons

Densities (number per hectare) of age 1 and older brown trout were higher in 2002 than in any previous year in all sections of Lee Vining Creek, but were lower in all sections of Rush Creek (Figure 9). Densities in 2002 were similar as previous years in Walker Creek and similar to 2001, but higher than 1999 and 2000, in Parker Creek. We note that standard errors for some estimates were extremely low and either do not show up on the graph, or were actually estimated as zero, due to extremely high capture efficiencies (see Hunter et al. 2002). Mark-recapture estimates in the Upper Rush Creek section may have been an over-estimate in both 2000 and 2002 due to block fence failure allowing movement of fish into and out of the section between the mark and recapture events. However, the data suggest that while this may have been a problem in 2000, it probably was not too significant a problem in 2002 (Figure 9). The Rush Creek, Lower Main Channel of Lee Vining Creek, Parker Creek, and Walker Creek sections supported similar densities of age 1 and older brown trout, from 1,000 to 1,500 per hectare, during 2001. Densities of age 1 and older rainbow trout were higher in 2002 in the lower portion of Lee Vining Creek, but similar to past years in the upper portion (Figure 10). Densities of age 1 and older rainbow trout were slightly lower in all Rush Creek sections (Figure 10).

Estimates of trout standing crops (kg/hectare) were similar in Lower and Upper Rush Creek between 2002 and 2001, but lower than in 1999 and 2000 (Figure 11). Standing crops were lower in the County Road section of Rush Creek in 2002 than in previous

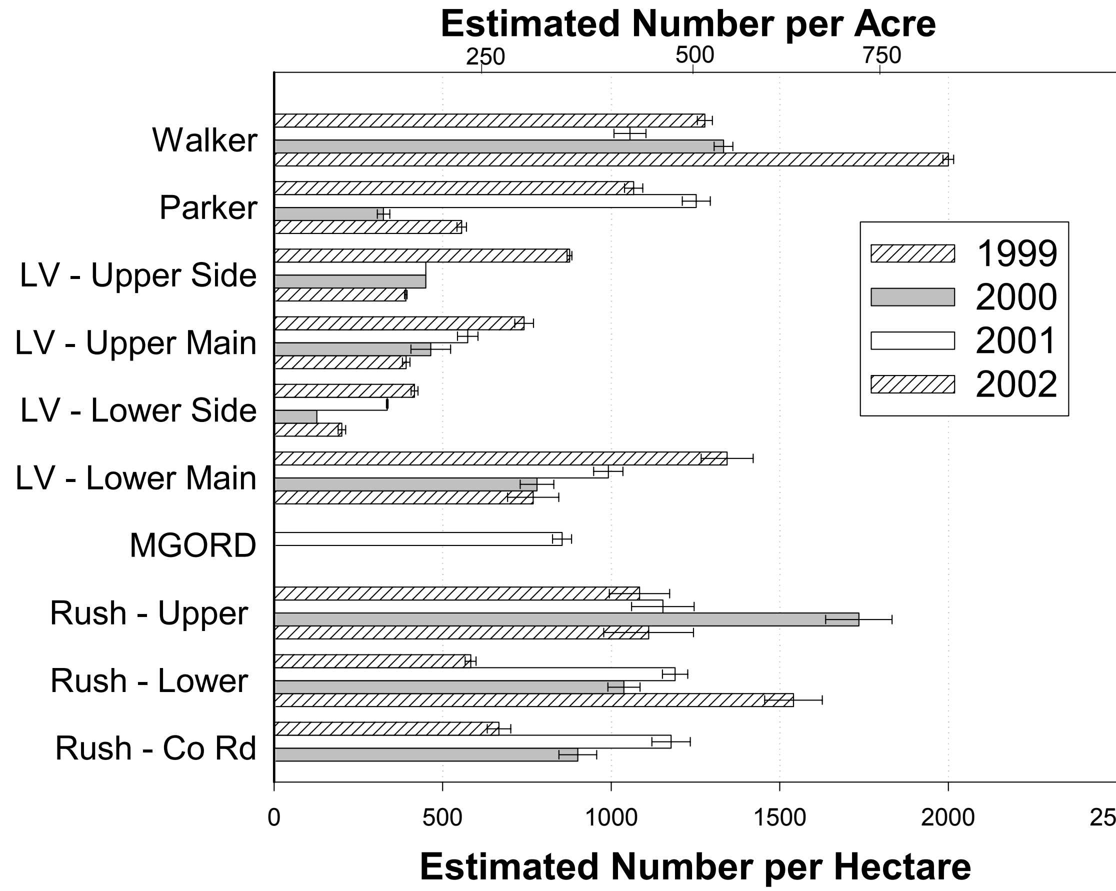


Figure 9. Estimated number (standard errors shown as capped horizontal lines) of age 1 and older brown trout per hectare (bottom axis; or per acre on top axis) in sections of Walker, Parker, Rush, and Lee Vining creeks during September 1999, 2000, 2001, and 2002.

years. Estimated trout standing crops were higher in 2002 in all Lee Vining Creek sections, except the main channel portion of the Upper section. Standing crops in 2002 were the highest yet estimated in both the Walker and Parker creek sections. As mentioned previously, a rainbow trout was captured in Walker Creek in 2002. Estimated standing crops of rainbow trout appeared to have either leveled off or declined in Lee Vining Creek in 2002, compared to previous years' estimates.

Sampling has indicated that age 0 brown trout have been extremely abundant (2,000 to 14,000 per hectare); however, the abundance of age 0 brown trout declined from 2000 to 2001 and remained lower or declined slightly more in 2002 in all sections except for Walker Creek and Upper Lee Vining (Figure 12). These declines may help explain the drop in age 1 and older brown trout in Rush Creek from 2001 to 2002; however, a similar, but slightly lower, drop in age 0 brown trout also was documented in Lee Vining Creek from 2000 to 2001 and we saw no evidence of a subsequent drop in abundance of age 1 and older brown trout from 2001 to 2002 in this stream (Figure 9).

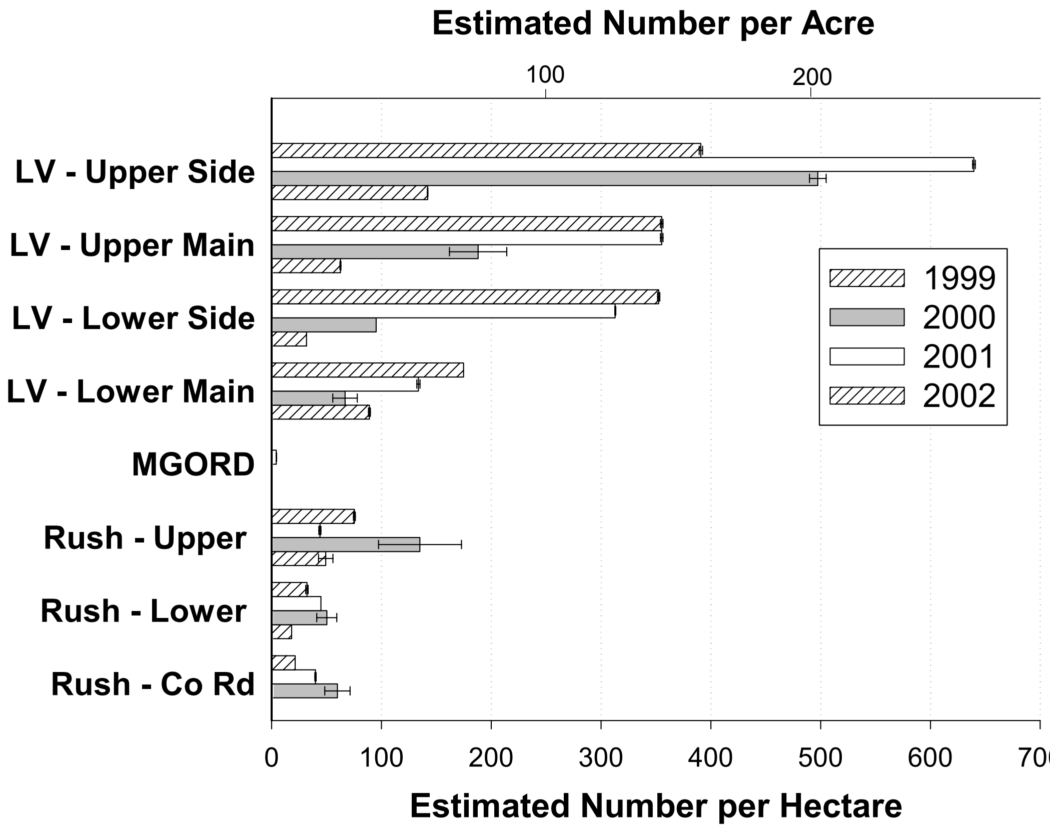


Figure 10. Estimated number (standard errors shown as capped horizontal lines) of age 1 and older rainbow trout per hectare (bottom axis; per acre shown on top axis) in sections of Rush and Lee Vining creeks during September 1999, 2000, 2001, and 2002.

Pool Habitat in Rush Creek

Pool surveys conducted in Rush Creek during 2002 indicated that the types of deep pool habitats with low water velocities (< 0.5 mps) other research has shown to be preferred by brown trout (Blades and Vincent 1969; Heggenes 1988; Kocik and Taylor 1996; Heggenes 2002) were relatively uncommon in Rush Creek. Most (61.4%) brown trout observed by Heggenes' (2002) were found in stream velocities ranging from 0.06 to 0.25 mps. In the upper portion of Rush Creek (Pools 2 through 7), the proportion of measured pool habitats that were deeper than 0.9 m and had water velocities lower than 0.45 mps ranged from 8 to 25% (Table 8; Appendix C). At the pools below the Narrows through our Lower Rush sample section (Pools 9 through 15) depth and velocity conditions improved somewhat, although velocities were still severely limiting in Pools 11 and 15. Pools 17 and 20, where 44 to 67% of the transect measurements were deeper than 0.9 m and water velocities were slower than 0.45 mps, probably offered the best habitat for large brown trout.

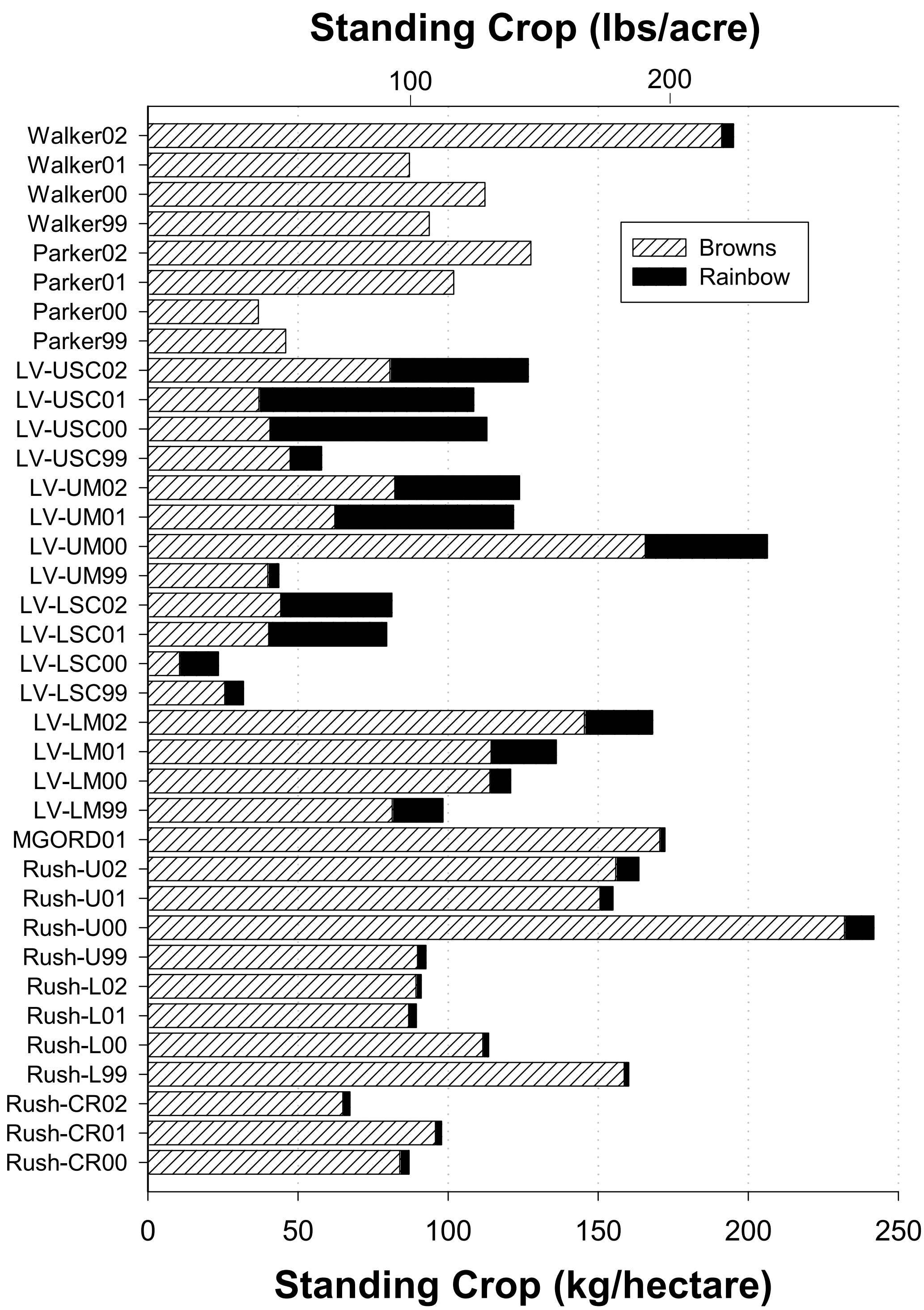


Figure 11. Standing crop (kg/hectare) of age 0 and older brown and rainbow trout in selected Mono Lake tributaries in 1999, 2000, 2001, and 2002. Vertical axis shows stream (LV = Lee Vining), section (U = Upper, L = Lower, SC = side channel, M = main channel, CR = County Road, and MGORD), and year.

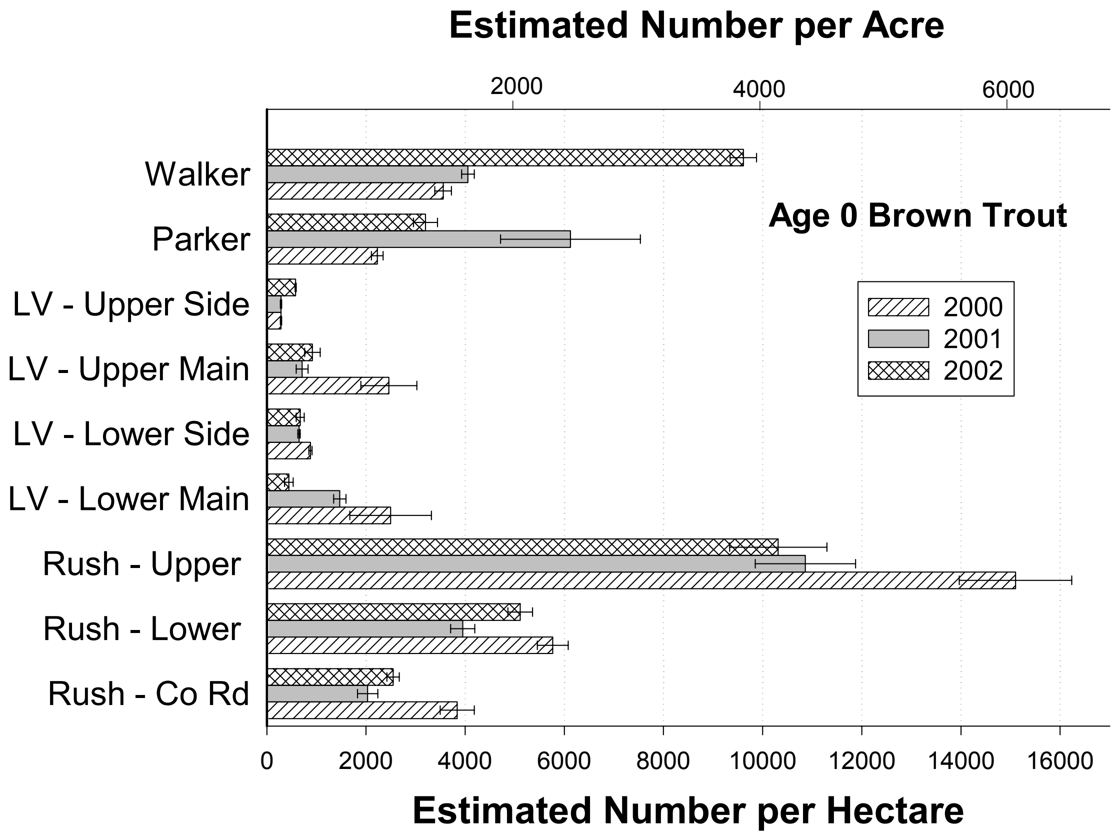


Figure 12. Estimated number (standard errors shown as capped horizontal lines) of age 0 brown trout per hectare in sections of Walker, Parker, Lee Vining, and Rush creeks during September 2000, 2001, and 2002.

Methods Evaluation

Mark-recapture electrofishing appears to be providing relatively reliable estimates; however, our difficulty in maintaining block fences may be biasing estimates. We recommend having an individual dedicated to maintaining block fences during future sampling and obtaining new block fence material every three years to ensure block fences remain effective.

The stream channels, particularly in Rush Creek, are very dynamic. We have observed significant channel migrations and shifts during the four years we have been sampling, even though the last significant flow event that occurred during that time was in 1998 (Figure 13). The changing channel configurations, particularly within our sample sections, change the amount and, in some cases, quality of habitats we sample. While

Table 8. Total number of depth and velocity measurements and number of measurements (%) deeper than 0.9 m and both deeper than 0.9 m with velocities less than 0.45 mps in Class 5 pools in Rush Creek during 2002.

		Depth > 0.9 m		Depth > 0.9 m and velocity < 0.45 mps	
Pool #	Number of measurements	Number		Number	
2	11	5	45%	2	18%
4	8	3	38%	2	25%
6	12	3	25%	1	8%
7	11	4	36%	1	9%
9	11	8	73%	4	36%
11	11	5	45%	1	9%
14	9	6	66%	3	33%
15	9	3	33%	0	0%
17	9	4	44%	4	44%
20	9	7	78%	6	67%

we do not believe these changes have yet been significant enough to render our annual comparisons invalid, we caution that future channel changes following a major high-flow event may be significant enough to make annual comparisons difficult. We will permanently reference upstream and downstream boundaries of all sample sections, re-measure channel lengths and wetted widths, and roughly map each sample section annually to ensure we document significant channel changes within our sample sections.

The relative weights of brown trout in Rush Creek (Figure 7) indicated that brown trout were is slightly better condition in 2000 and slightly lower condition during 2001 than in other years. There may be a relationship between summer flows in Rush Creek below Grant Lake during the two to three years prior to our fall sampling and the relative condition of brown trout (Figure 13); however, it is too soon to definitively assess this potential relationship. Water temperature also likely influences condition of brown trout.

The pool habitat survey we conducted in Rush Creek this past year will help us determine whether our sample sections are representative of overall pool habitat availability throughout Rush Creek. These preliminary results suggest that the Upper Rush sample section has a higher frequency of pools than adjacent reaches (partly a result of earlier habitat enhancement efforts), while the Lower Rush sample section pool habitat may be of lower quality than that found in adjacent reaches. We recommend completing this pool survey from the top of the County Road sample section down to Mono Lake during 2003. Using information from these pool surveys, we will further analyze these data in 2003 to statistically determine how well our sample sections

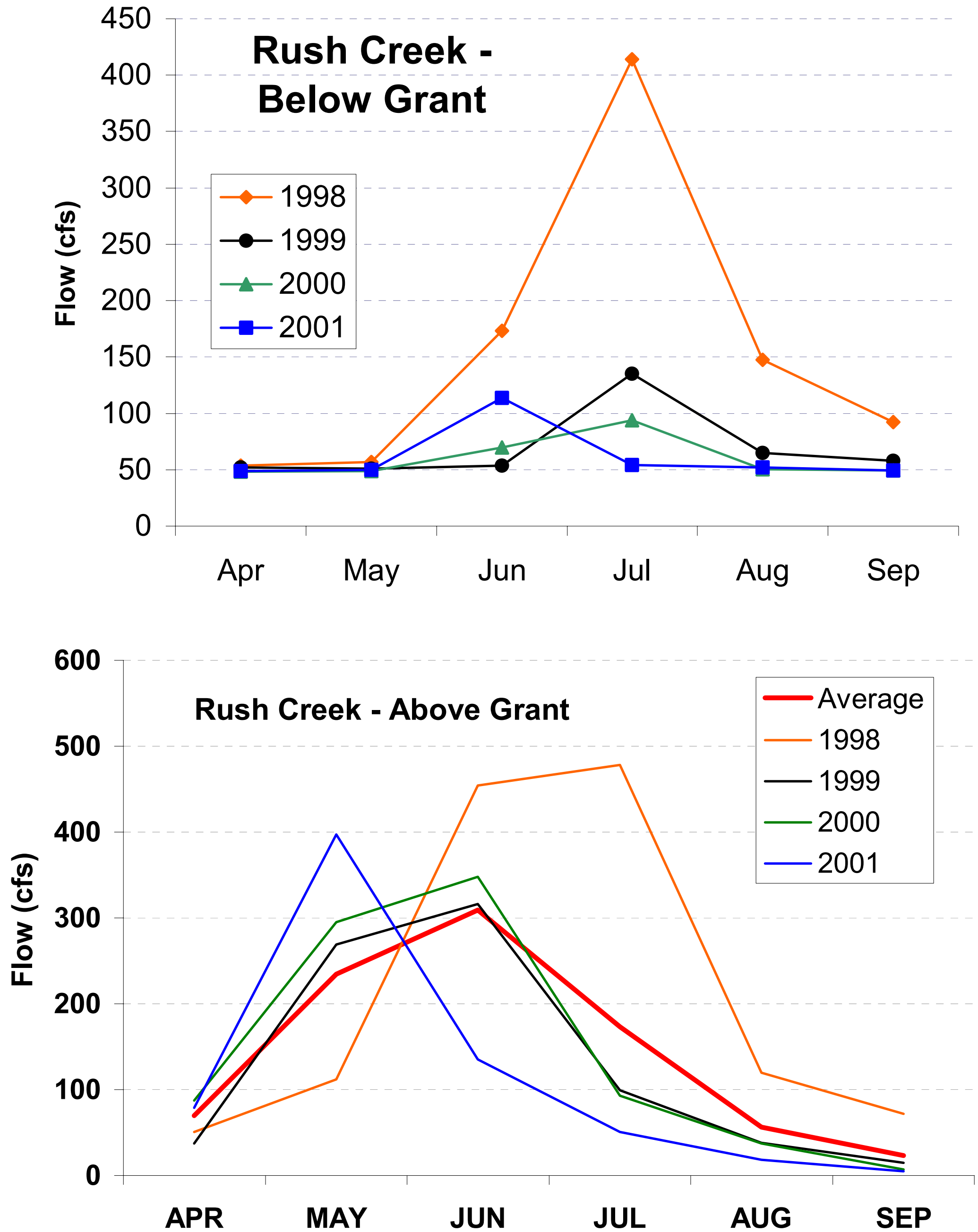


Figure 13. Mean monthly flows (cfs) in Rush Creek from April through September from 1999 to 2001 flowing out of Grant Lake (top) and flowing into Grant Lake (bottom). The long-term (67 years) average monthly flows flowing into Grant Lake are shown on the bottom graph in red.

represent pool habitats in Rush Creek. Our ability to draw conclusions from our sample sections and apply those conclusions throughout Rush Creek will be important in determining whether termination criteria have been met.

Our sampling has indicated that, with the exception of the MGORD, few larger, older trout inhabit these streams, especially Rush Creek. We need to determine if this is because growth is extremely slow, if survival of trout older than age 3 is low, or if older trout migrate up into the MGORD and remain there due to more favorable conditions. We recommend conducting age-growth, survival, and movement studies to determine what mechanism may be responsible for the lack of larger trout in main Rush Creek. We have recommended these studies be included as part of our work plan for 2003-2006. We have recommended that a graduate student and their advisor conduct the movement study through a nearby University to ensure a concentrated and focused study.

Termination Criteria

The agreed upon termination criterion for Lee Vining Creek is to sustain a fishery for brown trout that average 8-10 inches in length with some trout reaching 13 to 15 inches. In 2002 we estimated that the main channel portions of Lee Vining Creek supported 28 to 29 trout 200 mm (~8 inches) and longer per 100 m of channel length and the side channel portions supported 18 to 23 per 100 m. Brown trout comprised from about half to over 80% of these trout. We captured only two trout that exceeded 330 mm (~13 inches) during sampling of Lee Vining Creek during 2002 and these were both rainbow trout (339 and 340 mm) captured in the Lower Main Channel. The density of trout over 200 mm in Lee Vining Creek was 485 to 780 per hectare in 2002 and while brown trout predominated, rainbow trout made up 17 to 41% of these larger fish (Figure 14). Modified Peterson mark-recapture estimates of all trout (both rainbow and brown trout combined) that were longer than 225 mm (~ 9 inches) and longer than 250 mm (~ 10 inches) indicated that it appears that it may be possible to meet previously defined termination criteria in Lee Vining Creek, as sample sections now have about 200-300 trout 225 mm and longer per hectare (about 80-120 trout 9 inches and longer per acre; Figure 15).

The agreed upon termination criterion for Rush Creek states that Rush Creek fairly consistently produced brown trout weighing 0.75 to 2 pounds. Trout averaging 13 to 14 inches (330 to 355 mm) were also allegedly observed on a regular basis prior to the dewatering of this stream. We captured only six brown trout in Rush Creek during 2001 that exceeded 330 mm (~13 inches) in length. Five of these were captured in the Upper Rush Creek section and one in the County Road section. Three of the five larger fish captured in the Upper section were longer than 450 mm (17.7 inches) and the longest was 485 mm (19.0 inches). Only four of these fish weighed more than 340 g (0.75 pound). The estimated densities of larger trout in Rush Creek during 2002 do not indicate that this stream is close to reaching termination criteria (Figures 13 and 14).

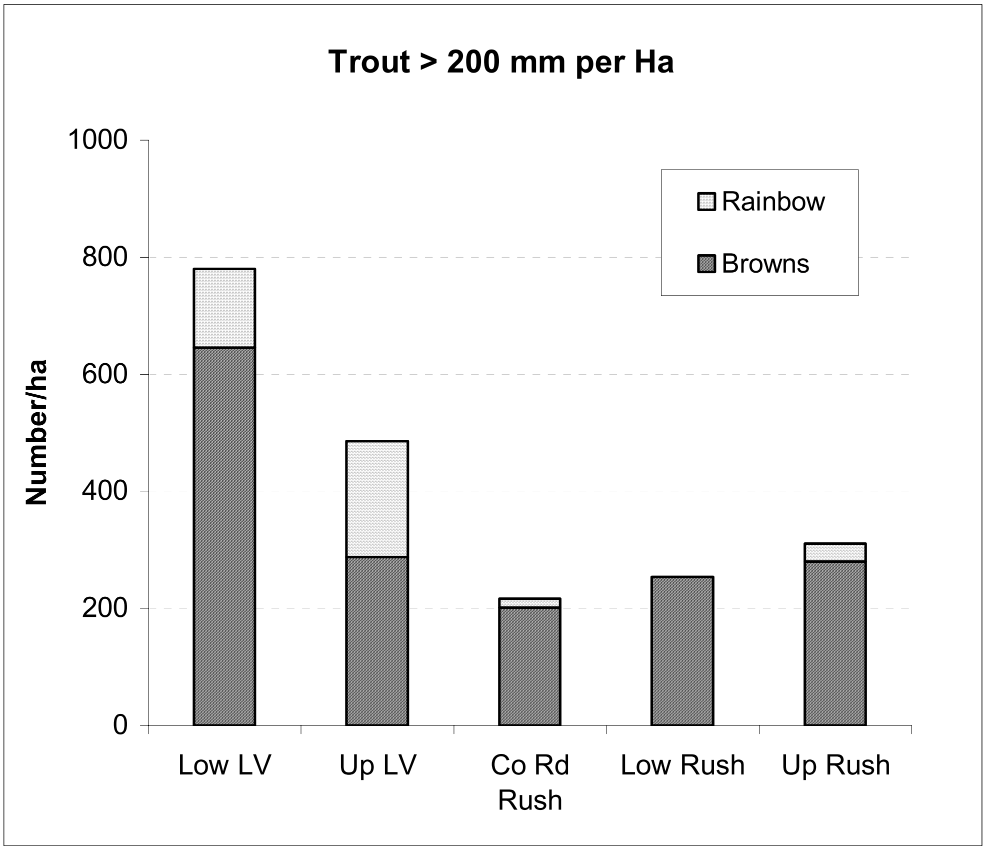


Figure 14. Density (number/ha) of rainbow and brown trout 200 mm and longer in the five sample sections in Lee Vining (LV) and Rush creeks during 2002.

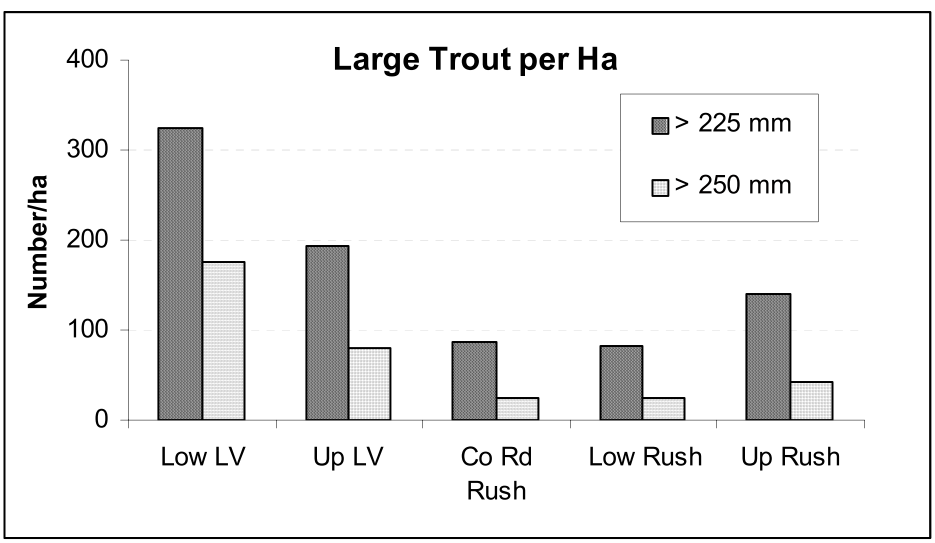


Figure 15. Density of trout (rainbow and browns combined) longer than 225 mm and longer than 250 mm in the five sample sections in Lee Vining (LV) and Rush creeks during 2002.

The pool habitat reconnaissance fish surveys supported information from the annual sample sections, concluding that Rush Creek likely supports few larger brown trout. At this time we do not believe that Rush Creek is meeting the termination criteria. However, if the trout within the MGORD are included as part of Rush Creek's population, Rush Creek may also be able to meet the previously defined termination criteria (Hunter et al. 2002).

Recommended Termination Criteria

Our 2000 report noted that there is virtually no data available that provides an accurate picture of trout populations that these streams supported on a self-sustaining basis prior to 1941 (Hunter et al. 2000). We recommended that additional fish population data be collected from these streams for several years until we have a suitable amount of data upon which to base additional quantitative termination criteria (Hunter et al. 2000 and 2001). This continues to be our recommendation. We also believe that obtaining at least six, and preferably ten, years of continuous fish abundance information will allow us to assess potential relationships between fish populations and physical habitat components, such as flows, physical habitat parameters, and water temperatures.

We are currently considering applying termination criteria that are based upon standing crop estimates. We believe standing crop estimates will be more stable, more quantifiable, and will better relate to carrying capacity of particular stream sections. We also believe some secondary criteria related to population size structure could be developed. Both standing crop and size structure criteria would be related to habitat capability so that as habitat conditions improve, as expected, in Mono Basin streams, both standing crops and proportions of larger fish within the populations should increase.

Acknowledgements

We would like to thank Los Angeles Water Power for their continued support of this project, especially Steve McBain and Dave Martin. Dave Martin of LADWP has provided technical support and field help. Kelly Cashman, Kevin Peterson, Gary Hoopen, Helen Stroud, and numerous others assisted with fish sampling efforts. The owners and staff of the Latte Da and Mobile Station in Lee Vining, and Boulder Lake Lodge at June Lake have consistently provided good lodging, good food, and good conversation. The Mono Lake Committee has assisted with copying field data sheets and allowing us to use their Internet computer terminals. McBain and Trush Consultants provided maps, water temperature information, and completed physical surveys of sample sites. Darren Mierau of McBain and Trush assisted with fieldwork and logistic support during 1999 and 2000.

References

Baldes, R.J. and R.E. Vincent. 1969. Physical parameters of microhabitats occupied by brown trout in an experimental flume. Transactions of the American Fisheries Society 98:230-238.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, and L.E. Grove. 1981. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flows. Pages 62-73 *in* N. B. Armantrout, editor. Acquisition and Utilization of Aquatic Habitat Inventory Information. American Fisheries Society, Bethesda, Maryland.

Hasencamp, B. 1994. Lower Rush Creek Flow Analysis. LADWP Aqueduct Division, Los Angeles, CA. 13 p.

Heggenes, J. 1988. Effects of short-term flow fluctuations on displacement of, and habitat use by, brown trout in a small stream. Transactions of the American Fisheries Society 117:336-344.

Heggenes, J. 2002. Flexible summer habitat selection by wild, allopatric brown trout in lotic environments. Transactions of the American Fisheries Society 131:287-298.

Hunter, C., B. Shepard, K. Knudson, R. Taylor. 2000. Fisheries monitoring report for Rush, Lee Vining, Parker and Walker creeks: 1999. Annual report to Los Angeles Department of Water and Power, Los Angeles, California.

Hunter, C., B. Shepard, K. Knudson, R. Taylor. 2001. Fisheries monitoring report for Rush, Lee Vining, Parker and Walker creeks: 2000. Annual report to Los Angeles Department of Water and Power, Los Angeles, California.

Kocik, J.F. and W.W. Taylor. 1996. Effect of juvenile steelhead on juvenile brown trout habitat use in a low-gradient Great Lakes tributary. Transactions of the American Fisheries Society 125:244-252.

Lisle, T. E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. North American Journal of Fisheries Management 6:538-550.

Lisle, T. E. 1987. Using "residual depths" to monitor pool depths independently of discharge. Research Note PSW-394, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Platts, W. S., Megahan, W. F., and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service, Intermountain

Forest and Range Experiment Station, General Technical Report INT-138. Ogden, Utah.

Riley, S. C. and Fausch, K. D. 1992. Underestimation of trout population size by maximum-likelihood removal estimates in small streams. North American Journal of Fisheries Management 12(4):768-776.

Thurow, R. F. 1994. Underwater Methods for Study of Salmonids in the Intermountain West. General Technical Report INT-GTR-307, Intermountain Research Station, Ogden, Utah.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-Recapture and Removal Methods for Sampling Closed Populations. LA-8787-NERP UC-11. U.S. Department of Energy, Los Alamos National Laboratory, Los Alamos, New Mexico.

Appendix A – Platts et al. (1983) Pool Quality Criteria

Rating of pool quality; in streams of order 3 through 5		
	Description	**Pool Rating**
1A	Maximum pool diameter is within 10 percent of the average stream width of the study site …………………...Go to 2A, 2B	
1B	Maximum pool diameter exceeds the average stream width of the study site by 10% or more………………….Go to 3A, 3B, 3C	
1C	Maximum pool diameter is less than the average stream width of the study site by 10% or more………………….Go to 4A, 4B, 4C	
2A	Maximum pool depth is less than 2 feet ………………………...Go to 5A, 5B	
2B	Maximum pool depth is greater than or equal to 2 feet…………Go to 3A, 3B, 3C	
3A	Maximum pool depth is greater than or equal to 3 feet in depth, regardless of cover conditions, or depth is greater than or equal to 2 feet with abundant fish cover (1)……………………..	Rate 5
3B	Maximum pool depth is less than 3 feet, with intermediate to abundant cover, or is between 2 and 3 feet and lacks abundant cover………………………..	Rate 4
3C	Maximum pool depth is less than 2 feet and fish cover is rated as exposed……………………………………………………………………...	Rate 3
4A	Maximum pool depth is greater than or equal to 2 feet with intermediate (2) or better cover …………………………………………………	Rate 3
4B	Maximum pool depth is less than 2 feet, but fish cover is intermediate or better, or depth is greater than or equal to 2 feet with exposed cover conditions…………………………………………………...	Rate 2
4C	Maximum pool depth is less than 2 feet and pool is rated as exposed (3)…………………………………………………………………	Rate 1
5A	Pool with intermediate to abundant cover…………………………………………..	Rate 3
5B	Pool with exposed cover conditions………………………………………………...	Rate 2

(1) If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.
(2) If cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.
(3) If cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

Appendix B – Rush Creek Pool Survey Measurements

Appendix Table 1. Locations of class-4 and class-5 pools, as well as other stream landmarks, and summaries of dimensional and current velocity measurements collected at the pools during the summer of 2002.

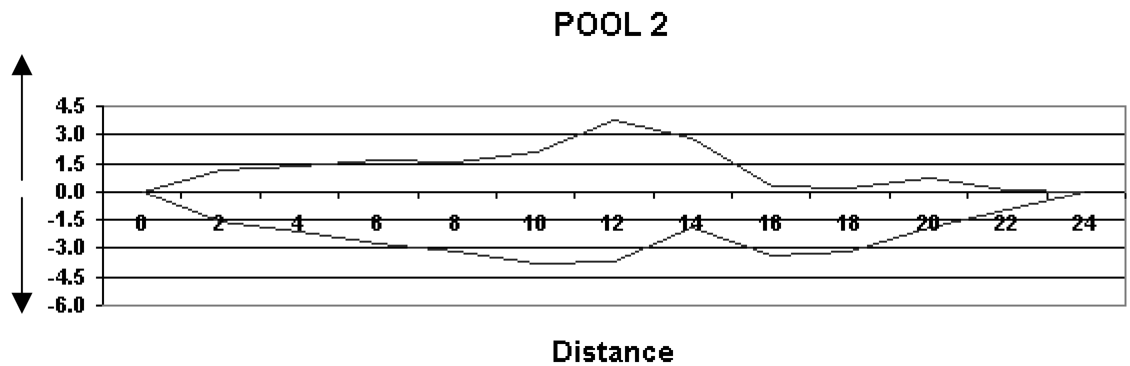
Pool Number or other Stream Feature	Distance Below MGORD (ft)	Lat. N37	Long. W119	Pool Depth Maximum	Pool Depth Riffle Crest	Pool Depth Residual	Pool Length	Pool Approx. Width	Pool Approx. Area	Water Velocity (cfs) Maximum	Water Velocity (cfs) Mean
Class 5 No. 1	717	52.283	06.387	5.1	0.9	4.2	54	29	1566	3.2	1.3
Class 4 No. 1	1200	52.354	06.388	3.6	1.1	2.5	69		1056		
Class 5 No. 2	1284	52.367	06.396	3.8	0.8	3.0	44	24	1056	3.8	2.1
Class 4 No. 2	1298	52.367	06.396	3.2	0.8	2.4	32				
Class 4 No. 3	1786	52.447	06.438	3.2	0.8	2.4	40				
Class 5 No. 3	2060	52.470	06.472	3.8	0.8	3.0	43	29	1247	2.6	1.2
Class 4 No. 4	2585			3.3	1.0	2.3	25				
Class 5 No. 4	2700	52.560	06.428	4.1	0.9	3.2	44	27	1188	2.7	1.1
Class 4 No. 5	2780	52.571	06.432	4.5	1.0	3.5	18				
Class 4 No. 6	5698	52.878	06.033	3.1	0.8	2.3	46				
Start of Up. Rush Sec.	6444	52.917	05.893								
Class 5 No. 5	6875	52.955	05.823	2.9	0.6	2.3	72	28	2016	2.7	1.8
Class 5 No. 6	7300	52.990	05.774	3.6	0.7	2.9	52	32	1664	1.7	1.0
Class 5 No. 7	7685	53.019	05.705	3.9	0.7	3.2	111	30	3300	1.9	1.1
End of Up. Rush Sec.	7768	53.032	05.685								
Hwy 395 Bridge (upper)	11013										
Hwy 395 Bridge (lower)	11310										
Class 4 No. 7	14420	53.900	05.244	2.5	0.5	2.0	68				
Class 4 No. 8	17750	54.357	04.969	2.6	0.6	2.0	42				
Mouth of Parker Cr.	17870	54.379	04.975								
Class 4 No. 9	20660	54.706	04.757	3.2	1.0	2.2	38				
Mouth of Walker Cr.	20850	54.814	04.745								
Class 4 No. 10	20915	54.824	04.743	3.3	1.2	2.1	32				
Class 4 No. 11	22730	55.008	04.468	2.2	0.4	1.8	30				
Class 5 No. 8	23016	55.005	04.416	3.8	1.0	2.8	68	26	1768	4.1	3.1

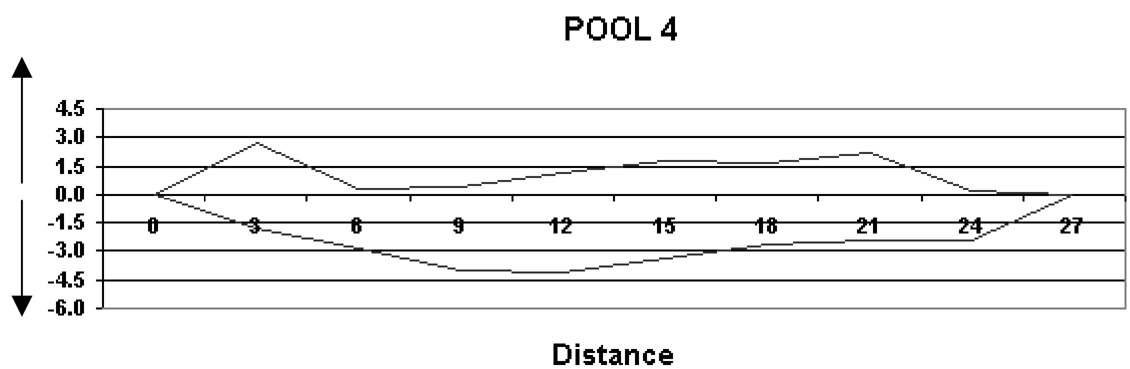
Table 1. Continued…

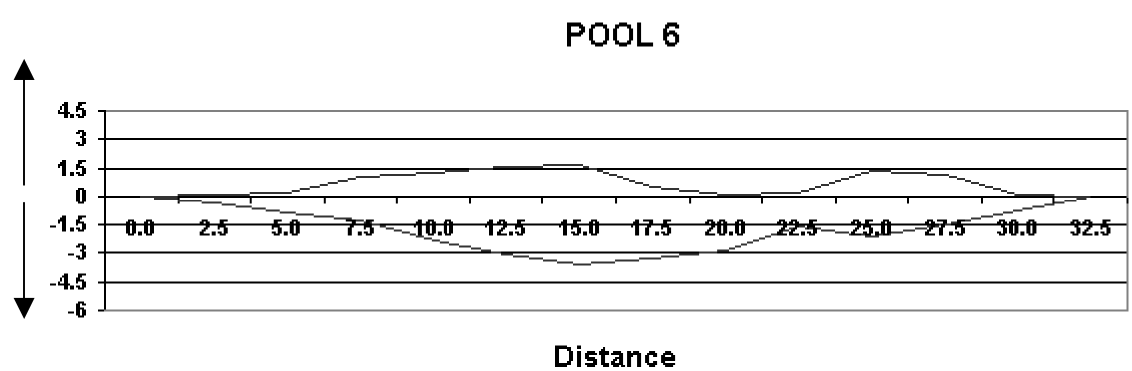
Pool Number or other Stream Feature	Distance Below MGORD (ft)	Lat. N37	Long. W119	Pool Depth Maximum	Pool Depth Riffle Crest	Pool Depth Residual	Pool Length	Pool Approx. Width	Pool Approx. Area	Water Velocity (cfs) Maximum	Water Velocity (cfs) Mean
Class 4 No. 12	23135	55.022	04.403	3.5	0.7	2.8	38				
Class 5 No. 9	23375	55.049	04.373	4.1	1.2	2.9	70	22	1540	3.3	2.3
Class 5 No. 10	24050	55.150	04.335	4.6	1.3	3.3	44	24	1056	3.2	2.4
Class 5 No. 11	24110	55.157	04.329	4.1	0.8	3.3	56	23	1288	2.8	1.7
Class 4 No. 13	24560	55.222	04.288	3.2	1.0	2.2	52				
Class 5 No. 12	24950	55.275	04.259	3.6	0.8	2.8	72	24	1728	3.5	2.6
Class 4 No. 14	25090	55.291	04.238	3.2	1.4	1.8	46				
Class 5 No. 13	26070	55.407	04.137	4.5	1.3	3.2	37	36	1332	3.3	1.0
Class 4 No. 15	27600	55.604	03.973	3.6	1.5	2.1	30				
Class 5 No. 14	27725	55.621	03.972	4.5	1.3	3.2	54	14	756	3.8	3.2
Start of Low. Rush Sec.	28860										
Class 4 No. 16	29470	55.819	03.995	3.5	1.0	2.5	40				
Class 4 No. 17	29720	55.834	03.975	3.3	1.0	2.3	38				
Class 4 No. 18	29945	55.867	03.953	3.4	1.1	2.2	46				
Class 5 No. 15	30250	55.886	04.003	3.9	0.8	3.1	45	17	765	2.9	2.7
End of Low. Rush Sec.	30285	55.892	04.005								
Class 4 No. 19	30948	55.999	04.004	3.7	1.1	2.6	54				
Class 5 No. 16	31669	56.090	04.068	5.4	0.8	4.6	166	43	7138	1.6	0.8
Class 4 No. 20	32128	56.160	04.048	4.0	1.2	2.8	38				
Class 5 No. 17	32193	56.156	04.051	4.9	0.8	4.1	68	22	1496	1.2	1.2
Class 4 No. 21	32387	56.167	04.073	3.5	1.1	2.4	41				
Class 5 No. 18	32833	56.215	04.032	5.1	0.9	4.2	62	26	1612	2.1	1.5
Class 5 No. 19	33235	56.218	03.981	4.1	0.8	3.3	78	18	1404	1.8	1.0
Class 4 No. 22	33431	56.263	03.959	3.0	0.7	2.3	58				
Class 4 No. 23	33749	56.293	03.960	3.4	0.9	2.3	68				
Class 4 No. 24	34375	56.292	03.880	3.5	1.1	2.4	72				
Class 5 No. 20	34542			5.2	1.0	4.2	58	38	2204	2.1	0.9
Class 4 No. 25	34835	56.335	03.863	3.5	0.9	2.6	38				
Start of Co. Rd. Sec.	35205	56.381	03.834								

Appendix C – Depth and Velocity Profiles of Pools in Rush Creek

Appendix Figure 1. Velocity (cfs) and depth (-ft) measurements taken along cross-sections (transects)--shown as "Distance"--at ten class-5 pools on Rush Creek during the summer of 2002.







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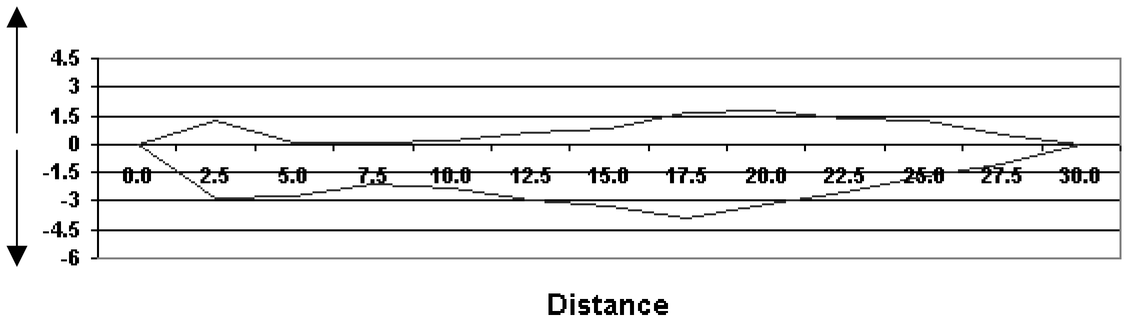
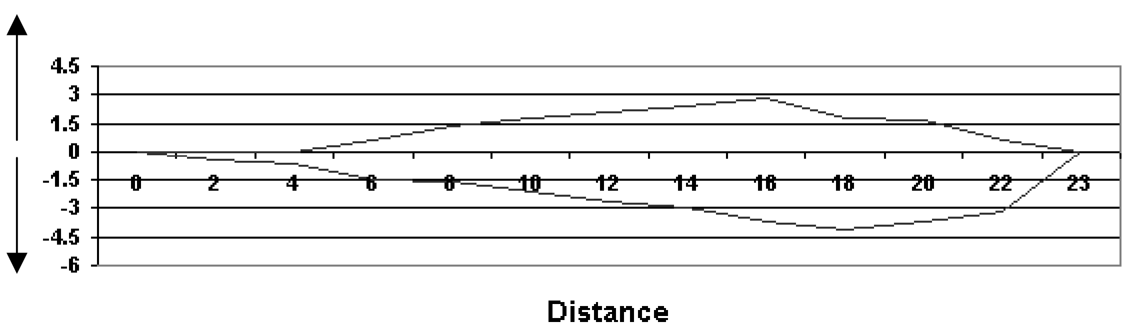
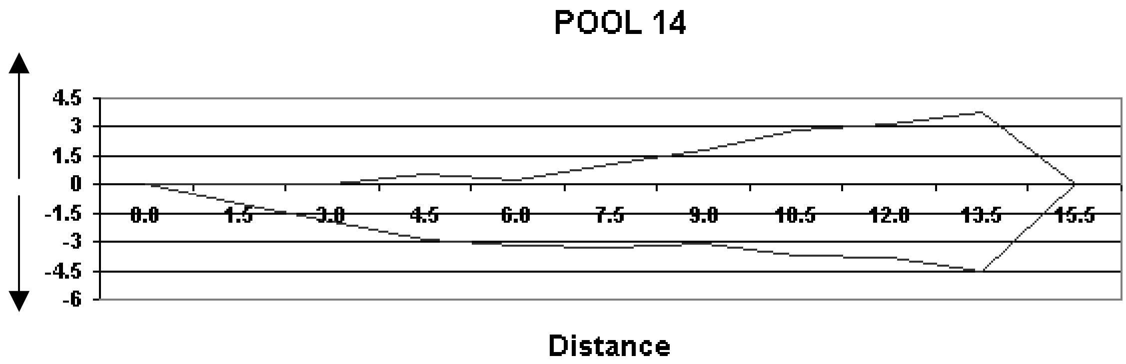


POOL 9

POOL 11

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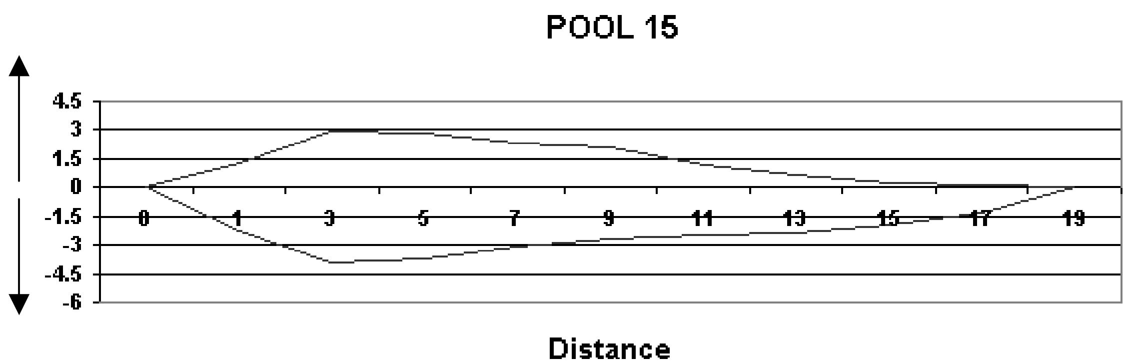
13.5
15.5
Distance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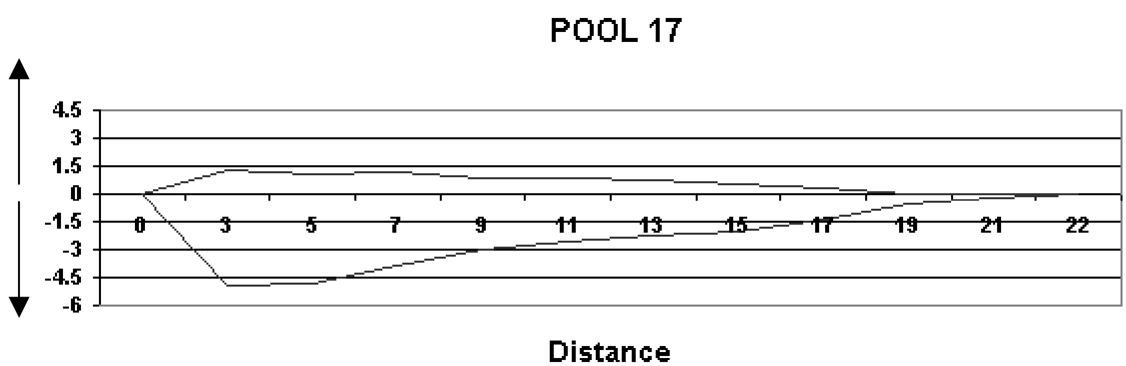
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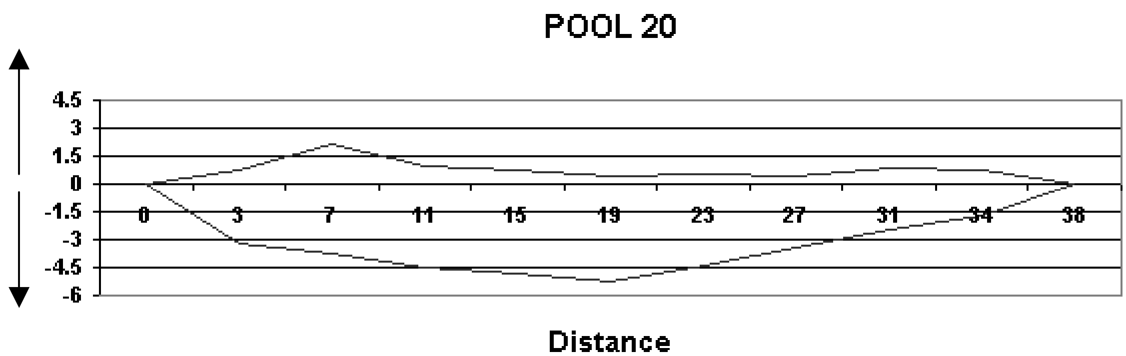
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23
27
31
34
38
Distance

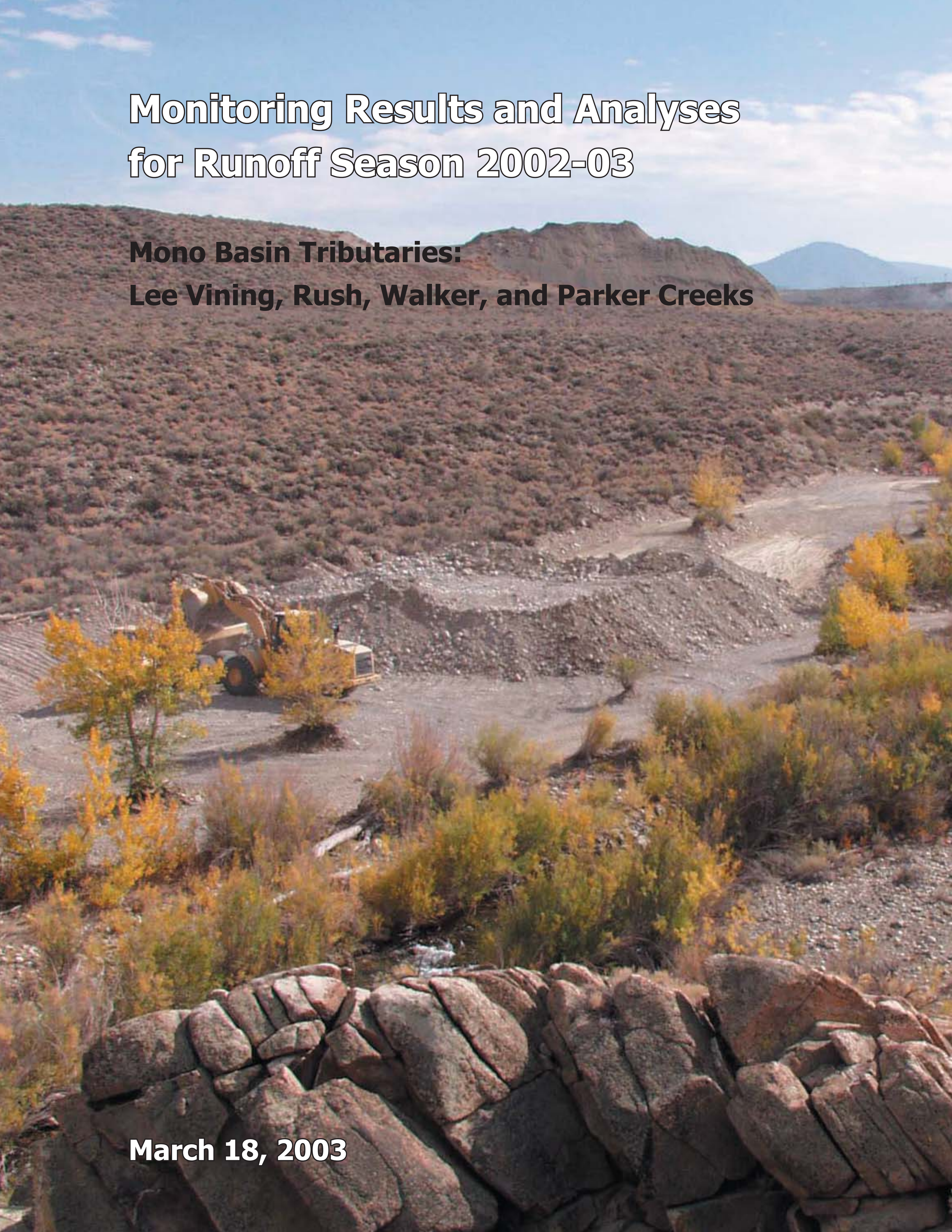
Section 4

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analysis
for Runoff Season 2002-2003

Monitoring Results and Analyses for Runoff Season 2002-03

Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks



March 18, 2003

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analyses for
Runoff Season 2002-03

Prepared for:

Los Angeles Department of Water and Power

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March 18, 2003

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1 MONITORING RESULTS AND ANALYSES FOR RUNOFF SEASON 2002-03

1.1 Introduction

This report presents information for the sixth consecutive year of stream monitoring in the Mono Basin, and fourth year of "official" monitoring following completion of the settlement agreement (State Water Resources Control Board Decision 1631). This report includes data and analyses for Runoff Year 2002-03, which began April 1, 2002. Since the stream monitoring began in 1997, much work has been initiated, completed, or is still in progress. Major activities relating to the stream restoration and monitoring include:

- **Monitoring reaches.** Three monitoring reaches have been established on Rush Creek, two reaches on Lee Vining Creek, and one reach on each of Parker and Walker creeks. Monitoring sites contain a total of 55 cross sections, each monumented with rebar, labeled, with real coordinates established with GPS. Cross sections have been surveyed several times in the past 6 years. Monitoring reaches have also been planmapped and their longitudinal thalweg profile surveyed. Each reach has a valley-wide cross section, two of which have original surveys beginning in 1995 (one with photo documentation). Temperature thermographs are located within or near monitoring reaches, three on Rush Creek, and one on each of Parker, Walker and Lee Vining Creeks.
- **Channel Dynamics.** Selected cross sections within each monitoring reach have numerous replicate bed mobility and bed scour experiments (painted tracer rocks and scour cores), with data collected in each of the past 6 years.
- **Vegetation Surveys.** Vegetation within the Rush Creek and Lee Vining Creek valleys has been surveyed to document vegetation acreages, vegetation species composition, and plant stand structure (e.g., herb, shrub, tree layers). Vegetation sampling was stratified by different geomorphic surfaces, which were also mapped across the entire stream valleys.
- **Construction Projects.** Several side channel rewatering projects have been completed in the last 6 years, primarily along the Rush Creek corridor. These sites include: (1) reopening of approximately 600 ft of side-channel upstream of the Old Hwy-395 Bridge, (2) the 3D Floodplain Rehabilitation Project upstream of the narrows (described in detail below) which lowered the floodplain elevation to allow inundation during snowmelt floods, (3) the 8-Channel Entrance project designed to re-water the west-side floodplain at discharges exceeding 200 to 300 cfs. In addition, closure of unimproved access roads in the valley bottomlands of Rush and Lee Vining creeks has been completed. Finally, large woody debris was added to the channels to increase structural complexity.
- **Rush Creek Return Ditch.** The Mono Gate One Return Ditch modification was completed, and can now convey peak flow releases up to 380 cfs back to the Rush Creek channel. This modification included quantitative surveys of fish habitat, buttressing the berm containing the ditch, and excavation in the Ditch to increase the flow capacity.
- **Lower Rush Creek Gaging Station.** The gaging station on Lower Rush Creek at the County Road culvert was established in November 2000, with the permanent installation completed in November 2001. LADWP now operates the gage.
- **Fish Population Dynamics.** The fish monitoring crew has broadened its investigations of the fish populations in Rush and Lee Vining creeks. In addition to the annual electrofishing in the study reaches to assess the population abundance, size class distributions, and young-of-year production, the fish monitoring has also assessed the corridor-wide distribution of deep holding pools for adult brown trout, evaluated fish use of the Return Ditch, and evaluated fish passage through culverts at new and existing road crossings.

- **Sediment Bypass.** Sediment bypass strategies and/or structures have been developed on Walker, Parker, and Lee Vining Creeks.

Along with reviewing past accomplishments, this year also offers an opportunity to look forward to the next phase of restoration and monitoring. With the monitoring program "up and running" and many construction-related activities completed or near completion, the focus of the monitoring program will now begin to shift to evaluating the magnitude, duration, and frequency of the post-SRF (Stream Restoration Flow) channel maintenance flows and baseflows. Much of the annual monitoring activities are geared toward obtaining information on streamflow, groundwater, and riparian vegetation dynamics to support this goal of developing a flow regime over a range of water year types.

During the next several years, another important area of monitoring will be to focus on the seasonal fluctuations in groundwater elevation, the relationship of groundwater to streamflow, and the influence of groundwater on regeneration of riparian vegetation. The SWRCB Orders also specify several monitoring activities that are triggered on a five year interval, including the corridor-wide vegetation monitoring, and planmapping of monitoring reaches. The first set of planmaps were prepared in 1999 and presented in the Runoff Year 2000 Monitoring Report; planmapping will therefore be repeated during the 2004 field season. Vegetation monitoring also began in 1999 with the corridor-wide mapping of geomorphic surfaces, followed the next year by vegetation structure and composition sampling. This work will be repeated in 2005.

Finally, the SWRCB Order No. 98-05 specifies that the evaluation of Stream Restoration Flows shall take place at "no less than eight years nor more than 10 years after the monitoring program begins." This target will require (at least) preliminary channel maintenance flows be established and termination criteria be re-evaluated by 2008.

1.2 Hydrology

1.2.1 Annual Hydrographs

The 2002-03 Runoff Year (RY) was the third consecutive year of below-average runoff conditions in the Mono Basin. The year was classified as Dry Normal I (83,655 < – < 92,207 AF annual runoff), requiring baseflow releases to Rush Creek of 47 and 44 cfs for Apr-Sep and Oct-Mar periods, respectively, and Stream Restoration Flow releases of 200 cfs for 7 consecutive days (Figure 1). Because construction of the Return Ditch was not completed in time to allow safe conveyance of the SRF flow releases, the maximum SRF flows released to Rush Creek targeted a maximum of 160 cfs.

The LADWP gage "Rush Creek at Damsite" had a mean daily discharge of approximately 60 cfs for RY 2002 [Note: We use Runoff Year (RY) for some statistics but Water Year (WY) for others], with minimum daily average flow of 21 cfs and a peak of 102 cfs on June 1, 2002 (Figure 1). The computed unimpaired peak for runoff into Grant Lake was 243 cfs on June 1, 2002 (Table 1). Releases from Grant Lake to Rush Creek (Return Ditch) averaged 51 cfs during WY 2002, with minimum daily average flow of 32 cfs and annual (daily average) peak of 168 cfs on June 8, 2002. Finally, Rush Creek below the Narrows (including Parker and Walker Creeks) had a minimum daily average flow of 49 cfs, and peaked at 225 cfs on June 8, 2002 (Figure 1). The new Rush Creek at County Road gage reported a daily average peak of 151 cfs. This is a much lower peak than the 225 cfs reported at the Narrows, and probably reflects the new rating curve not being fully calibrated at the upper flow range, as well as losses of streamflow to groundwater. The total annual runoff for Rush Creek into Mono Lake for WY 2002 was approximately 46,790 AF, based data from the "Rush Creek below the Narrows" site.

Lee Vining Creek had flow-through conditions throughout the year, with no diversions to augment Rush Creek. The mean annual flow was 51 cfs for WY 2002, with a minimum flow of 14 cfs and a peak daily average flow of 236 cfs on June 1, 2002 (Figure 2). Several secondary peak flows surrounded the annual maximum (175, 227, 169 cfs), corresponding to warmer days with consequently higher snowmelt runoff.

Parker and Walker creeks also had no diversions for water export during RY 2002. The mean annual flow for Parker Creek was 9 cfs, with daily average minimum and maximum flows of 2.9 cfs and 37 cfs respectively (Figure 3). The mean annual flow for Walker Creek was 5 cfs, with daily average minimum and maximum flows of 0.9 cfs and 26 cfs respectively (Figure 4).

1.2.2 Synoptic Streamflow Gaging

During RY 2002, we continued measuring discharges within our study sites on Rush and Lee Vining creeks (synoptic streamflow gaging). At Lower Rush Creek we took five new discharge measurements (Table 2). These measurements recorded the total flow in the Lower Rush Creek bottomlands, and the flow divided into the planmapped main channel and the 10-Channel. These flow measurements were compared to estimated or measured flows upstream at the Narrows and from the Return Ditch, and downstream at the new County Road Culvert gaging station.

The Lower Rush Creek 10-Channel entrance and the entrance to the 10-Return Channel are dynamic channel locations, frequently changing in response to the spring peak flows. Our synoptic gaging data indicated that in general, the 10-Channel has been gradually capturing a larger percentage of the total flow at moderate discharges, but is conveying a smaller proportion of the flow at baseflows. For example (from Table 2), of the 135 cfs total flow during a Sept 1998 measurement, the 10-Channel had 26% of the flow. In June ’01, at 138 cfs, that proportion had increased to 40%. In June ’02 at 130 cfs, the 10-Channel conveyed 36% of the flow. At similar baseflows of 52 cfs in May ’99 and August ’01, the 10-Channel conveyed 20% and 31% of the flow, respectively.

An important hydrologic condition in the Rush Creek stream corridor is the balance in gains and losses between streamflow and groundwater. To evaluate this relationship, we compared discharges reported for Rush Creek below the Narrows (daily average flow derived from Rush Creek Return Ditch+Parker Creek+Walker Creek) to measured flows at the Lower Rush Creek Study Site, and to measured flows at the Rush Creek County Road Culvert. The data indicated approximately 15% reduction in flow from the Narrows to Lower Rush Creek, and a 12% loss from Lower Rush Creek to the County Road. This occurrence is not unusual. Vorster (1985) reports that data for lower Rush Creek indicate the stream may “lose” water to the shallow groundwater aquifer in dry years, and “gain” water from the aquifer in wet years. Our data reported in Table 2 indicated only losses in the downstream direction along the Rush Creek corridor. As the last three years have all been dry years, this finding agreed with Vorster (1985).

Synoptic discharge measurements on Lee Vining Creek indicated that the distribution of flow between the Upper Lee Vining mainstem and the A-4 Channel has been relatively stable over several years (Table 3). Lee Vining Creek flows of 180, 166, and 169 cfs during June ’99, June ’00, and May ’01 respectively, have contributed 70%, 70%, and 71% to the upper mainstem channel. The B-Connector channel that conveys flow laterally across the floodplain to the A-4/B-1 channel intersection has gradually increased the proportion of baseflow it conveys, meaning that the B-1 channel has also increased its proportion of the baseflow. These increases are slight, however, and the flow proportions are overall stable.

1.3 Cross section surveys

Following the RY 2002 peak snowmelt floods, we visited all cross sections within the Rush and Lee Vining Creek study reaches to assess whether resurveying cross sections was necessary. If topographic changes were visible, such as bank erosion, scour, etc., we resurveyed the cross section within the bankfull channel. The moderate magnitude peak floods had minor effects on the channel topography. We resurveyed 60% of the cross sections. We have not included figures of cross section surveys in this report.

Most changes to the cross section topography were minor, generally involving channel downcutting, deposition of material on the leading edge of gravel bars, and lateral channel migration from bank erosion. For example, cross section 0+50 at the upstream end of the 10 channel (where the 10-Return Channel diverges) continued to be very dynamic. The channel adjacent to the left bank (that conveys flow into the Return Channel) continued to slowly aggrade, while the channel adjacent to the right channel (that conveys flow into the 10-Channel) continued to gradually downcut. If this trend continues, the 10-Channel may eventually become the dominant channel and convey more (or all) flow than the main channel.

One important observation resulting from our cross section surveys was the *lack* of change in the past four years in response to relatively dry runoff conditions. Cumulative changes at our monitoring cross sections resulting from these past four snowmelt floods were generally measured in the range of several inches. These minor changes contrasted with the large channel changes during the larger magnitude 1998 snowmelt flood, and illustrates the slow pace of stream channel recovery that can be expected during cycles of dry years.

Several permanent cross sections in RY 2002 were added at the 8-Channel and 3D Floodplain construction sites. These cross sections were installed and surveyed prior to the construction activities, then re-surveyed following construction to establish the baseline “as-built” conditions. These projects are discussed in more detail in Section 2.5 below. Cross section plots for the new 8-Channel site are presented in Appendix A.

1.4 Long profile surveys

No additional longitudinal profiles were surveyed in RY 2002, except at side channel construction sites, discussed in Section 2.5 below.

1.5 Bed mobility experiments

We collected bed mobility data in RY 2002 for the fifth year. With the exception of spring 1998, the previous four snowmelt floods have all been small peak floods. At Rush Creek below the Return Ditch, we have measured bed mobility resulting from peaks of 538, 201, 204, 162, and 168 cfs. Below the Narrows, snowmelt peaks have been 635, 247, 284, 202, and 225 cfs. While these data are necessary for a complete evaluation of bed mobility thresholds, they are generally below thresholds, or are just attaining limited bed mobility (except 1998). During RY 2002, for example, only experiments located at relatively mobile features such as high gradient riffles or fine-grained pool-tails had significant mobility (mobility of several D_{84} particles). No cross section had ALL particles mobilized, and no cross section even had all D_{31} particles mobilized (Table 4). At the Rush Creek County Road study site, the upstream-most cross section (15+19) had 80% mobility of the D_{31}, but no mobility of the D_{84} particles. At Lower Rush Creek study site, the two cross sections 07+25 and 07+70 traversing the wide-sweeping meander (near the now-abandoned parking area) had mobility ranging from 40-70% for each of the particle sizes. The Upper Rush Creek study site continued to exhibit higher thresholds to mobilization, with less than 20% of any particle clast mobilized. Finally, at all sites where bed mobility occurred, tracer rocks moved on average only 2 to 8 ft.

On Lee Vining Creek, a similar pattern occurred. Bed mobilization, as indicated by tracer rock experiments, was limited, many particle mobility thresholds were not exceeded, and those tracers that were mobilized only moved a short distance (Table 5). Another general pattern observed again this year was a higher degree of mobility in the Lee Vining Creek A-4 and B-1 channels compared to the mainstem channel. In the tracer rock set at A-4 Channel XS 5+15, where the left bank bar has been migrating and growing, sediment continued to deposit on the leading edge of the bar, burying the tracer rocks up to 0.3 ft deep.

Bed scour experiments showed minor scour in RY 2002. On Rush Creek, the maximum scour was at a medial bar feature in Upper Rush with only 0.31 ft of scour. Most sites scoured only as much as 0.10 ft with comparable redeposition. Similarly, on Lee Vining Creek XS 10+44, scour cores in the fine-grained medial bar were scoured up to 0.39 ft. Other experiments showed little or no scour.

1.6 Planmapping

We did not planmap in RY 2002. The SWRCB Orders require planmapping every five years. This task will therefore be repeated in the RY 2004 field season.

1.7 2000-2002 Aerial Photographs

In order to assess the usefulness of the available imagery for future mapping efforts, we acquired the 2000, 2001 and 2002 aerial photo sets flown by I.K. Curtis. The photos were flown at high altitude, which results in a maximum enlargement scale of 1”=200’. The resolution of these digital images is one meter per pixel.

In order to conduct future fish habitat and vegetation mapping, larger scale aerial photos are necessary. For vegetation mapping, true color images at a maximum scale of 1”=100’ and minimum resolution of 0.5’ per pixel will be required. Even larger-scale imagery is required for fish habitat mapping. For this purpose, 1”=10’ scale imagery is preferable, but 1”=20’ with 0.12’ pixel scale would be acceptable.

In addition to the incompatibility of the I.K. Curtis imagery scale and resolution with our imagery needs, there is another issue that can be avoided. Because the images are integrated into AirPhoto USA’s Photomapper software, the imagery must be exported from the proprietary format to a standard geotiff format for use in any CAD or GIS software. The export process consists of manual selection of multiple rectangular areas on the visible imagery “scale”. During export, Photomapper resamples the imagery at the resolution (pixel dimensions) specified by the user. This resampling appears to decrease the clarity of the images even further. Photomapper also adds an “AirPhoto USA” logo to the lower right corner of the image. An extra step must then be taken in the destination software (in our case, AutoCAD Raster Design) to crop this region off of the photo as it obscures the underlying imagery.

This process of exporting, cropping, etc. and the problems this introduces may be avoidable. Before the images are incorporated into Photomapper, the orthorectified, mosaicked images are in geotiff format. In discussions with IK Curtis, there was indication that they could be contractually obligated to provide these images to LADWP for use directly, in addition to inclusion in the Photomapper product. The geotiff imagery would be fully owned by LADWP and could be used in most any GIS or CAD software.

We have therefore recommended that LADWP acquire aerial photographs for geomorphic and riparian monitoring at the imagery scales recommended above. We have obtained recent cost estimates for this work from Aerial Photomapping Services, and this information is available on request.

1.8 Geomorphic Termination Criteria

Given the low floods in RY 2002-03, no updates to the geomorphic termination criteria for primary channel length, sinuosity, and gradient were made in 2002. We anticipate another measurement of these termination criteria in RY 2004-05 when the planmapping is performed. The 2000 Annual Report noted that Reach 4C in the Rush Creek bottomlands may have an unrecoverable pre-1941 channel gradient and sinuosity given its major change in slope caused by cutting-off Channel 14. No progress was made on resolving this in 2002. We will examine the available data and aerial photographs to propose a solution.

The other two geomorphic termination criteria, channel confinement and complexity, still have not been entirely quantified for the pre-1941 condition. The following sections address these two criteria.

1.8.1 Channel Confinement

The 2000 Annual Report (reporting on the Runoff Year 1999-00) develops the concept of channel confinement as one of the termination criteria (pp.27 to 29, and Figure 44 in the 2000 Annual Report, reproduced here as Figure 5). Channel confinement is a condition allowing streamflow to exert a force on the streambed sufficient to perform necessary geomorphic work. Assuming other variables are held constant, greater water depth increases the force exerted on the streambed. A channel that is wide and has shallow banks has relatively low confinement compared to a narrow channel with high banks. Given the same slope and same high flow, greater force per unit area will be exerted on the bed of the narrower, deeper (i.e., confined) channel.

Aggradational floodplains will restore and maintain channel confinement. Channel confinement serves as a measure for how effective this aggradational process, depositing silt and sand, is being accomplished by flood magnitudes exceeding bankfull discharge (Q_{bf}).

Channel confinement is quantified by computing bed averaged shear stress (τ_b), measured as a force per unit area (lbs/ft^2). To function as a termination criterion, a linear regression equation for pre-1941 channel confinement has τ_b (lbs/ft^2) as the dependent variable and channel slope (ft/ft) as the independent variable (Figure 5). Data to construct this relationship were derived from channel segments (e.g., the 1A Channel) adequately reflecting the pre-1941 morphology in Lower Rush Creek (refer to 2000 Report for details) and computed for the unregulated bankfull discharge (Q_{bf}). A similar regression equation was constructed from the contemporary channel in 1999 by calculating τ_b measurements in the field. Figure 5 shows that considerably less bed averaged shear stress is being exerted on monitored segments in the contemporary Lower Rush Creek channelbed than the pre-1941 channelbed. No statistically significant difference between the two regression equations would have signaled this termination criterion had been achieved. Given the apparent difference between the pre-1941 and contemporary regression equations plotted in Figure 5, no statistics were performed.

Channel confinement as a termination criterion has not advanced beyond the 2000 Annual Report's results. Only Lower Rush Creek has the pre-1941 and contemporary bed averaged shear stress – slope regressions computed (i.e., Figure 5). Lee Vining Creek and Upper Rush Creek have none. Figure 5 required several assumptions that were anticipated to have been subsequently better quantified by taking measurements during high flows. Unfortunately RY 2000 through RY 2002 have not had sufficiently high peak flows to allow the necessary measurements. With the Mono Ditch now functioning at capacity, we now need a melting snowpack to cooperate.

We do not anticipate appreciable differences between pre-1941 channel confinement and contemporary confinement in Upper Rush Creek (based on preliminary calculations not reported in the 2000 Annual Report). But differences in Lee Vining Creek will be significant. The A4 Channel (above the B1 connector but downstream of the abandoned road crossing), an intact remnant of pre-1941 channel morphology, and the adjacent mainstem comprise an ideal paired monitoring design to compare shear stresses. Even if snowmelt peak flows are low this spring/early-summer 2003, we will develop a pair of channel confinement curves for Lee Vining Creek making necessary assumptions until sufficient peak flows in the future allow their refinement.

Different sampling approaches are possible; there are no established protocols in the scientific literature. In Figure 5 for Lower Rush Creek, values for τ_b were derived from available cross sections throughout the Lower Rush Creek mainstem and in side-channels with remnant pre-1941 morphologies, such as the 1A Channel. A similar approach could be adopted for Lee Vining Creek. However, bed averaged shear stresses also could be computed along the channel thalweg at regular intervals over the entire length of the A4 and mainstem planmap reach or other similarly sized channel reach. Estimated shear stresses can be presented as in Figure 5, with slope on the X-axis or with distance along the thalweg on the X-axis. Both will be plotted.

We will also be experimenting with the actual computation of bed-averaged shear stress (τ_b) at a given channel location. Slope is a key variable not always easy to measure. 'Slope' is an averaged value dependent on the distance over which elevational change is calculated. Local slope may be much lower than a reachwide slope, or vice versa. A steep riffle during baseflows will have a much lower local slope at high flows, when the riffle is drowned-out. Distinguishing the appropriate slope for calculating τ_b at regular intervals will require field testing. Three-dimensional hydraulic modeling is an available option, and a HEC-RAS model may be used. Keeping data collection and analyses as basic as possible will be an important goal.

Ultimately, all termination criteria should relate to beneficial uses addressed in the SWRCB Orders. An explicit connection can be established by quantifying the relationships between channel confinement and fish habitat. On the Lee Vining Creek A4 and adjacent mainstem channels, rearing habitat for older age classes of brown trout and rainbow trout would be drawn onto the planform maps, then plotted three-dimensionally with shear stress and thalweg distance (or slope) as the other two variables.

Channel confinement possibly is the least appreciated termination criterion, yet likely is the most important process for achieving long-term recovery. Lower Rush and Lee Vining creeks will not be self-sustaining if they cannot achieve and maintain channel confinement. Channel confinement probably is the hardest termination criterion to measure and evaluate. As a criterion it does not fit neatly into a table. Rather, channel confinement requires a pair of shear stress relationships, either plotted as a dependent variable of slope or as a dependent variable of distance along the thalweg profile for a specified channel reach (e.g., a planmap reach). For Lee Vining Creek, we propose a single pair derived from the upper Lee Vining planmap reach described above. For Upper Rush Creek, only bed-averaged shear stresses at a few cross sections are needed to demonstrate satisfactory confinement already exists. For Lower Rush Creek, two reaches may be analyzed. One pair would be the 1A Channel and the adjacent mainstem channel. A second reach has not been identified, though this second reach will not be paired with a surrogate pre-1941 channel as the 1A Channel serves. No other pre-1941 channel templates of sufficient distance exist (with possible exception of the 14 Channel). The planmap reach downstream of the Ford is a strong candidate for establishing a baseline and monitoring confinement over time. Both Lower Rush Creek reaches would be surveyed, and shear stress computed, in 2004.

1.8.2 Channel Complexity and Variation in Thalweg Profile

The 2000 Annual Report concluded that the variance in thalweg profile had promise as a termination criterion for quantifying channel complexity. Surprisingly, less variance, rather than more, characterized pre-1941 channel thalweg profiles compared to contemporary thalweg profiles in planmapped reaches (refer to 2000 Annual Report for details). Surveyed thalweg profiles indicated maximum residual variances of 0.040 to 0.045 in lower Rush Creek and lower Lee Vining Creek are reasonable upper values for pre-1941 channel complexity. Contemporary reaches in both streams surveyed in 1999 had higher variances. As the 2000 Annual Report concludes: *The County Road channel probably should have a restored thalweg variance near 0.400 rather than its present 0.824 variance. This would require a more sinuous and confined channel than presently exists, fitting-in well with our vision of channel restoration.*

The pre-1941 variances comprise only a few measurements (refer to 2000 Annual Report). Since 2000 we examined other candidate channel reaches, intending to augment the number of pre-1941 sites, but they simply are not there. While more theoretical approaches were considered, they lacked the specificity required of effective termination criteria. For example, idealized patterns of thalweg variances were estimated for an alternating bar sequence and riffle/pool sequence. Preliminary comparisons of the variance in thalweg profiles for the planmapped channel reaches relative to these ideal patterns are instructive, but still too theoretical to serve as quantitative termination criteria. Therefore, we recommend against using thalweg variance as a termination criterion. Thalweg profiles will still be surveyed as part of the planmapping to provide valuable information on (1) whether each channel is stable, degrading, or aggrading and (2) documenting changes in local sinuosity within the bankfull channel.

More habitat signals greater channel complexity. A more direct way to evaluate channel complexity would be to document its effect on beneficial uses. The SWRCB and other parties in the settlement agreement have been most interested in channel complexity as a mechanism for increasing fish habitat quality and/or quality. Rearing habitat for older age classes of brown trout and rainbow trout can be mapped onto the planmaps using habitat preference curves for preferred flow depth, velocity, and overhead cover. These criteria were developed in previous PHABSIM studies specific to Rush and Lee Vining creeks. This approach removes the ‘middleman’ variable of channel complexity, and provides a tighter conceptual model associating physical change to biological benefit. It would be easier to estimate a threshold level of fish habitat availability, than identify a threshold level of channel complexity, to serve as a termination criterion.

2 CHANNEL CONSTRUCTION PROJECTS

Two construction projects were completed this year, the 3D Floodplain Reconstruction project, and the 8-Channel Entrance Modification project. In addition, the Narrows Pilot Revegetation Project was implemented. These projects are described below.

2.1 Rush Creek 3D Floodplain Restoration Project

The 3D Floodplain Restoration Project is the largest restoration project implemented to-date on Rush Creek. The project area is approximately 10 acres and extends from the “Narrows” 1,375 feet upstream to the eastern extent of Desert Aggregates plant operations. The objectives of the project were to re-grade the right bank floodplain to allows inundation during moderate magnitude floods (approximately 250 cfs and greater), raise the groundwater elevation across the floodplain, and reduce channel confinement along the main channel to encourage geomorphic processes.

The construction was completed in RY 2002, and entailed removal of approximately 35,000 cu yds of sediment to lower the floodplain elevation approximately 4-6 ft (Figures 6-8). Sediment was hauled to the Desert Aggregates plant site to be used commercially. Following excavation of the sediment, large woody debris and large boulders were placed, and overflow channels were formed to create topographic diversity and to encourage floodplain vegetation to establish naturally in subsequent high flow events. The small side channel meandering along the south margin of the floodplain was opened at low flows to allow approximately 1-3 cfs flow down the channel to distribute flow across the floodplain and raise the groundwater table (Figure 9).

The site will now be monitored to (1) observe the effects of these restoration treatments on the groundwater elevation and channel dynamics, and (2) evaluate natural recruitment and establishment of riparian vegetation.

Approximately 5.3 acres of riparian vegetation are needed to meet the termination criterion for this reach. Based on the current vegetation recovery trajectory, we estimate this reach of Rush Creek will achieve its riparian vegetation acreage targets by roughly 2080. One method for accelerating the termination acreage for this reach (i.e., increase the recovery trajectory) would be to plan a manual seed dispersal effort similar to B. Tillemans' work in the Owens River Gorge to coincide with the snowmelt hydrograph. Riparian plantings may also be considered after the first year to supplement natural or induced regeneration. Riparian planting before the 2003 year end would be premature because it is unknown how the physical design of this site will perform with streamflows.

2.2 8-Channel Invert Excavation

The 8-Channel Entrance project was intended to employ relatively less extensive construction methods than the 3D Floodplain project, but nevertheless still excavated a large quantity of sediment and dirt to remove the sediment plug deposited at the entrance to the 8-Channel. Approximately 1,200 cu yds of sediment were excavated and trucked to the Marzanno Aggregate Plant on Rush Creek. The 8-Channel plug was removed, and the 8-Channel was widened at the upstream end. The excavation zone was rehabilitated by replacing willow cuttings that were excavated, and spreading woody debris across the disturbed areas (Figures 10-11). At the newly constructed 8-Channel entrance, the channel was contoured to slope slightly upwards along the longitudinal profile for approximately 50 ft, then crest and slope downward. This upward-sloping portion was designed to reduce the risk of severe downcutting that could result in the new 8-Channel entrance capturing more flow than was intended. The overall design elevations targeted capturing a small proportion of mainstem Rush Creek flows when the Rush Creek discharge exceeds 250 cfs. Flow directed down the 8-Channel will fan out across the broad northbank floodplain area, with the intent of increasing riparian vegetation and groundwater elevation in this area. We will monitor Rush Creek discharge that sends flow into the 8-Channel, riparian vegetation regeneration, and groundwater elevations to determine the effects of the channel re-opening. Cross section and longitudinal profile surveys showing pre- and post-construction conditions are presented in Appendix A.

We predict the 8 channel will be inundated annually or semi annually (at least every two years) and that there will be a short term and long term riparian response. Using the Black Cottonwood-Wood's Rose and the Black Cottonwood patch type descriptions and the groundwater gradient model as tools (described in the Riparian Monitoring section below), we can describe expected changes to the riparian vegetation at this site. We predict that the current Black Cottonwood – Wood's Rose patch will undergo clonal reproduction in the short term. Root cloning is especially important for black cottonwood, as it might establish a much younger and robust second cohort. Wood's rose clones may also increase in the short term, but would ultimately be shaded out by a developing cottonwood canopy (i.e., the younger wave of root sprouts created by the periodic rewatering of the 8 channel and floodplain). In the longer term, groundwater may be elevated locally by the growing wave of black cottonwood clones, reducing desert plant species and Wood's rose. The final transformation should occur when the herbaceous understory develops higher abundances of Juncus and creeping wild rye. Our prediction therefore is that the current patch type (e.g., Black Cottonwood –Wood's Rose patch type) prevalent along the 8 channel invert area should convert to a Black Cottonwood patch in the long term.

2.3 Rush Creek Narrows pilot Revegetation Project

In May 2002, we obtained over 60 Jeffery Pine seedlings from the USDA Forest Service in Mammoth, CA. Two-year-old seedlings were dug bareroot in December at the Forest Service Nursery in Placerville (the western sierra). Seedlings were kept in cold storage before planting. The ideal temperature for storing seedlings is 45ºF; this criterion was exceeded several times shortly before planting, leaving the plants highly stressed.

Planting at the project site began May 20, 2002. Black cottonwoods had already broken bud and had begun flowering. We intended to plant cottonwood cuttings, but concluded that cottonwood seasonal growth was too far along to take cuttings and plant them successfully. Jeffery pine seedlings were wrapped in wet burlap and taken to the project site and set in the shade.

The first day we established a ¾" black poly water pipe irrigation system. The second day planting of seedlings began at three planting sites (Figure 12). Ideally all three sites would have similar exposure and substrate conditions. Substrate between the sites was variable, ranging from fine silts to cobble-gravel. These cobble sites were very difficult to plant. Each planting site had two irrigation treatment planting areas (Figure 13).

Trees within irrigation treatment areas were planted at 5 ft on center, and given one of three different irrigation treatments (Figure 14). Individual Irrigation treatments were separated by 10 ft. We planted three trees with Driwater, three trees with Terrasorb water polymers, and three trees without any water (the control) within each treatment area. Each treatment area was repeated twice within a planting site. A shallow hole was dug to accommodate the seedlings root mass (Figure 15). Superthrive (a vitamin supplement) was sprayed on the roots before planting (Figure 15). The irrigation treatment was either buried along side of the plant (Driwater) or mixed into the native backfill and placed around the plant (Terrasorb) (Figure 15). A browse protector was placed around each plant (Figure 15).

Each plant was watered three times during the experiment. After planting, each tree was watered with 5 gallons of water (including the no irrigation treatment (Figure 15). All plants were watered again August 8 and October 10, 2002. During the August visit, expired 1 quart Driwater containers were replaced with full quarts. Survivorship was collected within each treatment planting area and tallied for the site. The experiment was concluded in October 2002 with observations of total survival. Trees will be observed in the next several years to see if they survive without irrigation.

2.3.1 Results/Discussion

Survivorship was patchy (Figure 16), but the downstream planting had the highest proportion of survivors (Table 6). Browse protection appeared valuable, as one plant had lost its browse protection, and the foliage was browsed to the stem presumably killing the plant (Figure 17).

To evaluate the costs and benefits of the project, we analyzed our labor and material expenses (Table 7). Survivorship exceeded 20% in all irrigation treatments. Material and labor costs for individual plants totaled about $50.00 each to install and irrigate for the summer. Driwater was the most expensive treatment to install. However, Driwater outperformed the Terrasorb water polymer by almost 3:1 (Table 6). Given the improved survival associated with Driwater, this treatment cost less than half of the other treatments when compared to the relative survival rates (Table 6). In other words, given the survivorship associated with Driwater (Table 6), this irrigation method was more successful because of lower costs per surviving tree, though initial labor costs were higher (Table 7).

The ecological value (and therefore the benefit to the streams' riparian corridor recovery) of each surviving tree cannot be estimated. The 11 planted Jeffery Pine trees establishing at the revegetation site could ultimately affect the structure and microclimate of this area. These trees may become established at this site much faster than if relying on natural recolonization. If the entire project area had been planted with Driwater, survivorship could have been as high as 21 plants (or higher). In any case, if all 11 Jeffery pines establish, this area would have the largest Jeffery pine stand in the Rush Creek corridor.

3 RIPARIAN VEGETATION MONITORING

3.1 Introduction

As stated in SWRCB Order No.98-05, the stream restoration program will be terminated when the stream restoration and recovery process has "resulted in a functional and self-sustaining stream system with healthy riparian ecosystem components for which no extensive physical manipulation is required on an ongoing basis." Recovery of riparian vegetation is a primary goal for the Mono Basin Implementation Plan (LADWP 2000). The Plan and SWRCB Order No. 98-05 also recognize the importance of riparian recovery toward achieving other termination criteria, recognizing that the acreage of riparian vegetation, including mature trees must be of "sufficient diameter, height, and location to provide woody debris in the streams." Other stream ecosystem benefits derived from a healthy riparian community include channel shading, stream bank stabilization, and floodplain aggradation. All these physical processes promote better fish habitat, and should accelerate the recovery of brown and rainbow trout populations.

Since the Settlement Agreement (SWRCB Decision 1631) and subsequent SWRCB Orders No. 98-05 and No. 98-07, monitoring in the bottomlands of Rush Creek and Lee Vining Creek has required a significant effort. Quantification of riparian acreage for pre-1941 and contemporary conditions addressed the termination criteria. SWRCB Order No. 98-05 stopped short of quantitatively defining "healthy riparian ecosystem components." But a quantitative understanding of species composition and abundance in relation to fluvial geomorphic processes will be needed to forecast riparian recovery and recommend management actions that will achieve, and possibly accelerate, riparian plant recovery.

The following riparian-related tasks from 2001-2002 included in this 2002 Annual Report are: (1) progress report on riparian vegetation termination criteria, especially riparian cover acreages derived from the 1929 aerial photographs, (2) results from the nested frequency transects inventoried in 2001 to quantify species composition and abundances, (3) development of 'patch types' from cluster analyses, (4) establishment of valley-wide band transects, and (5) progress report on the Rush Creek Narrows Pilot Revegetation Project planted in May 2002 (reported above).

3.2 Riparian Vegetation Termination Criteria

3.2.1 Rush and Lee Vining Creeks

Termination criteria for healthy riparian communities in Rush Creek and Lee Vining Creek required a benchmark. The 1929 aerial photographs are the basis for establishing the pre-1941 riparian vegetation acreages as reach-specific termination criteria, acknowledging that early settlement and ranching along both creeks already were having their impacts. Riparian corridors along Lee Vining and Rush creeks had already undergone at least one (if not two) previous episode(s) of vegetation clearing, grazing, and canal building by the time the aerial photos were taken in 1929. The riparian corridor in 1929 was wider in many locations than it would have been prehistorically (naturally) simply because irrigation water was being distributed on low lying terraces next to both creeks.

These conditions imposed serious limitations on identifying riparian corridors and acreages in the 1929 aerial photographs. In many locations, side channels can appear as natural conduits that either feed irrigation canals or drain them (a great example is the Indian Ditch area of Rush Creek, (Figure 18). Many wet meadows can be associated with a canal structure, such as an irrigation ditch outlet. This pervasive manipulation of surface water in 1929 blunts attempts to quantify what seepage and tributary inputs are natural, or how wide the "natural" riparian corridor might have been prior to human influence.

Natural wet meadows are difficult to separate from irrigated pastures, especially when addressing or defining acreages used for termination criteria. Fortunately, this is the only patch type that creates this difficulty. The greatest challenge is defining the degree of "naturalness" that wet meadows represented. Whether natural or not, riparian vegetation present in 1929 reflected the pre-DWP diversion condition.

Wet meadows (Juncus-Creeping Wild Rye Patch Types) are common in the riparian corridors of Lee Vining, Rush, Walker and Parker Creeks. Initial efforts to convert the riparian corridor to pasture over a century ago most likely were focused in locations where natural wet meadows occurred and brush clearing would have been minimal. Early settlers would simply have had to increase local surface irrigation in wet meadows to increase their coverage. Wet meadows that are currently within 1.5 to 2 ft of the groundwater (i.e., sites with shallow groundwater) will probably stay wet meadows until the stream channel migrates away and the groundwater retreats, or the site is eroded by channel migration. Only in marginal locations near the riparian corridor boundary is there the greatest concern.

When the irrigation water is turned off, the riparian corridor retreats to the areas where it is supported by favorable groundwater conditions. When irrigation stops, groundwater retreats to the depth supported either by streamflow or local precipitation. Irrigation effectively extended the riparian corridor in many areas, but the question of how far, and to what extent, is unknown. Grazing also influenced the wet meadow species composition. Currently, plants that prefer drier conditions, such as sagebrush, are beginning to establish in many wet meadows. Sagebrush and other species will only encroach into those patches where groundwater is deep enough (3 to 4 ft).

We currently have no way of determining how extensive the conversion of wet meadows to drier patch type will be. This has serious implications when trying to define termination criteria for Walker and Parker creeks. The irrigation of alluvial surfaces around Walker and Parker Creek ceased a few years ago and sheep were removed. The wet meadows around these creeks that compose much of their riparian corridors will likely begin to show the establishment of sagebrush and other "drier" species; in time these patches convert to more xeric patches entirely. It will only be in those locations were groundwater is shallow or locally elevated (i.e., the true riparian corridor) that the wet meadows will persist. Ecologically this is not really an issue, however wet meadows were a large part of the riparian acreage along these creeks pre-diversion, and the ability to discern where the "true" riparian boundary occurred, or will be in the future, is impossible.

We recommend that all wet meadows that can be directly associated with irrigation infrastructure in 1929 not be considered as a riparian patch type when summarizing acreages for the termination criteria. Rather, where wet meadows can be linked to irrigation they will be classified as irrigated pastures and included as part of the patches that are related to human disturbance. Therefore, riparian acreages clearly a result of irrigation in the 1929 aerial photographs will not be included in the reach-specific tally of riparian acreages potentially impacted by DWP since 1941. If no connection to irrigation can be identified, then the patch will be classified as a wet meadow and included in the acreage tally comprising the termination criterion.

3.2.2 1929 Aerial Photo Interpretation

Jones and Stokes mapped the 1929 riparian vegetation (Jones and Stokes 1993), quantifying total riparian vegetation acreages along Lee Vining, Rush, Parker and Walker creeks. Their original map was hand drawn and planimetered. Jones and Stokes included the wet meadow acreages as a riparian patch type, and therefore also in the total riparian acreages (Jones and Stokes 1993). Original termination criteria for riparian acreage presented in Ridenhour et al. (1995) are based on the mapping results presented by Jones and Stokes in the Mono Basin EIR (Jones and Stokes 1993).

In 2002, our task was to recreate a spatially accurate map to estimate acreages of the 1929 vegetation in the riparian corridors of Lee Vining, Rush, Parker and Walker creeks, using classification consistent with the vegetation mapped in 1999. This technological approach provided a more accurate riparian inventory of the 1929 stream corridors than was possible when Jones and Stokes did the original mapping. Our mapping was based on film diapositives of the original 1929 aerial photos negatives. The 1929 aerial photos were scanned at 1200 dots per inch and color corrected in Photoshop to improve contrast and interpretability. Using AutoCAD Map, the photos were rubbersheeted with 1998 USGS Digital Orthorectified Quarter Quadrangles (DOQQs) to locate horizontal coordinates for ground control points, typically road intersections. Following rubbersheeting, the 1929 photos were printed at a 1:1800 scale and laminated for the purpose of vegetation patch mapping.

Vegetation patches were mapped directly onto the laminated 1929 photos, with the original film diapositives viewed concurrently through an enlarging "photo loop" on a light table for additional accuracy of patch determination. Patch types were named using the patch type classification developed in the 1999 mapping (Figure 18).

Although the mapping is complete, the final acreage of mapped vegetation patches is still pending. Due to the significant topographic relief within the extent of the 1929 aerial photos, we have determined that rubbersheeting did not correct the images and associated mapping to the level of accuracy attainable and warranted for the determination of fixed termination criteria (i.e., criteria to be used to judge when LADWP has met it's obligations under the SWRCB Orders). Using solely horizontal control, but not vertical control, rubbersheeting corrects images for distortions related to parallax, unevenness of terrain, or lens distortion. Conversely, orthorectification provides a more accurate correction by introducing vertical control. To provide the best possible data for these streams, orthorectification of the images used for vegetation mapping will be completed.

We will therefore orthorectify the 1929 aerial photos using ERDAS Imagine software with OrthoBASE Pro module. The rectification process in ERDAS incorporates multiple techniques. In addition to horizontal and vertical ground control points, the spectral characteristics of the overlapping imagery are used for rectification. Digital Elevation Models (DEMs) are also incorporated to rectify relief distortion produced from the relations between the topography and the flat photographic film. When possible, spectral characteristics from the camera are used to rectify the radial distortion induced by the lenses of the camera used to acquire the images.

Following orthorectification of the 1929 images, the vegetation mapping already completed will be corrected to the new imagery. The resulting mapping and acreages will be as accurate as possible using the best available technology. We will complete this task and provide final 1929 vegetation maps and acreages by June 2003.

Pending the final acreages, the 1929 mapping has revealed interesting trends. While exact tree size, height, and canopy diameter cannot be quantified from the aerial photographs, the number of patch types that include trees compared to those that do not, for the 1929 and contemporary conditions were quantified. A larger percentage of the 1929 riparian stands were composed of trees than shrubs than in the contemporary riparian corridor. Patch sizes in 1929 were also generally larger and more contiguous. The final 1929 maps and patch type composition, size, and continuity will be compared to contemporary riparian vegetation conditions.

Tables 8 and 9 summarize riparian cover acreages for 1929 (relying on the original Jones and Stokes estimates), 1989, and 1999 in Rush Creek and Lee Vining Creek, as well as forecast when riparian termination criteria for specific stream segments might be met. We will report reach-specific riparian acreages determined from our mapping of the 1929 photos by June 2003, and discuss our findings in the 2004 annual report. The riparian corridor boundary defined in our 1999 mapping served as the riparian corridor boundary in 1929 (presumably the corridor width as M&T defined it has not changed in the last 100 years). Acreages originally inventoried by Jones and Stokes will be compared on a reach specific basis to our mapped acreages. Site-specific differences will be addressed. For example, a higher quality aerial photo basemap may account for differences, or a different interpretation of a wet meadow's history may be the factor.

3.2.3 Walker and Parker Creeks Riparian Vegetation

Valley walls were used to define the boundaries of the riparian corridors along Lee Vining and Rush creeks. The riparian corridors of Walker and Parker creeks are defined as 150 meters on either side of the stream. These values are arbitrary, and in some respects misleading. A riparian corridor that is defined as the land adjacent to watercourses, whose flowing water provides groundwater sufficiently in excess of that otherwise available through local precipitation (Warner and Hendrix 1984, McBain and Trush 2000), is one that could in theory be quantitatively defined; a quantitative definition however is un-necessary.

We anticipate the near future conversion of much of the riparian corridors along Walker and Parker creeks to drier patch types, given the removal of grazing and irrigation practices. However once this conversion (or transition) occurs, the riparian boundary will track with the stream and will be a direct function of the rate at which groundwater elevation tapers off adjacent to the stream. The likelihood is high that streamflow reductions in the future will affect the riparian corridor boundary (i.e., diversion will likely reduce the groundwater defined corridor width). Termination criteria for Walker and Parker creeks would be difficult to formulate under these conditions, but trend monitoring to document the anticipated transition is advised.

3.3 Vegetation Structure and Composition Sampling

3.3.1 Nested Frequency Transects and Patch Type Determinations

During the summer of 2001 we sampled 172 nested frequency transects in the Lee Vining (96 transects) and Rush Creek (76 transects) riparian corridors to quantify riparian plant species composition and abundance. The purpose of the nested frequency transects was to quantify plant species composition and structure (stand characteristics) within the most frequently occurring stands on different geomorphic units within the riparian corridors of Rush Creek and Lee Vining Creek. The nested frequency transect methodology was presented in the 2002 Annual Report (McBain and Trush 2002). In this report we present our results.

During transect sampling 490 plants were cataloged. Plants were either identified or assigned a code if the species was not known in the field. Initially 235 plants could not be identified to species in the field. Several factors influenced whether a plant could be identified. Many plants were not in flower in every location, morphological characteristics vary, and field technicians were not familiar with every plant species. In some cases, a field tech did not collect enough material to identify the plant. We could not identify all unidentified plants to the species level; so unknown plants were prioritized by the frequency that they were sampled and the amount of collected plant material to identify the plant. We identified many unknown plants and reduced our catalogued plant number to 235. We identified 163 plants to species (Table 10).

Dominant riparian hardwood species all belong to the willow family (Salicaceae, including willow and cottonwood species). Willows habitually grow into either trees or shrubs, while cottonwoods typically grow into trees. Growth habit is important because the distribution and ecology of willow species can influence the number of patches that include other tree and shrub species. The number of transects along Lee Vining and Rush creeks that had plant species growing into the shrub layer (above 4 ft but below 15 ft high) was similar (Figure 19). However, there was a disparity in the number of sampled transects with plant species in the tree layer (Figure 19). Rush Creek had only 7% of sampled transects with plant species in the tree layer; Lee Vining had almost three times as many. The lack of transects with tree species on Rush Creek will likely not change substantially until more floodplain surfaces evolve on which to recruit tree species (e.g., black cottonwood) or riparian trees are planted.

3.3.2 Cluster Analyses

Transect data were clustered into related groups, based on presence/absence of sampled species and their abundances within each transect, to determine patch types. Previously, patch types had been assigned to mapped vegetation as part of the riparian inventory. Patches were field mapped and a patch type assigned based on the dominant species in the canopy (McBain and Trush 2002). The purpose of the cluster analysis was therefore to quantify and describe the patch types based on species abundance and frequency; the patch type classification used in mapping should be close to the patch type classification derived from the cluster analysis. Field sampling methods are detailed in the 2002 Annual Report (McBain and Trush 2002). Two statistical methods were used to aggregate transect data into clusters. A hierarchal cluster analysis and a TWINSPAN analysis were performed for Lee Vining Creek and Rush Creek transect data separately, then combined in another analysis using PC-ORD version 4 software (MJM Software Design 1999). Ecological relationships can be inferred from discrete clusters. However, infrequent or “rare” species often skew the cluster analysis and obscure potential ecological relationships between clusters (McCune and Grace 2002). To reduce the influence of rare/infrequent species, those plant species occurring in less than 12% of all transects were excluded from the cluster analyses. The final number of species included in the cluster analysis was 62.

Cluster analyses defined eight clusters on Lee Vining (Figure 20) and seven clusters on Rush Creek (Figure 21). When the analyses for both creeks was combined, thirteen clusters were defined (Figure 22). We used these clusters to define patch types. The patch types defined using the cluster analysis were comparable to the original patch type classification used in mapping (Figure 21).

The hierarchal cluster and TWINSPAN methods aggregate transects based on structure inherent in the data; however, TWINSPAN is used less frequently because it can only effectively cluster related samples if one singular “strong” environmental gradient is influencing the data structure. Therefore, the influence of multiple environmental gradients was assessed using a de-trended correspondence analysis (DCA). This analysis found that generally one environmental variable explained most variation in the transect data. We interpreted this variable to be a “wetness gradient”, or the availability of groundwater. The resulting groups indicated a high degree of influence from the “wetness” or groundwater gradient (Figure 23). The number of groups defined by the TWINSPAN analysis was similar to that of the hierarchal cluster analysis(Figures 24-26).

Several factors influenced how well a mapped patch type clustered with other samples of similar mapped patch types. The primary influence on how well a patch description "fit" the assigned mapping classification was the location of the vegetation transect within the randomly located map unit. Traditionally, patch description methods rely on judgment (i.e., the sampling location is chosen on the basis of the most representative portion of the patch, usually the center or the patch interior). The method we implemented eliminated the subjective placement of transects (and therefore reduced sampler bias), placing sampling transects systematically in the center of the identified patch regardless of whether or not the mapped patch's center was the best representation of the patch composition. The pie chart included on the individual patch description sheets portrays how well the patch description fit the mapping classification.

The three most abundant species from each of the transects clustered together were used to develop the dominant plant species that would define each patch type. Each cluster therefore represents a patch type. We defined thirteen patch types for the Lee Vining and Rush Creek riparian corridors (Figures 27-39). Using both the TWINSPAN analysis and the cluster analysis results, we generated an alphabetical list of species commonly found within each patch type. Though some patch types might generally be found on only one creek (e.g., Juncus - Creeping Wild Rye patch types on Rush, Mugwort – Soapwort patches on Lee Vining), patch type descriptions are presented as universal within the Mono Basin. Presumably plant species migration and channel process will create similar types of environmental gradients in both stream systems. What will differ between creeks are the areas where a patch could arise, how much area they cover, and the locations where they may potentially regenerate. In other words, one patch type may currently exist in one creek, but the conditions that allow it to recruit or persist may be created on any of the streams feeding Mono Lake.

Some interesting observations of plant species occurrences along the 172 transects were:

- Sagebrush was the most frequently sampled plant (found in 110 transects)
- Wood's rose was the second most frequently sampled plant (found in 107 transects)
- Creeping wild rye was the most frequent herbaceous species sampled (found in 69 transects)
- Kentucky bluegrass was the most common riparian obligate plant (though exotic), occurring in 64 transects
- *Juncus mexicanus* was the most frequently sampled native riparian obligate plant, occurring in 61 transects
- Black cottonwood was the most common riparian hardwood sampled, found in 45 transects

The riparian corridors of Lee Vining and Rush creeks are fortunate not to have severe infestations of exotic plant species. However, tamarisk was sampled on Rush Creek and soapwort sampled on Lee Vining Creek. LADWP is aware of the tamarisk plants in the Rush Creek corridor and has coordinated eradication efforts with the Mono Lake Committee and other interested parties. Vigilance regarding tamarisk is especially important to prevent this species from gaining a foothold in the Rush Creek riparian corridor. Reporting observations of this plant is the primary tool in reducing the invasion threat. Soapwort has escaped from the Lee Vining community and now forms extensive patches in the Lee Vining riparian corridor (it has a patch type named after it!). Some method of control and management of this plant should be considered. Kentucky bluegrass is found extensively on Lee Vining Creek and control is unlikely.

One notable herbaceous plant, *Arnica sororia*, was sampled during the summer of 2001. *Arnica sororia* is considered to be "uncommon" by the California Native Plant Society (CNPS) and is listed in their Inventory of Rare and Endangered Vascular Plants of California (CNPS 2002). The CNPS maintains *A. sororia* on this list because it is infrequently encountered in California. The uncommonness of *A. sororia* is attributable to its association with the flora of the Great Basin; Great Basin flora is not usually encountered in California except in Mono and a few other Counties. Because Great Basin flora is rarely encountered, plants associated with flora are also rarely encountered. The CNPS concludes that *A. sororia* is not at threat of extirpation. It is abundant and well distributed in the range where Great Basin Flora naturally occurs. We also found that *A. sororia* was locally abundant and commonly associated with riparian patch types (particularly the Juncus-Creeping Wild Rye Patch Type, (Figure 29). Special management considerations are not necessary to maintain local *A. sororia* populations along Lee Vining and Rush creeks.

3.3.3 Valley-Wide Band Transect Sampling

In RY 2001-2002, five valley-wide band transects spanning the riparian corridor were established and sampled, one in each of the five planmapped study sites (two on Lee Vining Creek and three on Rush Creek). Band transects (methodology presented in 2001 Annual Report) will be used to document future trends in riparian woody plant initiation, establishment, and mortality, particularly in relation to groundwater and stream channel/floodplain elevation. Plant stand structure, woody plant recruitment, and species distribution were quantified within all five band transects.

Two data types were collected along the band transects in 2001, vegetative cover by species and riparian hardwood location along the band transect. The methods for band transect sampling was presented in our 2001 annual report (McBain and Trush 2002). The results from the cover data were used to develop the structural histograms included on the patch type description sheets (Figures 27-39). The results of the location data were used to develop maps of riparian hardwood locations (Figure 40).The maps for each valley-wide cross section with band transect sampling progress from individual species and their relationship to geomorphic units and the patch type they are growing in (e.g., Figure 23), to locations of annual cohorts of the dominant hardwoods species (e.g., Figure 41).

3.3.3.1 Lower Lee Vining Band Transect along Bill's Valley wide Cross Section

The lower Lee Vining Creek valley wide cross section was established in 1995. Bill Trush and Gary Smith (CDFG) took photographs along the cross section when it was originally surveyed (Figure 42), and these photos can be compared to photos we took during a 2001 resurvey of the cross section. We sampled the vegetation along the band transect in 2001. The valley wide cross section in this location intersects wet side channels, and many areas that are perennially wet. Patches of black cottonwood, mixed willow, sagebrush, sagebrush-bitterbrush and sagebrush-rose grow along the band transect. We sampled many black cottonwoods and the results suggest that black cottonwood regeneration is episodic and frequently located in high flow scour channels or abandoned channels (Figure 41).

3.3.3.2 Upper Lee Vining Band transect along Cross Section 10+44

Cross section 10+44 was originally established on the mainstem channel in 1996 and extended to the right and left valley walls in 2001 when vegetation was sampled. We sampled the vegetation along the band transect in 2001. The valley wide cross section intersects the A4 and mainstem channel and one side channel. There are no perennially wet areas beyond those immediately adjacent to these three channels. The A4 channel is higher in elevation than the mainstem and has a very thin (narrow) riparian corridor, presumably because the groundwater drops off rapidly. The valley wide cross section is mostly sagebrush, it is only where the groundwater is shallow enough that patches of black cottonwood, and willows can establish and thrive (Figure 43). We sampled some black cottonwoods along the transect, most of which were associated with active floodplain surfaces adjacent to the mainstem channel (Figure 44).

3.3.3.3 Rush Creek County Road Band Transect along Cross Section 08+30

Cross section 08+30 was originally established in 1998, and extended in 2001 to reach the left valley wall and the right bank riparian corridor boundary. We sampled the vegetation along the band transect in 2001. There is only one channel in this reach of Rush Creek and channel incision has abandoned the pre-diversion floodplains and low terraces. The areas immediately adjacent to the mainstem support willows, however much of the surfaces that are adjacent to the creek are open space (Figure 45). We did not sample any black cottonwoods on this cross section, yellow willow was the dominant plant species, and regeneration of this species has been located along high water channels and immediately adjacent to the mainstem channel (Figure 46).

3.3.3.4 Lower Rush Creek Site Band Transect along Cross Section 07+25

The lower Rush Creek cross section 07+25 was surveyed to the right bank valley wall in 1995 before the 10 channel was reopened. Bill Trush and Gary Smith (CDFG) took photographs along the cross section when it was originally surveyed (Figure 47), and these photos can be compared to photos we taken in 1998 and 1999. Some channel incision is evident, and many surfaces that were riparian before diversion still have shallow groundwater tables (thus maintaining them as riparian). We sampled the vegetation along the band transect in 2001. The valley wide cross section in this location intersects wet side channels near the mainstem, and at the 10 channel (Figure 48). Patches of black cottonwood, mixed willow, sagebrush, sagebrush-creeping wild rye and sagebrush-rose grow along the band transect. This was the only band transect on Rush Creek where black cottonwood was sampled. The black cottonwoods we sampled are either pre-diversion cottonwoods that survived, or those that were planted after the 10 channel was reopened (Figure 49). Natural regeneration of hardwoods from seed has resulted exclusively from yellow, shiny and narrowleaf willow. Regeneration has been concentrated along the floodplains adjacent to the mainstem.

3.3.3.5 Upper Rush Creek Site Cross Section 13+36

Cross section 13+36 was originally established in 1998 between the right and left valley walls. We sampled the vegetation along the band transect in 2001. There is only one channel in this reach of Rush Creek, though there are several prehistoric side channels near the left bank valley walls. The “off-channel wetland” along the right bank valley was constructed in the early 1990’s. Most of the cross section is the Juncus-creeping wild rye patch type, and the dominant riparian hardwood is narrowleaf willow (Figure 50). We did not sample any black cottonwoods on this cross section. We sampled many narrowleaf willow cohorts, the most recent regeneration is located near the mainstem channel accessible to overbank flooding (Figure 51).

3.4 General Observations

- In the Rush Creek bottomlands, floodplain surfaces are limited in area, and most woody vegetation is in the shrub layer. Much more time and successive years’ high flows are needed to create new nursery sites and floodplains along the Rush Creek corridor. Vegetation in the tree layer on Rush Creek is mostly related to the re-sprouting of pre diversion survivors (i.e., the data suggest recruitment is related to cloning and not seedling regeneration).
- The riparian “islands” on Lee Vining are young and growing vigorously, but will take time to fill in the space between them.
- Vegetation is clearly responding to the increase in streamflow and the influence of elevated groundwater adjacent to the creeks. Stand structures on both Lee Vining Creek and Rush Creek still need more patches with plant species growing into the tree vegetation layer (i.e., greater than 15 ft) to resemble the pre-diversion conditions exemplified by the 1929 photos.

4 2003-04 MONITORING SEASON

Upcoming Geomorphic Monitoring:

(1) Bed-averaged shear stresses will be measured along a pair of channel segments in the Upper Lee Vining Creek planmap site to represent contemporary and pre-1941 conditions for the purpose of developing confinement termination criteria in Lee Vining Creek.

(2) The entrance to the 4bii side-channel is located in a multi-channeled portion of mainstem Rush Creek. This side-channel was targeted for modification in the SWRCB Order, but its anticipated function of allowing streamflow to access the floodplain may already be happening without modification. Thus in 2003, we will monitor stage heights at the entrance during the snowmelt period and map surface flows (and standing water) and groundwater elevations in the floodplain should this year's snowmelt flood enter the 4bii side-channel complex.

(3) Explore feasibility of trout habitat mapping for selected life stages over a wide range of baseflows within the planmap reaches of Rush Creek and Lee Vining Creek.

(4) Establish corridor-wide stationing on Rush and Lee Vining creeks for longitudinal profile and aerial photograph control.

Upcoming Riparian Monitoring:

(5) Riparian vegetation survival and establishment in the 3-D Floodplain Restoration Project and at the Narrows Revegetation Project will be monitored.

(6) Finalize pre-1941 riparian acreages mapped on orthorectified 1929 aerial photographs and compare to earlier acreage estimates by Jones & Stokes.

(7) Documenting riparian and groundwater response to re-watering of the 8 Channel during peak snowmelt runoff. One anticipated response is an upsurge in clonal growth by mature cottonwoods.

(8) Relate patch types created in the 2002 cluster analysis to patch types used in earlier riparian inventories.

(9) Monitor riparian patch types along Parker and Walker creeks.

(10) Establish monitoring plots to quantify cottonwood establishment dynamics during the snowmelt recession limb in Rush Creek and Lee Vining Creek, especially using exposed bar surfaces in the 3-D Floodplain Restoration Project.

5 REFERENCES

Baldwin, B. G., S. Boyd, B. J. Ertter, R. W. Patterson, T. J. Rosatti, and D. H. Wilken (eds). 1993. *The Jepson Desert Manual: Vascular Plants of Southeastern California*. University of California Press, Berkeley, CA.

California Native Plant Society. 2001**.** California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California. CNPS Special Publication, Sacramento, CA.

California State Water Resources Control Board. 1994. Decision 1631 Lee Vining Creek, Walker Creek, Parker Creek, Rush Creek, Mono County, Sacramento, CA.

California State Water Resources Control Board. 1998. State Water Control Board Order 98-05, Sacramento, CA.

California State Water Resources Control Board. 1998. State Water Control Board Order 98-07, Sacramento, CA.

Hickman, J. C. (ed). 1993. *The Jepson Manual: Higher Plants of California*. University of California Press, Berkeley, CA.

Jones and Stokes Inc. 1993. Draft environmental impact report for the review of the Mono Basin Water Rights of the City of Los Angeles, Volumes 1 and 2 and Appendices, Los Angeles Department of Water and Power, Sacramento, CA.

Los Angeles Department of Water and Power. 2000. Mono Basin Implementation Plan, To Comply with State Water Resources Control Board Decision 1631 and Order No. 98-05 and 98-07, Los Angeles, CA.

McBain and Trush, 2000. Monitoring Results and Analyses for Water Year 1999: Lee Vining, Rush, Walker and Parker Creeks, Report provided to the Los Angeles Department of Water and Power pursuant to State Water Resources Control Board Decision 1631, Arcata, CA.

McBain and Trush. 2002. Mono Basin Tributaries: Lee Vining, Rush, Walker and Parker Creeks, Monitoring Activities and Results for Runoff Year 2001, Arcata, CA.

McCune, B., and M. J. Mefford. 1999. PC-ORD, Multivariate Analysis of Ecological Data, Version 4, MJM Software Design, Gleneden Beach, OR.

McCune, B. and J.B Grace. 2002. *Analysis of Ecological Communities*, MJM Software Design, Gleneden Beach, OR.

Ridenhour, R.L., C. Hunter and B. Trush. 1995. Mono Basin Stream Restoration Work Plan, Los Angeles Department of Water and Power**.**

Vorster, P**.** 1985. A water balance forecast model for Mono Lake, California. 341 pages. California State University, Hayward.

Warner, R. E. and K. M. Hendrix (eds). 1984. *California Riparian Systems: Ecology, Conservation, and Productive Management*, University of California Press, Berkeley, CA.

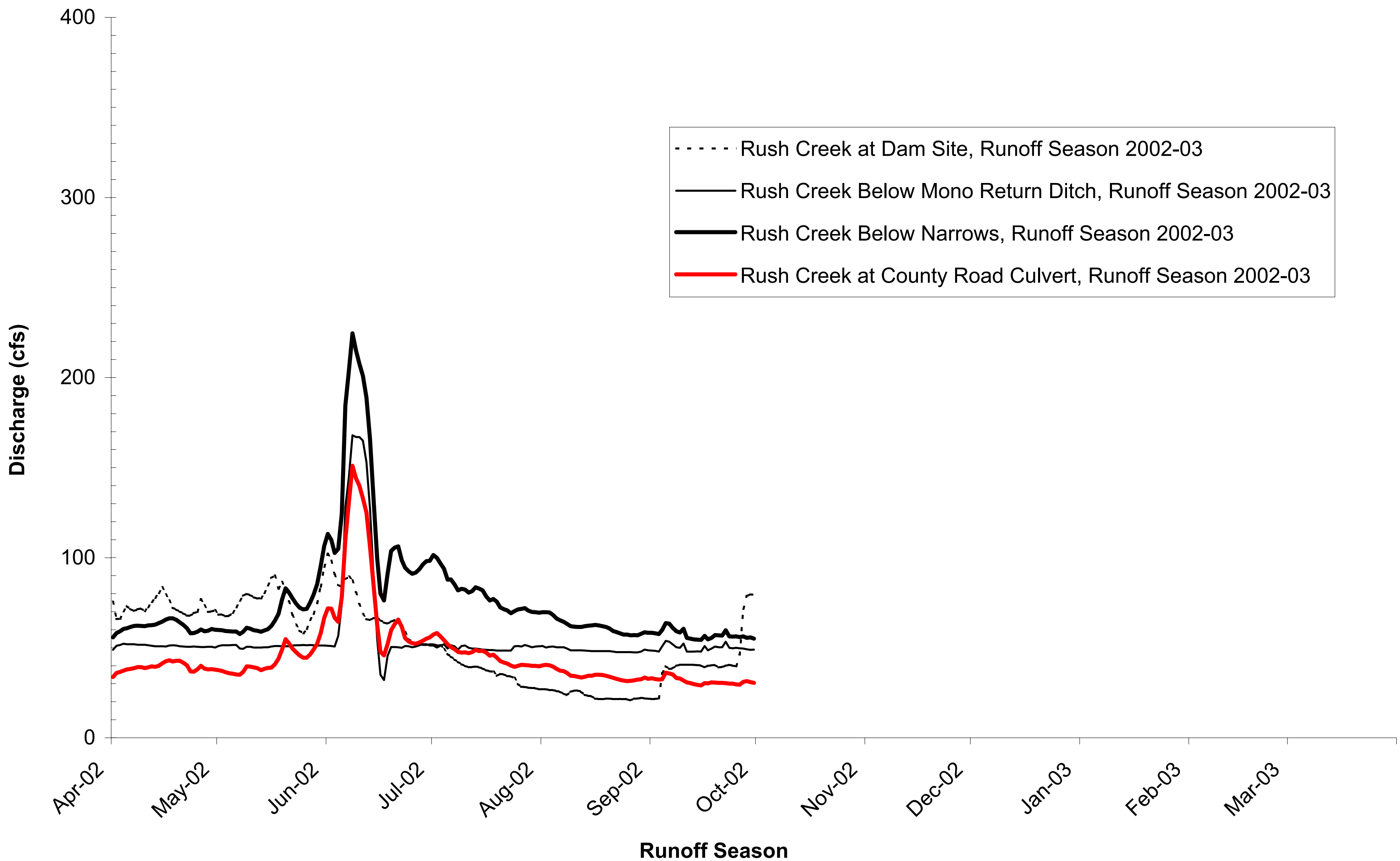


Figure 1. Daily average annual hydrograph for Rush Creek for the first half of Runoff Year 2002-03. The snowmelt peak of 236 cfs occurred on June 1, 2002.

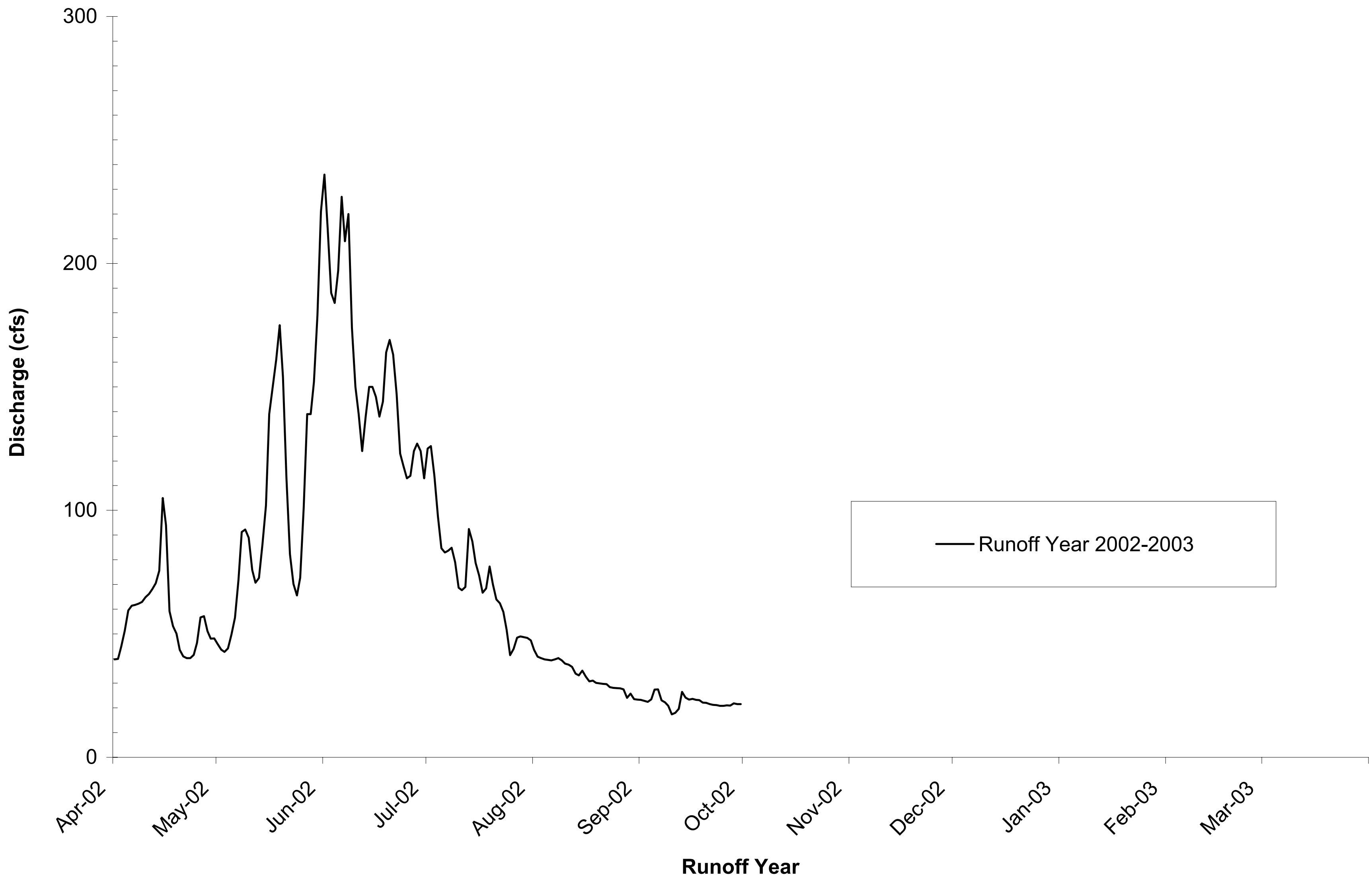


Figure 2. Daily average annual hydrograph for Lee Vining Creek at Intake for the first half of Runoff Year 2002-03. The snowmelt peak of 236 cfs occurred on June 1, 2002.

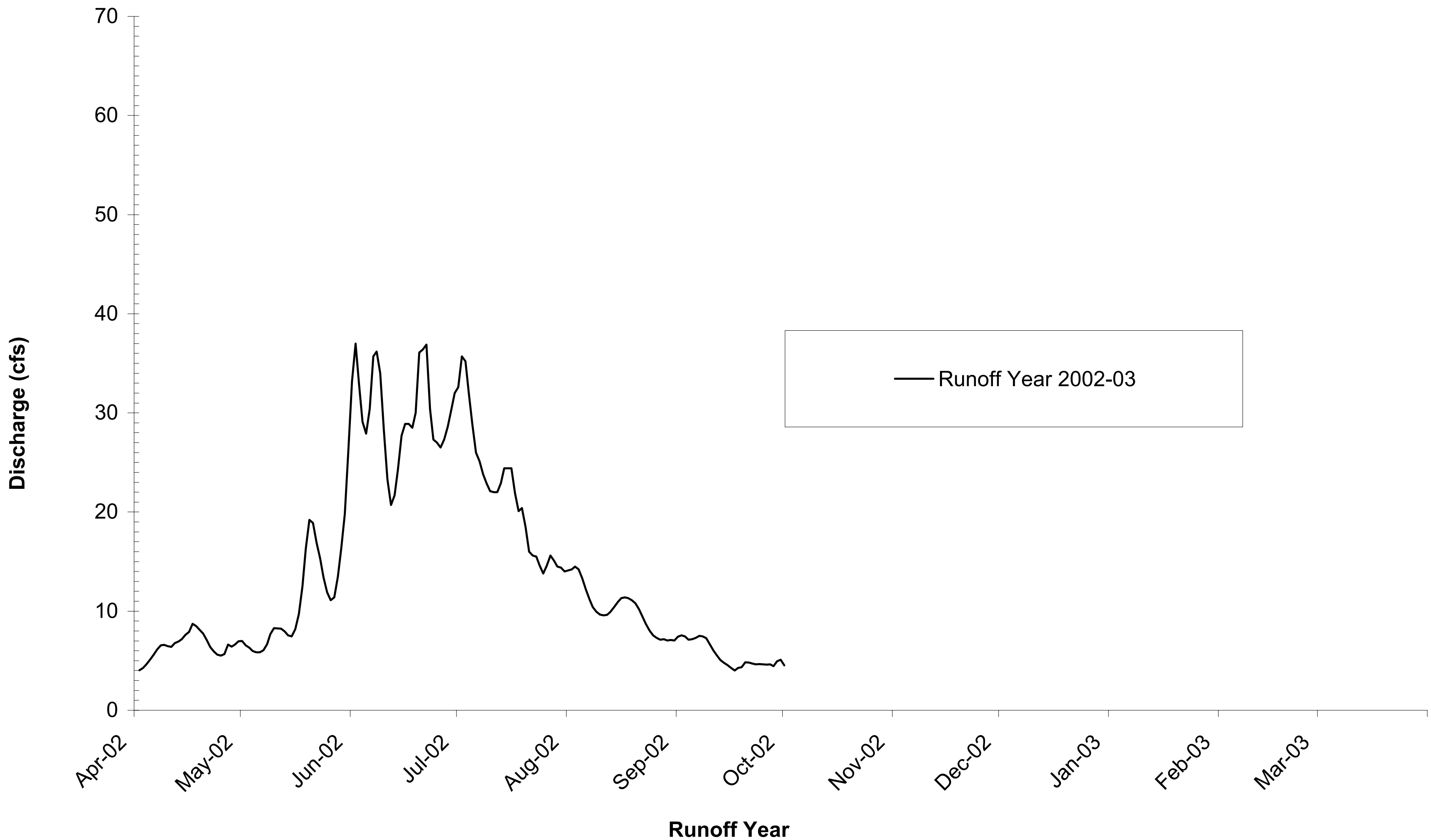


Figure 3. Daily average annual hydrograph for Parker Creek for the first half of Runoff Year 2002-03. The snowmelt peak of 37 cfs occurred on June 2, 2002.

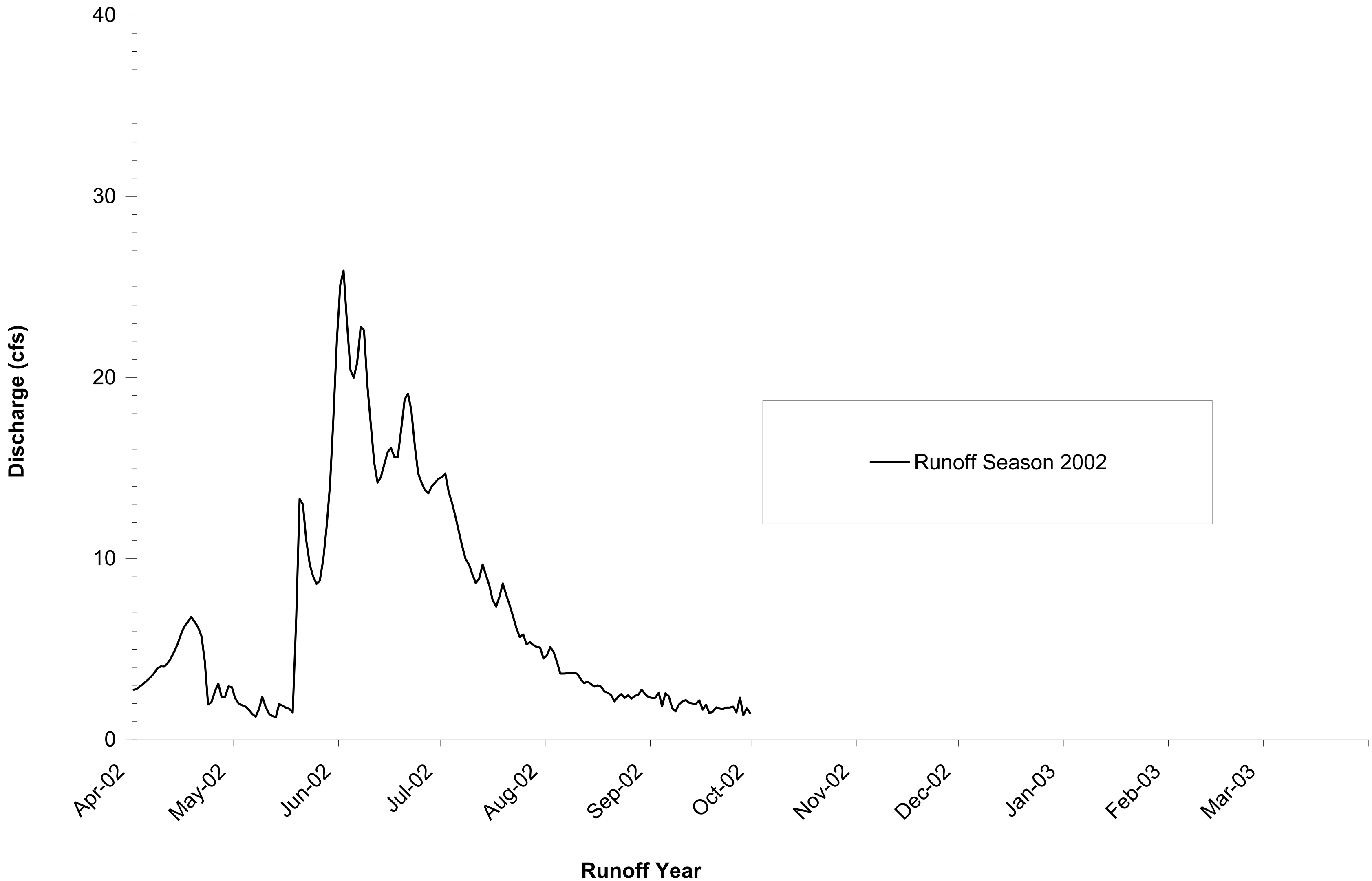


Figure 4. Daily average annual hydrograph for Walker Creek for the first half of Runoff Year 2002-03. The snowmelt peak of 26 cfs occurred on June 2, 2002.

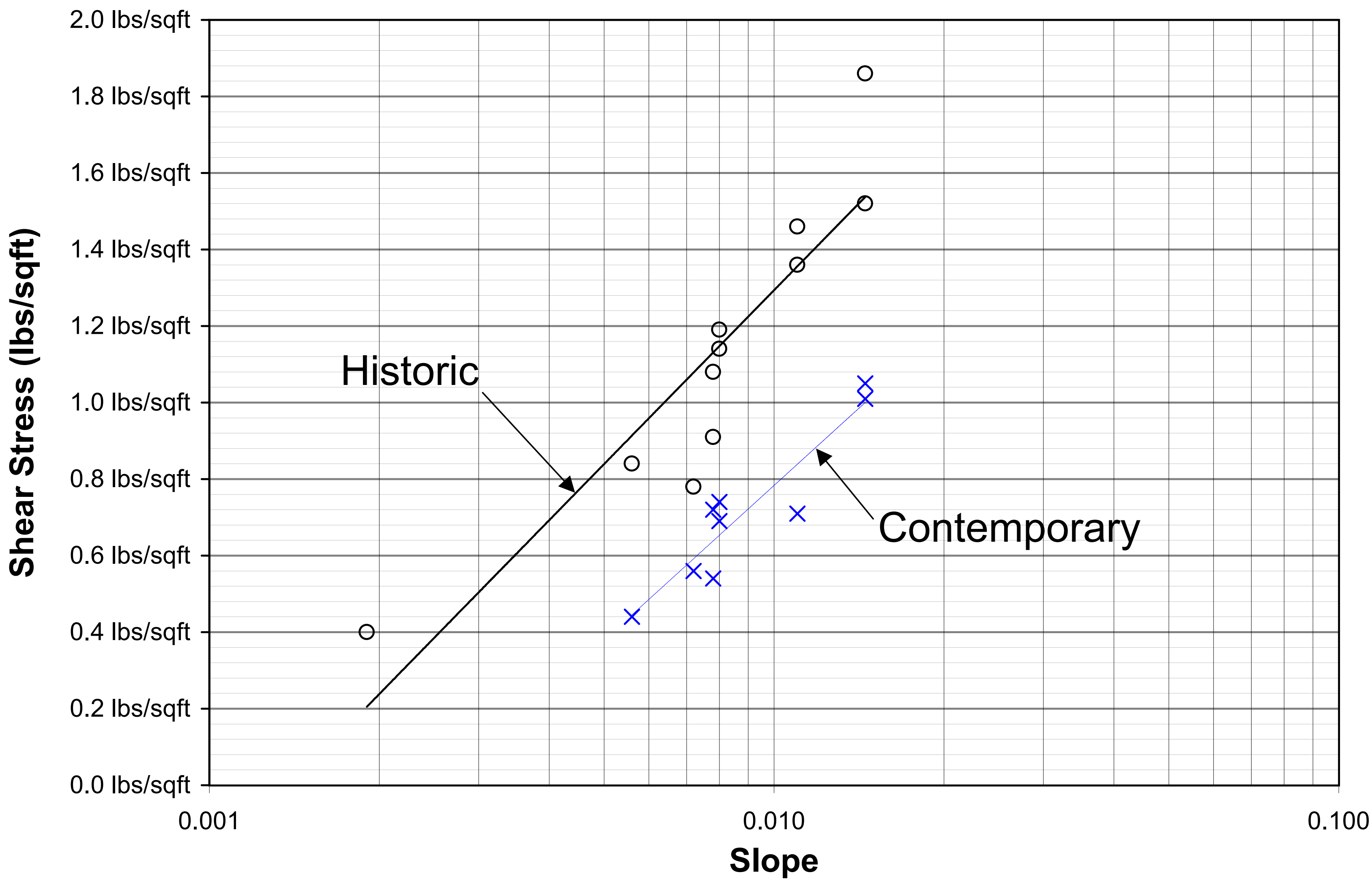


Figure 5. Figure 44 from the 2000 Annual Report, showing Lower Rush Creek shear stress at the $Q_{1.5}$ impaired for contemporary cross sections and the shear stress at the $Q_{1.5}$ unimpaired for historic/restored cross sections.

Figure 6. Photograph of the 3D Floodplain Restoration site, taken from the Narrows prior to excavation of the floodplain surface.

Figure 7. Photograph of the 3D Floodplain Restoration site, taken from the Narrows after the floodplain excavation was nearly completed.

Figure 8. Photograph of the 3D Floodplain Restoration site, taken from the south side of the 3D valley wall.

Figure 9. Photograph of the 3D Floodplain Restoration site, taken from the upstream end of the floodplain showing the side-channel flowing with approximately 2 cfs flow [Photo by Dave Martin].

Figure 10. Photograph of the 8-Channel Entrance site looking "upstream" showing the small floodplain with riparian vegetation at the entrance to the 8-Channel, prior to construction.

Figure 11. Photograph of the 8-Channel Entrance site looking "downstream" from the entrance to the 8-Channel, prior to construction.

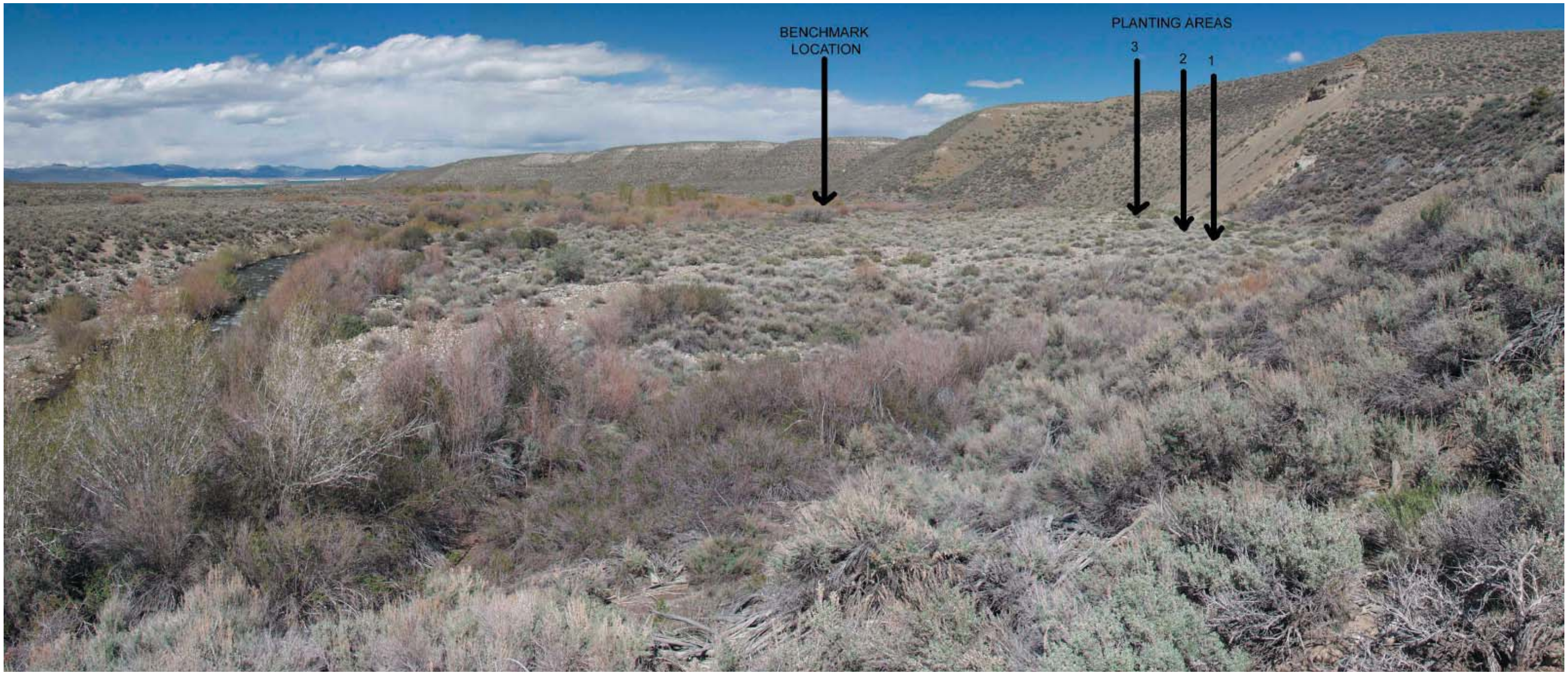


Figure 12. Pilot revegetation below the Rush Creek Narrows Project area showing the benchmark location and planting sites.

Figure 13. Pilot revegetation project below the Rush Creek Narrows. Blue flags indicate where trees were planted; a set of three flags makes an individual irrigation treatment planting.

Figure 14. Different types of irrigation methods used. Driwater was applied in paper quart containers, Terrasorb polymer was applied as a hydrated crystalline material to the backfill.

Figure 15. Planting methods used in the Pilot Revegetation Project below the Rush Creek Narrows.

Figure 16. In October, following the first irrigation season at the Pilot Revegetation Project, there was patchy survivorship within irrigation treatments.

Figure 17. The importance of browse protection cannot be underestimated.

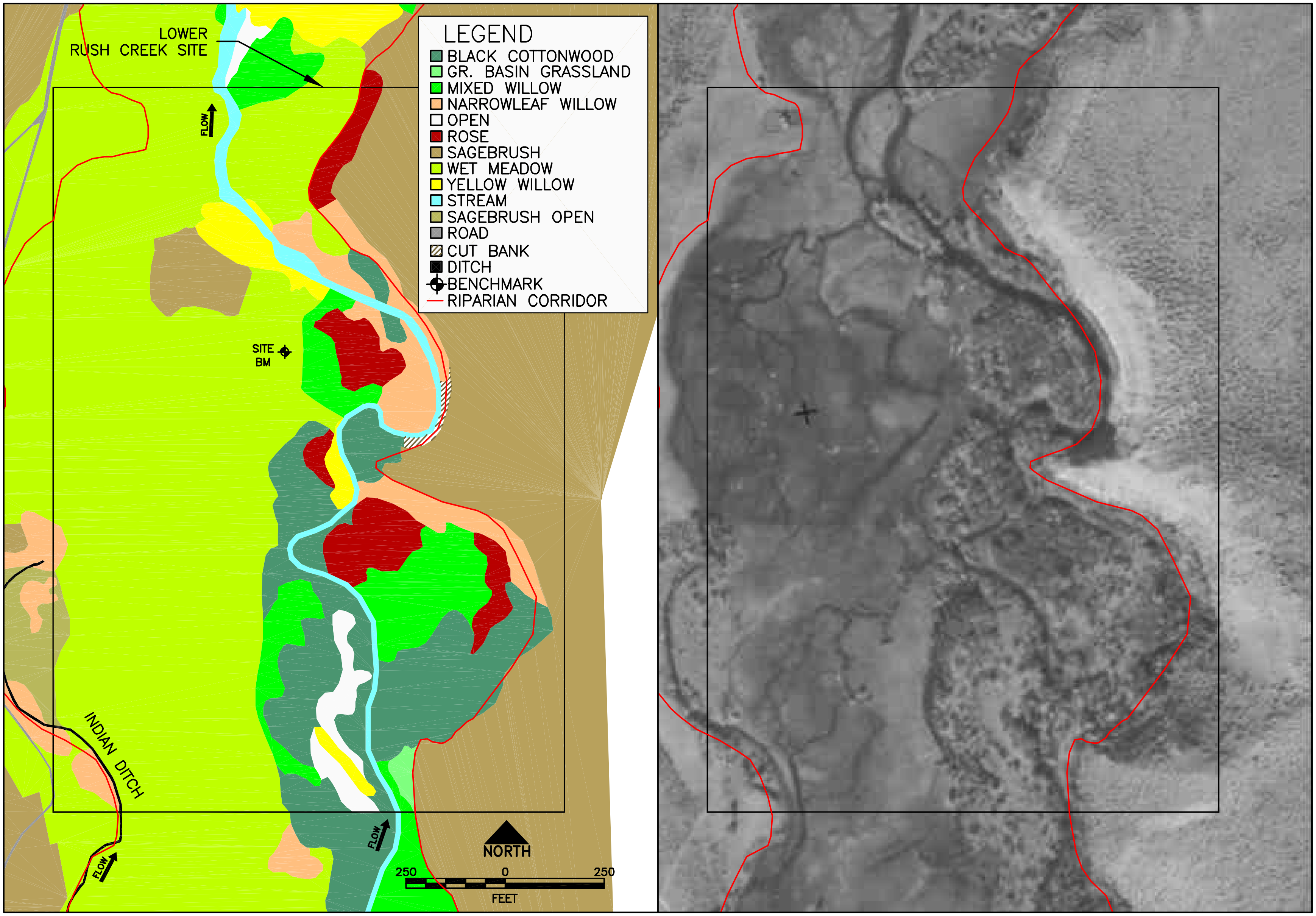


Figure 18. Example of the (a) 1929 aerial photograph and (b) riparian mapping and inventory at the Lower Rush Creek site.

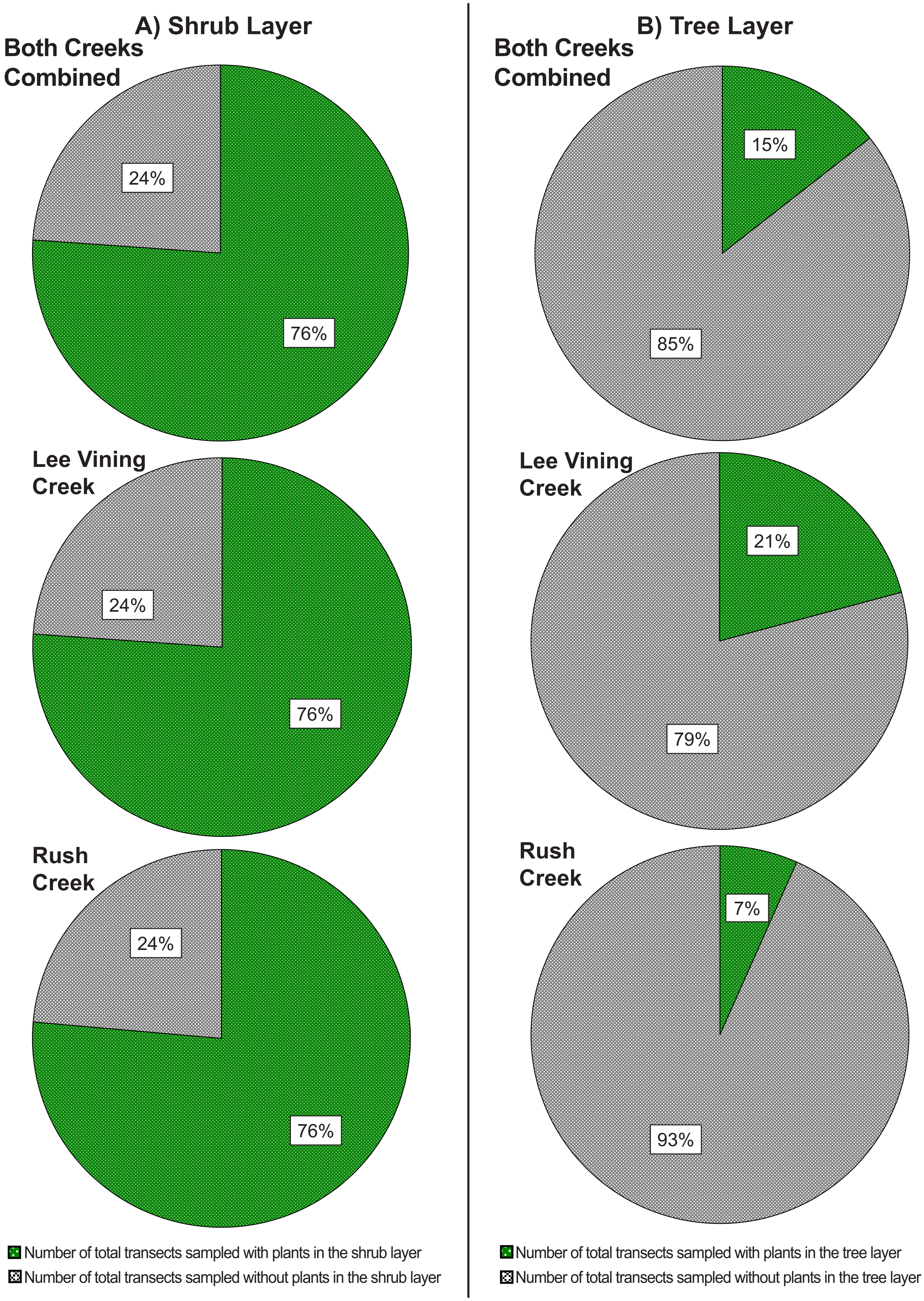


Figure 19. The percentage of sampled transects that have plant species growing the (a) shrub layer and (b) trees layers of both creeks combined, and Lee Vining and Rush Creeks separately.

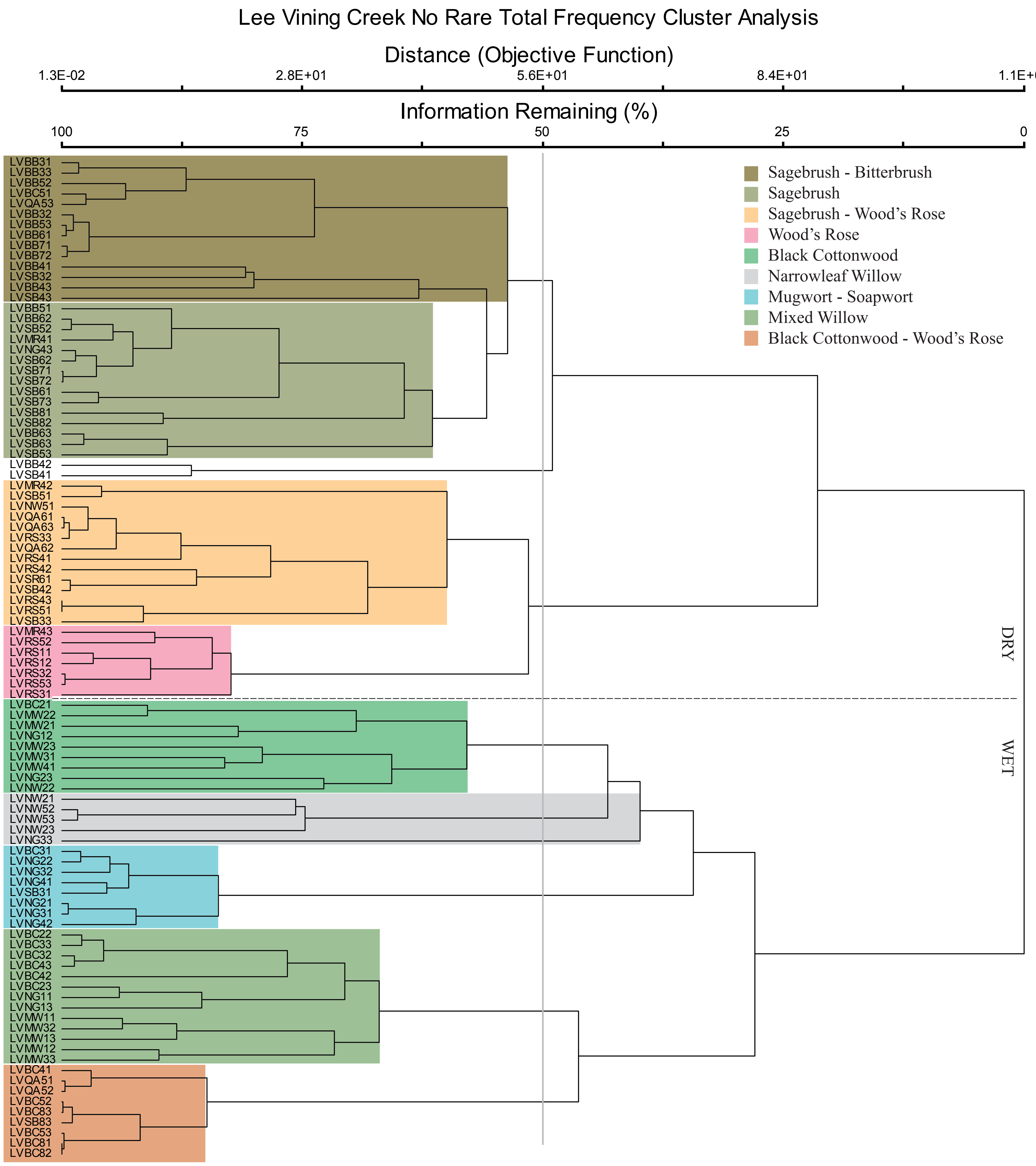


Figure 20. The Lee Vining Creek dendrogram. Results of the nested frequency cluster analysis of frequently sampled plants species.

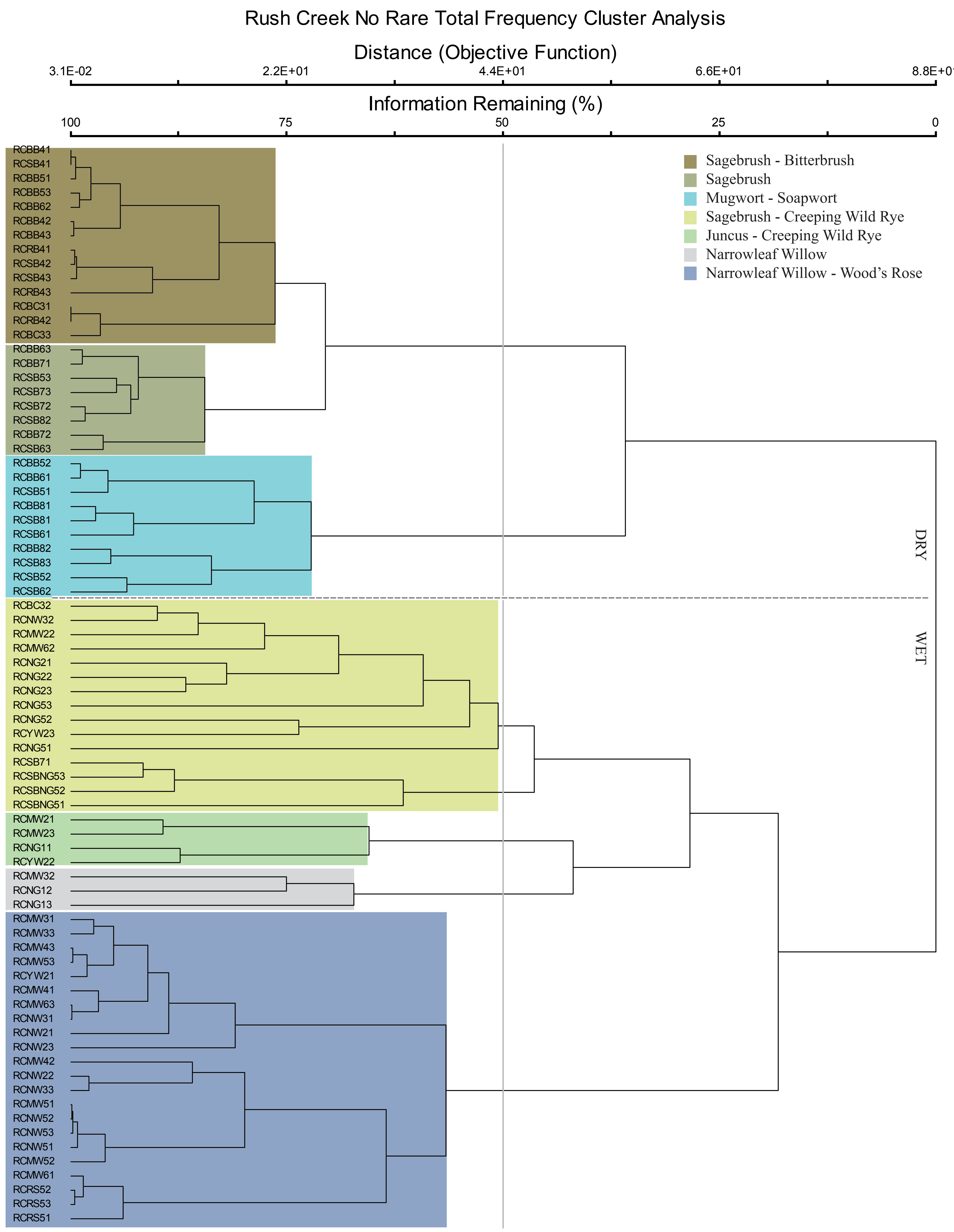


Figure 21. The Rush Creek dendrogram. Results of the nested frequency cluster analysis of frequently sampled plants species.

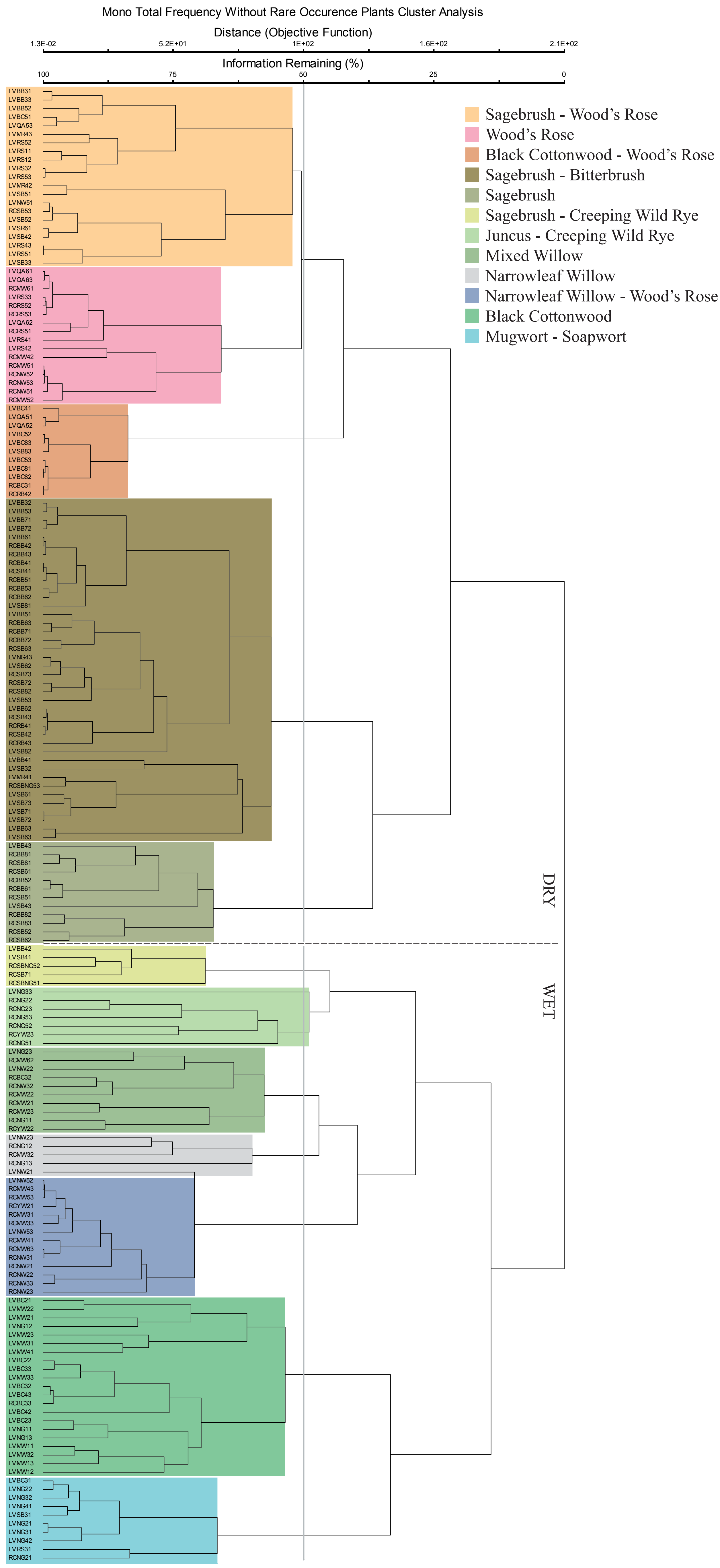


Figure 22. A combined Lee Vining and Rush Creek dendrogram. Results of the nested frequency cluster analysis of frequently sampled plants species.

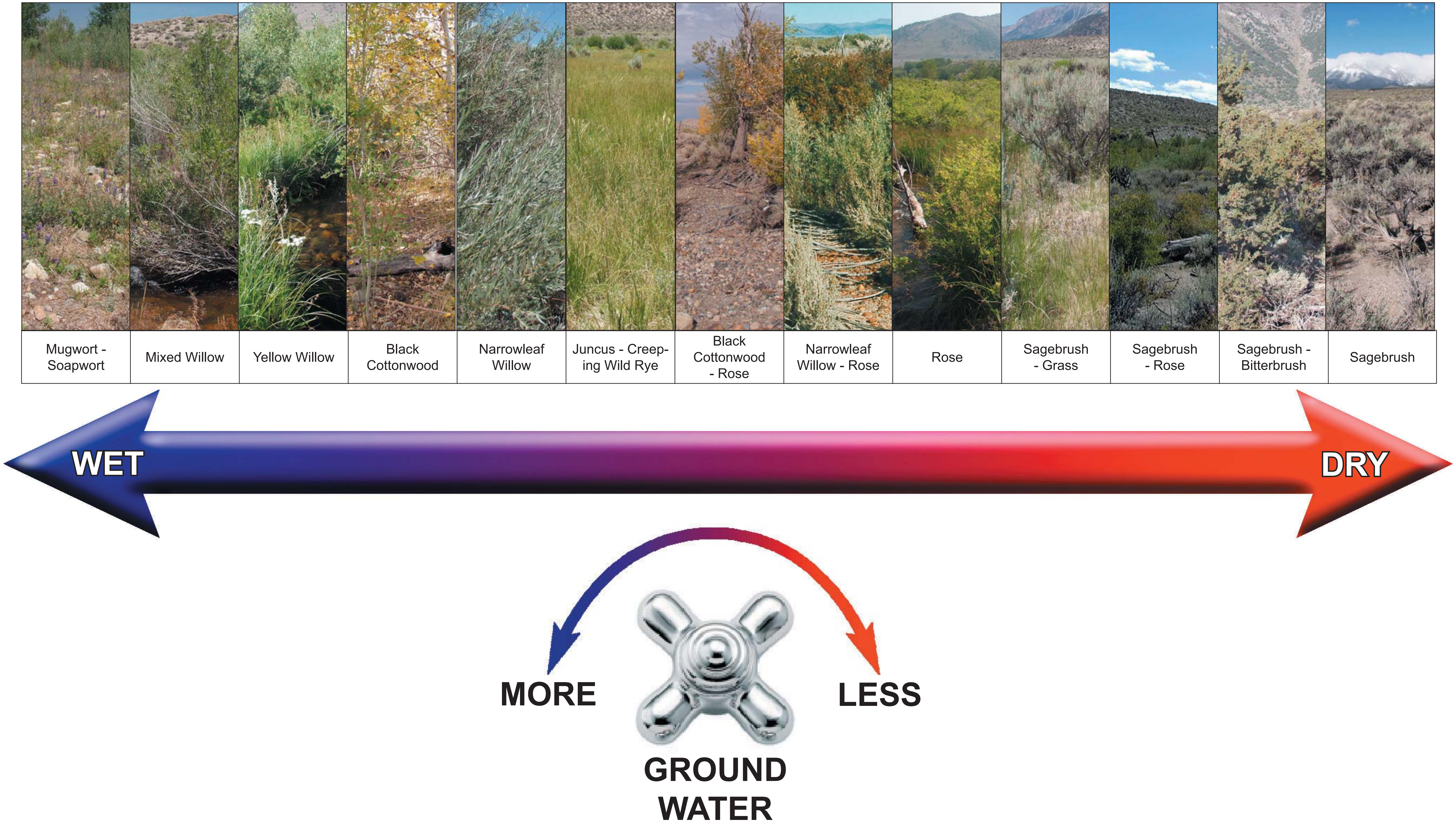


Figure 23. The relationship of individual patch types to the groundwater gradient. Increases or decreases in groundwater (i.e., turning the knob) may cause a shift in patch type.

LEE VINING CREEK FREQUENCY TWO-WAY ORDERED TABLE (CULLED OF RARE OCCURRENCE SPECIES)

	WET/WET									WET/DRY	
		545533514	1433133124344	667556612445756244	22226	67757777	8 77 12563688368	189 11888999 189 38	2299		
		145789692	7335667501480	780021983693990657	12782	48281453	21367834432613155	5617429046891237240400	5956		
14	CANE	----2---2	-------3--3-5	------------------	-----	--------	-----------------	1---------1---4-------	----	00000	
36	JUME	5-5535445	3---3-4534553	-----------3-3----	34---	-------3	5---------5------	53------------------3-	----	00000	
43	MUFI	--5--5---	-------------	----------3-------	-----	--------	-----------------	--------------------4-	----	00000	
2	ACMI	53-532---	-43-455-2----	---1---112--------	-----	--------	-----------------	----------------------	----	000010	
7	ARSO	--------4	----------5--	------------------	-----	--------	-----------------	----------------------	----	000010	
25	DISP	---5-----	-------------	------------------	-----	--------	-----------------	----------------------	----	000010	
34	GATR	-34-31---	--3425521-55-	-1-3------------4-	-----	--------	-----------------	----3-----------------	----	000010	R
35	JUCO	532-----5	-----------2-	------------------	-1---	--------	-----------------	----------------------	----	000010	I
41	MEAL	-45555555	----421------	------------------	-----	--------	-----------------	----------------------	----	000010	P
42	MOSS	355545-32	4545355554551	2113----------5-2	-----	--------	-----------------	----------------3-----	----	000010	R
47	POA1	55-5---24	----45554224-	---3--------------	-----	---4----	-----------------	----------------------	----	000010	I
64	TRMO	-------45	5343444533---	----------4-----2-	-----	--------	-----------------	----------------------	----	000010	A
65	TRWO	--------5	-32---3341-2-	---2------------1-	-----	--------	-----------------	----------------------	----	000010	N
11	CALA	-3443----	---445554-3-5	---5--5----------1	-----	--------	-----------------	----------------------	----	000011	
28	EPCI	--5555521	-335545433-4-	---51-2-----------	-----	--------	-----------------	----------------------	----	000011	S
37	JUPH	-55-55455	5545555545554	22-22--14--5----5-	3----	--------	-1---------------	----------------------	----	000011	P
58	SALAS	--5-43-44	-----54--44-4	----------2-2----3	-----	--------	---------------5-	----------------------	----	000011	E
59	SALU	-55-55-25	4-5555-535555	-----1-4--4-4----5	-----	--------	-----------------	----------------------	----	000011	C
12	CAMIN	--45-1---	4---22433----	--------13--5-----	-----	--------	-----------------	----------------------	----	00010	I
16	CAPR	-3---35--	542-4--45554-	431----5-23------1	-----	--------	---------------2-	----------------------	----	00010	E
56	RUCR	-5-4321-2	22-1-1222-42-	21-25-----------22	1----	--------	-----------------	----------------------	----	00010	S
57	SAEX	--55555-4	334--555----4	----3---4-13-55-2-	-----	---5----	-----------------	----------------------	----	00010	
22	COCA	---------	----2--3---3-	--2-1------------1	-----	--------	-----------------	----------------------	----	00011	
29	EQAR	---4-----	-522--3------	---------------132	-----	--------	-----------------	----------------------	----	00011	
54	RONA	---------	-344354----2-	3--3------------4-	-----	--------	-----------------	----------------------	----	00011	
60	SALUC	----4---1	5554--45-433-	4----1-----44--454	-----	--------	-----------------	----------------------	----	00011	
44	OEEL	-5-2455-4	33-----------	---1---2--443---22	-----	--------	--1-------1------	----------------------	----	00100	
63	TAOF	25-------	1-34---4--42-	---42--1-2-22--134	-----	--------	-----------------	----------------------	----	00100	
5	ARDO	554555545	5554555545543	454555554555544455	5---4	--------	-3343-----4------	----------------------	----	00101	
62	SEEDLING	--5------	--------4----	--45-------------5	-----	--------	-------------2---	----------------------	----	00101	
66	VETH	-2-4-----	21-----------	-3---1------2-1-5-	-----	--------	---2-------------	----------------------	----	00101	
13	CAMIC	-3--5---5	----2-1-1----	-4--3----2------3-	-----	--5-----	-----------------	----------------------	----	0011	
48	POBAT	-53455-55	55555555555-5	---5-5-45-3-5--555	55555	--------	-------5-5-------	----------------------	55-5	0011	
50	POPR	552355555	5555554555554	4325555555555341-5	55---	--------	3-45-3-2-4-------	4---2--2--------------	-1--	0011	
27	ELGL	---------	--2-2---135--	-2--------32----5-	-----	-----55-	------------5----	----------------------	----	010	
39	LULE	431555454	44--554325--1	---55--4445-534--2	12---	-3------	-412------5-4-5-5	3----5--------3-4-1555	----	010	
49	POCU	----55324	-----12------	------------------	-5---	--5-----	3----------------	3------------------5--	----	010	
38	LETR	-4-------	241-3--1-----	55-4433545535----2	-----	--------	5-25-124--4---555	5--3-4--------3-3-----	-4--	011	
61	SAOF	-5-551---	4543-5--23--4	555551554555545155	53---	----2---	-5555535355-54-43	---------------2---5-3	----	011	
19	CHNA	---------	1------------	-3-33---2--342----	-----	--------	-42452-3543-4-3--	3-1-5----2-----33--4--	2-54	10	
20	CHNE	---------	55-----------	------------44----	-----	24------	-----------------	44--2--1------------1-	125-	10	
51	POSE	---------	--12----1----	5535-23---53-2--2-	-----	--------	--5-3545-44--2---	---------1-----4553-34	2---	10	
55	ROWO	242251-22	343-553543431	5554555422343---52	52435	55555555	41455555-55555555	------3-25---311---355	-4--	10	
9	BRTE	---------	--------34552	---5535---3-------	5----	-------1	---------1443-53-	45455----2----2245-555	4555	1100	
8	ARTR	-----5---	-------------	443-5-----3-1----2	-2---	-5555555	55554555555555535	5555555455555555555555	5555	11010	
21	CHVI	---------	-------------	---------------4--	-----	--------	5---3--2------2--	-43--411-1-1---------1	----	11010	
45	OXDE	---------	-------------	------------------	-----	--------	-1--------4-34---	---------3-2-24-----1-	----	11010	
53	PUTR	--------1	--------22---	4-422---3-1-2--2--	-----	--------	3555-555234443114	5544555554----55555545	----	11010	
10	CADO	5-------3	-------------	--------------2---	-5---	-------4	2----5--4-5------	35---55---5-555-5--255	----	11011	D
26	ELEL	---------	-------------	--------3-------2-	55---	-3------	--55-5-2-5512----	-5---4554-44--55555-4-	53-4	11011	E
3	ACOC	---------	-------------	---1-------------3	-----	-------5	-------3---------	------3----------55-54	3---	11100	S
40	MACA	---------	-------------	------------------	-----	--------	------322--33-1--	24-255-355--2-5-23--15	4455	11100	E
46	PHBI	---------	-------------	------------------	-----	-2------	-----------------	---3------------------	-25-	11100	R
6	ARPU	---------	-------------	--2---------------	----1	--------	----2-----4--2-3-	-3-------------5355-45	-4--	11101	T
24	CRWA	---------	-------------	------------------	-----	--------	----------4-4----	-5-1------------23-515	-1--	11101	
17	CARO	---------	-------------	------------------	-----	-5------	-----------------	-----2----54--4-35--3-	----	111100	S
32	ERUM	---------	-------------	------------------	-----	--------	----12---3-------	---5--22--------535---	----	111100	P
33	GARA	---------	-------------	------------------	-----	-----2-1	-----3----5-4253-	45-5-422-453345-45-555	----	111100	E
1	ACHY	----5----	-------------	------------------	-----	--4-----	------------3----	-545313-243435444---2-	1--1	111101	C
30	ERAM	---------	-------------	------------------	-----	--------	----------2-2----	52--5-----5--35----445	----	111101	I
52	PRAN	---------	-------------	------------------	-----	--------	-----4-----------	35-34---13-3---5-53--3	----	111101	E
15	CANE*	---------	-------------	------------------	-----	--------	-----------------	--------------------34	----	111110	S
18	CHDO	---------	------------2	---3--------------	-----	--------	-----1-----------	-23----2--2----44--4-4	----	111110	
23	CRCI	---------	-------------	------------3-----	-----	-------1	------------1----	---42--1------44-5-214	----	111110	
31	ERSP	---------	-------------	---------------2--	-----	--------	---3-2---------1-	-2--432-------552535-3	----	111110	
4	ARCA	-3-------	-------------	------------------	-----	--------	---------1-------	--3------------12----5	1---	111111	
		000000000	0000000000000	000000000000000000	00000	11111111	11111111111111111	1111111111111111111111	1111		
		000000000	0000000000000	111111111111111111	11111	00000000	00000000000000000	1111111111111111111111	1111		
		000000000	1111111111111	000000000000000000	11111	00000000	11111111111111111	0000000000000000000000	1111		
		011111111	0000000111111	000000000000000111	00111	00111111	00000000001111111	0000000000000001111111			
		00011111	0011111000001	000000011111111		011111	01111111110000111	0000011111111110000111			
		00011	0011100011	000111100000011		00001	000011111				

RIPARIAN PATCHES DESERT PATCHES

RUSH CREEK FREQUENCY TWO-WAY ORDERED TABLE (CULLED OF RARE OCCURRENCE SPECIES)

		137271347	31223343343	3146774	12235424444522	1	5 225555	56 5 166 111566666677			
		796549255	36014715620	8505233	82913664789547	4	314384807	2112656802779123903468901			
28	EQAR	5-1--53-3	---2-------	-------	--------------	-	---------	------------------------	-	000000	
58	SALUC	5---55-3-	----5-----5	-------	--------------	-	---------	------------------------	-	000000	
61	TRWO	535--45-5	3--4-------	-------	--------------	-	---------	------------------------	-	000000	
7	ARSO	45----3--	-1453544--4	5------	2-------------	-	---------	------------------------	-	000001	
12	CAMIN	------3--	4-1----34-5	-------	--------------	-	---------	------------------------	-	000001	
13	CAMIC	-------5-	-3-55-5----	-------	--------4-----	-	---------	------------------------	-	000001	
22	COCA	---------	5--45-23---	-------	--------------	-	---------	------------------------	-	000001	
27	EPCI	--2--1---	5-32--4-44-	------5	--------------	-	---------	------------------------	-	000001	R
33	GATR	3--------	--42---4224	-------	--------------	-	---------	------------------------	-	000001	I
34	JUCO	55-------	---3253-5--	-------	--------------	-	---------	------------------------	-	000001	P
36	JUPH	555-155--	5-553454545	-------	--------------	-	---------	------------------------	-	000001	R
40	MEAL	---------	----------5	-------	--------------	-	---------	------------------------	-	000001	I
43	OEEL	--5----42	31-55--4---	-------	--------------	-	---------	------------------------	-	000001	A
46	POA1	5--------	54155-3----	------4	--------------	-	---------	------------------------	-	000001	N
48	POPR	----24551	-4455-3554-	-------	--------------	-	---------	------------------------	-	000001	
52	RONA	---------	---3--3---5	-------	--------------	-	---------	------------------------	-	000001	S
54	RUCR	---------	-2353-2343-	-------	--------------	-	---------	------------------------	-	000001	P
59	SEEDLING	---------	-5555--42--	-------	--------------	-	---------	------------------------	-	000001	E
60	TAOF	-5-------	--1--5412-4	4------	--------------	-	---------	------------------------	-	000001	C
2	ACMI	-55----42	-325-4144--	5------	4----2--------	-	---------	------------------------	-	00001	I
16	CAPR	4--------	----25-14--	--5----	--------------	-	---------	------------------------	-	00001	E
49	POSE	-5-----2-	-3--4--55-4	-24-2-5	--------------	-	---------	------------------------	-	00001	S
62	VETH	----4----	5--15-54-1-	5------	--------------	-	--------2	------------------------	-	00001	
38	LULE	4-5434-15	55-5-1-----	------5	--------------	-	---------	-----4--2-------2-------	-	0001	
41	MOSS	5--------	54455-2----	-5-----	--------------	-	21-------	-----4--------2---------	-	0001	
56	SALAS	--3-----3	--44-------	-------	4-------------	-	---------	------------------------	-	0001	
11	CALA	5554353-3	--4----5-5-	------2	-----5---2--52	-	---------	------------------------	5	0010	
14	CANE	-54--4---	-----------	5-----1	--------------	-	---------	------------------------	-	0010	
57	SALU	5-5-55555	5-4151----5	------2	555---------33	-	---2-----	------------------------	-	0010	
25	DISP	----12555	----1------	-45-53-	--------------	-	-------1-	------------------------	-	0011	
35	JUME	555-45555	51415545555	5555455	5--2-244--2-5-	-	---------	------------------------	5	0011	
42	MUFI	-55------	5----3-----	5255-55	1-------------	-	---------	------------------------	5	0011	
55	SAEX	4-5555555	5355555-553	-5----5	55-5-555555-55	-	---55-4--	------------------------	-	0011	
5	ARDO	-3544225-	5245533545-	-5----1	55-345-41-----	-	-12----44	532---------------------	-	010	
10	CADO	------5--	-----54-3--	5555555	51-45---------	-	---5---44	3-----------------------	-	010	
37	LETR	-55-4-33-	-1---52554-	2-555--	44355555555-5-	-	--55-434-	----------3-------------	5	010	
53	ROWO	-----2-1-	2133-255555	------3	44555555555555	-	--45-5---	35---3------------------	-	010	
3	ACOC	---------	---3-------	-----5-	------------55	-	--2------	5-----------3---2-------	-	011	
15	CANE*	5-----33-	--2--------	-4-1---	--------------	-	---2----4	------------------------	1	011	
47	POBAT	---------	-52-4------	-3-----	--------------	5	-5---4---	------------------------	-	100	
4	ARCA	---------	----3------	-------	--------------	-	-33------	-------2----------------	-	101	
18	CHDO	---------	-----------	-------	-------1------	-	5-------4	5-----------------------	-	101	
19	CHNA	---44----	------22-3-	-------	---3----------	-	214-434-3	5-43543--5---------5----	-	101	
21	CHVI	-33---3--	13---3-----	4----14	-------44-3-4-	-	-1-4-2455	24---3--4-4-333-4354-41-	-	101	
6	ARPU	---------	-------4---	-------	------------1-	-	-3-------	---2----------45--3----3	-	110	D
8	ARTR	---22-3--	--2-5331---	-1-555-	---333-3--2-1-	-	-35544554	455455555555555555555555	5	110	E
9	BRTE	------24-	1-----355--	-------	--41-3--------	-	--5------	51545545-535--4-5----1--	4	110	S
26	ELEL	---------	2-44--5---5	52-----	55-----1------	1	1--------	-5335433552251554-53-531	-	110	E
31	ERUM	---------	-----------	-------	--------------	4	---------	------------2---3-------	-	1110	R
39	MACA	---------	-----------	-------	--------------	-	-2-------	1-----------------------	-	1110	T
51	PUTR	-----1-1-	-------1-2-	-------	---2---3------	2	5454---3-	3-55555543-555555--54415	-	1110	
1	ACHY	---------	-----------	-------	--------------	-	---4----2	4--4---2-2-1-44-342--5--	-	11110	S
20	CHNE	---------	-----------	-------	--------------	-	--1------	3----------3------------	3	11110	P
24	CRWA	---------	-----------	-------	-----4--------	-	-23-1---2	5--2-4455-5331-5525---14	5	111110	E
30	ERSP	---------	-----------	-----2-	--------------	-	--232----	---2-53-455555-55-55-4-4	-	111110	C
44	OXDE	---------	---1-------	-------	--------------	-	-2------2	------1-----24334344--12	-	111110	I
50	PRAN	---------	-----------	-------	--------------	-	-------2-	-----1-----4-----55-----	-	111110	E
17	CARO	---------	-----------	-------	--------------	-	-------3-	-----5-453-554-5555--355	-	111111	S
23	CRCI	---------	-----------	-------	--------------	-	-22------	3----44--5-5-5555-242544	-	111111	
29	ERAM	---2-----	-----------	-------	--------------	-	---1-----	43-------4-3-5323-45-445	-	111111	
32	GARA	---------	3----------	---4---	--------------	-	---------	54---53415-5455555554555	5	111111	
45	PHBI	---------	-----------	-------	--------------	-	---------	---2---2-1-3-5-55---5344	-	111111	
		000000000	00000000000	0000000	00000000000000	1	111111111	111111111111111111111111	1		
	DRY/WET	000000000	00000000000	1111111	11111111111111	0	000000000	111111111111111111111111	1	DRY/DRY	
		000000000	11111111111	0000000	11111111111111	0	111111111	000000000000000000000000	1		
		000111111	00000111111	0111111	00000111111111		001111111	000001111111111111111111			
		001111	01111000001	000001	00011000000011		0000011	001110000001111111111111			
			00111	01111	0111111						
		RIPARIAN PATCHES				DESERT PATCHES					

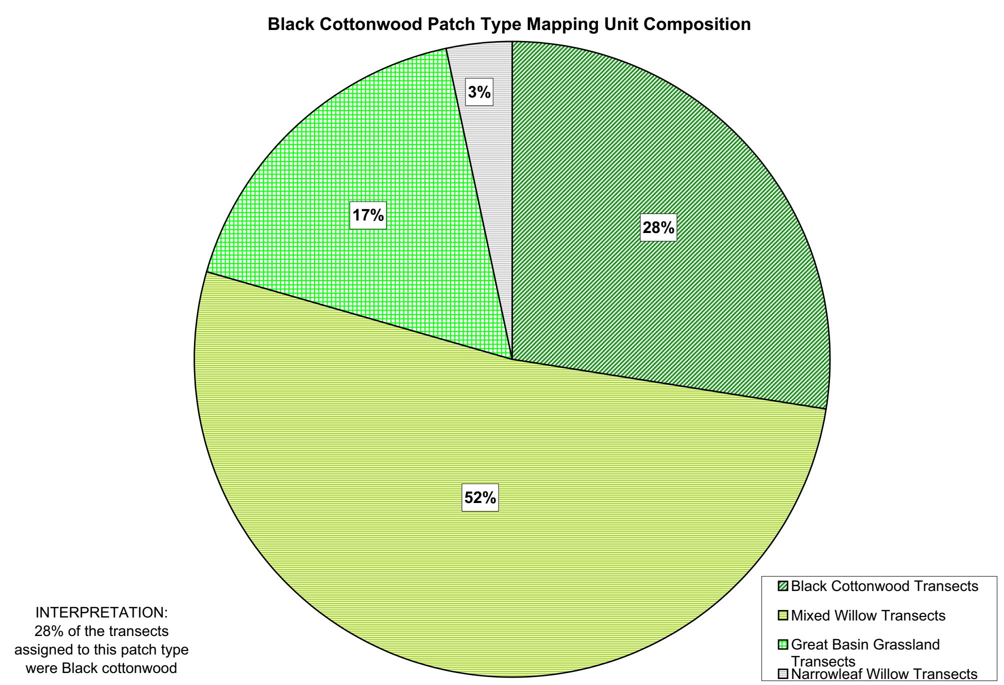
Figure 25. Results of the two-way ordered table from the Rush Creek TWINSPAN analysis of frequently sampled plant species.

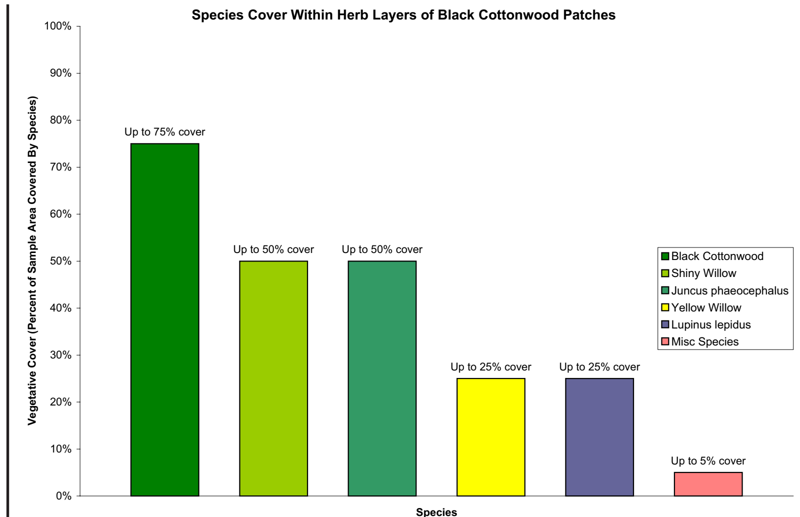
- Sagebrush - Bitterbrush
- Sagebrush
- Sagebrush - Creeping Wild Rye
- Juncus - Creeping Wild Rye
- Mixed Willow
- Narrowleaf Willow
- Narrowleaf Willow - Wood’s Rose
- Black Cottonwood

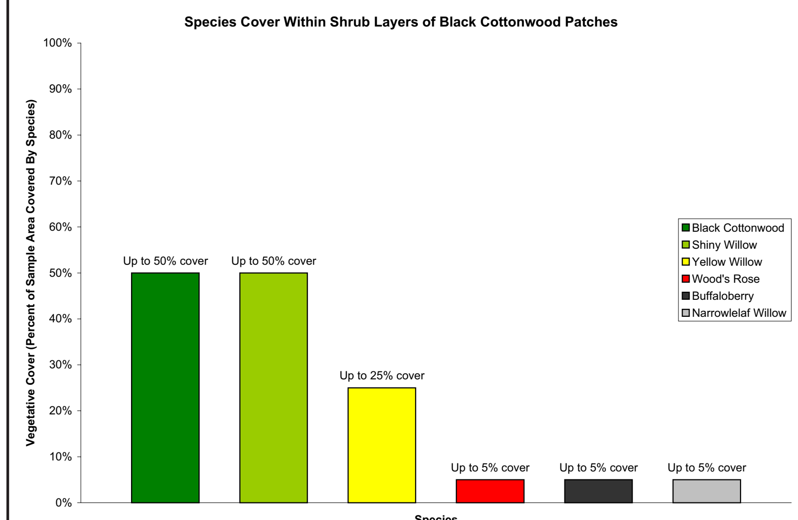
LEE VINING AND RUSH CREEK COMBINED FREQUENCY TWO-WAY ORDERED TABLE (CULLED OF RARE OCCURRENCE SPECIES)

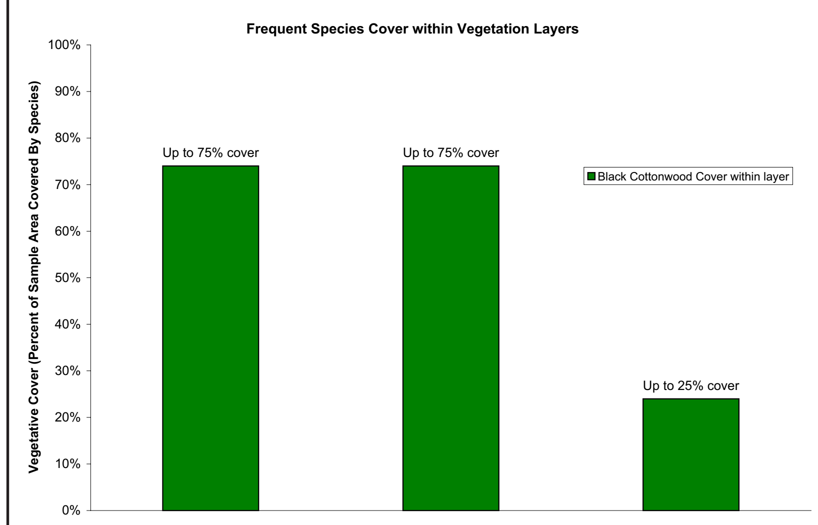
		11 11111 111	1 1 1	11111111111 111111111111	11 11 11 1	1 11	11 11	1 11 11111111111111111 1		
	WET/WET	1113333445556112344133444111235332	25525563667314446727	333337112472124442242244226	7668145257772	16775366805 1256778	229989955 3366	894 1111899994588000000000555666668895		
		3596789025670560418735345267901276	33910298780186791960	345692148112820350341729782	3892968442455	041811565001383443673	59561123750217	4604827901246078972471234567895890234568936		
34	GATR	3--5531--4---2215-5-34-34-42---2-4	----3--2-1-4--------	--------------------------	-------------	---------------------	--------------	---3---------------------------------------	000000	
41	MEAL	--52155-5555--4--------4---------5	--------------------	--------------------------	-------------	---------------------	--------------	---	000000	
64	TRMO	--444---5----543-3-5433-2---------	---------------4----	--------------------------	-------------	---------------------	--------------	---	000000	
12	CAMIN	---24-1--4-5-323---4------1-4--4-5	35---------31-------	--------3-----------------	-------------	---------------------	--------------	---	000001	
22	COCA	-------------32---3--------455--2-	-----1----23--1-----	--------------------------	-------------	---------------------	--------------	---	000001	
28	EPCI	-124555-1555-453-34-353---325--44-	----5124------------	----52--------------------	-------------	---------------------	--------------	---	000001	
37	JUPH	55555554554--554555545555-5553-555	45-322-422-41------1	4-5--5--5-----------------	-------------	-----------1---------	--------------	---	000001	
42	MOSS	5-35545125-5553554544555-445553-2-	----3---211---2-----	------5-------------------	-------------	---------------------	--------------	----------3-----21---4------2--------------	000001	
47	POA1	5-255---4--5-544224----5-415555-3-	----3---------------	----4---------------------	------4------	---------------------	--------------	---	000001	R
54	RONA	---54---------3---2-443-4--3----35	----3---3-----------	--------------------------	-------------	---------------------	--------------	---	000001	I
56	RUCR	---1232-2-14-2-24-22-1252235-3-42-	---125-321-3--2-----	--------------------------	-------------	---------------------	--------------	---	000001	P
16	CAPR	4-----3---5--44555452-43-----2-4--	--------43115213----	5--5----------------------	-------------	-----2---------------	--------------	---	000010	A
44	OEEL	-----45-4-52-------3--3521-535----	-4--1------42-24-3--	-----5---42---------------	-------------	-----------1---------	-----------1--	---	000010	R
60	SALUC	55--44--1----5--3435545-5----5---5	-4------4-----4-1445	---------3----------------	-------------	---------------------	--------------	---	000010	I
62	SEEDLING	---------5-----4---------555-5-2--	----5-----44--5-----	--------------------------	-------------	--------------------2	--------------	---	000011	A
66	VETH	-----------41------2--125--155--5-	-------1-3-4----12-4	-5------------------------	-------------	------------------2--	-------2------	---	000011	N
13	CAMIC	----15--5-----21-------333-5-5--5-	-----3---4---2------	---------5-----4----------	---------5---	---------------------	--------------	---	000100	
29	EQAR	55--3------4--------225-3--2------	--------------2---1-	-----1--3-3---------------	-------------	---------------------	--------------	---	000100	S
58	SALAS	--45443445------44---------44------	--------------32-2--	-----3-4--3---------------	-------------	-----5---------------	--------------	---	000100	P
59	SALU	5525-55555---553555455-5--4155---5	------------4-5414-5	1---25-5555-5----33-------	----2-------5	---------------------	--------------	---	000100	E
63	TAOF	-------------4--4-2134-53-1---2244	-2--42-----1124--21-	545-----------------------	-------------	---------------------	--------------	---	000100	C
11	CALA	55-553-5-4-4-5443----4-3--4-------	----5-55---5--1----3	--5-25--3-3------5224-5---	-------------	---------------------	-------------5	---	000101	I
65	TRWO	54--3---5----3-4-12-2-3-1--43-----	----2---------------	--3--5--5-5---------------	-------------	---------------------	--------------	---	000101	E
2	ACMI	---5532----5--42----3-43-325--541-	1---1------412------	455--5-4-42----------2----	-------------	---------------------	--------------	---	00011	S
7	ARSO	4-------4-------5--------145-3--44	-----------4--------	555----23-----------------	-------------	---------------------	--------------	---	00011	
35	JUCO	5-------52--------2----3---3-2553-	--------------------	5-5--------1--------------	-------------	---------------------	--------------	---	00011	
14	CANE	-4---2-52----3--3-----------------	--------------------	-55-14--------------------	-------------	---------------------	---------1----	--1-4-	0010	
36	JUME	554-43535545-5335453-----141555545	-333---5---5-------4	55555555554-44-25---22----	3455---------	---------------------	---------53555	-3---	0010	
57	SAEX	45-55554455555-----34-3-235555-553	435--3-5-------1---5	5---5555555-5555555555----	----5-554----	---------------------	--------------	---	0010	
5	ARDO	-2455535455455455455455524555543-	45455555454555555544	3-3-155525--5-41----4354--4	-----4-------	---------2-33-----43-	-------43--4--	----5---------2--1-------------------------	0011	
48	POBAT	--55555553-4-55555-55555552--4----	5--55-------4-53555-	------3----5-----------555	-------------	5---------4----5-5---	55-5----------	-------------------5-----------------------	0011	
50	POPR	-45545545253455555555555-445-5553-	55355554432555555512	--------5515--------------	---3---------	-------------43-2-45--	-1-------4----	---2----2----------------------------------	0011	
39	LULE	4455455141454352-5-4--43-5-55-4---	4-3155------4425-5-3	1---55---152--------4-----	-------------	---3-5--5--41-----2--	----4----355--	5-5--5----4--1--------4----2---2---------3-	0100	
49	POCU	--21255-4-3-----------------------	--------------------	-----------5--------------	---3-----5---	---------------------	----------3---	5--	0100	
27	ELGL	--------------2153--2---5---------	-2-------2-----3----	--------------------------	----------55-	---------------------	----5---------	---	0101	
51	POSE	---------------1----12--23---4-5-4	-32-5-3-5535---52---	--545-2--2----------------	-2-----------	------------5545-4-32	2---------34--	--4---4---5-13-----5-----------------------	0101	
61	SAOF	---5-514---55--2-3-443555---------	4545555-555-5555151-	-----------3--------------	-------------	--2---4-3--5553535554	----5------5--	5-3---2------------------------------------	0101	
15	CANE*	5-------------------------2-------	--------------------	------4-33----------------	----2--------	---------------------	--------4--3-11	--4--	011	
25	DISP	-2---------5-----------------1----	-------------------1	---5--4-555---------------	-53--1-------	---------------------	--------------	---	011	
38	LETR	-------------13----21-44-1-----52-	43--443455-5552535-4	5255-5-433--455555-5-555---	-5-554--3---3	-----55-554-2124--5--	-4-------5-455	-----4----3---------3-------------3-----3-	011	
43	MUFI	------5--5------------------5-----	--------------3-----	35555521------------------	--5----------	---------------------	-----------4-55	---	011	
55	ROWO	-225351122-2-55443333-4451332-2555	24-545555555422353--	2---3--4-1-245555555-555435	5--45-5--5555	-555555554514555-5555	-4--5-3-5-55--	3-5-3-13---25--------3------------------1-	10	
10	CADO	--------3---2-----------------534-	--------------------	55-55-555--51--------4-5---	455254-------	--------------5--4----	-----554-3555-	255-35-5--5-----------------------------5-5-	1100	
21	CHVI	-------------------------3--1-----	-------------------4-	343-43--3-----4434--------	--1545--4----	-----2----2----2---3-	--------54-----	-41-24-113--1----1---3---3433-4-54-441--1-3	1100	
3	ACOC	----------------------------3------	----1---------3-----	------------------55------	5-5----------	---------2-----3-----	3---------5---	--4-5--3-----5-----5-----3----2------------	11010	
19	CHNA	------------------1------------2-	232-33-3-3-2-----4-4	---------------------43---	-------44----	-----3---43422-35445-	2-544--3-3-3--	4--55-3--13-2-43215--43--------5-5---------	11010	
20	CHNE	------------------5--5------------	-4--------------4--	--------------------------	-------------	-2-4-----1-----------	125------41--3	-4-23---1----------------3-----------------	11010	
4	ARCA	-------------------------3-----3----	--------------------	--------------------------	-------------	---------3-------1---	1-------------	--5---1--32------3------2------------------	11011	D
9	BRTE	-------2-------3545---------1--53-	---5555----5---33---	---------24-----------13----	1-----------4	-----534-5-------1---	45553---1454-4	55555-2--44-2-54--5555455---4-55---31----2-	11011	E
26	ELEL	------------------------2-442---55	3--5----------------	-5----25---55-1-----------	-------------	1--3---1----55-2-55--	53-42---5-45--	-5---4555-54-5331-55-4323551554553-2531445-	11011	S
8	ARTR	------5-------------------2--5--3-	-----5--4431--23-1-2	3-----1-3--2--3-21--2333---	555555545555-	--55-5355545555555545	55555554555555	5555455545555554-35555555555555555555555555	1110	E
53	PUTR	-1------1------2-2----------------	3---22-24-41---1-22-	----------1----3------2-----	---343-------	2----11445-55555235-3	----4----544--	55553555545545555455455555455553-54-415--5-	1110	R
18	CHDO	-------2--------------------------	----3---------------	----------------1---------	-------------	-------------1-------	-------4------	424-5-4-234-----5---------------------2---	11110	T
32	ERUM	----------------------------------	--------------------	--------------------------	-------------	4------------2---3-1-	--------------	-------22-5--5-----35----2----3------------	11110	
40	MACA	----------------------------------	--------------------	--------------------------	-------------	-----1-3------322----	445532---21---	-45515--3-255----2-32--------------------5-	11110	S
31	ERSP	----------------------------------	------------------2-	--------------------------	--2-3--2-----	------1--2---2----3--	--------------	5234-352--2--3-2---5-535-545-55555-54-4--5-	111110	P
52	PRAN	----------------------------------	--------------------	--------------------------	-----2-------	-------------4-------	----------3----	-534--5----133-----531-4--------5-------3-5	111110	E
1	ACHY	-----5----------------------------	--------------------	--------------------------	----4----4---	---------------------	1--13352--2---	-5-34143-4424--4----5--12--44-322---5--3444	111111	C
6	ARPU	----------------------------------	----------24--------	------------------1-------1	-------------	------3------------22	-4---------44--	-35---5---3--5-2-3-5--------45--3-----3----	111111	I
17	CARO	----------------------------------	--------------------	--------------------------	-----3-------	---5-----------------	----------3---	-----2----3--------5-5-54554-5535---3555445	111111	E
23	CRCI	----------------------------------	-3------------------	--------------------------	1------------	-------1-2-----------	----------1---	2-423-4-1--------2-54445---55555242-544--4-	111111	S
24	CRWA	----------------------------------	--------------------	---------------------4----	-------1-----	---------3-----------	-1--4--2--14-5	555-5-----2----2-2-314435351-55-5--5-14---2	111111	
30	ERAM	----------------------------------	--------------------	--------------------2-----	----1--------	---------------------	----2-3-3542--	42554------------------3---5323445--4455-5-	111111	
33	GARA	----------------------------3-----	--------------------	--------------------------	1---------2--	-----53------3------2	----434-445545	555-54-22-4-4------5553544155555554-5555355	111111	
45	OXDE	--------------------------1-------	--------------------	--------------------------	-------------	-----------1--------4	----3-22--14--	------------3----2----1--2-4334-44---12-243	111111	
46	PHBI	----------------------------------	--------------------	--------------------------	-------------	---2-----------------	-25-----------	---------------2----3--32--5-551--5-344----	111111	
		0000000000000000000000000000000000	00000000000000000000	000000000000000000000000000	1111111111111	111111111111111111111	11111111111111	1111111111111111111111111111111111111111111		
	DRY/WET	0000000000000000000000000000000000	00000000000000000000	111111111111111111111111111	0000000000000	000000000000000000000	11111111111111	1111111111111111111111111111111111111111111		
		0000000000000000000000000000000000	11111111111111111111	000000000000000000000000111	0000000000000	111111111111111111111	00000000000000	1111111111111111111111111111111111111111111		
		0000000000000000000000000111111111	00000000000001111111	0000000000001111111111	0000001111111	011111111111111111111	00001111111111	0000000000000000000111111111111111111111111		
		0000000000000111111111111000000001	00000000111100000001	00000011111100000001111	0001110001111	0000000000111111111	0000011111	0000011111111111111110000000000000000001111		
		001111111111100000011111100000111	00011111 0000001	00001100000100000111		0000111111100000000				
			RIPARIAN PATCHES					DESERT PATCHES		

Figure 26. Results of the two-way ordered table from the combined Lee Vining and Rush Creeks TWINSPAN analysis of frequently sampled plant species.









BLACK COTTONWOOD PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

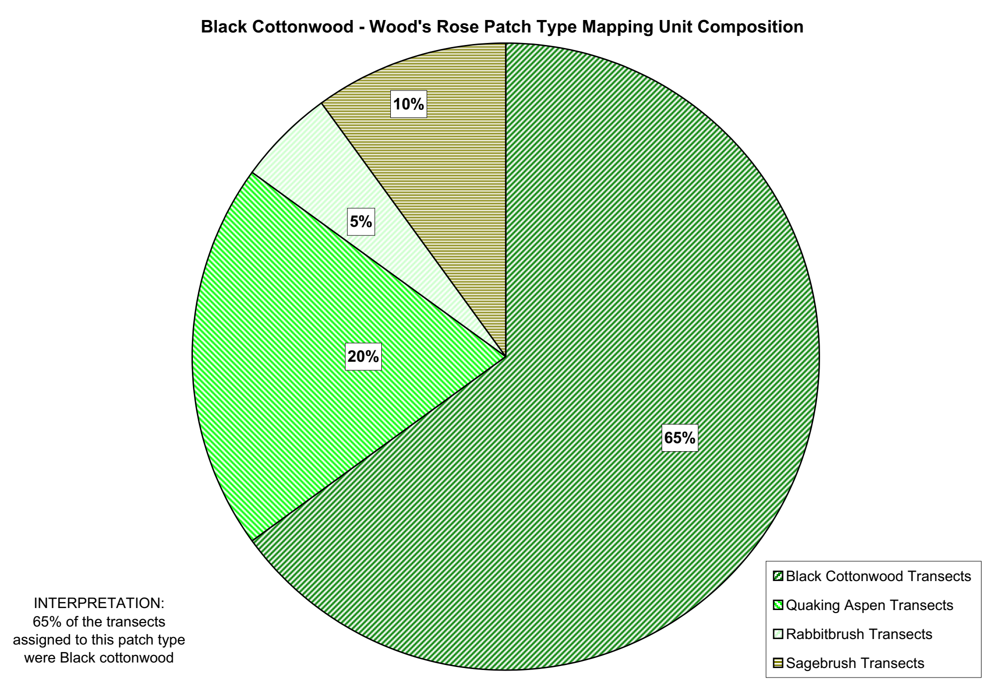
Common constituents in alphabetical order of scientific name.

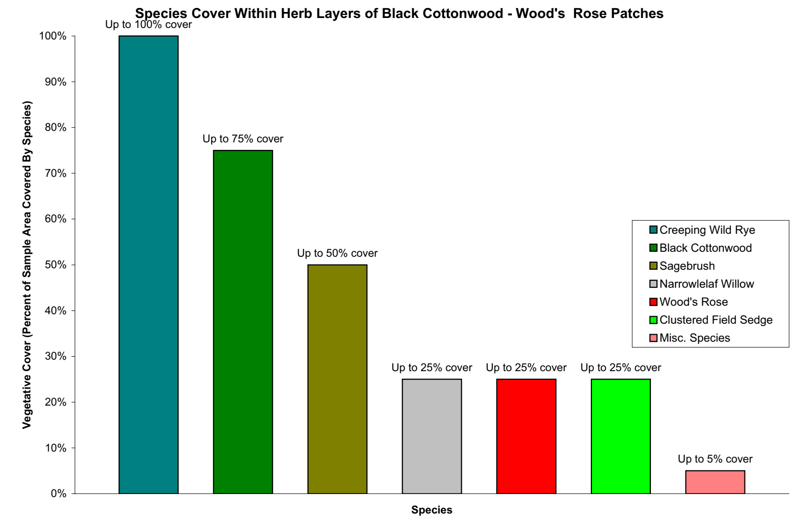
The listing written in red indicates an exotic plant.

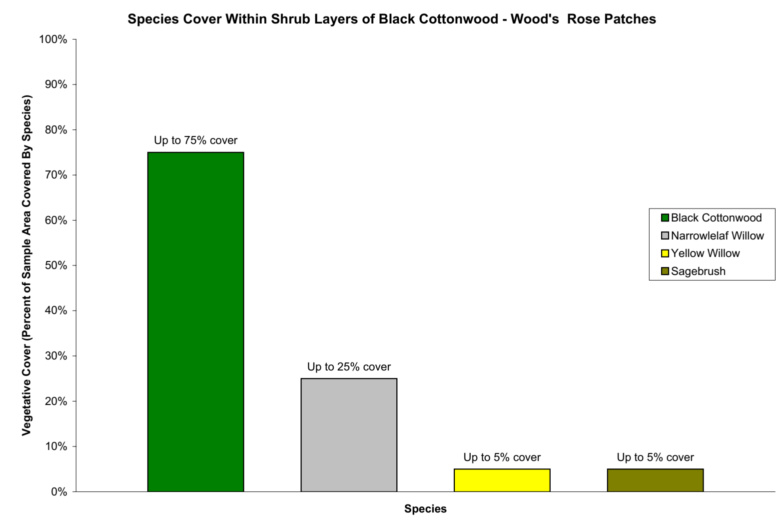
Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Mugwort	*Artmesia douglasii*	Herb	FAC+
	Carex douglasii	Grass	FACU
Wooly sedge	*Carex lanuginose*	Em Herb	OBL
Clustered field sedge	*Carex praegracilis*	Em Herb	FACW-
Bedstraw	*Gallium trifidum var. pacificum*	Herb	OBL
	Juncus mexicanus	Em Herb	FACW
	Juncus phaeocephalus	Em Herb	FACW
Creeping wild rye	*Leymus triticoides*	Grass	FAC+
	Lupinus lepidus	Herb	NA
Moss		Herb	NA
	Poa cusikii ssp. cusikii	Grass	NA
Kentucky bluegrass	*Poa pratensis ssp. pratensis*	Grass	FAC
Black cottonwood	***Populus balsamifera ssp. trichocarpa***	**Tree**	**FACW**
Narrowleaf willow	*Salix exigua*	Shrub	FACW
Shiny willow	*Salix lucida ssp. lasiandra*	Tree	OBL
Yellow willow	*Salix lutea*	Tree	OBL

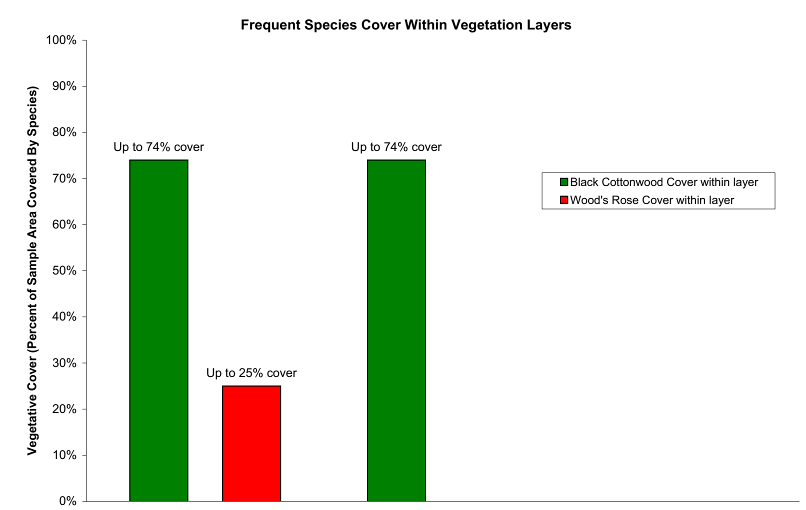
BLACK COTTONWOOD PATCH DESCRIPTION: Black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* [Torrey and A. Gray] Brayshaw) dominates the canopy and understory of this patch type. Kentucky bluegrass (*Poa pratensis* L.) and *Juncus phaeocephalus* Engelm. are common subdominants or associates in the herb layers of these patches. Over 95% of sampled transects identified as belonging to the Black Cottonwood patch type are currently found on Lee Vining Creek. Black Cottonwood patches are correlated with active floodplains (Geomorphic unit 2) that have been created and maintained by channel migration, floodplain deposition and channelbed scour. Black Cottonwood patches are usually found where there is shallow groundwater and that flood at a minimum of every 2 years.

Figure 27. Black Cottonwood patch type description.



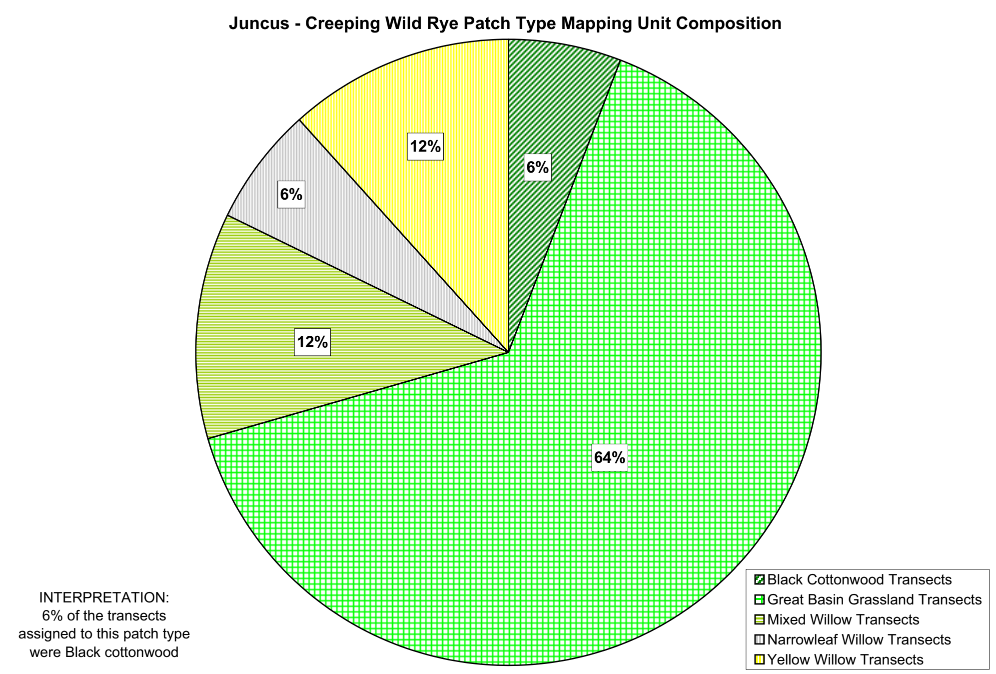


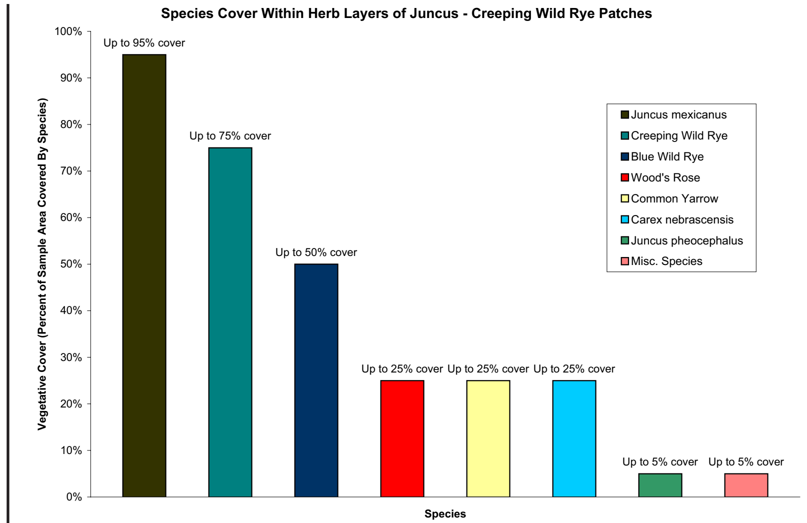


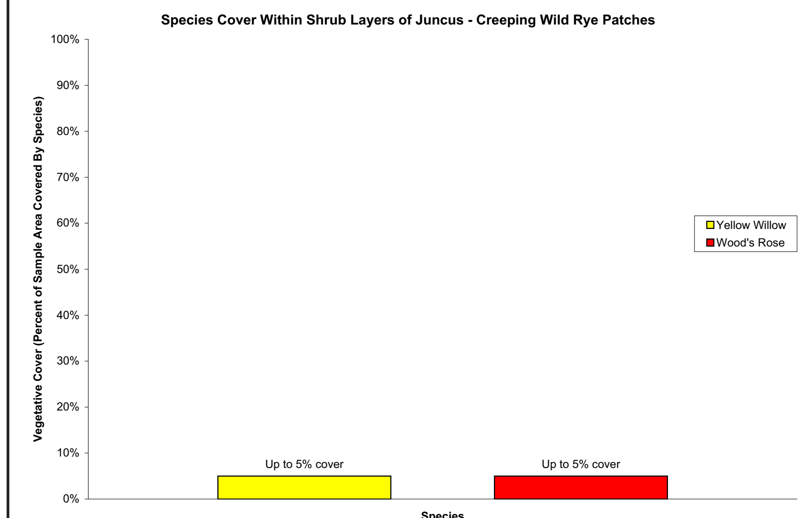


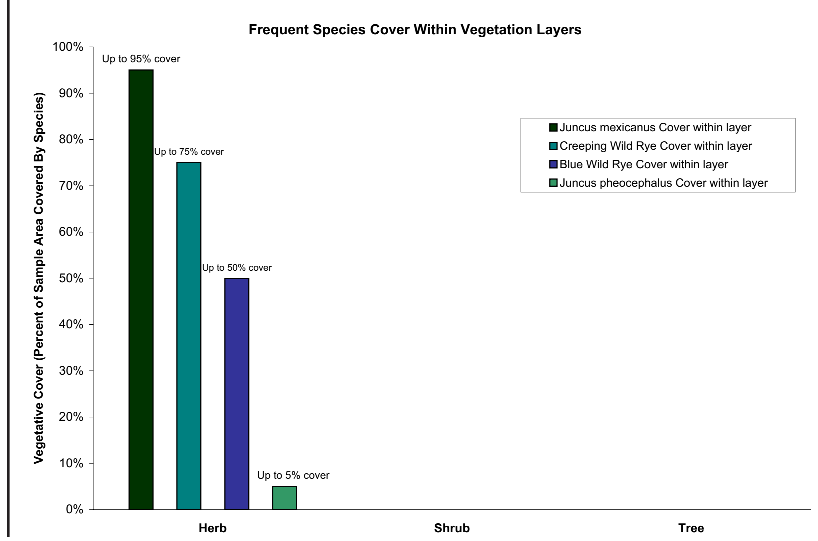
BLACK COTTONWOOD – WOOD'S ROSE PATCH DESCRIPTION: Black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* [Torrey and A. Gray] Brayshaw) dominates the canopy and understory of this patch type. Wood's rose (*Rosa woodsii* L.) is a co-dominant plant species in the shrub and herb layers. Over 88% of sampled transects identified as belonging to the black cottonwood – Wood's rose patch type are currently found on Lee Vining Creek. Black Cottonwood – Wood's Rose patches are correlated with contemporary middle terraces, valley walls, and up to Pre-1941 terraces (Geomorphic units 4-8). The sites where Black Cottonwood – Wood's Rose patches are likely to be found, were either active floodplains or seeps historically (i.e., within the last 65 yrs); locations where the groundwater has diminished with time (or recently returned in the cases of re-watering). Contemporary floods generally no longer inundate Black Cottonwood – Wood's Rose patches.

Figure 28. Black Cottonwood – Wood's Rose patch type description.









JUNCUS-CREEPING WILD RYE PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

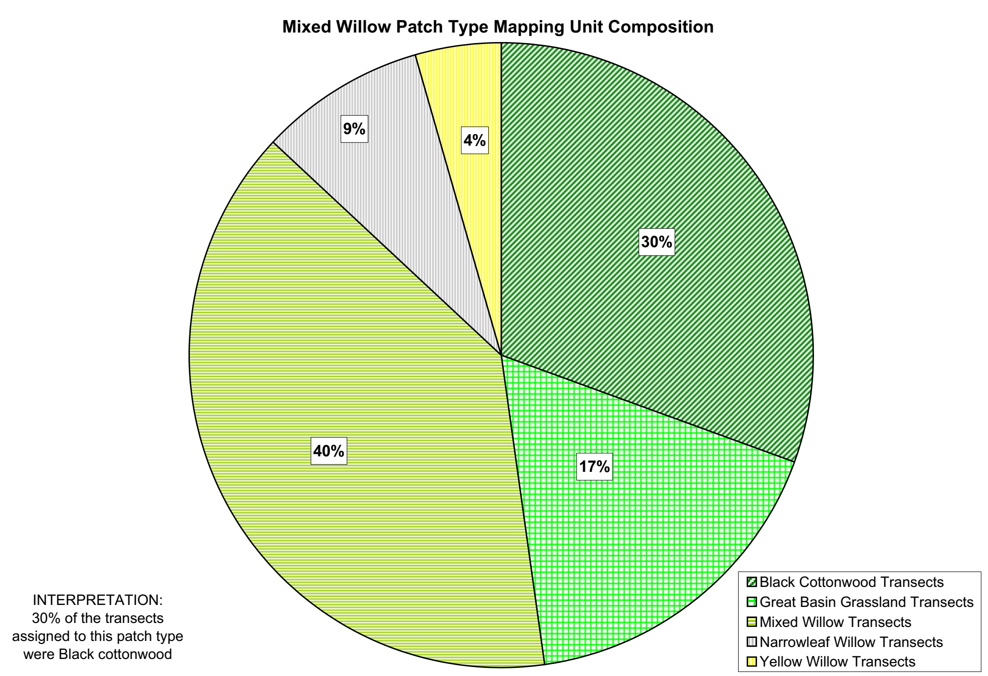
Common constituents in alphabetical order of scientific name.

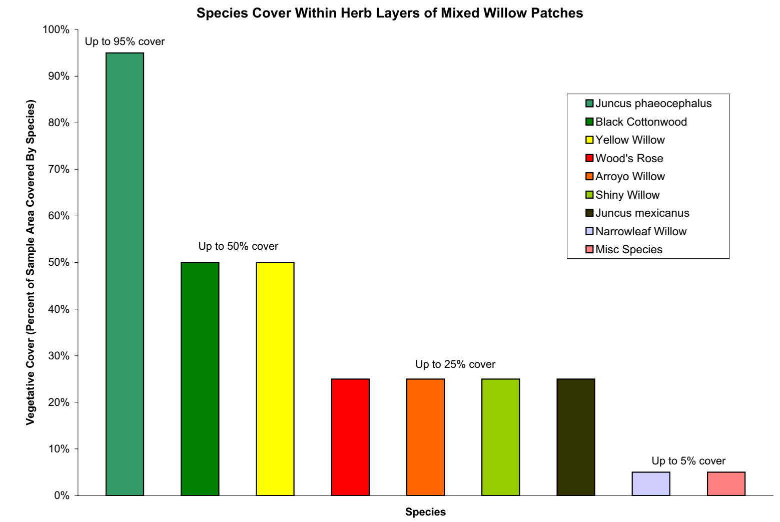
The listing written in red indicates an exotic plant.

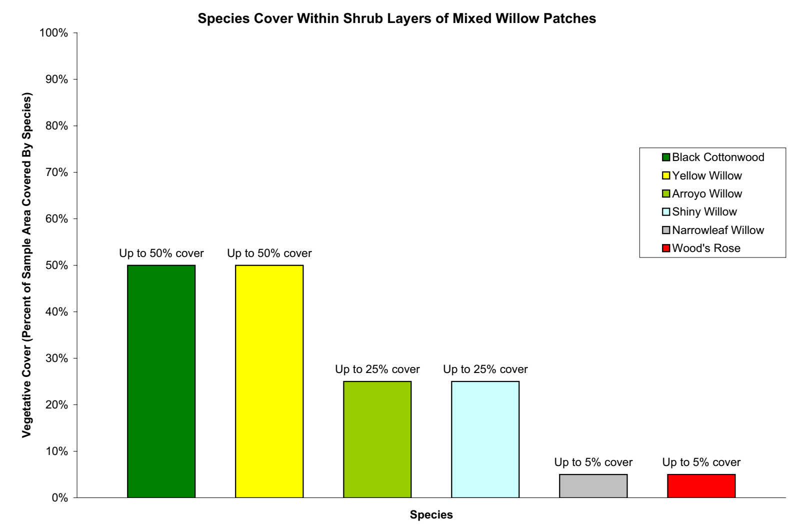
Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Common yarrow	*Achillea millefolium*	Herb	FACU
	Arnica sororia	Herb	NA
Mugwort	*Artmesia douglasii*	Herb	FAC+
Cheat grass	*Bromus tectorum*	Grass	NA
	Carex douglasii	Grass	FACU
Wooly sedge	*Carex lanuginosa*	Em Herb	OBL
	Carex nebrascensis	Em Herb	OBL
Clustered field sedge	*Carex praegracilis*	Em Herb	FACW-
Squirrel tail	*Elymus elymoides ssp. elymoides*	Grass	FACU-
Blue wild rye	*Elymus glaucus ssp. glaucous*	Grass	FACU
	Juncus mexicanus	**Em Herb**	**FACW**
	Juncus phaeocephalus	**Em Herb**	**FACW**
Creeping wild rye	***Leymus triticoides***	**Grass**	**FAC+**
Moss			
Wood's rose	*Rosa woodsii*	Shrub	FAC
Narrowleaf willow	*Salix exigua*	Shrub	FACW
Yellow willow	*Salix lutea*	Tree	OBL

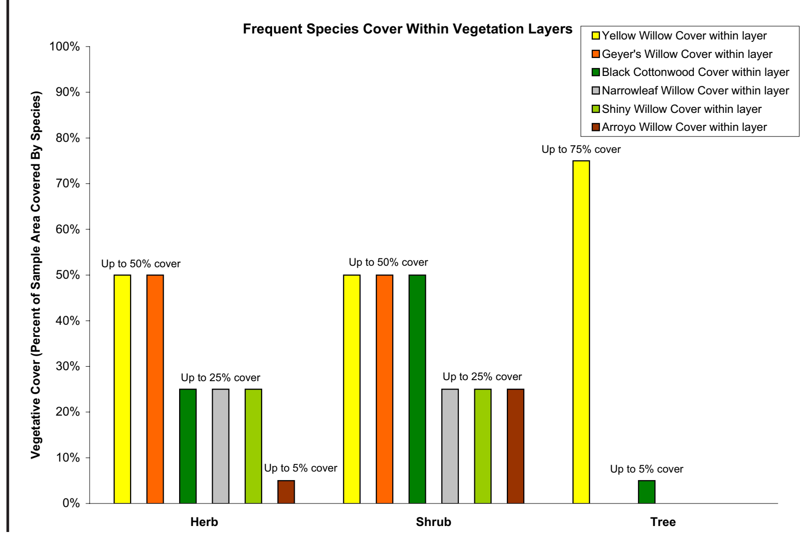
JUNCUS – CREEPING WILD RYE PATCH DESCRIPTION: *Juncus phaeocephalus* Engelm, *Juncus mexicanus* Willd., and creeping wild rye (*Leymus triticoides* Buckley) all co-dominate the herbaceous layers of this patch type. Blue wild rye (*Elymus glaucus ssp. glaucus* Buckley) is a common associate in herb layer. Yellow willow (*Salix lutea* Nutt.) and Wood's rose (*Rosa woodsii* L.) infrequently provide some shrub cover. All sampled transects associated with the Juncus – Creeping Wild Rye patch types are currently found on Rush Creek. The Juncus – Creeping Wild Rye patch types are correlated with contemporary floodplains up to Pre-1941 low terraces (Geomorphic units 2-6). Juncus – Creeping Wild Rye patches commonly occur where pasture was created through irrigation historically (i.e., within the last 65 yrs). Currently, Juncus – Creeping Wild Rye patch types are locations where the groundwater is sustained by streamflows though generally no longer flooded.

Figure 29. Juncus – Creeping Wild Rye patch type description.



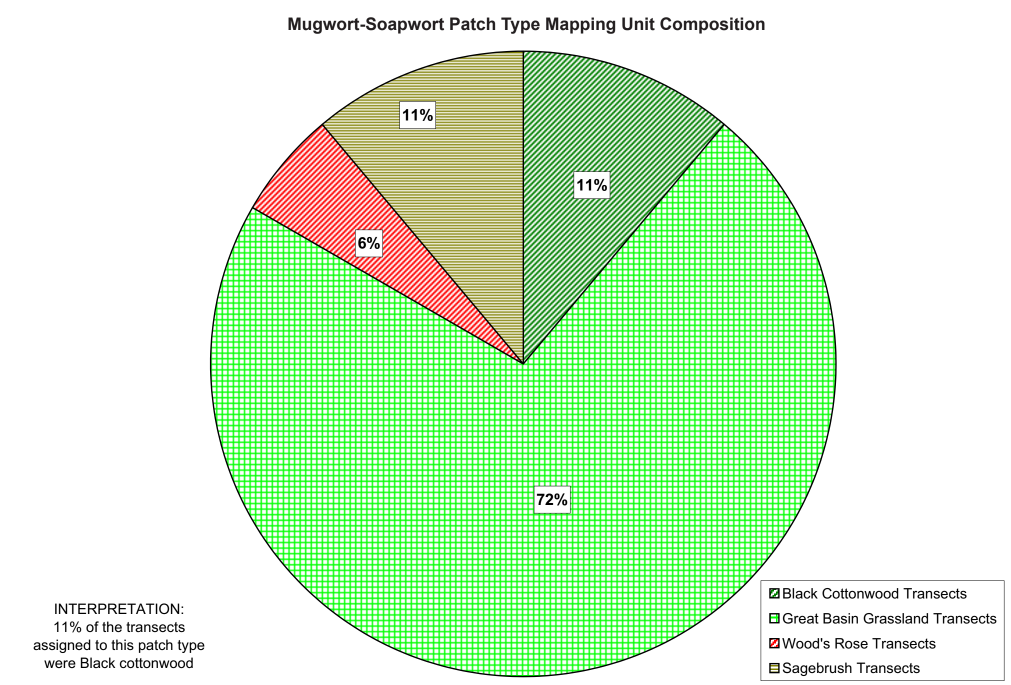


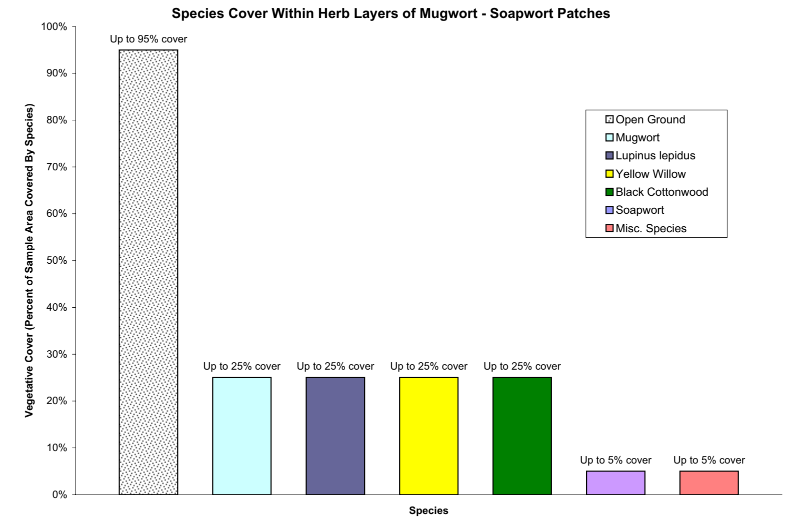


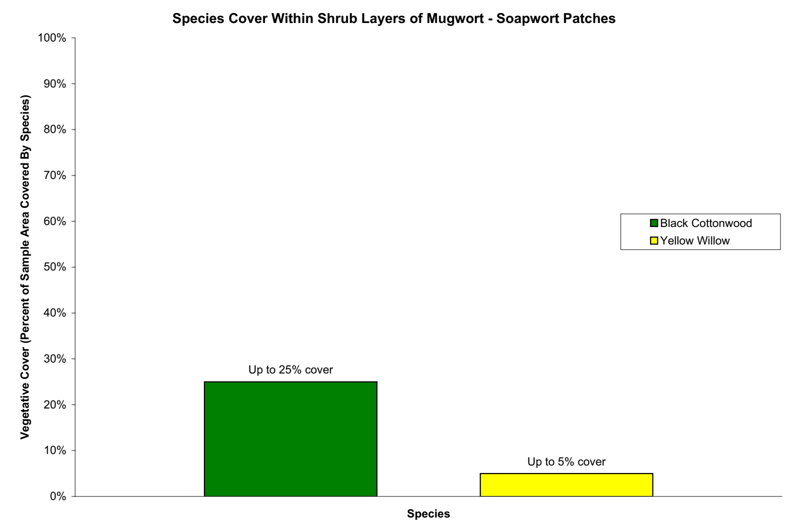


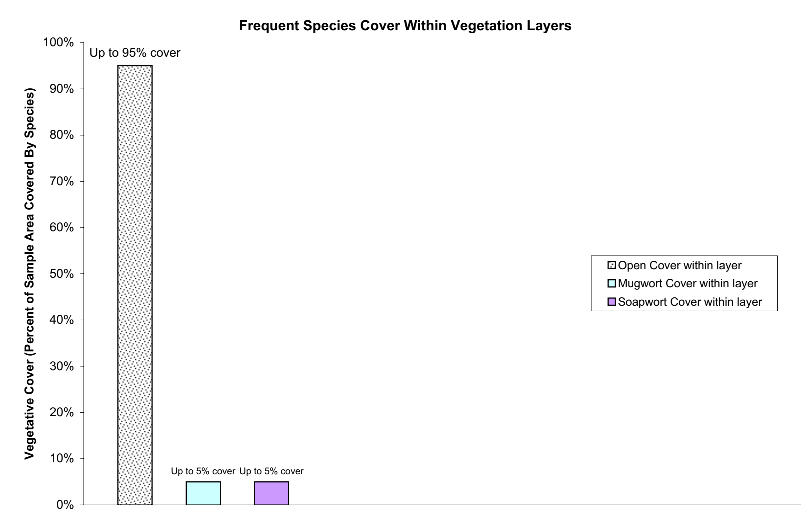
MIXED WILLOW PATCH DESCRIPTION: Black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* [Torrey and A. Gray] Brayshaw), arroyo willow (*Salix lasiolepis* Benth.), narrowleaf willow (*Salix exigua* Nutt.), shiny willow (*Salix lucida* Muhlenb. ssp. *lasiandra* [Benth] E. Murray), and yellow willow (*Salix lutea* Nutt.) dominate the canopy and understory of this patch type. Wood's rose (*Rosa woodsii* L.) is a frequent associate in the shrub and herb layers. Over 80% of sampled transects identified as belonging to the Mixed Willow patch type are currently found on Rush Creek. Mixed Willow patches are correlated with active floodplains up to contemporary middle terraces (Geomorphic units 2-4). The most robust patches are those that have within the last 15 yrs been created and maintained by channel migration, floodplain deposition and channelbed scour. Mixed Willow patches are found where there is shallow groundwater and that flood at least every 2 to 5 years.

Figure 30. Mixed Willow patch type description.









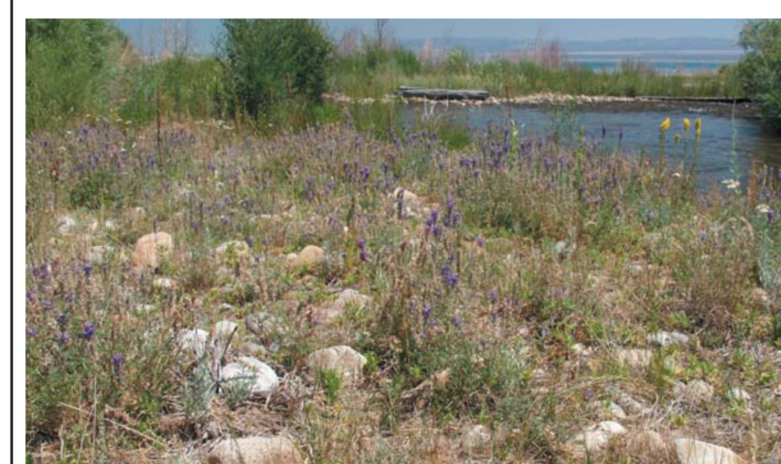
MUGWORT-SOAPWORT PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

Common constituents in alphabetical order of scientific name.

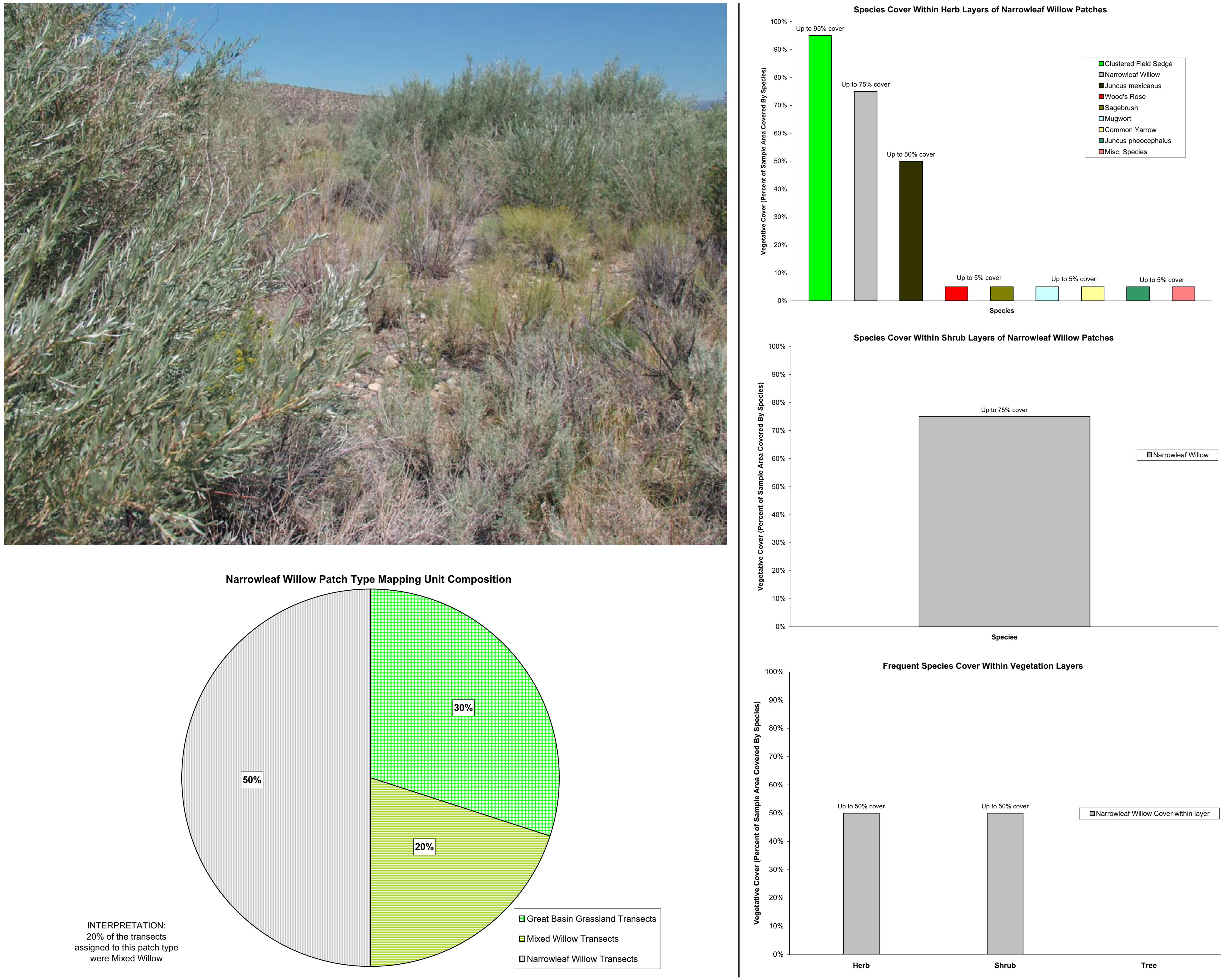
The listing written in red indicates an exotic plant.

Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Mugwort	***Artmesia douglasii***	**Herb**	**FAC+**
Cheat grass	*Bromus tectorum*	Grass	NA
Wooly sedge	*Carex lanuginosa*	Em Herb	OBL
	Juncus mexicanus	Em Herb	FACW
	Lupinus lepidus	Herb	NA
Kentucky bluegrass	*Poa pratensis ssp. pratensis*	Grass	FAC
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	Tree	FACW
Wood's rose	*Rosa woodsii*	Shrub	FAC
Soapwort	*Saponaria officinalis*	Herb	FACU
Yellow willow	*Salix lutea*	Tree	OBL



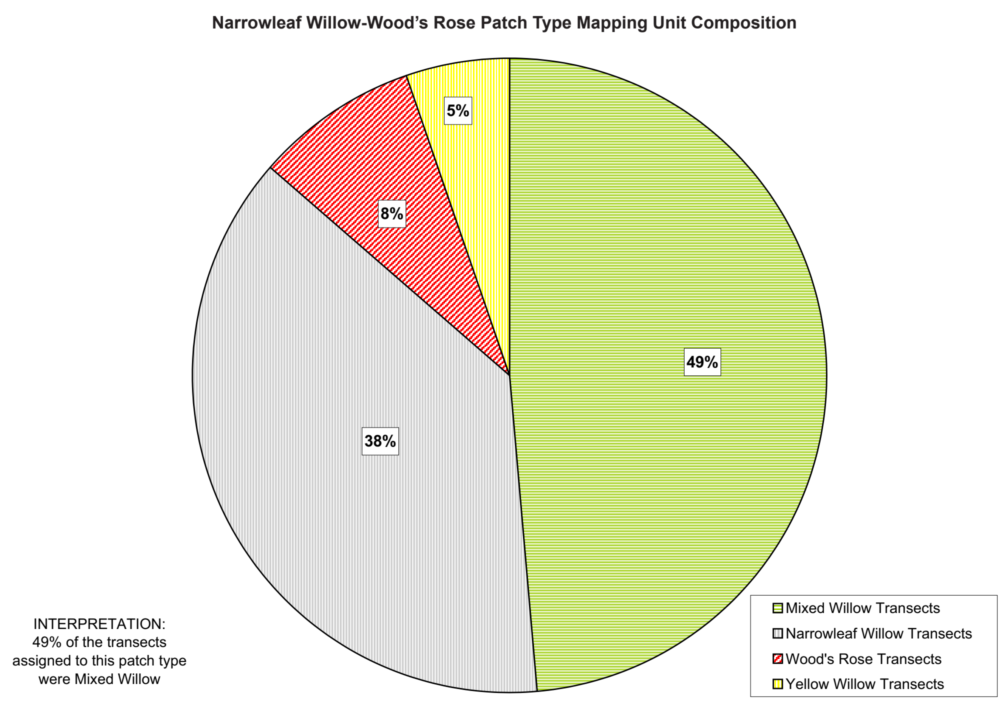
MUGWORT - SOAPWORT PATCH DESCRIPTION: Soapwort (*Saponaria officinalis* L.) an introduced exotic plant, and mugwort (*Artmesia douglasiana* Besser) dominates the herb layers of this patch type. Yellow willow (*Salix lutea* Nutt.) and black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* [Torrey and A. Gray] Brayshaw) are common associates growing into the shrub layers. Over 90% of sampled transects identified as belonging to the Mugwort – Soapwort patch type are currently found on Lee Vining Creek. Open ground is the dominant cover type because Mugwort - Soapwort patches are correlated with active gravelbars and floodplains (Geomorphic units 1 and 2). The sites where Mugwort - Soapwort patches have shallow groundwater tables and are flooded every year.

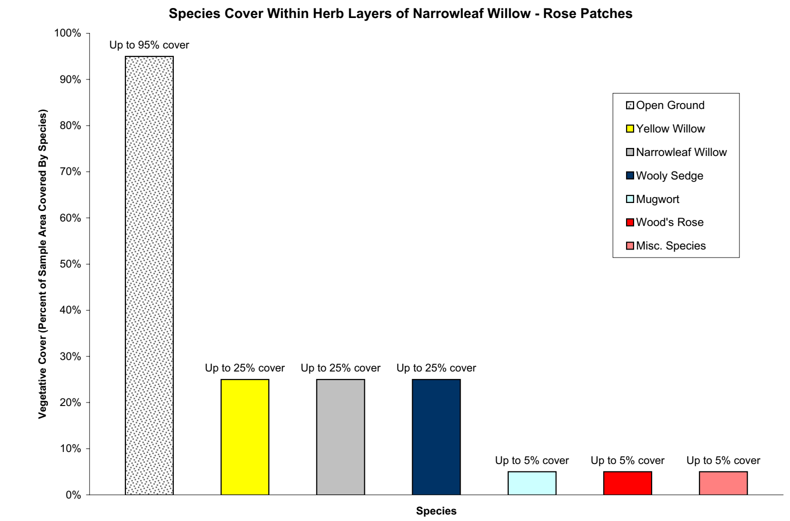
Figure 31. Mugwort – Soapwort patch type description.

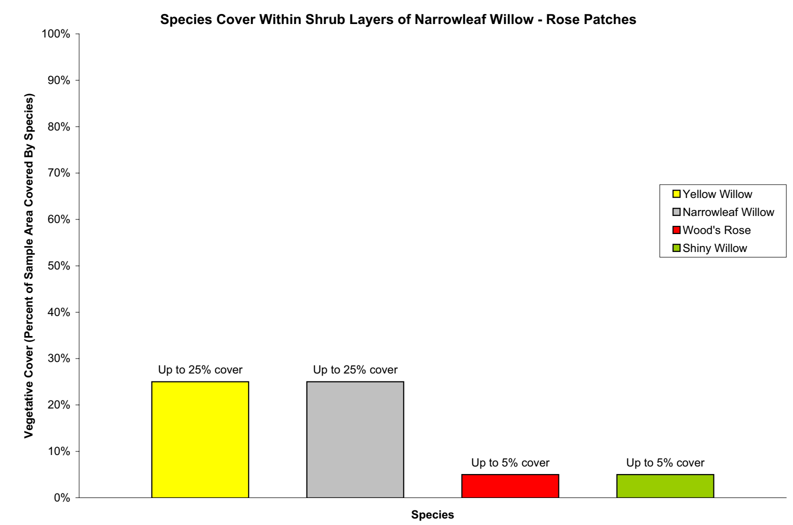


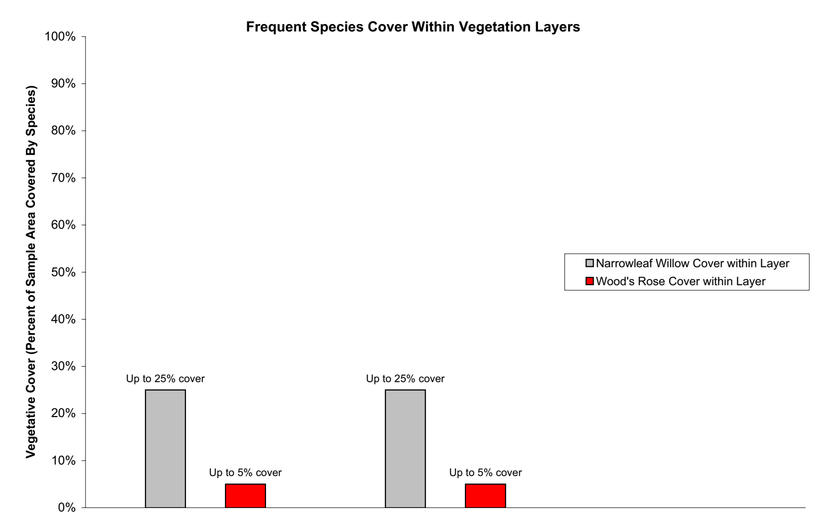
NARROWLEAF WILLOW PATCH DESCRIPTION: Narrowleaf willow (*Salix exigua* Nutt.) dominates the canopy and understory of this patch type. Clustered filed sedge (*Carex praegracilis* W. Boott) is a co-dominant plant species, and covers nearly all ground surfaces within this patch type. Over 75% of sampled transects identified as belonging to the Narrowleaf Willow patch type are currently found on Rush Creek. Narrowleaf Willow patches are correlated with abandoned contemporary floodplains up to pre-1941 floodplains (Geomorphic units 2-5) where the groundwater has diminished with time (or recently returned in the cases of re-watering). Narrowleaf Willow patches are found where groundwater is slightly higher than that available through local precipitation alone but not solely supplied by precipitation, and are generally flooded every 2 to 5 years.

Figure 32. Narrowleaf Willow patch type description.









NARROWLEAF WILLOW- ROSE PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

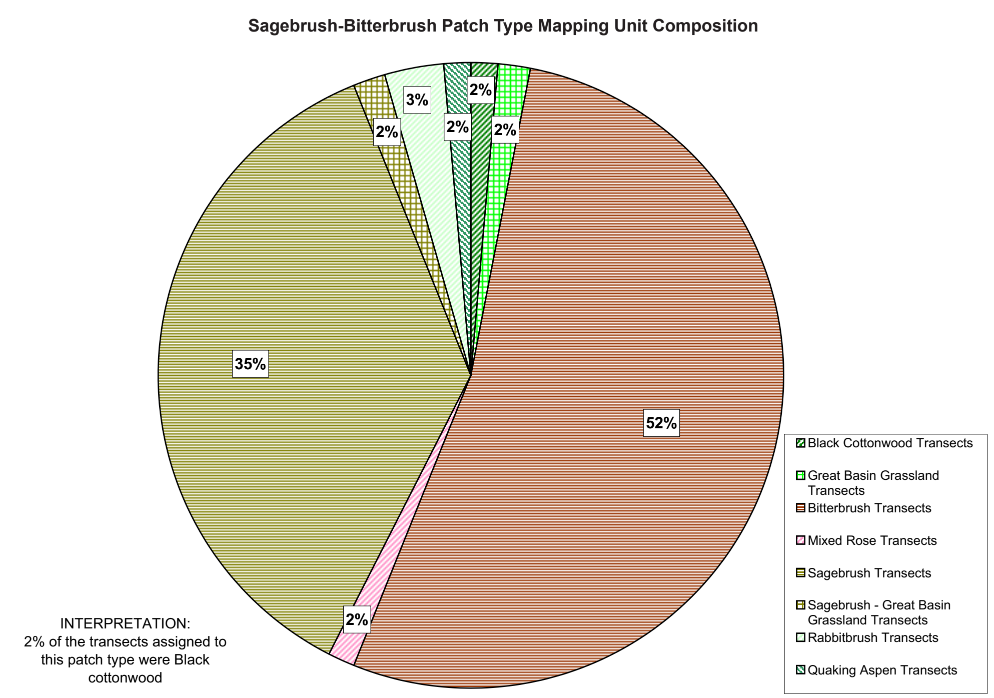
Common constituents in alphabetical order of scientific name.

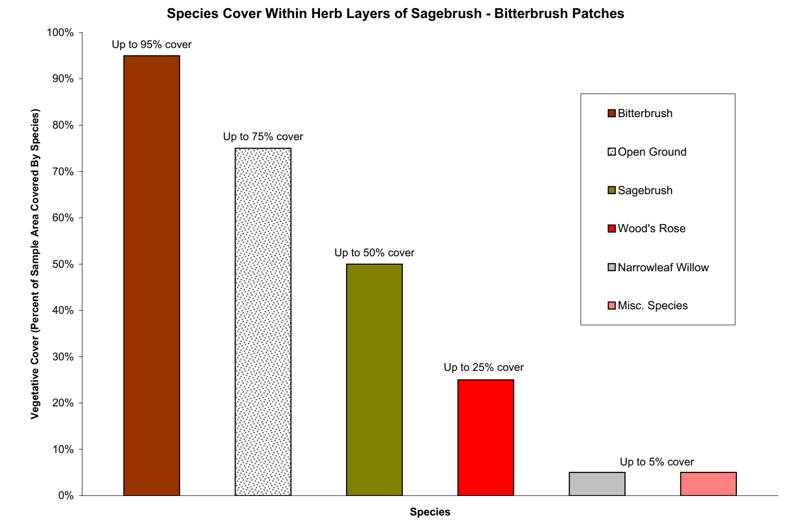
The listing written in red indicates an exotic plant.

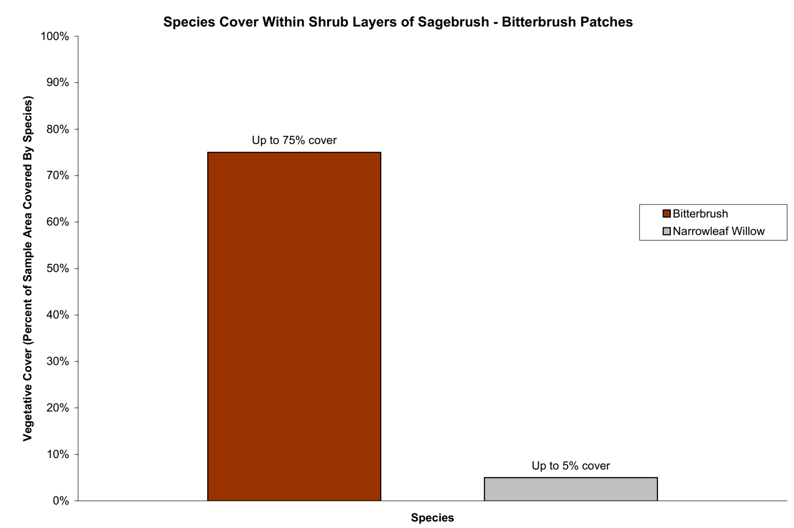
Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Indian rice grass	*Achnatherum hymenoides*	Grass	UPL
	Achnatherum occidentalis spp. Californicum	Grass	NA
Mugwort	*Artmesia douglasii*	Herb	FAC+
Sagebrush	*Artmesia tridentata*	Shrub	NA
Cheat grass	*Bromus tectorum*	Grass	NA
	Carex douglasii	Grass	FACU
Wooly sedge	*Carex lanuginosa*	Em Herb	OBL
Clustered field sedge	*Carex praegracilis*	Em Herb	FACW-
Rubber rabbitbrush	*Chrysothamnus nauseosus*	Shrub	NA
Horseweed	*Conyza canadensis*	Herb	FAC
Squirrel tail	*Elymus elymoides ssp. elymoides*	Grass	FACU-
	Juncus mexicanus	Em Herb	FACW
	Juncus phaeocephalus	Em Herb	FACW
Creeping wild rye	*Leymus triticoides*	Grass	FAC+
	Lupinus lepidus	Herb	NA
Moss		Herb	NA
Pull-up muhly	*Muhlenbergia filiformes*	Grass	FACW
Kentucky bluegrass	*Poa pratensis ssp. pratensis*	Grass	FAC
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	Tree	FACW
Wood's rose	***Rosa woodsii***	**Shrub**	**FAC**
Narrowleaf willow	***Salix exigua***	**Shrub**	**FACW**
Shiny willow	*Salix lucida ssp. lasiandra*	Tree	OBL
Yellow willow	*Salix lutea*	Tree	OBL
Soapwort	*Saponaria officinalis*	Herb	FACU

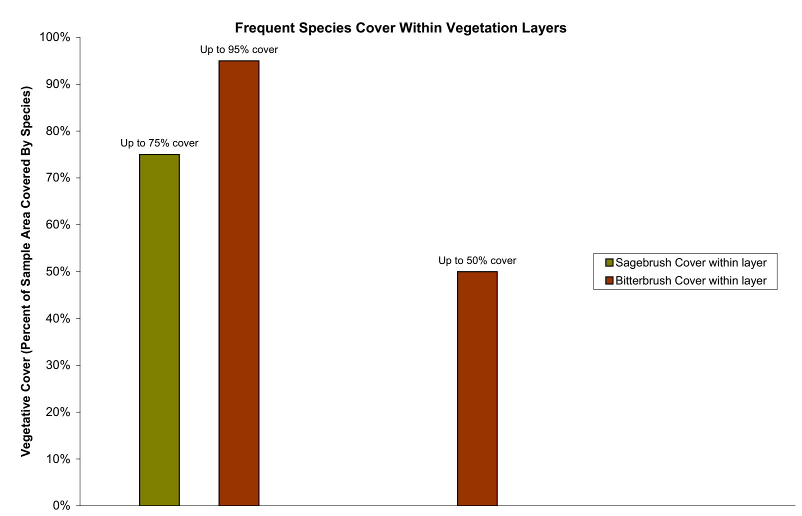
NARROWLEAF WILLOW – WOOD'S ROSE PATCH DESCRIPTION: Narrowleaf willow (*Salix exigua* Nutt.) dominates the canopy and understory of this patch type. Wood's rose (*Rosa woodsii* L.) is a co-dominant plant species in the shrub and herb layers. Yellow willow (*Salix lutea* Nutt.) and shiny willow (*Salix lucida* Muhlenb.ssp. *lasiandra* [Benth] E. Murray) are infrequent associates in the shrub layer. Over 80% of sampled transects identified as belonging to the Narrowleaf Willow – Wood's Rose patch type are currently found on Rush Creek. Narrowleaf Willow – Wood's Rose patches are correlated with contemporary low terraces up to Pre-1941 terraces (Geomorphic units 3-6). Narrowleaf Willow -Wood's Rose patches are likely to be found in drier sites where groundwater is slightly higher than that available through local precipitation alone or have been recharged through channel re-watering. Narrowleaf Willow- Wood's Rose patches are infrequently flooded, about every 5 years.

Figure 33. Narrowleaf Willow – Wood's Rose patch type description.



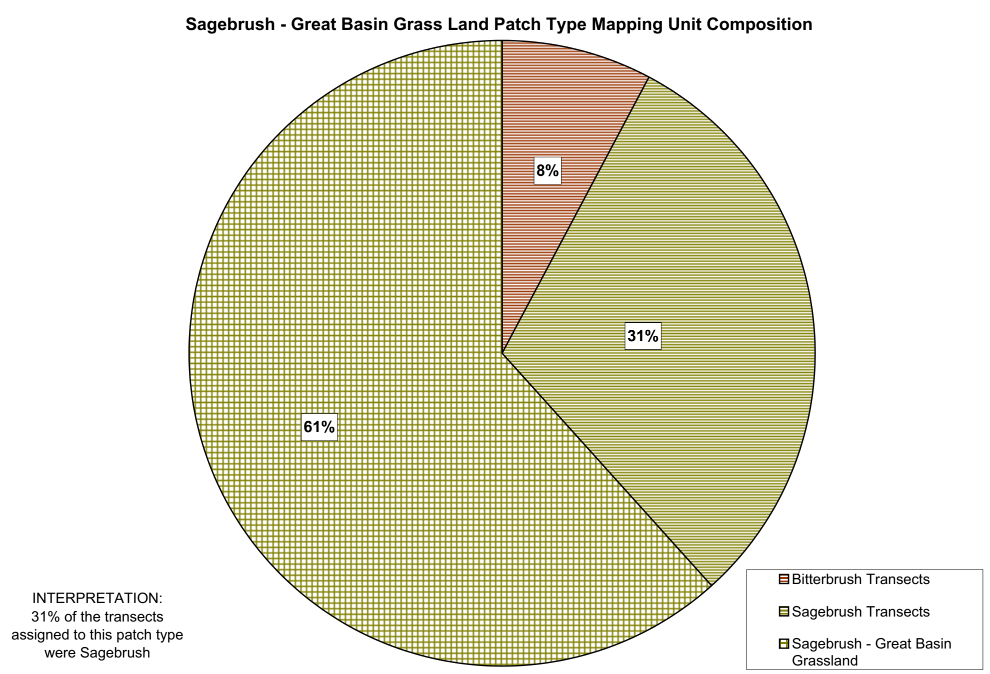


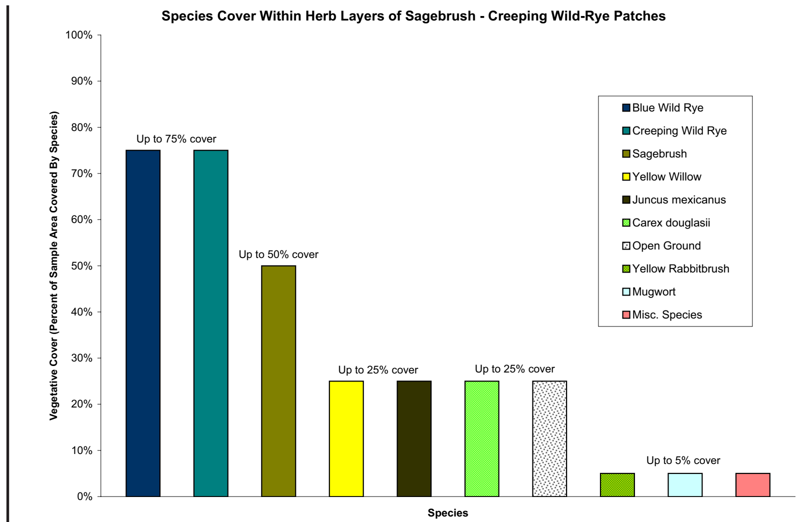


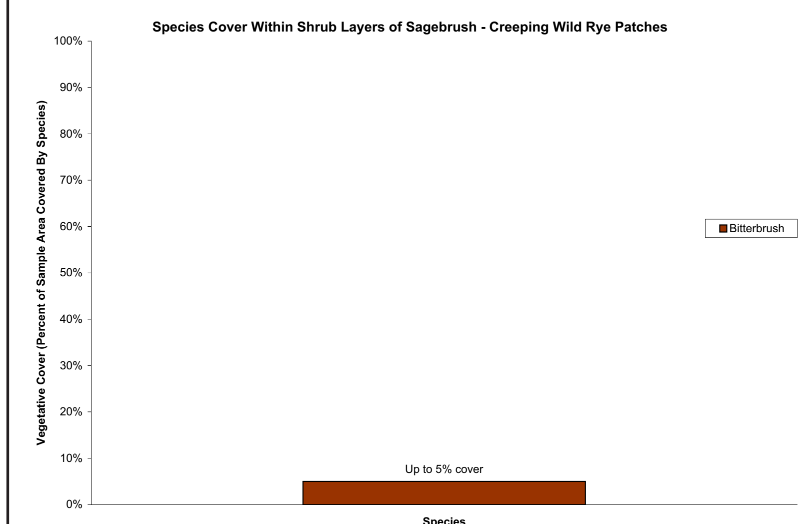


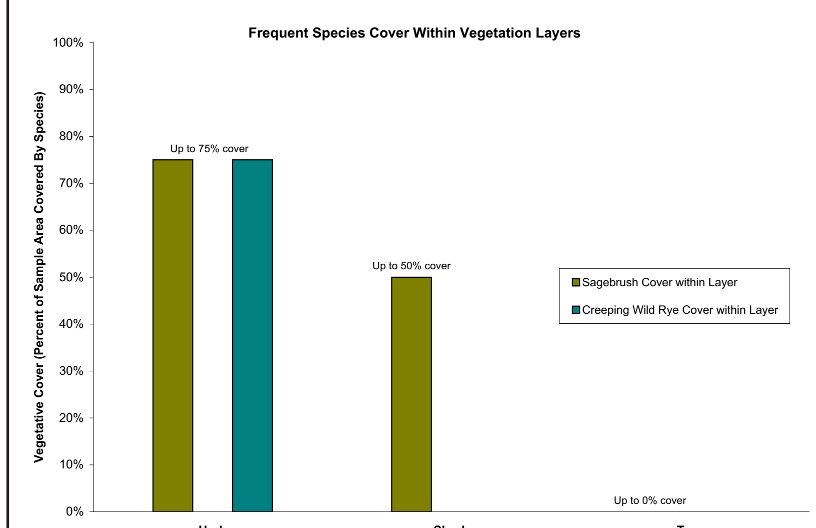
SAGEBRUSH – BITTERBRUSH DESCRIPTION: Sagebrush (*Artmesia tridentata* Nutt.) and bitterbrush (*Purshia tridentata* Pursh) are co-dominants in the shrub and herb layers. Wood's rose (*Rosa woodsii* L.) and narrowleaf willow (*Salix exigua* Nutt.) are common associates in the shrub and herb layers. Over 47% of sampled transects identified as belonging to the Sagebrush – Bitterbrush patch type are currently found on Rush Creek, though this patch appears to be equally distributed within the riparian corridors of each creek. Sagebrush – Bitterbrush patches are correlated with "desert" geomorphic units, contemporary middle terraces up to Pre-1941 terraces (Geomorphic units 3-6). Precipitation maintains the only available groundwater in Sagebrush - Bitterbrush patches. Sagebrush – Bitterbrush patches are rarely, if ever, flooded.

Figure 34. Sagebrush – Bitterbrush patch type description.









SAGEBRUSH-CREEPING WILD RYE PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

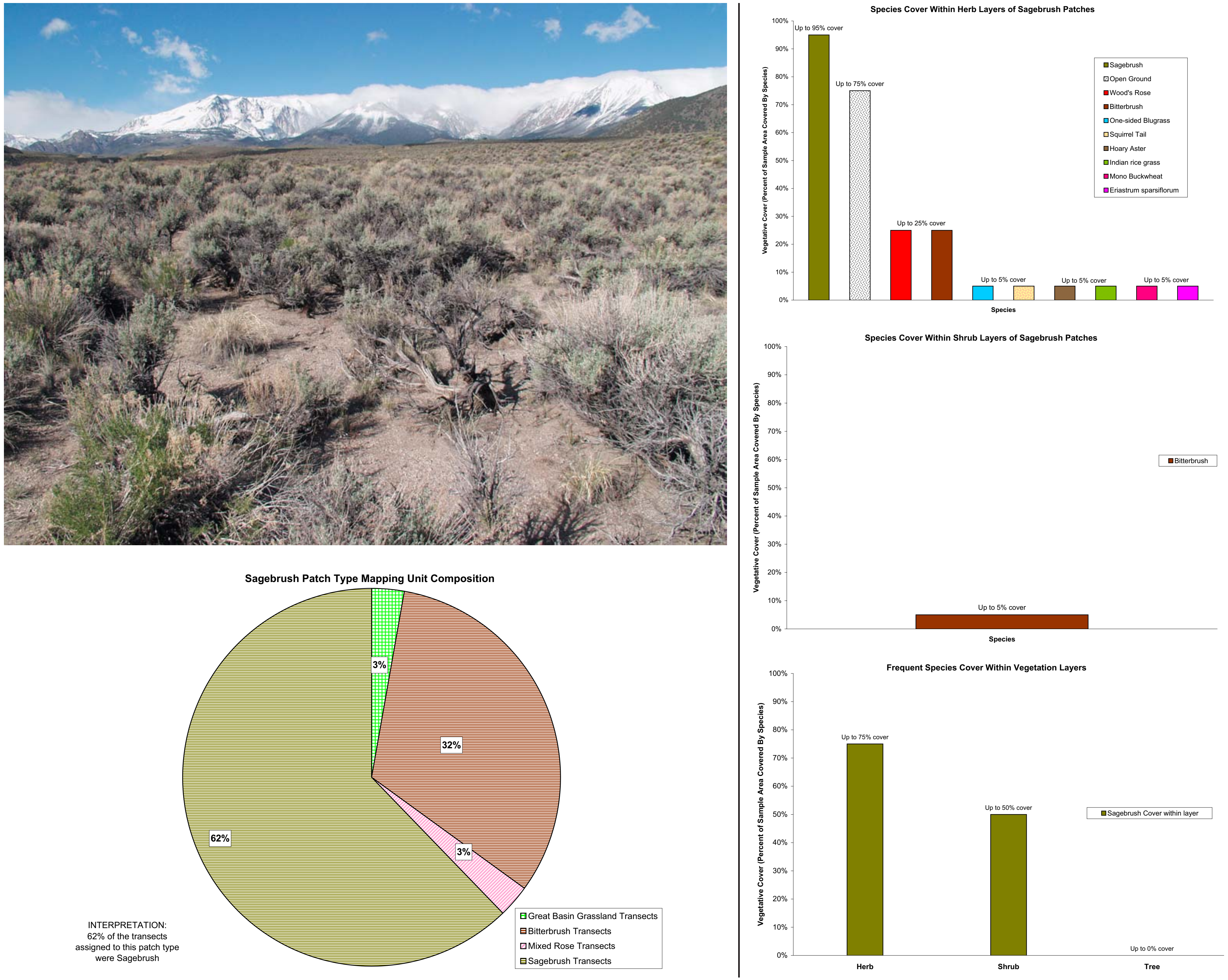
Common constituents in alphabetical order of scientific name.

The listing written in red indicates an exotic plant.

Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
	Achnatherum occidentalis spp. Californicum	Grass	NA
Mugwort	*Artmesia douglasii*	Herb	FAC+
Sagebrush	***Artmesia tridentata***	**Shrub**	**NA**
	Carex douglasii	Grass	FACU
Wooly sedge	*Carex lanuginosa*	Em Herb	OBL
Yellow rabbitbrush	*Chrysothamnus visidiflorus*	Shrub	NA
Blue wild rye	*Elymus glaucus ssp. glaucous*	Grass	FACU
	Juncus mexicanus	Em Herb	FACW
Creeping wild rye	***Leymus triticoides***	**Grass**	**FAC+**
Bitterbrush	*Purshia tridentata*	Shrub	NA
Yellow willow	*Salix lutea*	Tree	OBL

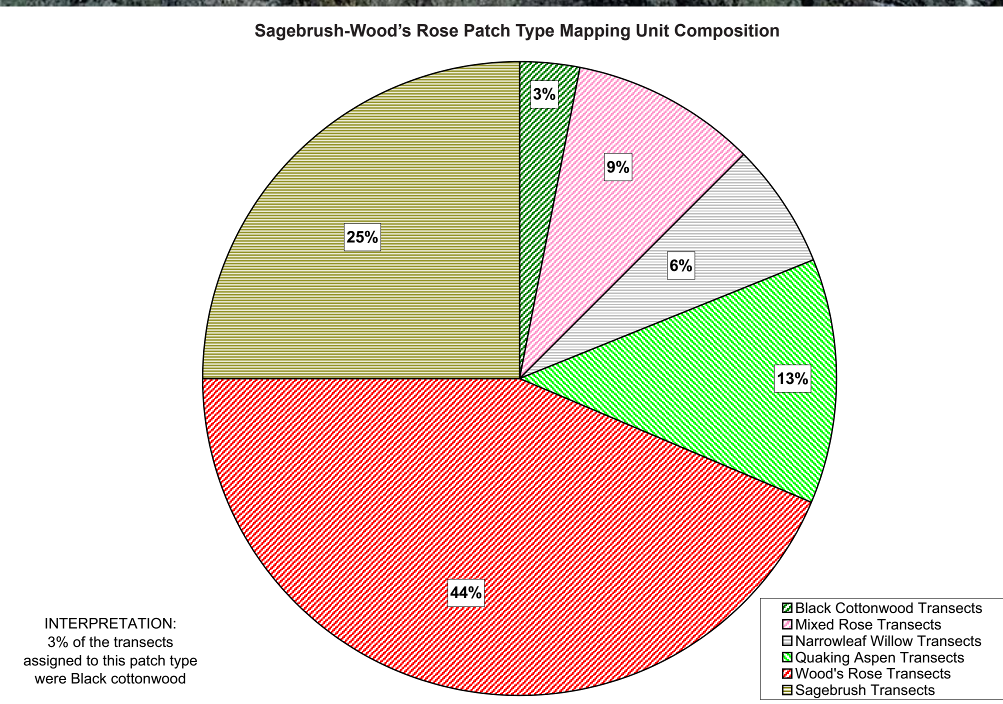
SAGEBRUSH – CREEPING WILD RYE DESCRIPTION: Sagebrush (*Artmesia tridentata* Nutt.) and Creeping Wild Rye (*Leymus triticoides* Buckley) are co-dominants in the herbaceous layers of this patch type. Sagebrush and bitterbrush (*Purshia tridentata* Pursh) are co-dominants in the shrub layer. Over 60% of sampled transects identified as belonging to the Sagebrush – Creeping Wild Rye patch type are currently found on Rush Creek. Sagebrush – Creeping Wild Rye patches are correlated with Pre-1941 floodplains and low terraces (Geomorphic units 5-6). The sites where Sagebrush-Creeping Wild Rye patches a found, were areas where pasture was created through irrigation historically (i.e., within the last 65 yrs). Currently Sagebrush – Creeping Wild Rye patch types are found where the groundwater is sustained by streamflows, though generally no longer flooded.

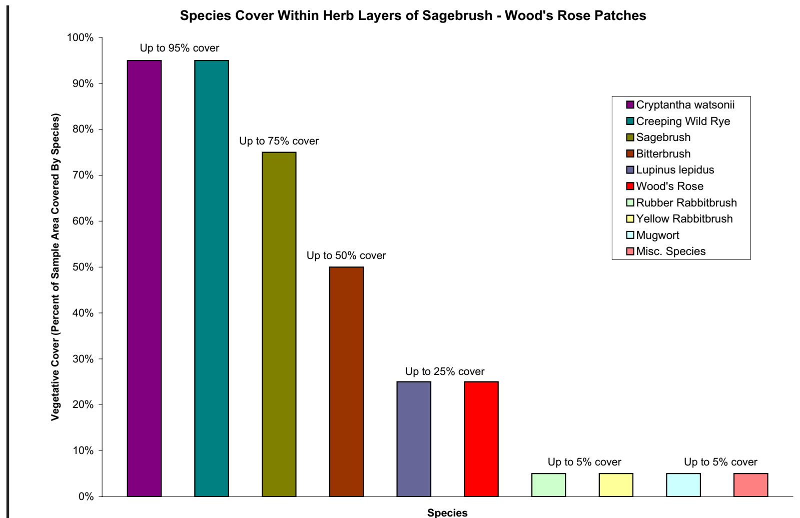
Figure 35. Sagebrush – Creeping Wild Rye patch type description.

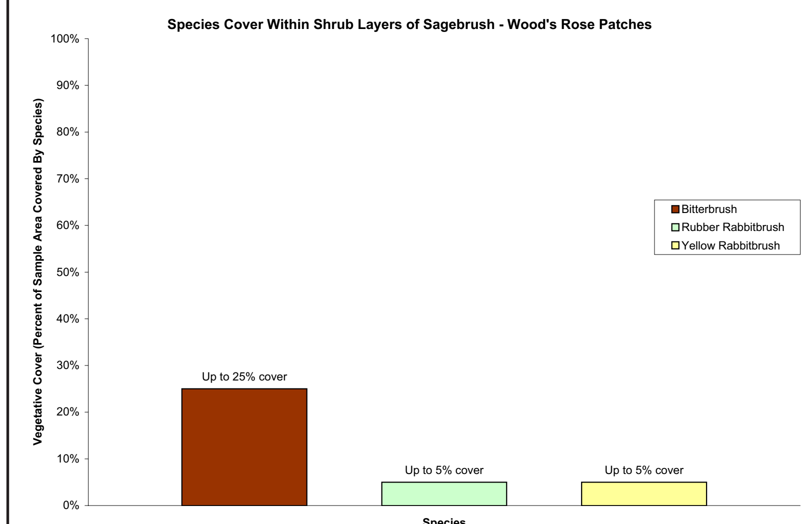


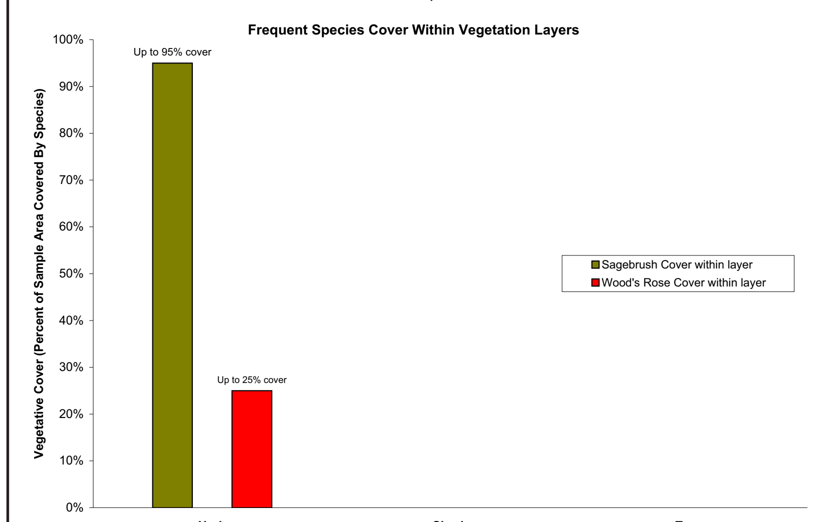
SAGEBRUSH DESCRIPTION: Sagebrush (*Artmesia tridentata* Nutt.) dominates the shrub and herb layers. Wood's rose (*Rosa woodsii* L.) and Bitterbrush (*Purshia tridentata* Pursh) are common associates in the shrub and herb layers. Over 83% of sampled transects identified as belonging to the Sagebrush patch type are currently found on Rush Creek. Sagebrush patches are correlated with "desert" geomorphic units, contemporary middle terraces up to Pre-1941 terraces (Geomorphic units 3-6). Precipitation maintains the only available groundwater in sagebrush patches. Sagebrush patches are rarely, if ever, flooded.

Figure 36. Sagebrush patch type description.









SAGEBRUSH-ROSE PATCH TYPE

The listing written in bold indicates a dominant or co-dominant plant species.

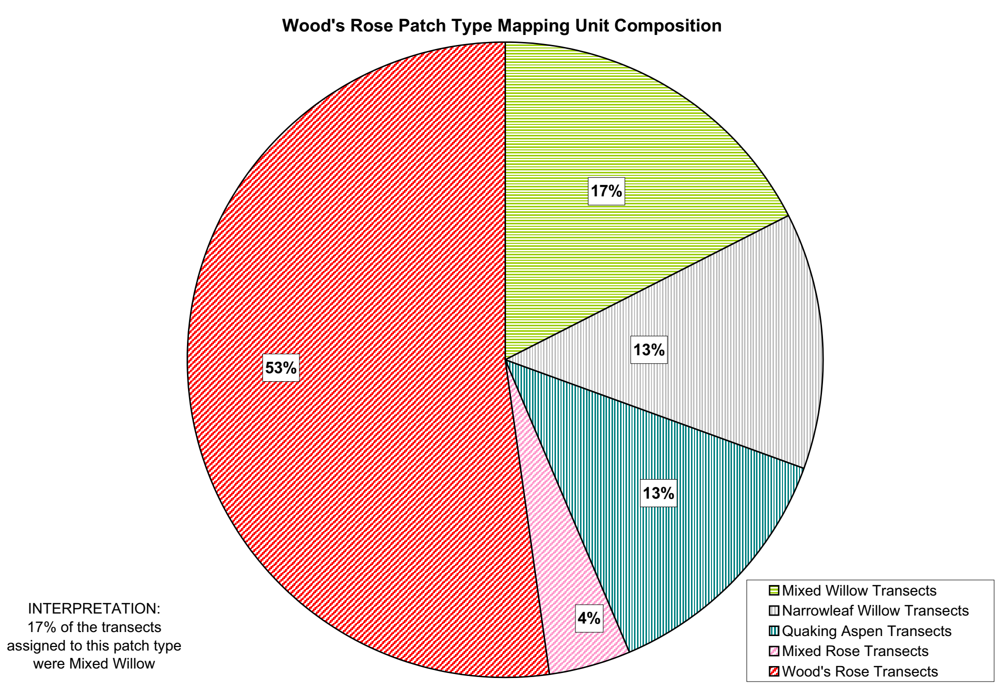
Common constituents in alphabetical order of scientific name.

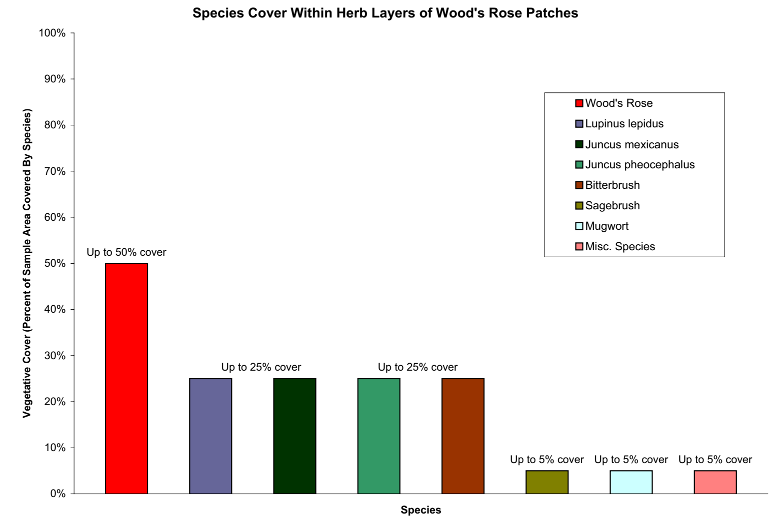
The listing written in red indicates an exotic plant.

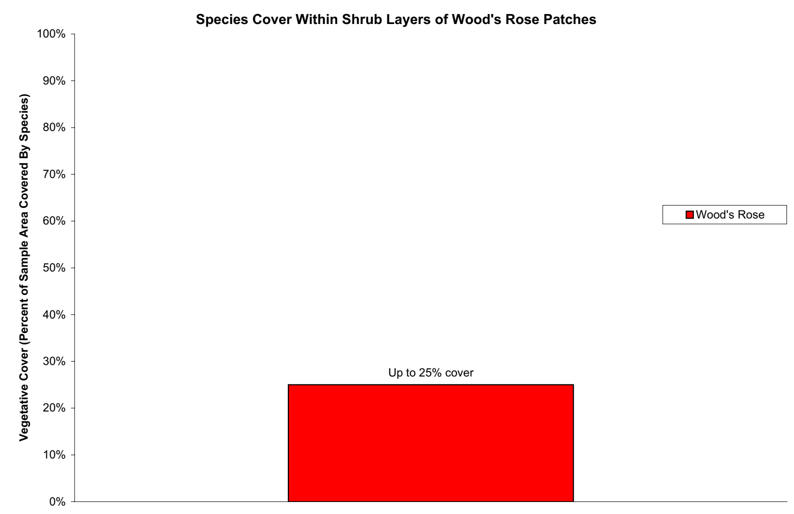
Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Indian rice grass	*Achnatherum hymenoides*	Grass	UPL
	Achnatherum occidentalis spp. Californicum	Grass	NA
Mugwort	*Artmesia douglasii*	Herb	FAC+
Sagebrush	***Artmesia tridentata***	**Shrub**	**NA**
	Calyptridium roseum	Herb	FACU
	Carex douglasii	Grass	FACU
Smallwing sedge	*Carex microptera*	Em Herb	FAC*
Rubber rabbitbrush	*Chrysothamnus nauseosus*	Shrub	NA
Yellow rabbitbrush	*Chrysothamnus visidiflorus*	Shrub	NA
	Cryptantha watsonii	Herb	NA
Squirrel tail	*Elymus elymoides ssp. elymoides*	Grass	FACU-
Blue wild rye	*Elymus glaucus ssp. glaucous*	Grass	FACU
Creeping wild rye	*Leymus triticoides*	Grass	FAC+
	Lupinus lepidus	Herb	NA
	Oxytheca dendroidea ssp. dendrodea	Herb	NA
	Poa secunda spp. juncifolia	Grass	FACU
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	Tree	FACW
Bitterbush	*Purshia tridentata*	Shrub	NA
Wood's rose	***Rosa woodsii***	**Shrub**	**FAC**
Narrowleaf willow	*Salix exigua*	Shrub	FACW
Arroyo willow	*Salix lasiolepis*	Shrub	FACW
Soapwort	*Saponaria officinalis*	Herb	FACU

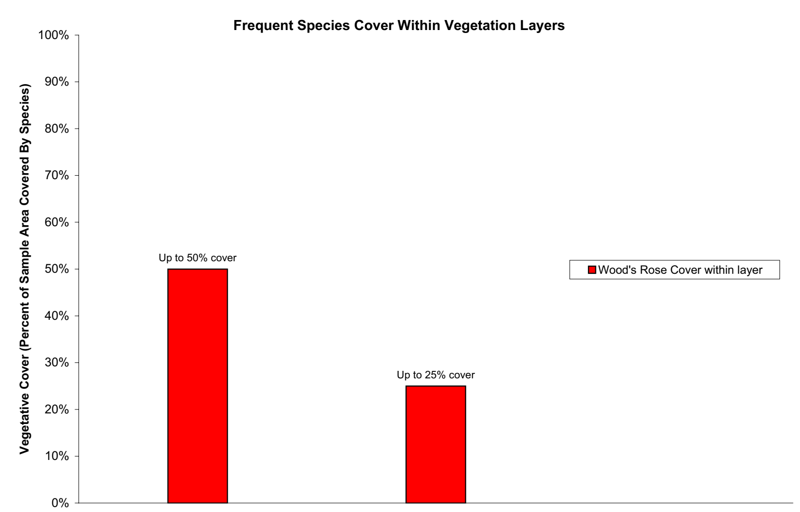
SAGEBRUSH – WOOD'S ROSE PATCH DESCRIPTION: Sagebrush (*Artmesia tridentata* Nutt.) and Wood's rose (*Rosa woodsii* L.) dominate the canopy and understory of this patch type. Creeping wild rye (*Leymus triticoides* Buckley) and bitterbrush (*Purshia tridentata* Pursh.) are common associates in the herb layers. Over 95% of sampled transects identified as belonging to the Sagebrush - Wood's Rose patch type are currently found on Lee Vining Creek. Sagebrush – Wood's Rose patches are correlated with contemporary middle terraces up to pre-1941 terraces (Geomorphic units 4-6). Sagebrush - Wood's Rose patches are found in drier sites where groundwater is slightly higher than that available through local precipitation alone or has been recharged through channel re-watering. Currently Sagebrush – Wood's Rose patch types are locations where the groundwater is sustained by streamflows, though generally no longer flooded.

Figure 37. Sagebrush – Wood's Rose patch type description.



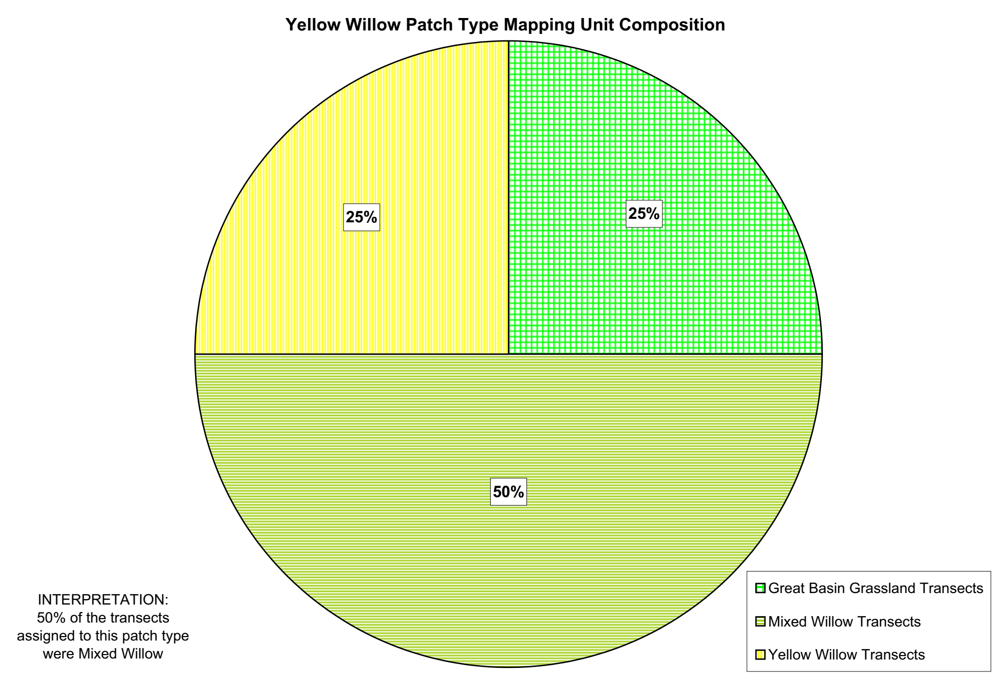


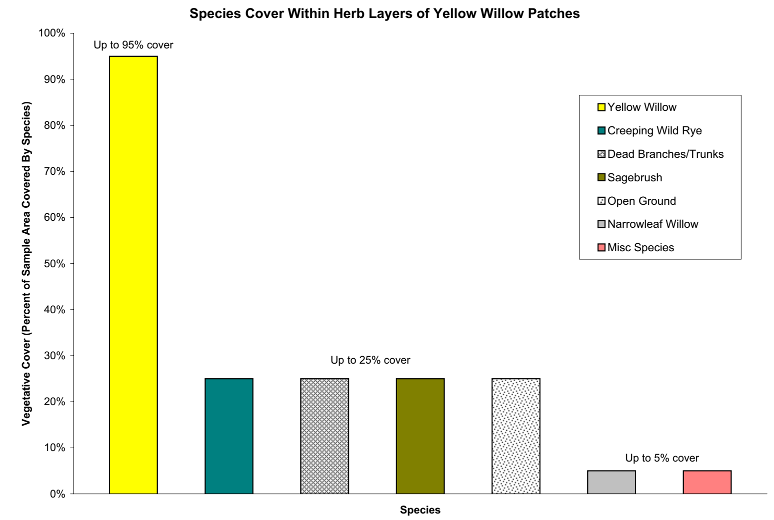


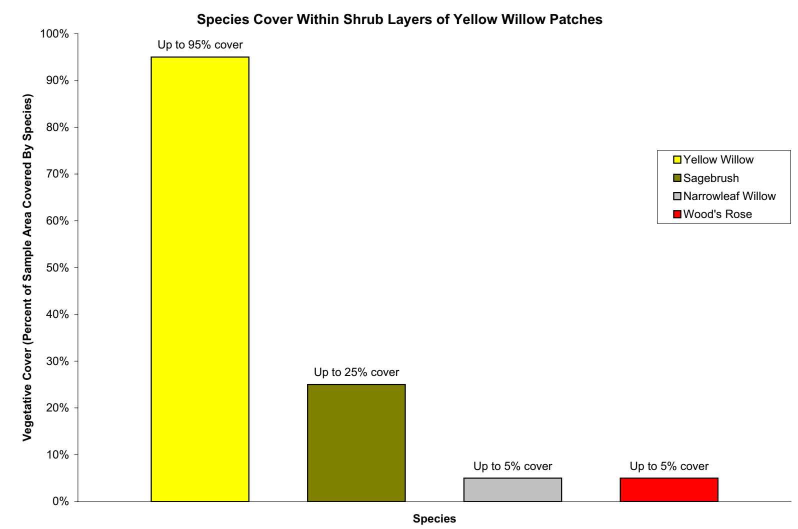


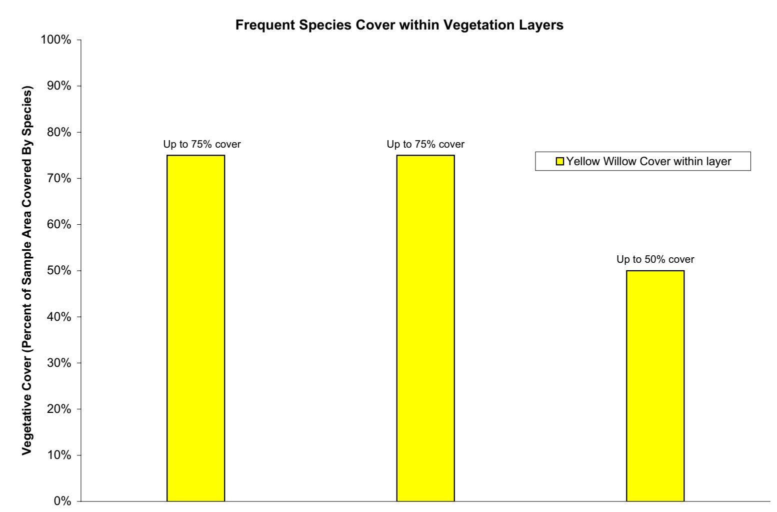
WOOD'S ROSE PATCH DESCRIPTION: Wood's rose (*Rosa woodsii* L.) dominates the shrub and herb layers. *Juncus phaeocephalus* Engelm, *Juncus mexicanus* Willd., and *Lupinus lepidus* Douglas., are common associates of the herbaceous layers. Over 65% of Wood's Rose patches are currently found on Rush Creek. Wood's rose patches are correlated with contemporary low terraces up to Pre-1941 terraces (Geomorphic units 3-6). Wood's Rose patches are likely to be found where groundwater has been recharged through channel re-watering. Wood's Rose patches are infrequently flooded, but can tolerate flooding every 2 to 5 years.

Figure 38. Wood's Rose patch type description.









YELLOW WILLOW PATCH TYPE

Stand dominant and co-dominant plant species are bolded.

Common constituents in alphabetical order of scientific name.

The listing written in red indicates an exotic plant.

Common Name	Scientific Name	Growth Habit	USFWS Hydric Code
Sagebrush	*Artmesia tridentata*	Shrub	NA
Wooly sedge	*Carex lanuginosa*	Em Herb	OBL
	Distichlis spicata	Grass	FACW
Common horsetail	*Equisetum arvense*	Em Fern	FAC
	Juncus mexicanus	Em Herb	FACW
	Juncus phaeocephalus	Em Herb	FACW
Creeping wild rye	*Leymus triticoides*	Grass	FAC+
Narrowleaf willow	*Salix exigua*	Shrub	FACW
Yellow willow	***Salix lutea***	**Tree**	**OBL**

YELLOW WILLOW PATCH DESCRIPTION: Yellow willow (*Salix lutea* Nutt.) dominates the canopy and understory of this patch type. Sagebrush (*Artmesia tridentata* Nutt.) and creeping wild rye (*Leymus triticoides* Buckley) are common associates in the herbaceous layers of this patch type. All the sampled transects identified as belonging to the Yellow Willow patch type are currently found on Rush Creek. Yellow Willow patches are correlated with active floodplains (Geomorphic unit 2) that have been created and maintained by contemporary channel migration, floodplain deposition and channelbed scour. Yellow Willow patches are found in sites where there is shallow groundwater and are flooded at a minimum every 2 years.

Figure 39. Yellow Willow patch type description.

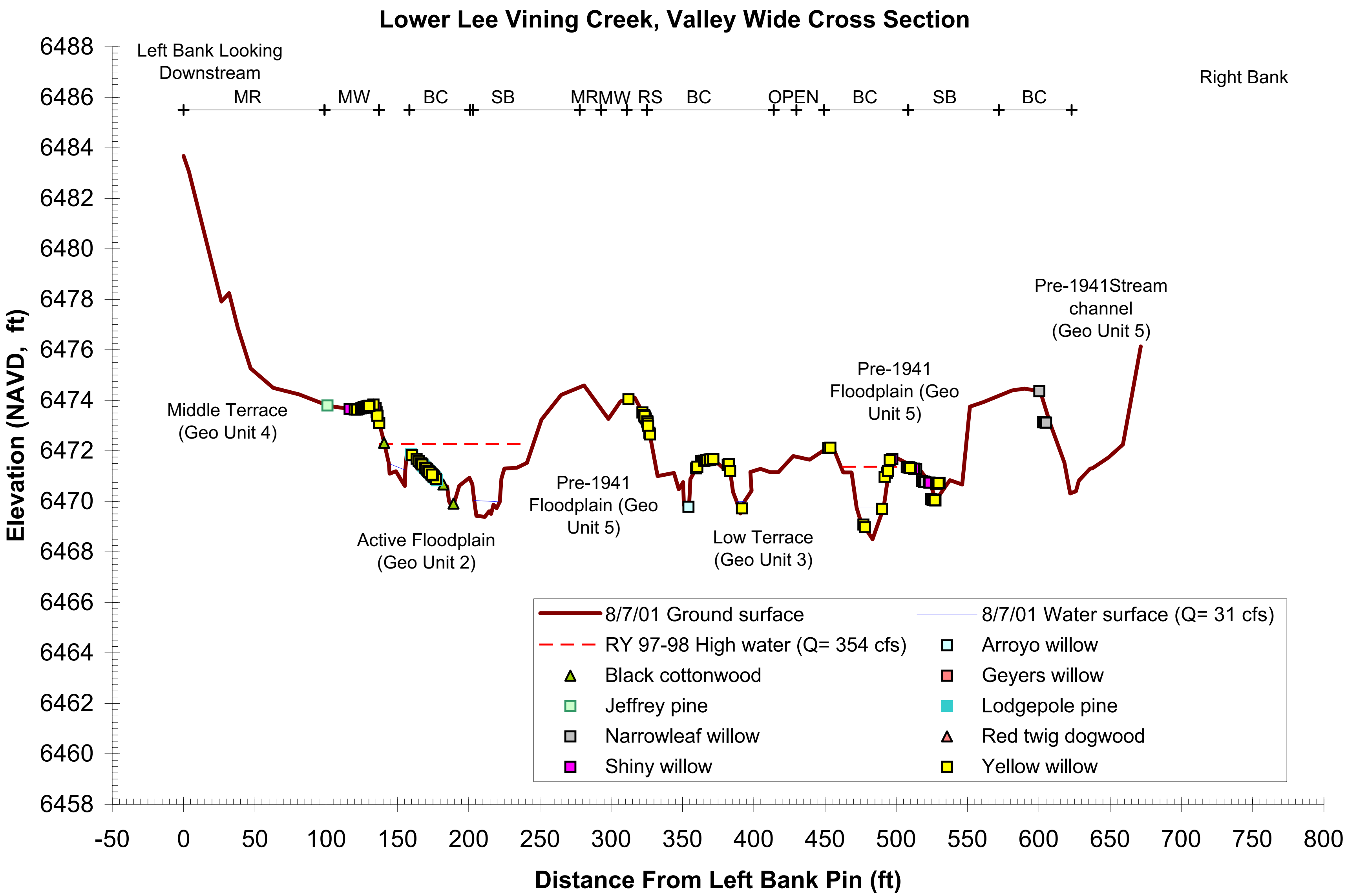


Figure 40. Lower Lee Vining Creek Site valley wide cross section showing the locations of riparian plants, geomorphic units and patch boundaries.

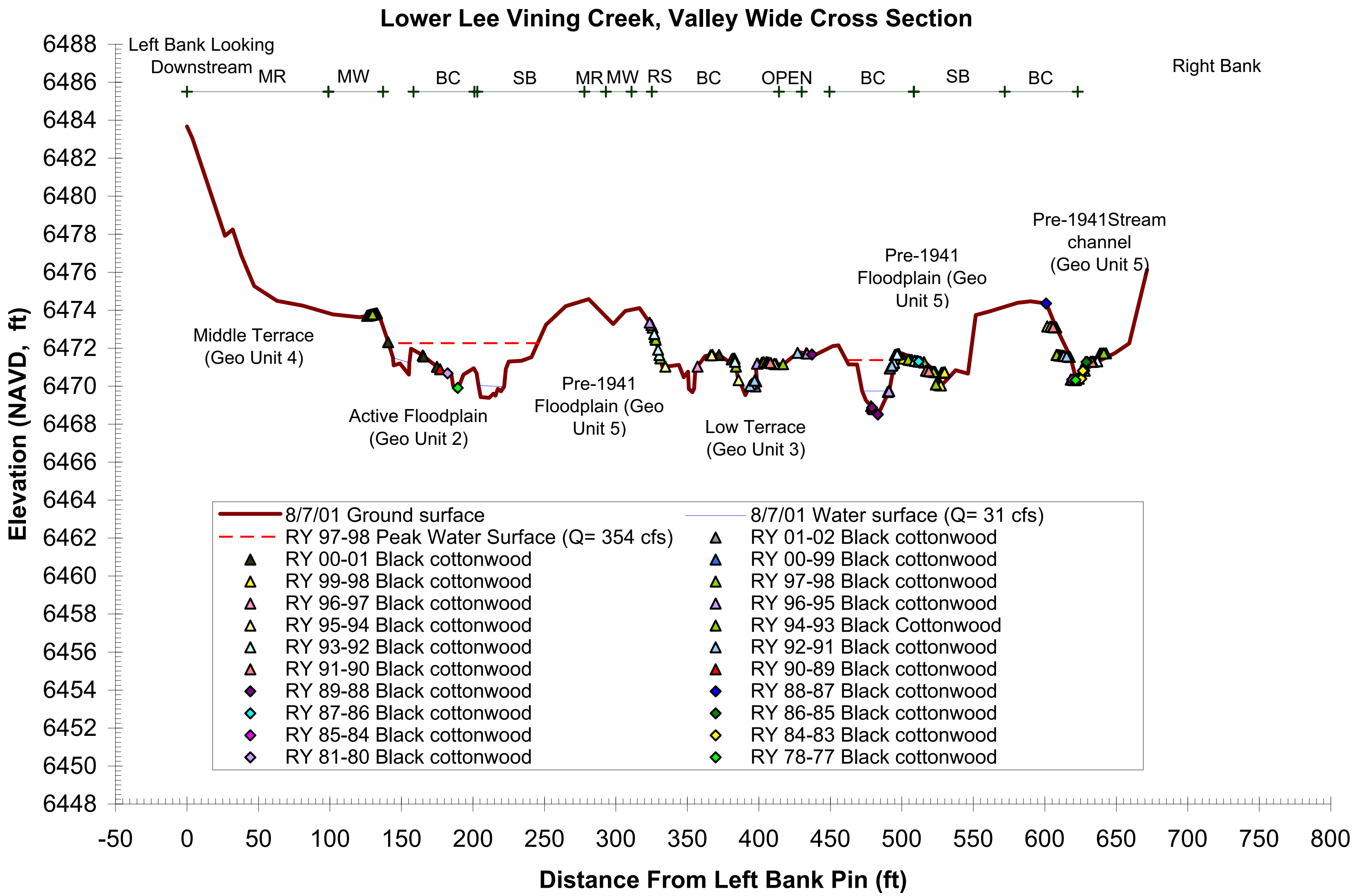


Figure 41. Lower Lee Vining Creek Site, Valley Wide Cross section showing the locations of the dominant riparian hardwood, black cottonwood, relative to geomorphic units and patch boundaries.

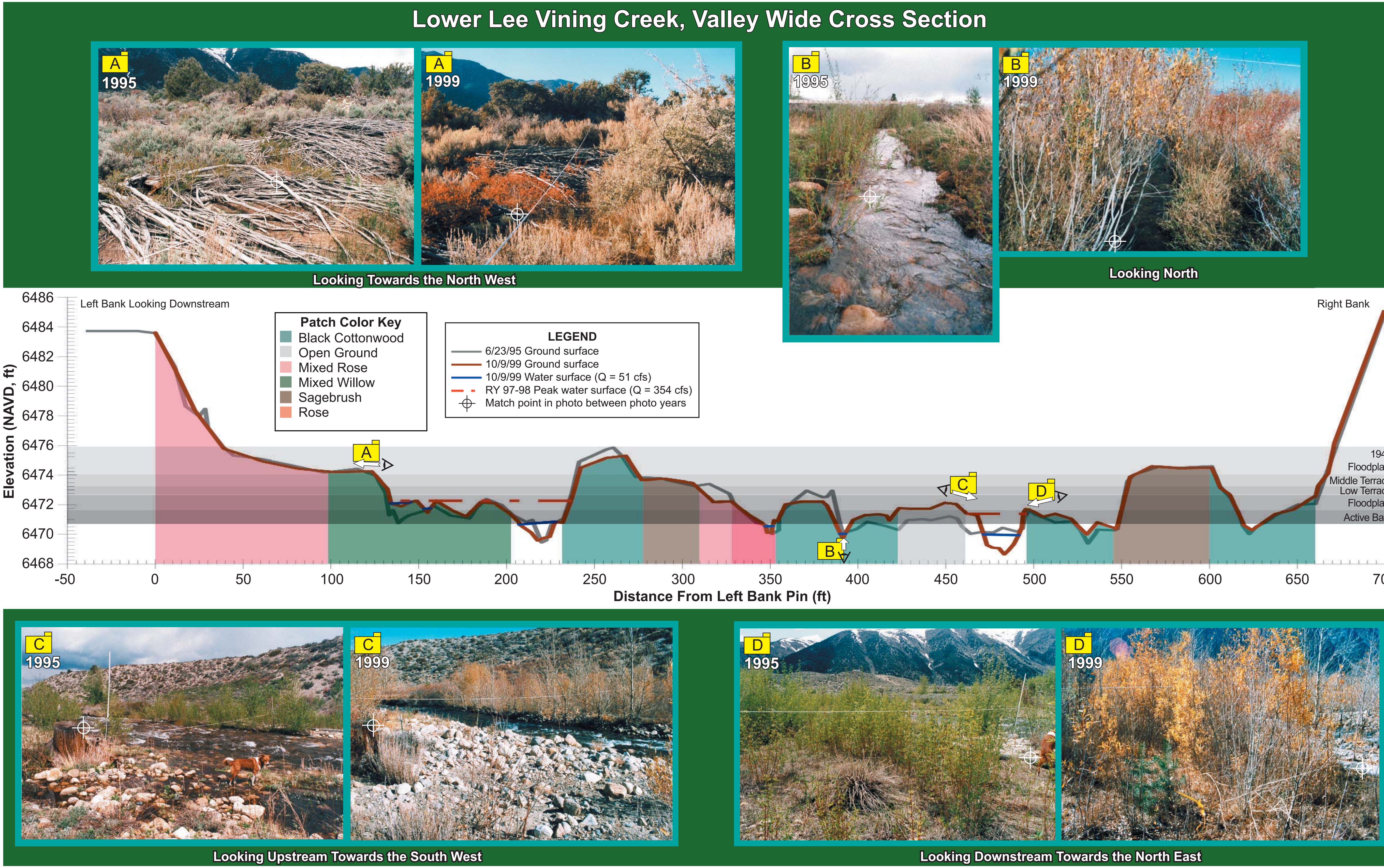


Figure 42. Lower Lee Vining Creek Sit valley wide cross section with 1995, and 1999 photographs and illustrating the locations of geomorphic units and patch boundaries.

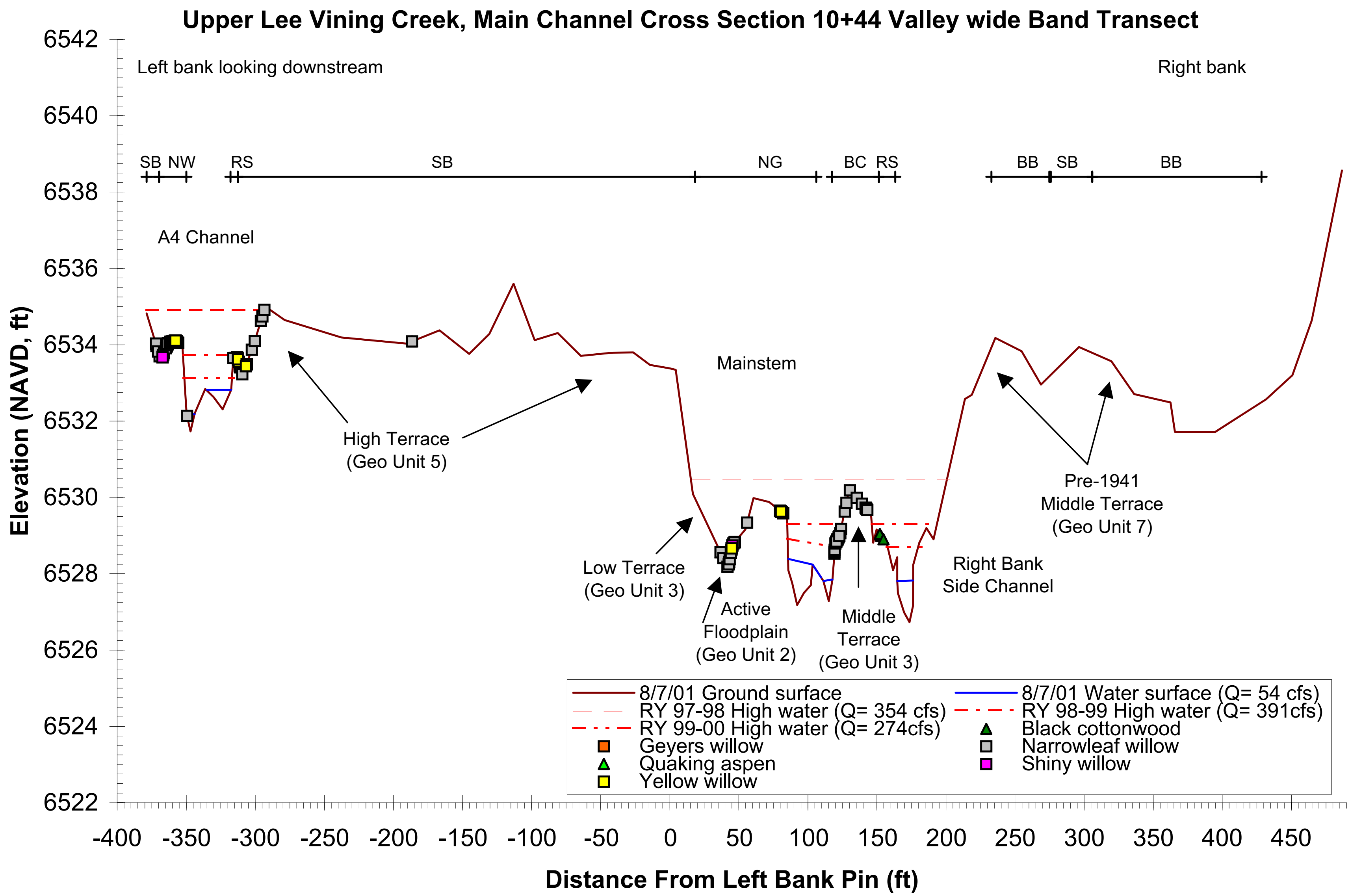


Figure 43. Upper Lee Vining Creek Site valley wide cross section 10+44 showing the locations of riparian plants, geomorphic units, and patch boundaries.

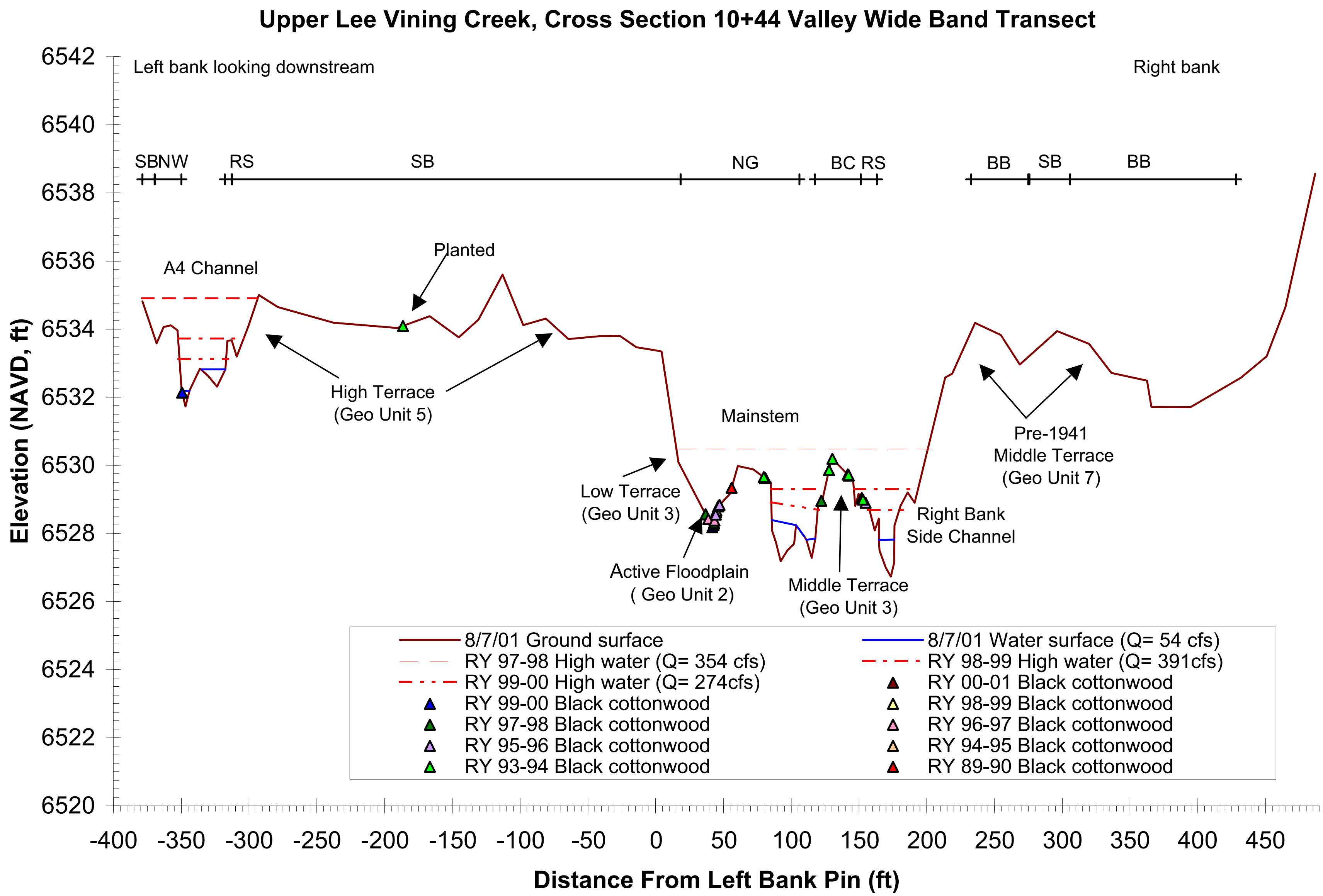


Figure 44. Upper Lee Vining Creek Site valley wide cross section 10+44 showing the locations of the dominant riparian hardwood, black cottonwood, relative to geomorphic units and patch boundaries.

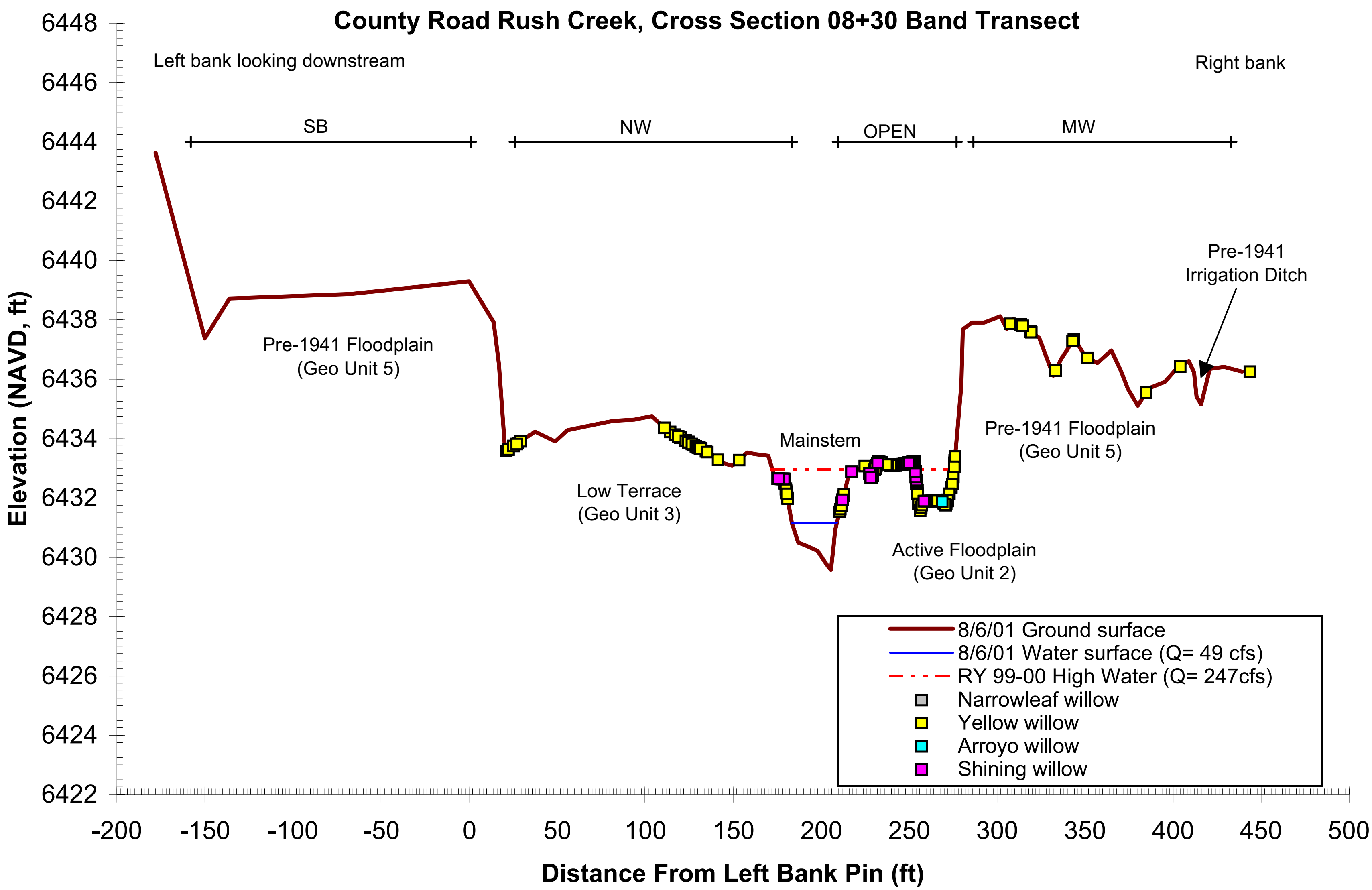


Figure 45. Rush Creek County Road Site valley wide cross section 08+30 showing the locations of riparian plants, geomorphic units, and patch boundaries.

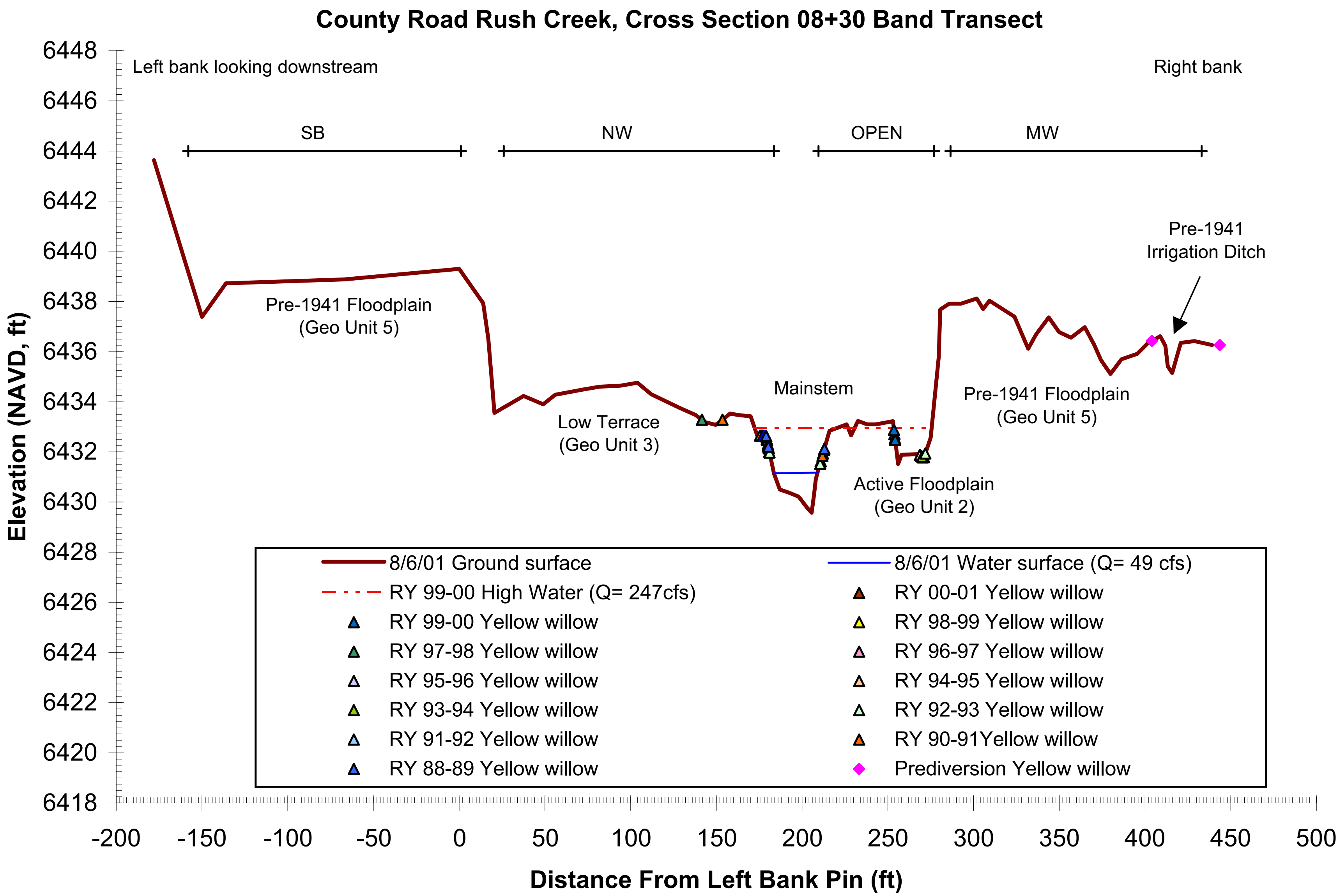


Figure 46. Rush Creek County Road Site valley wide cross section 08+30 showing the locations of the dominant riparian hardwood, yellow willow, relative to geomorphic units and patch boundaries.

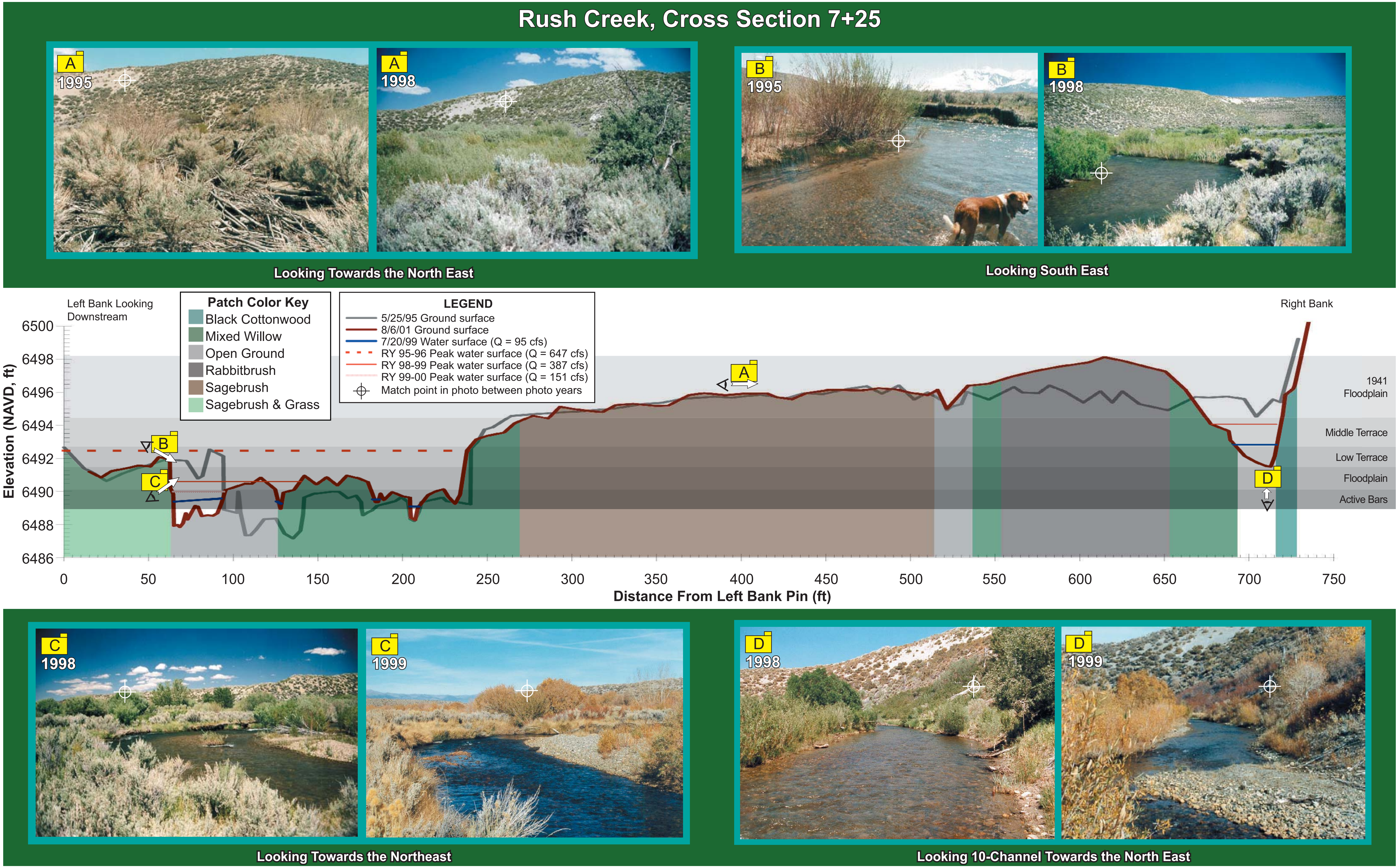


Figure 47. Lower Rush Creek Site valley wide cross section 07+25 with 1995, 1998 and 1999 photographs and illustrating the locations of, geomorphic units and patch boundaries.

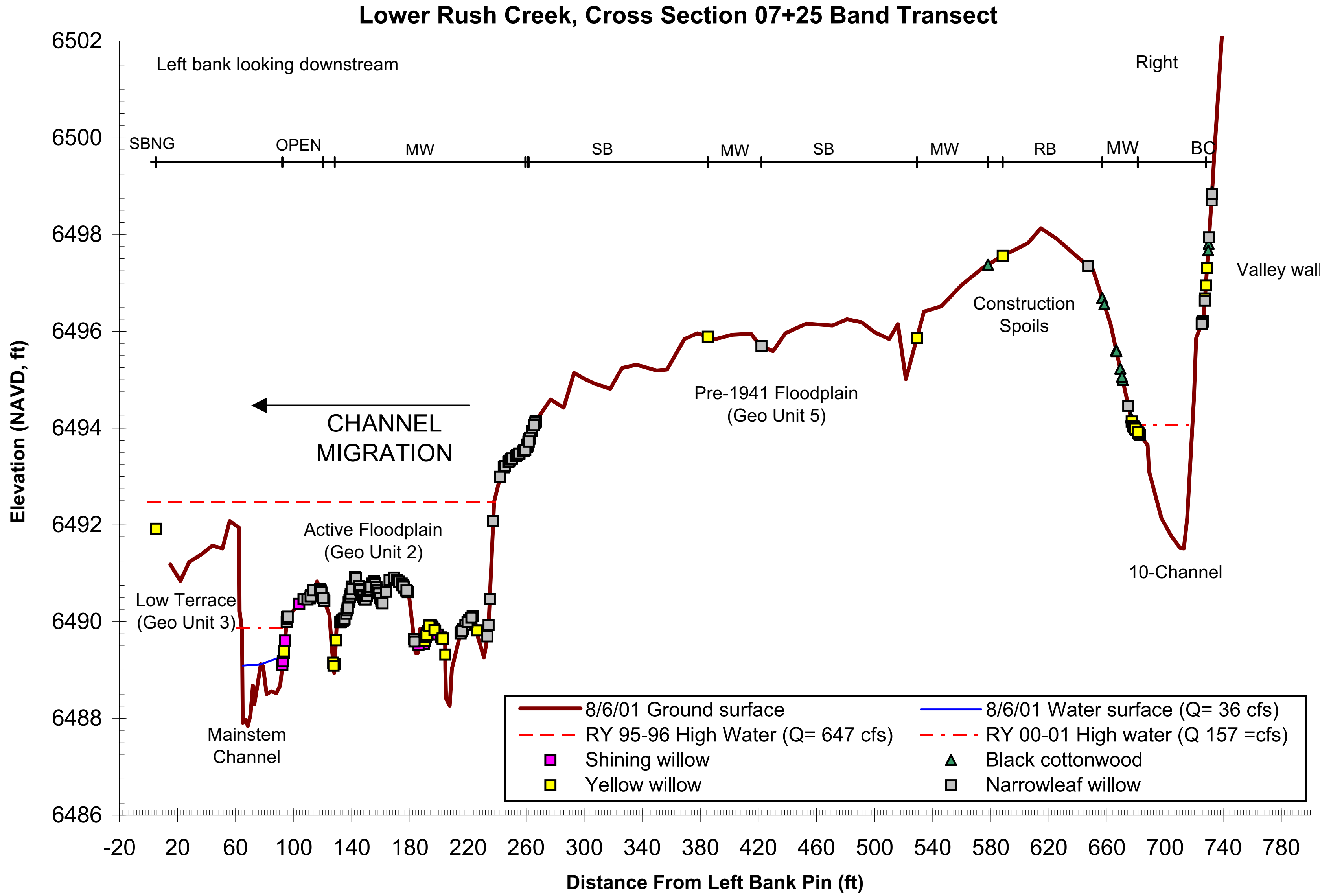


Figure 48. Lower Rush Creek Site valley wide cross section 07+25 showing the locations of riparian plants, geomorphic units, and patch boundaries.

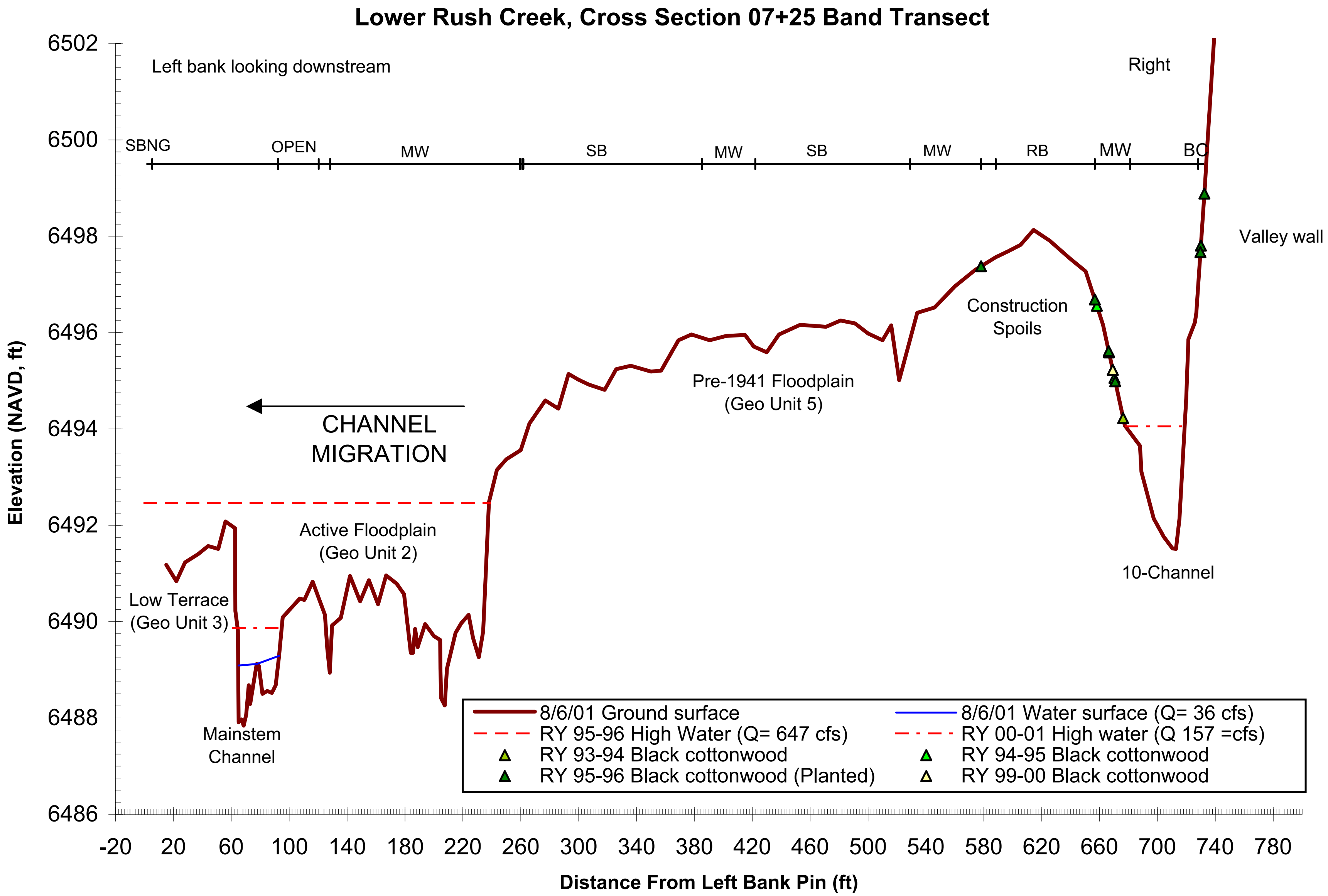


Figure 49. Lower Rush Creek Site valley wide cross section 07+25 showing the locations of black cottonwood relative to geomorphic units and patch boundaries.

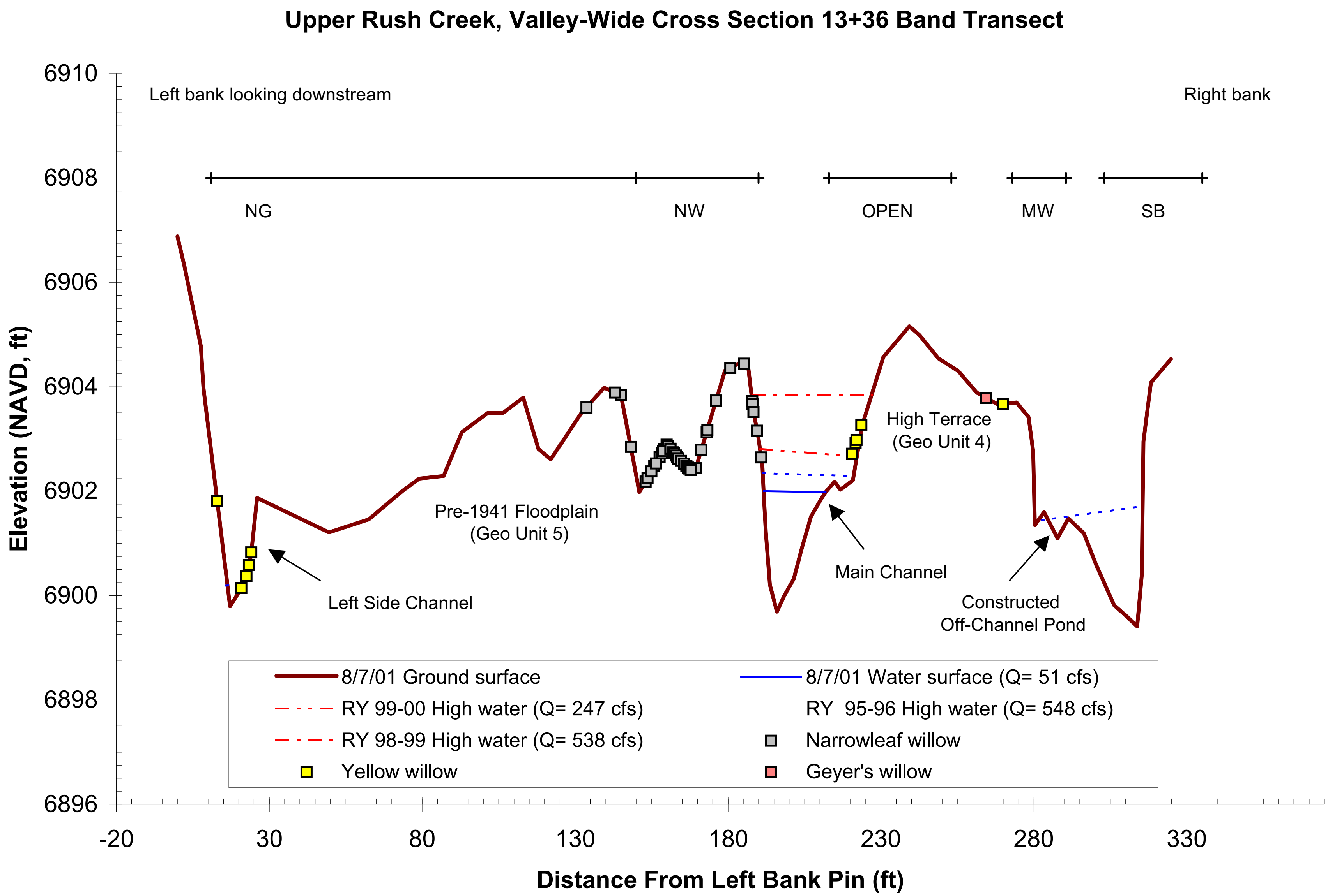


Figure 50. Upper Rush Creek Site valley wide cross section 13+36 showing the locations of riparian plants, geomorphic units, and patch boundaries.

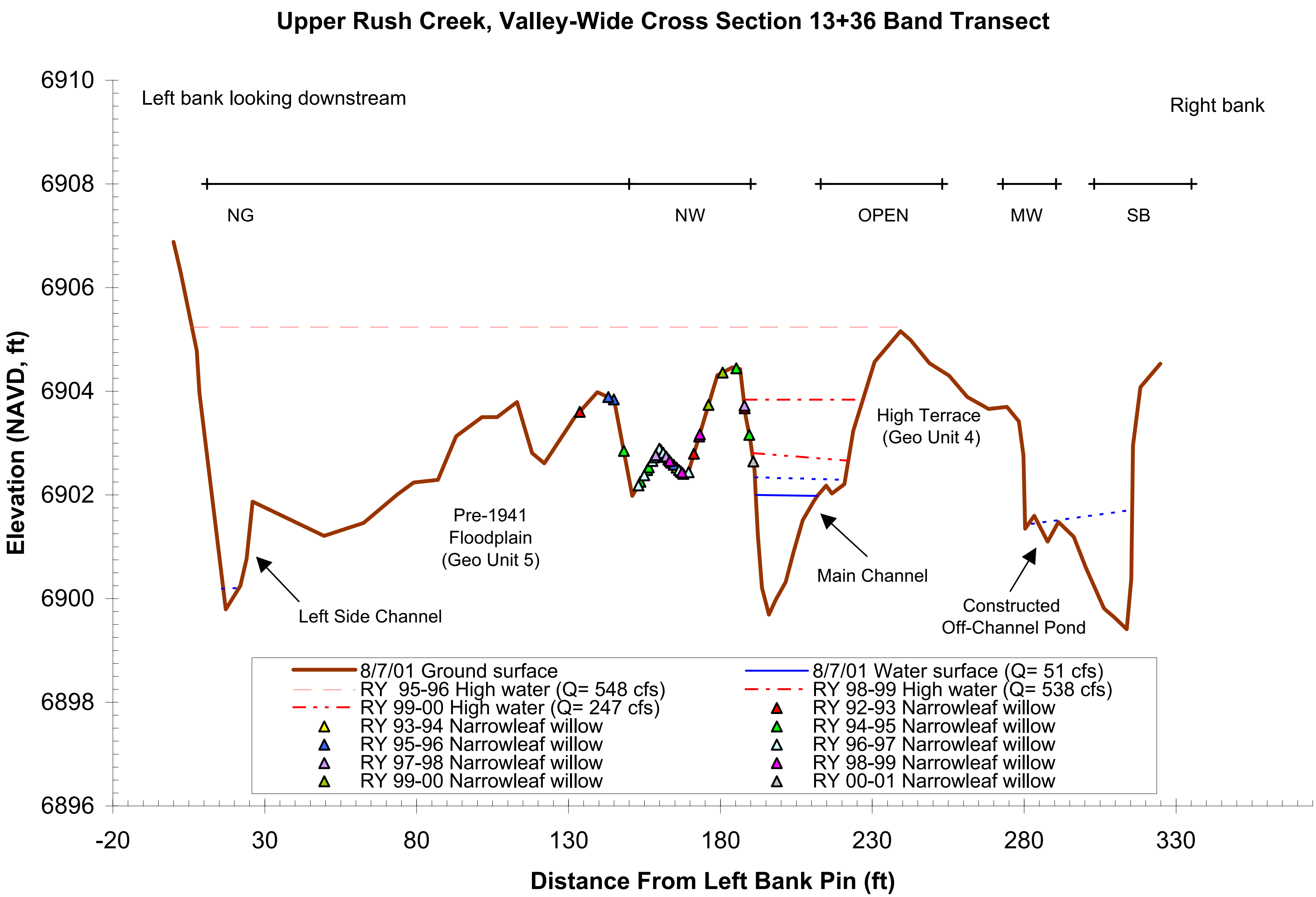


Figure 51. Lower Rush Creek Site, Valley Wide Cross section 07+25 showing the locations of the dominant riparian hardwood, narrowleaf willow, relative to geomorphic units and patch boundaries.

Table 1. Summary of peak flows for the Mono Basin tributaries at LADWP gaging sites and at channel monitoring sites within planmapped reaches.

Station	1998 Peak Daily Average (Instantaneous)	Peak Date	1999 Peak Daily Average (Instantaneous)	Peak Date	2000 Peak Daily Average (Instantaneous)	Peak Date	2001 Peak Daily Average (Instantaneous)	Peak Date	2002 Peak Daily Average (Instantaneous)	Peak Date
Rush Creek Runoff [1]	601	22-Jul-98	405	30-Jun-99	502	20-Jun-00	491	26-May-01	243	1-Jun-02
Rush Creek at Damsite (5013)	495 (519)	22-Jul-98	222 (266)	2-Jul-99	372 (381)	20-Jun-00	231	26-May-01	102	31-May-02
Rush Creek blw Return Ditch	538	23-Jul-98	201	10-Jul-99	204	30-Jun-00	162	11-Jun-01	168	8-Jun-02
Rush Creek blw Narrows (unimpaired) [2]	718	22-Jul-98	463	1-Jul-99	582	20-Jun-00	576	25-May-01	306	1-Jun-02
Rush Creek blw Narrows (actual) [3]	635	24-Jul-98	247	11-Jul-99	284	1-Jul-00	202	11-Jun-01	225	9-Jun-02
[Lower Rush Creek Main Channel in Study Site]	396	24-Jul-98	155	11-Jul-99	161 (178)	1-Jul-00	128	11-Jun-01	144	8-Jun-02
[Lower Rush Creek 10-Channel]	259	24-Jul-98	95	11-Jul-99	99 (111)	1-Jul-00	76	11-Jun-01	81	8-Jun-02
Rush Creek at County Road Culvert (5186)									151	8-Jun-02
Lee Vining Creek above Intake (5008)	419 (451)	9-Jul-98	285 (288)	19-Jul-99	264 (293)	28-May-00	201	17-May-01	238	1-Jun-02
Lee Vining Creek at Intake (5009)	391 (391)	9-Jul-98	274 ( )	19-Jul-99	258 (288)	28-May-00	201	17-May-01	236	31-May-02
[Upper Lee Vining Creek Mainstem]	270	9-Jul-98	190	19-Jul-99	179	28-May-00	140	17-May-01	164	31-May-02
[Upper Lee Vining Creek A-4 Channel]	140	9-Jul-98	96	19-Jul-99	90	28-May-00	69	17-May-01	82	31-May-02
[Upper Lee Vining Creek B-1 Channel]	176	9-Jul-98	122	19-Jul-99	115	28-May-00	89	17-May-01	105	31-May-02
[Lower Lee Vining Creek Main Channel]	215	9-Jul-98	152	19-Jul-99	143	28-May-00	112	17-May-01	131	31-May-02
[Lower Lee Vining Creek B-1 Channel]	176	9-Jul-98	122	19-Jul-99	115	28-May-00	89	17-May-01	105	31-May-02
Parker Creek (5003)	72	9-Jul-98	52	24-Jun-99	49 (52.4)	25-Jun-00	56	26-May-01	37	31-May-02
Walker Creek (5002)	47	21-Jul-98	30	29-May-99	31 (32.3)	28-May-00	42	16-May-01	26	June 1-02

[1] Computed natural flows, assuming no flow regulation;

[2] Computed by adding Rush Creek Runoff+Parker+Walker;

[3] Computed by adding RCBRD+Parker+Walker;

[4] Only gauged stations provide instantaneous peak discharges; stations that are calculated provide only the maximum daily average discharge;

Table 2. Summary of synoptic streamflow measurements on Rush Creek and flow proportions within study reach side channels.

	LADWP Reported Data		MEASURED FLOW PROPORTIONS						
Date	**Rush Creek blw Return Ditch (cfs)**	**Rush Creek blw Narrows (cfs)**	**Main Channel in Study Reach**	**10 Channel**			**10-Return Channel**	**Main Channel at XS -9+82**	**County Rd Culvert**
	blw Ditch	**blw Narrows**	**Q (cfs)**	**% of total Q**	**Q (cfs)**	**% of total Q**	**Q (cfs)**	**Q (cfs)**	
4-Jun-98	54	67	42	65%	23	35%	6	65	
3-Jul-98	267	321	198	61%	127	39%	73	325	
13-Sep-98	102	117	100	74%	35	26%	11	135	
6-May-99	51	54	42	80%	10	20%	7	52	
4-Jun-99	53	87	57	76%	18	24%	19	75	
27-Jul-99	85	105	72	63%	41	37%	2	113	
7-Oct-99	49	58	24	54%	21	46%	15	45	
14-Jun-00	52	109	54	60%	36	40%		90	
4-Nov-00	42	49	19	50%	18	50%		37	37
10-May-01	49	97	57	66%	29	34%		87	85
3-Jun-01	86	142	70	60%	47	40%		117	122
4-Jun-01	94	139	68	60%	45	40%		113	97
5-Jun-01	114	153	77	60%	51	40%		128	128
6-Jun-01	122	160	78	61%	51	39%	30	129	124
7-Jun-01	126	169	83	60%	55	40%		138	133
12-Jun-01	159	201	104	60%	68	40%		172	171
5-Aug-01	53	70	36	69%	16	31%		52	49
16-Nov-01	47	54							43
11-Jun-02	165	201	104	60%	68	40%		173	
13-Jun-02	127	166	88	59%	61	41%		149	
14-Jun-02	90	132	83	64%	47	36%		130	
13-Sep-02	48	55	33	76%	10	24%		43	44

Table 3. Summary of synoptic streamflow measurements on Lee Vining Creek and flow proportions within study reach side channels.

		MEASURED FLOW PROPORTIONS								
Date	**Lee Vining Creek at Intake (cfs)**	**Mainstem above B Connector**		**B Connector**		**A4 Channel**		**B1 Channel**		**Measured Total**
	Q TOTAL (cfs)	**Q (cfs)**	**% of total Q**	**Q (cfs)**	**% of total Q**	**Q (cfs)**	**% of total Q**	**Q (cfs)**	**% of total Q**	**Q TOTAL (cfs)**
05-Jun-98	115	76	69%	16	15%	35	31%	51	46%	110
18-Jun-98	274	161	62%	28	11%	99	38%	126	49%	260
11-Sep-98	76	56	68%	12	15%	26	32%	38	47%	82
06-May-99	45	25	79%	8	24%	7	21%	14	45%	32
04-Jun-99	180	142	71%	17	8%	59	29%	76	38%	201
26-Jul-99	64	48	75%	12	19%	16	25%	29	44%	65
08-Oct-99	27	19	73%	5	21%	7	27%	12	48%	26
01-Jun-00	166	127	71%	16	9%	52	29%	68	38%	179
02-Jun-00	170	127	70%	17	9%	55	30%	72	40%	182
11-May-01	151	105	68%	16	11%	50	32%	66	43%	155
22-May-01	169	129	70%	20	11%	56	30%	76	41%	185
07-Jun-01	95	72	72%	15	15%	28	28%	43	43%	100
03-Aug-01	33	22	84%	8	30%	4	16%	12	47%	26
15-Sep-02	23.4	15	77%	5	27%	4	23%	9	49%	19

Table 4. Summary of Rush Creek bed mobility for RY 2002.

REACH	CHANNEL	CROSS SECTION	PARTICLE SIZE (mm)	PARTICLE SIZE CLASS	NUMBER OF TRACER ROCKS PLACED	PEAK DIS-CHARGE AT CROSS SECTION (CFS)	NUMBER OF TRACER ROCKS MOBILIZED	PERCENT OF TRACER ROCKS MOBILIZED	GEOMORPHIC UNIT	NOTES
LOWER	MAIN	-9+82 (H)	125	D84	12	225	3	25%	Riffle	Rocks moved 1-4`
			63	D50	12	225	6	50%	Riffle	2 Rocks missing 4 Rock moved 1-20 `
			44	D31	12	225	9	75%	Riffle	6 Rocks missing; 3 rocks moved 0.5 to 6.5 `
		"rocks placed at stations 46, 48, …70."								Repainted D50 and D31 green
		-5+07 (D)	110	D84	10	225	1	10%	Riffle	Rock moved 3`
			52	D50	10	225	2	20%	Riffle	2 Rocks moved 2-4`
			36	D31	10	225	4	40%	Riffle	4 rocks moved 0.5 to 30`
		"rocks placed at stations 75, 77.5, …105."								LB Rock set was removed and abandoned
		4+08	56	D84	10	144	2	20%	Point Bar	1 rock missing; 1 rock moved 19`
			35	D50	10	144	4	40%	Point Bar	1 rock moved 32`(?) ; 3 rocks are missing
			28	D31	10	144	4	40%	Point Bar	2 rocks missing ; 2 rocks moved 2`
		"rocks placed at stations 19-20,21….28"								Repainted D50 and D31 fluorescent green
		7+25	99	D84	10	144	4	40%	Lower Point Bar	1 Rock missing; 3 rocks moved 2-8`
			53	D50	10	144	7	70%	Lower Point Bar	1 rock missing; 6 rocks moved 0.5 to 46`
			40	D31	10	144	4	40%	Lower Point Bar	3 rocks missing ; 1 rock moved 43`
		"Facies II rocks placed at stations19, 23, 27, …37."								Repainted D50 and D31 fluorescent green
		7+25	43	D84	10	144		0%	Upper Point Bar	
			26	D50	10	144		0%	Upper Point Bar	
			19	D31	10	144		0%	Upper Point Bar	
		"Facies I rocks placed at stations 39,40.5,43.5,45,46.5, 50, 52, …62"								
		7+70	99	D84	10	144	4	4%	Channel Bed	1 Rock missing ; 3 rocks moved 10-22`
			53	D50	10	144	1	1%	Channel Bed	1 rock missing
			40	D31	10	144	6	6%	Channel Bed	4 rocks missing; 2 rocks moved 1-19`
		"Facies II rocks placed at stations 26, 28, …38."								Repainted D50 and D31 fluorescent green
		7+70	43	D84		144		0%	Point Bar	
			26	D50		144		0%	Point Bar	Marked Rock Set Abandoned
			19	D31		144		0%	Point Bar	
		"Facies I rocks placed at stations 50, 52, …62"								

Table 4. Continued

REACH	CHANNEL	CROSS SECTION	PARTICLE SIZE (mm)	PARTICLE SIZE CLASS	NUMBER OF TRACER ROCKS PLACED	PEAK DIS-CHARGE AT CROSS SECTION (CFS)	NUMBER OF TRACER ROCKS MOBILIZED	PERCENT OF TRACER ROCKS MOBILIZED	GEOMORPHIC UNIT	NOTES
		10+10	78	D84	16	144	6	38%	Pool Tail	3 rocks missing; 3 rocks moved 1-13`
			46	D50	16	144	10	63%	Pool Tail	10 rocks missing
			28	D31	16	144	11	69%	Pool Tail	9 rocks missing; 2 rocks moved 2-3`
		"rocks placed at stations 20.5, 21.5….35.5"								quite embedded from last year.
	10-Channel	10B	108	D84	12	81	2	17%	Channel Bed	2 rocks moved 4-6`
			64	D50	12	81	6	50%	Channel Bed	1 rock missing; 5 rocks moved 3-25`
			44	D31	12	81	7	58%	Channel Bed	4 rocks missing; 3 rocks moved 2-25`
		"rocks placed at stations 18, 19, 20, …29"								
						"UPPER RUSH CREEK PEAK DISCHARGE = 168 cfs on June 8, 2002"				
UPPER	Main	0+74 (A)	132	D84	17	168	4	24%	Riffle	3 rocks moved <1 foot
			65	D50	17	168	1	06%	Riffle	1 rock moved 1`
			38	D31	17	168	0	0%	Riffle	
			26	D16	17	168		0%	Riffle	
		"rocks placed at stations 50, 52, …82."								
		5+45 (B)	122	D84	10	168	1	10%	Riffle	1 rock moved 4`
			75	D50	10	168	2	20%	Riffle	1 rock is missing; 1 rock moved 2`
			62	D31	10	168	2	20%	Riffle	1 rock missing; 1 rock moved1`
			49	D16		168		0%	Riffle	
		"rocks placed at stations 20, 21.5, 23, 24….30"								
		9+40	88	D84	8	168		0%	Pool Tail	
			46	D50	8	168		0%	Pool Tail	
			29	D31	8	168		0%	Pool Tail	
			18	D16	8	168		0%	Pool Tail	
		"rocks placed at stations 27.5,29.5,31.0,30, 32, …43."								
		11+68				Site Abandoned			Riffle	
		"six large boulders were painted and placed on cross section at stations 10, 12, …20 with assorted ""b"" diameter sizes."								

Table 4. Continued

REACH	CHANNEL	CROSS SECTION	PARTICLE SIZE (mm)	PARTICLE SIZE CLASS	NUMBER OF TRACER ROCKS PLACED	PEAK DIS-CHARGE AT CROSS SECTION (CFS)	NUMBER OF TRACER ROCKS MOBILIZED	PERCENT OF TRACER ROCKS MOBILIZED	GEOMORPHIC UNIT	NOTES
		12+95 (C)	140	D84	10	168	1	10%	Pool Tail	1 rock moved 0.5`
			77	D50	10	168	0	0%	Pool Tail	
			53	D31	10	168	2	20%	Pool Tail	2 rocks moved 1-4`
		"rocks placed at stations 11, 14, … 35"								
RUSH CREEK COUNTY ROAD PEAK DISCHARGE = ** cfs on ********										
County Rd		15+19	185	D84	12	227	0	0%	Low Gradient Riffle	
			71	D50	12	227	8	67%	Low Gradient Riffle	6 rocks missing; 2 rocks moved 1-3`
			40	D31	12	227	10	83%	Low Gradient Riffle	10 rocks missing
		"rocks placed at stations 11, 14, … 35"								Fair amount of movement from last year
		6+85	185	D84	12	227		0%		
			71	D50	12	227		0%		
			40	D31	12	227		0%		
		"rocks placed at stations 11, 14, … 35"								

Table 5. Summary of Lee Vining Creek bed mobility for RY 2002.

REACH	CHANNEL	CROSS SECTION	PARTICLE SIZE (mm)	PARTICLE SIZE CLASS	NUMBER OF TRACER ROCKS PLACED	PEAK DIS-CHARGE AT CROSS SECTION (CFS)	NUMBER OF TRACER ROCKS MOBILIZED	PERCENT OF TRACER ROCKS MOBILIZED	GEOMORPHIC UNIT
UPPER	MAIN	3+45	210	D84	16	164	2	0.125	Riffle
			104	D50	16	164	1	0.0625	Riffle
			84	D31	16	164	2	0.125	Riffle
		"rocks placed at stations 56, 58, …..84."							
		6+61	175	D84	12	164	0	0	Point Bar
			95	D50	12	164	0	0	Point Bar
			66	D31	12	164	0	0	Point Bar
		"rocks placed at stations 38, 40, 42,…60 "							
		9+31	144	D84	14	164	3	0.214285714	Side Channel/Medial Bar
			77	D50	14	164	9	0.642857143	Side Channel/Medial Bar
			54	D31	14	164	9	0.642857143	Side Channel/Medial Bar
		"rocks placed at stations 58, 61, 64, …106 [14 sets]"							
		9+31	144	D84	11	164	0	0	High Gradient Riffle
			77	D50	11	164	0	0	High Gradient Riffle
			54	D31	11	164	0	0	High Gradient Riffle
		"rocks placed at stations 109.5, 111, 112, 113.5, 115.5,117,118.5,120.5, 122,123.5,125.5,127.5 "							
		13+92	256	D84	11	164	0	0	Riffle
			95	D50	11	164	2	0.181818182	Riffle
			58	D31	11	164	1	0.090909091	Riffle
		"rocks placed at stations 44, 46, …64"							
	A4	4+04	165	D84	11	82	4	0.363636364	Medial Bar
			112	D50	11	82	4	0.363636364	Medial Bar
			90	D31	11	82	5	0.454545455	Medial Bar
		"rocks placed at stations 16, 19, 22, …43."							
		5+15	160	D84	10	82	0	0	Point Bar
			60	D50	10	82	2	0.2	Point Bar
			35	D31	10	82	4	0.4	Point Bar
		"rocks placed at stations 10, 12, …28."							

Table 5. Continued.

REACH	CHANNEL	CROSS SECTION	PARTICLE SIZE (mm)	PARTICLE SIZE CLASS	NUMBER OF TRACER ROCKS PLACED	PEAK DIS-CHARGE AT CROSS SECTION (CFS)	NUMBER OF TRACER ROCKS MOBILIZED	PERCENT OF TRACER ROCKS MOBILIZED	GEOMORPHIC UNIT
		6+80	250	D84	8	82	1	0.125	Riffle
			115	D50	8	82	0	0	Riffle
			86	D31	8	82	1	0.125	Riffle
		"rocks placed at stations 12.5, 14.5, 16.5, 18.5, 21.5, 24.5 (stn 12.5 missing D31)"							
	B1	06+08	240	D84	8	105	0	0	Riffle
			125	D50	8	105	0	0	Riffle
			81	D31	8	105	0	0	Riffle
		"rocks placed at stations 24, 26, 28, 30, 32, 34, 36, 38"							
					PEAK DISCHARGE = 236 cfs				
LOWER	MAIN	01+15	205	D84	10	131	1	0.1	Riffle
			106	D50	10	131	3	0.3	Riffle
			65	D31	10	131	5	0.5	Riffle
		"rocks placed at stations 19, 20, 20.5…33"							
	B1	01+80	153	D84	10	105	1	0.1	Riffle
			74	D50	10	105	6	0.6	Riffle
			54	D31	10	105	7	0.7	Riffle
		"rocks placed at stations 14,15 …23."							
	B1	00+87	98	D84	10	105	2	0.2	Point Bar
			56	D50	10	105	1	0.1	Point Bar
			40	D31	10		4	0.4	Point Bar
		"rocks placed at stations 22, 25, 26.5, 28, 29.5, 31, 32.5, 34, 35.5, 37, 38.5, 40."							

Table 6. Pilot revegetation project below the Rush Creek Narrows, listing survivorship within planting areas and irrigation treatment.

		Irrigation Treatment Area 1			Irrigation Treatment Area 2			Total Irrigation Treatments (Area1+ Area2)			TOTAL
		Terrasorb Polymer Planting 1	No Irrigation Planting 1	Driwater Planting 1	Terrasorb Polymer Planting 2	No Irrigation Planting 2	Driwater Planting 2	Total Terrasorb Polymer Planting	Total No Irrigation Planting	Total Driwater Planting	Total Surviving Trees in planting site
Upstream planting site	20-May-02	3 planted	3 planted	3 planted	3 planted	3 planted	3 planted	6 planted	6 planted	6 planted	18 planted
	9-Aug-02	0 survived	0 survived	0 survived	0 survived	0 survived	3 survived	0 survived	0 survived	3 survived	3 survived
	12-Oct-02	0 survived	0 survived	0 survived	0 survived	0 survived	3 survived	0 survived	0 survived	3 survived	3 survived
Middle planting site	20-May-02	3 planted	3 planted	3 planted	3 planted	3 planted	3 planted	6 planted	6 planted	6 planted	18 planted
	9-Aug-02	0 survived	0 survived	2 survived	0 survived	0 survived	2 survived	0 survived	0 survived	4 survived	4 survived
	12-Oct-02	0 survived	0 survived	1 survived	0 survived	0 survived	1 survived	0 survived	0 survived	2 survived	2 survived
Downstream planting site	20-May-02	3 planted	3 planted	3 planted	3 planted	3 planted	3 planted	6 planted	6 planted	6 planted	18 planted
	9-Aug-02	1 survived	2 survived	2 survived	1 survived	0 survived	0 survived	2 survived	2 survived	2 survived	6 survived
	12-Oct-02	1 survived	2 survived	2 survived	1 survived	0 survived	0 survived	2 survived	2 survived	2 survived	6 survived
Project Area Total	20-May-02	9 planted	9 planted	9 planted	9 planted	9 planted	9 planted	18 planted	18 planted	18 planted	54 planted
	9-Aug-02	1 survived	2 survived	4 survived	1 survived	0 survived	5 survived	2 survived	2 survived	9 survived	13 survived
TOTAL	**12-Oct-02**	**1 survived**	**2 survived**	**3 survived**	**1 survived**	**0 survived**	**4 survived**	**2 survived**	**2 survived**	**7 survived**	**11 survived**

Table 7. Cost analysis of the Pilot revegetation project below the Rush Creek Narrows.

Planting Material Quantities

	Number of plants	Number of irriga-tion units/plant	Browse protector and stake	Labor to install black poly pipe	Labor to plant and install material per plant
Driwater	18	4 quarts	1 per plant	0.2 hours/plant	0.3 hours/plant
No irrigation	18	N/A	1 per plant	0.2 hours/plant	0.3 hours/plant
Terrasorb polymers	18	2 oz	1 per plant	0.2 hours/plant	0.3 hours/plant
Total	54		54 protectors	0.6 hours	0.9 hours

Planting Expenses

Treatment	Labor costper hour	Price for seedling	Price per irrgation unit	Per per protector	Cost to plant each plant	Cost to plant the treament	Cost of survivors
Driwater	$60.00	$-	$1.50	$0.49	$35.38	$636.82	$90.97
No irrigation	$60.00	$-	$-	$0.49	$29.38	$528.82	$264.41
Terrasorb polymers	$60.00	$-	$0.32	$0.49	$30.02	$540.34	$270.17

Watering Expenses

Treatment	Number of plants	Labor to water plants	Labor costper hour	Cost to water a plant	Cost to water a treatment	Cost to water survivors
Driwater	18	0.2 hours/plant	$60.00	$11.11	$200.00	$28.57
No irrigation	18	0.2 hours/plant	$60.00	$11.11	$200.00	$100.00
Terrasorb polymers	18	0.2 hours/plant	$60.00	$11.11	$200.00	$100.00

Cost for each plant

	Driwater	Terrasorb	No treatment
Planting	$35.38	$30.02	$29.38
Watering (2x)	$22.22	$22.22	$22.22
Total	$57.60	$52.24	$51.60

Cost for each survivor

	Driwater	Terrasorb	No treatment
Planting	$90.97	$270.17	$264.41
Watering (2x)	$57.14	$100.00	$100.00
Total	$148.12	$370.17	$364.41

Table 8. Acreage of riparian vegetation mapped within the Lee Vining Creek riparian corridor.

Stream Segment	Riparian Acreage Termination Criteria	Riparian Acres Pre-1941 (Jones & Stokes 1993)	1989 Riparian Acres (Jones & Stokes 1993)	1999 Riparian Acres (preliminary McBain & Trush 2000)
1	20.0 acres	20.3 acres	19.8 acres	-
2	30.0 acres	29.9 acres	24.3 acres	-
3a	22.2 acres	23.2 acres	6.9 acres	12.9 acres
3b	32.9 acres	34.7 acres	7.5 acres	23.2 acres
3c	4.0 acres	4.3 acres	3.3 acres	4.1 acres
3d	n/a	0.0 acres	8.6 acres	15.0 acres
Total	**109.1 acres**	**112.4 acres**	**70.4 acres**	**55.2 acres**

Stream Segment	Acreage Change from 1941-1989	Acreage Change from 1989-1999	Acreage difference between 1999 and the Termination Criteria	Projected Year when Termination Criteria will be met (with current streamflows and livestock removal)
1	n/a	-	-	n/a
2	n/a	-	-	n/a
3a	-16.3 acres	6.0 acres	-9.3 acres	2013
3b	-27.2 acres	15.7 acres	-9.7 acres	2003
3c	-1.0 acres	0.8 acres	0.1 acres	1999
3d	8.6 acres	6.4 acres	n/a	2005
Total	**-35.9 acres**	**28.9 acres**	**-18.9 acres**	

Table 9. Acreage of riparian vegetation mapped with the Rush Creek riparian corridor.

Stream Segment	Riparian Acreage Termination Criteria	Riparian Acres Pre-1941 (Jones & Stokes 1993)	1989 Riparian Acres (Jones & Stokes 1993)	1999 Riparian Acres (preliminary McBain & Trush 2000)
1	6.2 acres	7.4 acres	1.7 acres	-
2	5.0 acres	8.1 acres	5.9 acres	10.3 acres
3a	21.5 acres	24.8 acres	12.7 acres	17.0 acres
3b	2.9 acres	1.5 acres	0.1 acres	2.1 acres
3c	11.2 acres	10.8 acres	4.1 acres	8.1 acres
3d	10.0 acres	22.1 acres	4.0 acres	4.7 acres
4a	26.0 acres	149.6 acres	90.0 acres	23.5 acres
4b	80.0 acres	combined with 4a	combined with 4a	67.1 acres
4c	38.7 acres	combined with 4a	combined with 4a	14.7 acres
5a	37.8 acres	37.8 acres	11.0 acres	19.6 acres
Total	**239.3 acres**	**262.1 acres**	**129.5 acres**	**167.0 acres**

Stream Segment	Acreage Change from 1941-1989	Acreage Change from 1989-1999	Acreage difference between 1999 and the Termination Criteria	Projected Year when Termination Criteria will be met (with current streamflows and livestock removal)
1	-5.7 acres	-	-	n/a
2	-2.2 acres	4.4 acres	5.3 acres	n/a
3a	-12.1 acres	4.3 acres	-4.5 acres	2009
3b	-1.4 acres	2.0 acres	-0.8 acres	2003
3c	-6.7 acres	4.0 acres	-3.1 acres	2007
3d	-18.1 acres	0.7 acres	-5.3 acres	2080
4a	-59.6 acres	15.2 acres	-2.5 acres	2025
4b	combined with 4a	combined with 4a	-12.9 acres	combined with 4a
4c	combined with 4a	combined with 4a	-24.0 acres	combined with 4a
5a	-26.8 acres	8.6 acres	-18.2 acres	2020
Total	**-132.6 acres**	**37.5 acres**	**-72.3 acres**	

Table 10. Plant species sampled and identified along Rush and Lee Vining Creeks, summer 2001. Common names and taxonomy are taken from Hickman, (1993) and Baldwin, (2002). The listing written in bold red indicates an exotic plant.

	Family	"Genus, species, variety and/or subspecies"	Common Name	Habit	Hydric Code
1	Asteraceae	*Arnica sororia*		Herb	NA
2	Asteraceae	*Artmesia cana*	silver sage	Herb	FACW
3	Asteraceae	*Artmesia douglasii*	mugwort	Herb	FAC+
4	Asteraceae	*Artmesia tridentata*	sage brush	Shrub	NA
5	Asteraceae	*Chaenactis douglasii var. douglasii*	dusty maidens	Herb	NA
6	Asteraceae	*Chrysothamnus nauseosus*	rubber rabbitbrush	Shrub	NA
7	Asteraceae	*Chrysothamnus visidiflorus*	yellow rabbitbrush	Shrub	NA
8	Asteraceae	*Cirisium vulgare*	bull thistle	Herb	FAC
9	Asteraceae	*Conyza canadensis*	horseweed	Herb	FAC
10	Asteraceae	*Erigeron aphanactis var. aphanactis*	brass buttons	Herb	NA
11	Asteraceae	*Eriophyllum lanatum var. integrifolium*	Oregon sunshine	Herb	NA
12	Asteraceae	*Machaeranthera canescens var. canescens*	hoary aster	Herb	FAC
13	Asteraceae	*Malacothrix torreyii*	desert dandelion	Herb	NA
14	Asteraceae	*Stephanomera spinosa*	wire lettuce	Herb	NA
15	Asteraceae	*Taraxacum officinale*	common dandelion	Herb	FACW
16	Asteraceae	*Tragopogon dubius*	goat's beard	Herb	NA
18	Asteraceae	*Wyethia mollis*	wooly mules ears	Herb	FACU-
19	Boraginaceae	*Cryptantha circumscissa*		Herb	NA
20	Boraginaceae	*Cryptantha watsonii*		Herb	NA
21	Boraginaceae	*Mertensia oblongifolia var. nevadensis*	Sagebrush bluebells	Herb	NA
22	Boraginaceae	*Plagiobothyrus kingii var. harknessii*	Great Basin popcorn flower	Herb	NA
23	Boraginaceae	*Tiquilia nuttallii*		Herb	UPL
24	Brassicaceae	*Arabis inyoensis*	Inyo rockcress	Herb	NA
25	Brassicaceae	*Arabis puberula*	rock cress	Herb	NA
26	Brassicaceae	*Caulanthus pilosus*	chocolate drops	Herb	NA
27	Brassicaceae	*Erysimum capitatum ssp. perenne*	western wallflower	Herb	NA
28	Brassicaceae	*Hutchinsia procumbens*		Herb	NA
29	Brassicaceae	*Lepidium sp.*		Herb	NA
30	Brassicaceae	*Phoenicaulis cheiranthoides*		Herb	NA
31	Brassicaceae	*Rorripia curvipes var. curvipes*	yellow cress	Herb	OBL
32	Brassicaceae	*Rorripia nasturtium-aquaticum*	Water cress	Em Herb	OBL
33	Caryophyllaceae	*Cerastrum beeringianum var. capillare*	mouse ear chickweed	Herb	NI*
34	Caryophyllaceae	*Sagina subulata*	scotch moss	Herb	NA
35	Caryophyllaceae	*Saponaria officinalis*	soapwort	Herb	FACU
36	Caryophyllaceae	*Stellaria longipes var. longipes*		Herb	FACW*

Table 10. Continued.

	Family	*"Genus, species, variety and/or subspecies"*	Common Name	Habit	Hydric Code
37	Chenopodiaceae	*Chenopodium nevadens*		Herb	NA
38	Chenopodiaceae	*Chenopodium sp.*		Herb	NA
39	Chenopodiaceae	*Grayia spinosa*	hop-sage	Herb	NA
40	Chenopodiaceae	*Salsola tragus*	russian thistle	Herb	NA
41	Cornaceae	*Cornus sericea*	red twig dogwood	Shrub	FACW
43	Cupressaceae	*Juniperus occidentalis var. australis*	Sierra juniper	Shrub	NA
44	Cyperaceae	*Carex disperma*		Grass	OBL
45	Cyperaceae	*Carex douglasii*		Grass	FACU
46	Cyperaceae	*Carex hassei*	golden sedge	Grass	FACW
47	Cyperaceae	*Carex lanuginosa*	wooly sedge	Em Herb	OBL
48	Cyperaceae	*Carex lenticularis var. impressa*	lens sedge	Em Herb	OBL
49	Cyperaceae	*Carex microptera*	smallwing sedge	Em Herb	FAC*
50	Cyperaceae	*Carex nebrascensis*		Em Herb	OBL
51	Cyperaceae	*Carex praegracilis*	clustered field sedge	Em Herb	FACW-
52	Cyperaceae	*Carex sp.*		Em Herb	NA
53	Cyperaceae	*Cyperus squarrosus*	nutsedge	Em Herb	OBL
54	Cyperaceae	*Eleocharis quinqueflora*	spike rush	Em Herb	OBL
55	Cyperaceae	*Scirpus microcarpus*	small fruited bulrush	Em Herb	OBL
56	Elaeagnaceae	*Shepherdia argentea*	buffalo berry	Shrub	UPL
57	Ephedradeae	*Ephedra viridis*		Shrub	NA
58	Equisetaceae	*Equisetum arvense*	common horsetail	Em Fern	FAC
59	Equisetaceae	*Equisetum hyemale*	common scouring rush	Em Fern	FACW
60	Fabaceae	*Lupinus lepidus*		Herb	NA
61	Fabaceae	*Melilotus alba*	white sweet clover	Herb	FACU
62	Fabaceae	*Trifolium monanthum*	mountain carpet clover	Herb	FACW
63	Fabaceae	*Trifolium sp.*		Herb	FACW
64	Fabaceae	*Trifolium wormskjoldii*	cow's clover	Herb	NA
65	Grossulariaceae	*Ribes aureum var. aureum*	golden currant	Shrub	NA
66	Hydrophyllaceae	*Phacelia bicolor var. bicolor*		Herb	NA
67	Iridaceae	*Iris missouriensis*	blue flag iris	Herb	FACW
68	Iridaceae	*Sisyrinchium idahoense*	blue-eyed grass	Herb	OBL
69	Juncaceae	*Juncus covilleii var. obtustatus*		Em Herb	FACW
70	Juncaceae	*Juncus mexicanus*		Em Herb	FACW
71	Juncaceae	*Juncus phaeocephalus*		Em Herb	FACW
72	Juncaceae	*Luzula subcongesta*	hairy wood rush	Em Herb	FACW
74	Lamiaceae	*Mentha arvensis*	horse mint	Herb	FACW
75	Liliaceae	*Allium lacunosum var. davisae*		Herb	NA
76	Liliaceae	*Allium nevadense*		Herb	NA

Table 10. Continued.

	Family	"Genus, species, variety and/or subspecies"	Common Name	Habit	Hydric Code
77	Liliaceae	*Calochortus bruneaunis*	desert mariposa lily	Herb	NA
78	Liliaceae	*Calochortus leichtlinii*		Herb	NA
79	Liliaceae	*Smilacina stellata*	star flowered solomons seal	Herb	NA
80	Liliaceae	*Zigadenus paniculatus*		Herb	NA
81	Loasaceae	*Mentzelia congesta*		Herb	NA
82	Loasaceae	*Mentzelia nitens*		Herb	NA
83	Nonvascular plant	*Lichen*		Lichen	NA
84	Nonvascular plant	*Liverwort*	nonvascular plants	Liver-wort	NA
85	Nonvascular plant	*Moss*			
86	Onagraceae	*Epilobium angustifolium*	fireweed	Herb	FAC
87	Onagraceae	*Epilobium ciliatum*		Herb	FACW
88	Onagraceae	*Gayophytum ramosissimum*	many flowered smoke weed	Herb	NA
89	Onagraceae	*Oenothera elata ssp. hirstuissima*	evening primrose	Herb	FACW
90	Orchidaceae	*Plantanthera hyperborea*		Herb	FACW+
91	Orobanchaceae	*Orobanche fasciulata*	clustered broom rape	Herb	NA
92	Pinaceae	*Abies magnifica*	red fir	Tree	FACU
93	Pinaceae	*Pinus contorta ssp. murrayana*	lodgepole pine	Tree	FAC
94	Pinaceae	*Pinus jeffreyi*	Jeffrey pine	Tree	NA
95	Pinaceae	*Pinus monophylla*	singleleaf pinyon	Tree	NA
96	Pinaceae	*Pinus sp.*		Tree	NA
97	Plataginaceae	*Plantago sp.*		Herb	NA
98	Poaceae	*Achnatherum hymenoides*	Indian rice grass	Grass	UPL
99	Poaceae	*Achnatherum occidentalis spp. Californicum*		Grass	NA
100	Poaceae	*Bromus tectorum*	cheat grass	Grass	NA
101	Poaceae	*Distichlis spicata*		Grass	FACW
102	Poaceae	*Elymus elymoides ssp. elymoides*	squirrel tail	Grass	FACU-
103	Poaceae	*Elymus glaucus ssp. glaucous*	blue wild rye	Grass	FACU
104	Poaceae	*Hesperostipa comata ssp. comata*	needle and thread	Grass	NA
105	Poaceae	*Leymus triticoides*	creeping wild rye	Grass	FAC+
106	Poaceae	*Muhlenbergia filiformes*	pull-up muhly	Grass	FACW
107	Poaceae	*Phleum alpinum*	Mountain timothy	Grass	FACW
108	Poaceae	*Poa cusikii ssp. cusikii*		Grass	NA
109	Poaceae	*Poa palustris*		Grass	FACW
110	Poaceae	*Poa pratensis ssp. pratensis*	kentucky bluegrass	Grass	FAC
111	Poaceae	*Poa secunda spp. juncifolia*		Grass	FACU
112	Poaceae	*Poa sp.*		Grass	NA

Table 10. Continued.

	Family	"Genus, species, variety and/or subspecies"	Common Name	Habit	Hydric Code
113	Polemoniaceae	*Eriastrum sparsiflorum*		Herb	NA
114	Polemoniaceae	*Gilia cana ssp. speciosa*		Herb	NA
115	Polemoniaceae	*Ipomopsis polycladon*		Herb	NA
116	Polemoniaceae	*Leptodactylon pungens*	prickley phlox	Herb	NA
117	Polemoniaceae	*Phlox stansburyi*		Herb	NA
118	Polygonaceae	*Eriogonum ampullaceum*	Mono buckwheat	Herb	NA
119	Polygonaceae	*Eriogonum umbellatum*	sulpher flowered buck-wheat	Shrub	UPL
120	Polygonaceae	*Oxytheca dendroidea ssp. dendrodea*		Herb	NA
121	Polygonaceae	*Rumex acetosella*	sheep sorrel	Herb	FACW-
122	Polygonaceae	*Rumex crispus*	curly dock	Herb	FACW-
123	Polygonaceae	*Rumex paucifolius*		Herb	OBL
124	Polygonaceae	*Rumex salicifolia*		Herb	OBL
125	Polygonaceae	*Rumex sp.*		Herb	OBL
126	Portulaceae	*Calyptridium roseum*	little red thing	Herb	FACU
127	Portulaceae	*Montia fontana*	water chickweed	Herb	FACW
128	Ranunculaceae	*Aquilegia formosa*	red columbine	Herb	FAC
129	Rosaceae	*Achillea millefolium*	common yarrow	Herb	FACU
130	Rosaceae	*Amelanchier alnifolia*	serviceberry	Shrub	FACU
131	Rosaceae	*Cercocarpus ledifolius*	mountain mahogany	Shrub	NA
132	Rosaceae	*Geum macrophyllum*	bigleaf avens	Shrub	FACW
133	Rosaceae	*Horkeliella congdonis*		Herb	NA
134	Rosaceae	*Potentilla gracilis var. elmeri*		Herb	FAC
135	Rosaceae	*Potentilla norvegica*		Herb	FAC*
136	Rosaceae	*Potentilla sp.*		Herb	FAC
137	Rosaceae	*Prunus andersonii*	desert peach	Tree	NA
138	Rosaceae	*Purshia tridentata*	bitterbush	Shrub	NA
139	Rosaceae	*Pyracantha angustifolia*		Shrub	NA
140	Rosaceae	*Rosa woodsii*	Wood's rose	Shrub	FAC
141	Rubiaceae	*Gallium trifidum var. pacificum*	bedstraw	Herb	OBL
142	Salicaceae	*Populus balsamifera ssp. trichocarpa*	black cottonwood	Tree	FACW
143	Salicaceae	*Populus tremuloides*	quaking aspen	Tree	FAC+
144	Salicaceae	*Salix exigua*	narrowleaf willow	Shrub	FACW
145	Salicaceae	*Salix geyeriana*	Geyer's willow	Tree	OBL
146	Salicaceae	*Salix laevigata*	red willow	Tree	FACW+
147	Salicaceae	*Salix lasiolepis*	arroyo willow	Shrub	FACW
148	Salicaceae	*Salix lucida ssp. lasiandra*	shiny willow	Tree	OBL
149	Salicaceae	*Salix lutea*	yellow willow	Tree	OBL

Table 10. Continued.

	Family	*"Genus, species, variety and/or subspecies"*	Common Name	Habit	Hydric Code
150	Scrophulariaceae	*Castilleja angustifolia*		Herb	NA
151	Scrophulariaceae	*Castilleja linariifolia*		Herb	NA
152	Scrophulariaceae	*Castilleja miniata ssp. miniata*	riparian indian paint-brush	Herb	CBL*
153	Scrophulariaceae	*Mimulus cardinalis*		Herb	OBL
154	Scrophulariaceae	*Mimulus guttatus*	monkey flower	Shrub	FACW+
155	Scrophulariaceae	*Mimulus lewisii*	Lewis's monkey flower	Herb	OBL
156	Scrophulariaceae	*Mimulus pilosus*		Herb	NA
157	Scrophulariaceae	*Mimulus sp.*		Herb/ Shrub	NA
158	Scrophulariaceae	*Penstemon rydbergii var. oreorachis*		Herb	FAC
159	Scrophulariaceae	*Penstemon speciosus*		Herb	NA
160	Scrophulariaceae	*Verbascum thapsus*	wooley mullien	Herb	NI
161	Scrophulariaceae	*Veronica serpyllifolia ssp. humifusa*		Herb	NI*
162	Tamaricaceae	*Tamarix ramosissima*	Tamarisk	Shrub/ Tree	FAC
163	Urticaceae	*Urtica dioica ssp. holosericea*	stinging nettle	Herb	FACW

Table 11. Summary of patch types derived by mapping and cluster analysis, and their relationship to plant stand types identified by previous research. Mapped patch types written in italicized red, are those that in combination with other stand types or by themselves, made up at least 80% of the vegetative cover on a geomorphic unit and were therefor included in the field sampling.

MCBAIN & TRUSH (2001) CLUSTER ANALYSIS DERIVED PATCH TYPE	MCBAIN & TRUSH (2000) PLANT STAND TYPES	JONES & STOKES (1993) FINE SCALE VEGETATION COVER TYPE	NDDB DATA BASE/HOLLAND TYPE
Not defined	Aquatic Vegetation	N/A	Montane Freshwater Marsh (52340 in part)
Sagebrush-Bitterbrush	*Bitterbrush*	Decadent bitterbrush scrub	Great Basin Mixed Scrub (35100)
		Mature bitterbrush scrub	
		Establishing bitterbrush scrub	
Black Cottonwood	*Black Cottonwood*	Decadent cottonwood-willow	Montane Black Cottonwood Forest (61530)
		Mature cottonwood-willow	
		Establishing cottonwood-willow	
Not defined	Buffaloberry	Decadent mixed riparian scrub	Great Basin Mixed Scrub (35100)
		Mature mixed riparian scrub	
		Establishing mixed riparian scrub	
Not defined	Cattail	N/A	Montane Freshwater Marsh (52340 in part)
Not defined	Ephedra	N/A	Great Basin Mixed Scrub (35100)
Juncus - Creeping Wild Rye	*Great Basin Grassland*	Mixed riparian meadow	Great Basin Grasslands (43000 in part)
		Pasture	
Not defined	Jeffery Pine	Decadent conifer-broadleaf	Jeffery Pine Forest (85100)
		Mature conifer-broadleaf	
		Establishing conifer-broadleaf	
Mugwort - Soapwort	Lupine	Sparsely vegetated floodplain	Great Basin Grasslands (43000 in part)
Sagebrush - Wood's Rose	Mixed Desert Rose	Decadent mixed riparian scrub	Great Basin Mixed Scrub (35100)
		Mature mixed riparian scrub	
		Establishing mixed riparian scrub	

Table 11. Continued

MCBAIN & TRUSH (2001) CLUSTER ANALYSIS DERIVED PATCH TYPE	MCBAIN & TRUSH (2000) PLANT STAND TYPES	JONES & STOKES (1993) FINE SCALE VEGETATION COVER TYPE	NDDB DATA BASE/HOLLAND TYPE
Black cottonwood - Wood's Rose	Mixed Riparian Rose	Decadent willow scrub	Southern Willow Scrub (63320 in part)
Narrowleaf Willow - Wood's Rose		Mature willow scrub	
Mixed Willow	*Mixed Willow*	Decadent willow scrub	Southern Willow Scrub (63320 in part)
		Mature willow scrub	
		Establishing willow scrub	
Not defined	Mountain Mahogany	Decadent mixed riparian scrub	Semi-Desert Chaparral (37400 in part)
		Mature mixed riparian scrub	
		Establishing mixed riparian scrub	
Narrowleaf Willow	*Narrowleaf willow*	Decadent willow scrub	Southern Willow Scrub (63320 in part)
		Mature willow scrub	
		Establishing willow scrub	
Black Cottonwood - Wood's Rose	*Quaking aspen*	Decadent aspen	Aspen Riparian Forest (61520)
		Mature aspen	
		Establishing aspen	
Black Cottonwood - Wood's Rose	*Rabbitbrush*	Decadent rabbitbrush scrub	Rabbitbrush Scrub (35400)
		Mature rabbitbrush scrub	
		Establishing rabbitbrush scrub	
Wood's Rose	*Rose*	Decadent mixed riparian scrub	Southern Willow Scrub (63320 in part)
		Mature mixed riparian scrub	
		Establishing mixed riparian scrub	

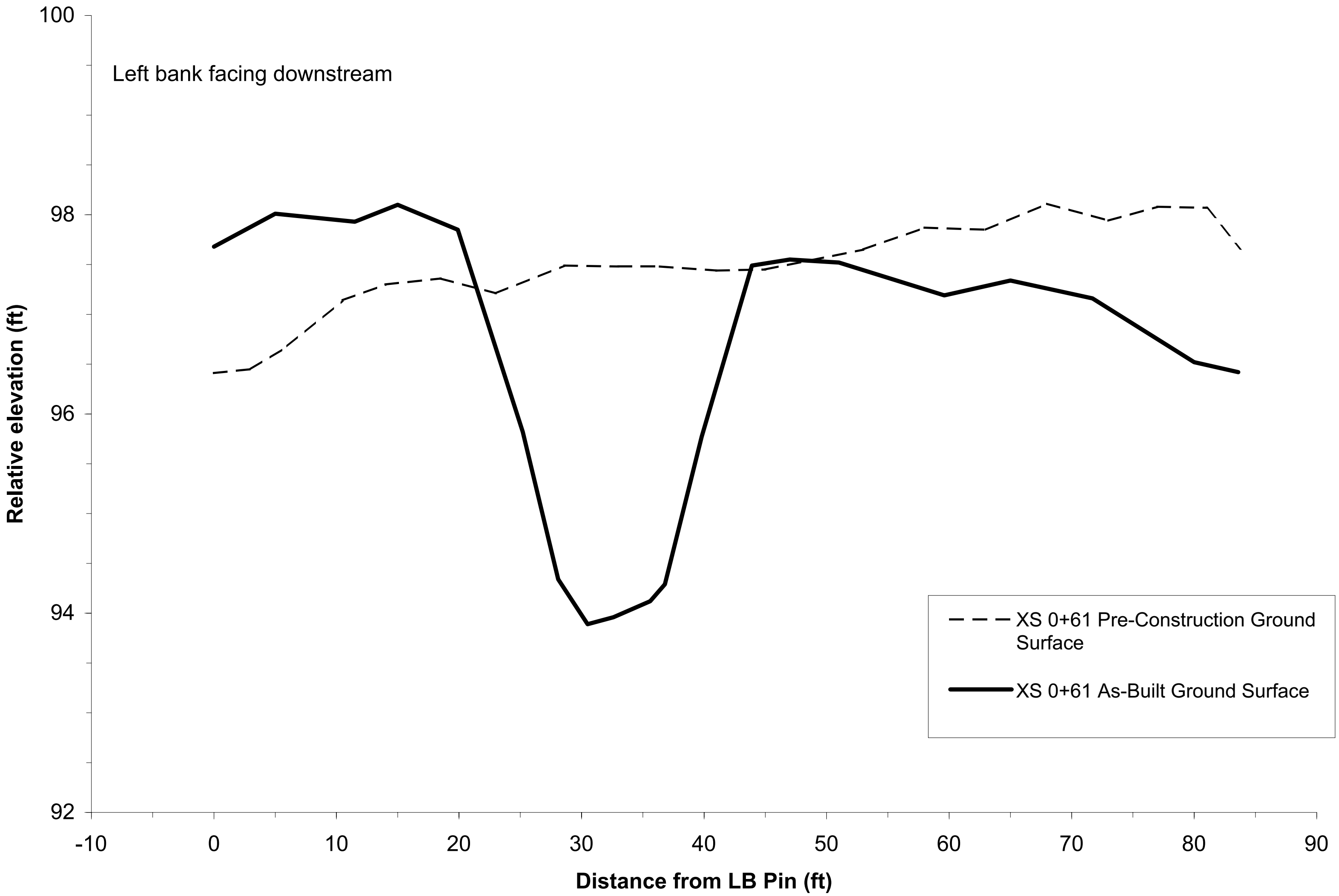
Table 11. Continued

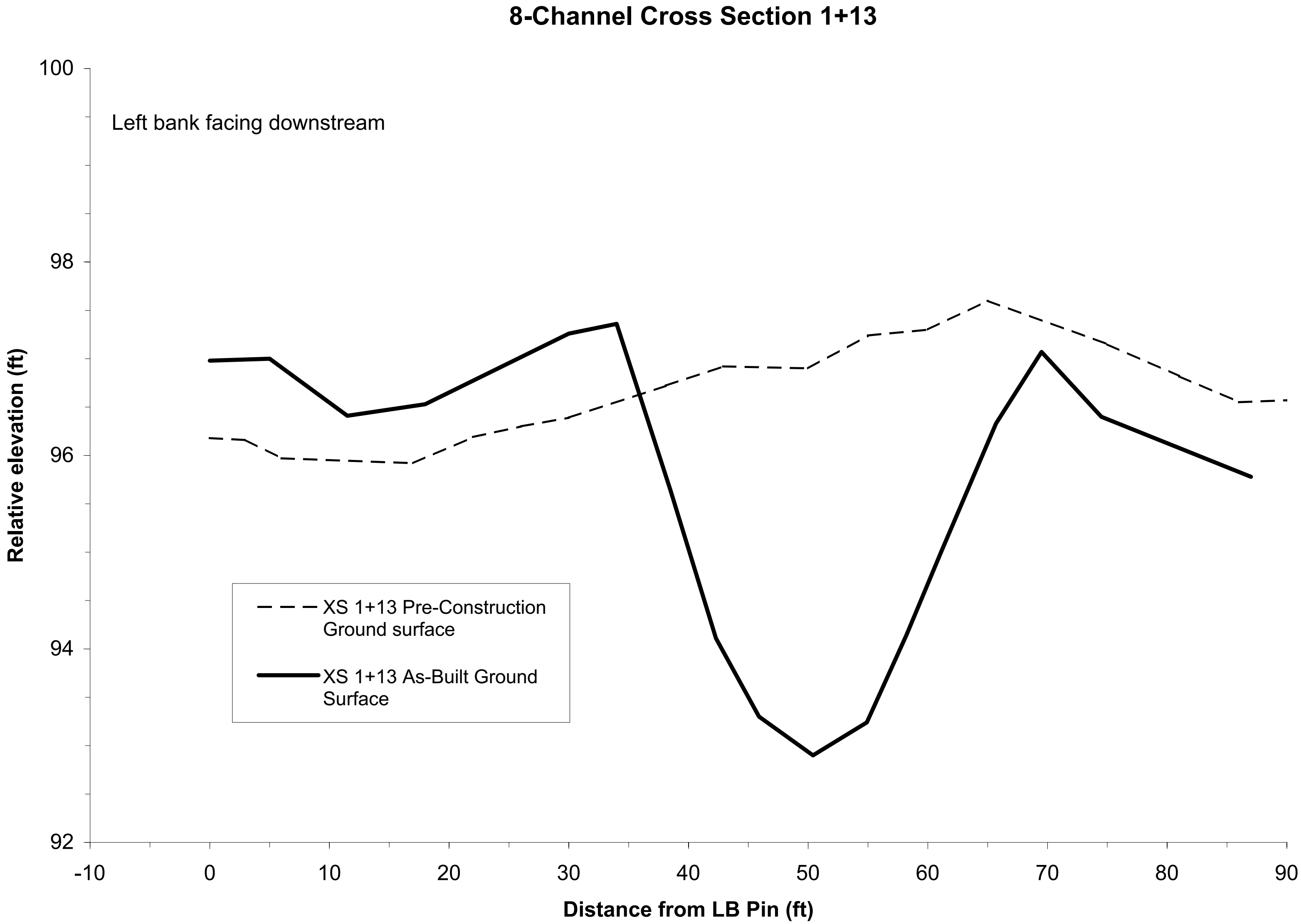
MCBAIN & TRUSH (2001) CLUSTER ANALYSIS DERIVED PATCH TYPE	MCBAIN & TRUSH (2000) PLANT STAND TYPES	JONES & STOKES (1993) FINE SCALE VEGETATION COVER TYPE	NDDB DATA BASE/HOLLAND TYPE
Sagebrush	*Sagebrush*	Decadent sagebrush scrub	Big Sagebrush (35210)
		Mature sagebrush scrub	
		Establishing sagebrush scrub	
Not defined	Sagebrush-Black Cottonwood	Decadent sagebrush scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub	
		Establishing sagebrush scrub	
Sagebrush - Creeping Wild Rye	*Sagebrush-Great Basin Grassland*	Decadent sagebrush scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub	
		Establishing sagebrush scrub	
Not defined	Sagebrush-Rabbitbrush	Decadent sagebrush scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub	
		Establishing sagebrush scrub	
Not defined	Shiny Willow	Decadent cottonwood-willow	Southern Willow Scrub (63320 in part)
		Mature cottonwood-willow	
		Establishing cottonwood-willow	
Juncus- Creeping Wild Rye	Wet Meadow	Wet meadow	Wet Montane Meadow (45110 in part)
Yellow Willow	Yellow Willow	Decadent willow scrub	Southern Willow Scrub (63320 in part)

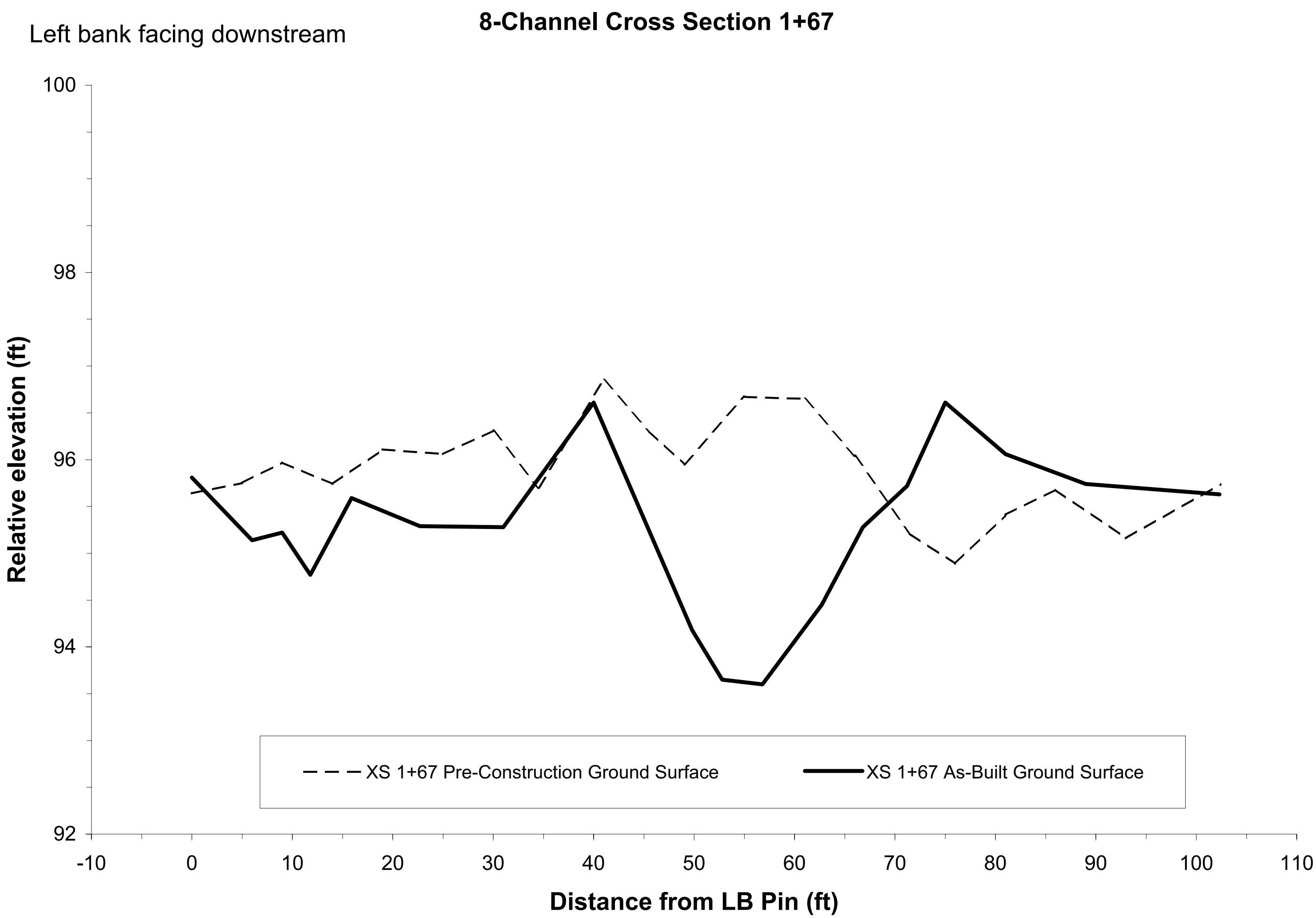
APPENDIX A

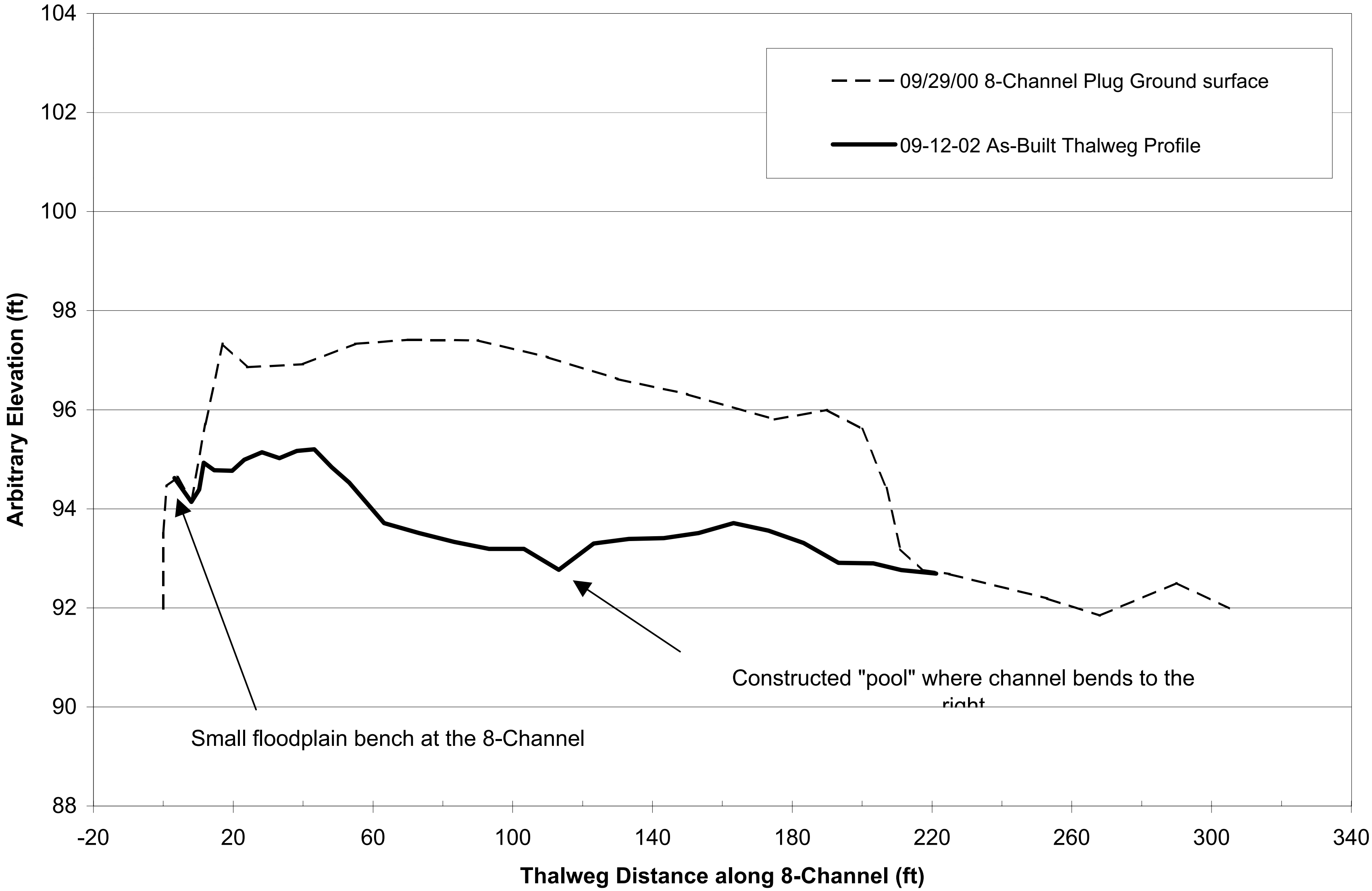
Rush Creek, 8-Channel, Pre and Post Construction Cross Sections and Long Profile.

8-Channel Cross Section 0+61




8-Channel Cross Section 1+13
Left bank facing downstream
Relative elevation (ft)
100
98
96
94
92
Distance from LB Pin (ft)
-10
0
10
20
30
40
50
60
70
80
90
XS 1+13 Pre-Construction Ground surface
XS 1+13 As-Built Ground Surface


Left bank facing downstream
8-Channel Cross Section 1+67
Relative elevation (ft)
100
98
96
94
92
Distance from LB Pin (ft)
-10
0
10
20
30
40
50
60
70
80
90
100
110
XS 1+67 Pre-Construction Ground Surface
XS 1+67 As-Built Ground Surface


09/29/00 8-Channel Plug Ground surface
09-12-02 As-Built Thalweg Profile
Arbitrary Elevation (ft)
104
102
100
98
96
94
92
90
88
-20
20
60
100
140
180
220
260
300
340
Thalweg Distance along 8-Channel (ft)
Small floodplain bench at the 8-Channel
Constructed "pool" where channel bends to the right

Section 5

Mono Basin Waterfowl
Habitat and Population Monitoring
2002-2003

Waterfowl Habitat Restoration Project
Annual Report
2002

Mono Basin Hydrology

Water exports for the Mono Basin are reported in Appendix 1.

The elevation of Mono Lake was measured on forty occasions during Runoff Year 2002-2003. The reads are reported in Appendix 1.

Lake Limnology

Dr. Robert Jellison of the University of California Santa Barbara conducted eleven limnological surveys on Mono Lake. The results are reported in Appendix 2.

Waterfowl Surveys

Ms. Debbie House, Range and Wildlife Biologist with the Los Angeles Department of Water and Power, conducted three summer ground counts and six fall aerial surveys. The results are reported in Appendix 3.

The aerial photographs of Crowley and Bridgeport reservoirs required by Order 98-05 have not been taken to date. This annual requirement will be fulfilled starting in 2003.

A revision of the waterfowl survey protocol proposed by Ms. House was negotiated with the Mono Lake Committee. The new protocol is described in Appendix 3. Peer review comments are presented in Appendix 4.

Mr. Robert McKernan was selected to provide peer review of the waterfowl survey program every five years starting in 2003. Mr. McKernan's Curriculum Vitae are presented in Appendix 5.

Vegetation

The next regularly scheduled vegetation surveys are set for 2005.

Mono Lake Waterfowl Restoration Project
Compliance Checklist
2002

Hydrology	**Appendix 1**
Mono Lake Elevation	☑
Walker Creek Flows	☑
Parker Creek Flows	☑
Lee Vining Creek Flows	☑
Rush Creek Flows	☑
Mono Basin Exports	☑
Limnology	**Appendix 2**
Meteorology	☑
Physicochemical Variables	☑
Primary Producers	☑
Secondary Producers	☑
Ornithology	**Appendix 3**
Population Surveys	☑
Aerial Photography	☐
Time Activity Budget	Required at Stabilization
Vegetation	**Required 2005**

Brian White

Brian White
Waterfowl Coordinator

Appendix 1 - Hydrology

November 1, 2002

To Enclosed Distribution List:

Update on Mono Basin Operations During 2002-03 Runoff Year

This year's runoff for the Mono Basin (Figure 1) could be termed "typical" with no significant events occurring. The peaks on all four creeks occurred earlier than forecasted and the magnitudes for three of the four creeks were lower than forecasted.

The following is a summary of the Los Angeles Department of Water and Power's (LADWP) operations to date in the Mono Basin for the 2002-03 runoff year:

- Mono Basin Exports: Exports were suspended on July 7 to help reduce the impacts to recreational uses at Grant Lake reservoir due to the below normal runoff year. Exports were resumed on September 5 and ramped up to an average flow rate of 32 cfs (Owens River flow including the addition of Mono Basin export is shown in Figure 2). The exports will continue through the remainder of the runoff year, and are expected to conclude in late March 2003. The flow rate will be adjusted to provide LADWP its allowable maximum export of 16,000 acre-feet.

- Walker Creek: There were no diversions for export during the year. The creek experienced its peak of a magnitude of 26 cfs (average daily) on June 1. The peak did not exceed the forecasted magnitude of 29 cfs (Figure 3).

- Parker Creek: There were no diversions for export during the year. The creek experienced its peak of a magnitude of 37 cfs (average daily) on May 31. The peak did not exceed the forecasted magnitude of 42 cfs (Figure 4).

- Lee Vining Creek: There were no diversions for export during the year. The creek experienced its peaks of a magnitude of 236 cfs (average daily) on May 31. The peak exceeded the forecasted peak of 212 cfs (Figure 5).

  There was no augmentation from Lee Vining Creek made to Rush Creek flows.

- Rush Creek: Grant Lake's elevation on April 1, 2002 was approximately 7,114.9 ft amsl, 15.1 ft below the lip of the spillway. The low elevation of the reservoir, coupled with a below normal runoff provided no opportunity to spill. A peak inflow into Grant Lake (Rush Creek at Damsite) of 168 cfs was forecasted to occur the week of June 5. Rush Creek at Damsite experienced its peak on May 31 with a magnitude of 102 cfs (average daily) (Figure 6, 7, and 8). Rush Creek below the confluence of the Return Ditch and Grant Lake spill channel experienced a flow of approximately 166 cfs (average daily) on June 7. The 166 cfs was achieved by ramping up the outflow to the return ditch to its temporary maximum capacity of approximately 160 cfs. Due to the low level of Grant Lake, the 166 cfs flow was only maintained for 2 days and then the flow was ramped back down to slightly above the minimum base flow of 47 cfs.

  Rush Creek below the narrows experienced a flow magnitude of approximately 223 cfs (average daily) on June 7 (Figure 8).

- Runoff - Actual vs. Forecasted: The forecasted runoff for the period April 1 through September 30 was 81,200 acre-feet while the actual runoff was measured at 71,600 acre-feet; a difference of nearly 10,000 acre-feet. The forecasted April through March runoff (99,800 acre-feet) may be closer to the measured runoff.

  The timing of the Mono Basin peak runoff occurred one to two weeks earlier than predicted for all four creeks. Lee Vining Creek experienced a peak with a slightly higher magnitude than predicted. The remaining three creeks had flow magnitudes lower than those forecasted and Rush Creek was down by approximately 40%. The table below compares May 1 forecasted values to those actually measured.

	Forecasted		Measured	
	Magnitude	Timing	Magnitude	Timing
Rush Creek @ Damsite (Figure 6)	168 cfs	June 2	102 cfs	May 31
Parker Creek (Figure 4)	42 cfs	June 18	37 cfs	May 31
Walker Creek (Figure 3)	29 cfs	June 14	26 cfs	June 1
Lee Vining Creek (Figure5)	212 cfs	June 5	236 cfs	May 31
Runoff (acre-feet)	81,200 ac-ft	N/A	71,600 ac-ft	N/A

- Grant Lake Reservoir: Flow releases from the reservoir to Rush Creek were maintained slightly above the minimum and exports were suspended on July 7 to help reduce impacts recreation at Grant Lake reservoir. (Figure 9).

If you have any questions or need additional information regarding operations, please contact me at (760) 873-0225.

Sincerely,

ORIGINAL SIGNED BY
GENE L. COUFAL

Gene L. Coufal
Manager
Aqueduct Business Group

Enclosures
SBM:lge
bc: Thomas M. Erb
Richard F. Harasick
Eugene L. Coufal
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Charlotte L. Rodrigues
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Peter Kavounas
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File: Mono Basin Restoration

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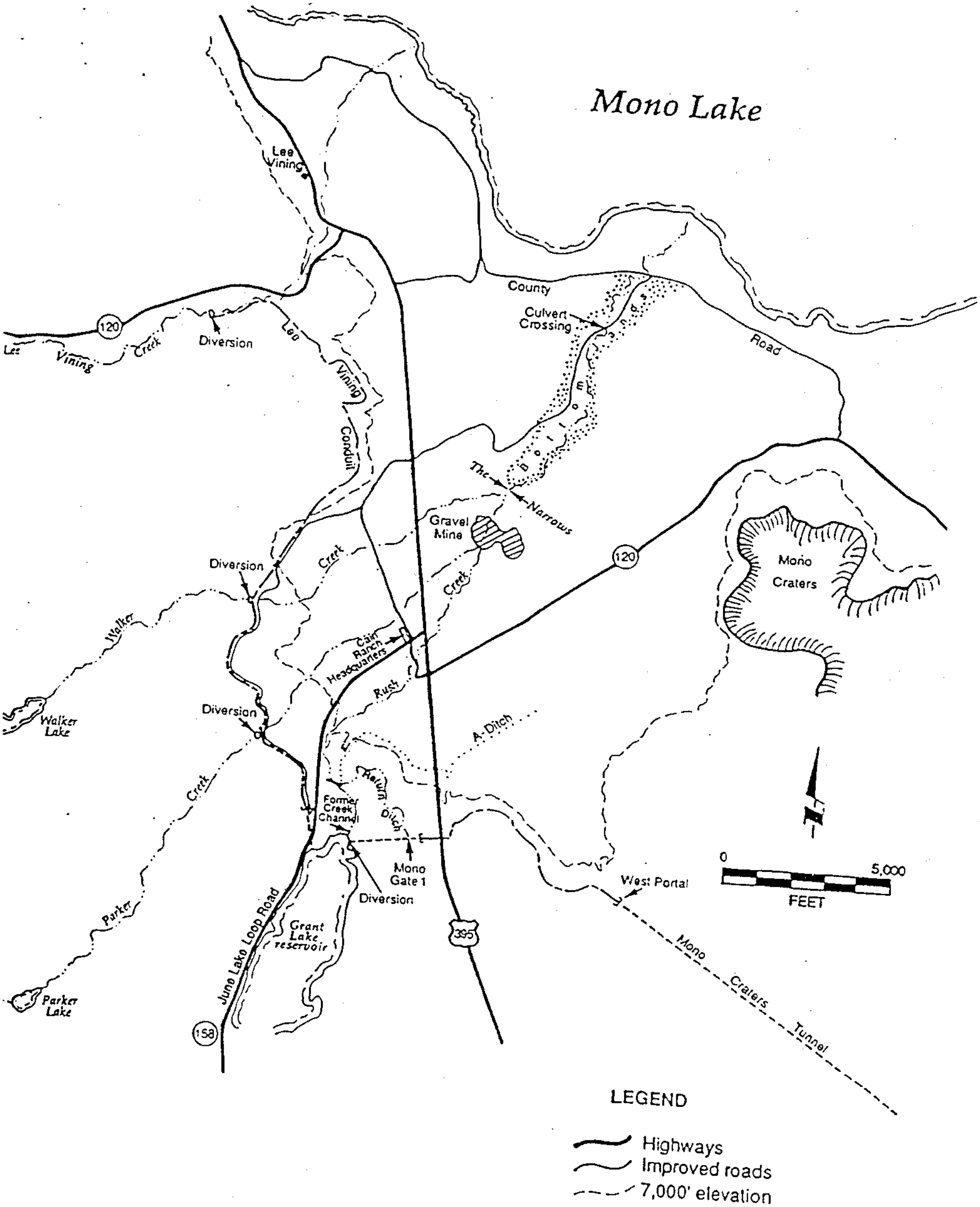
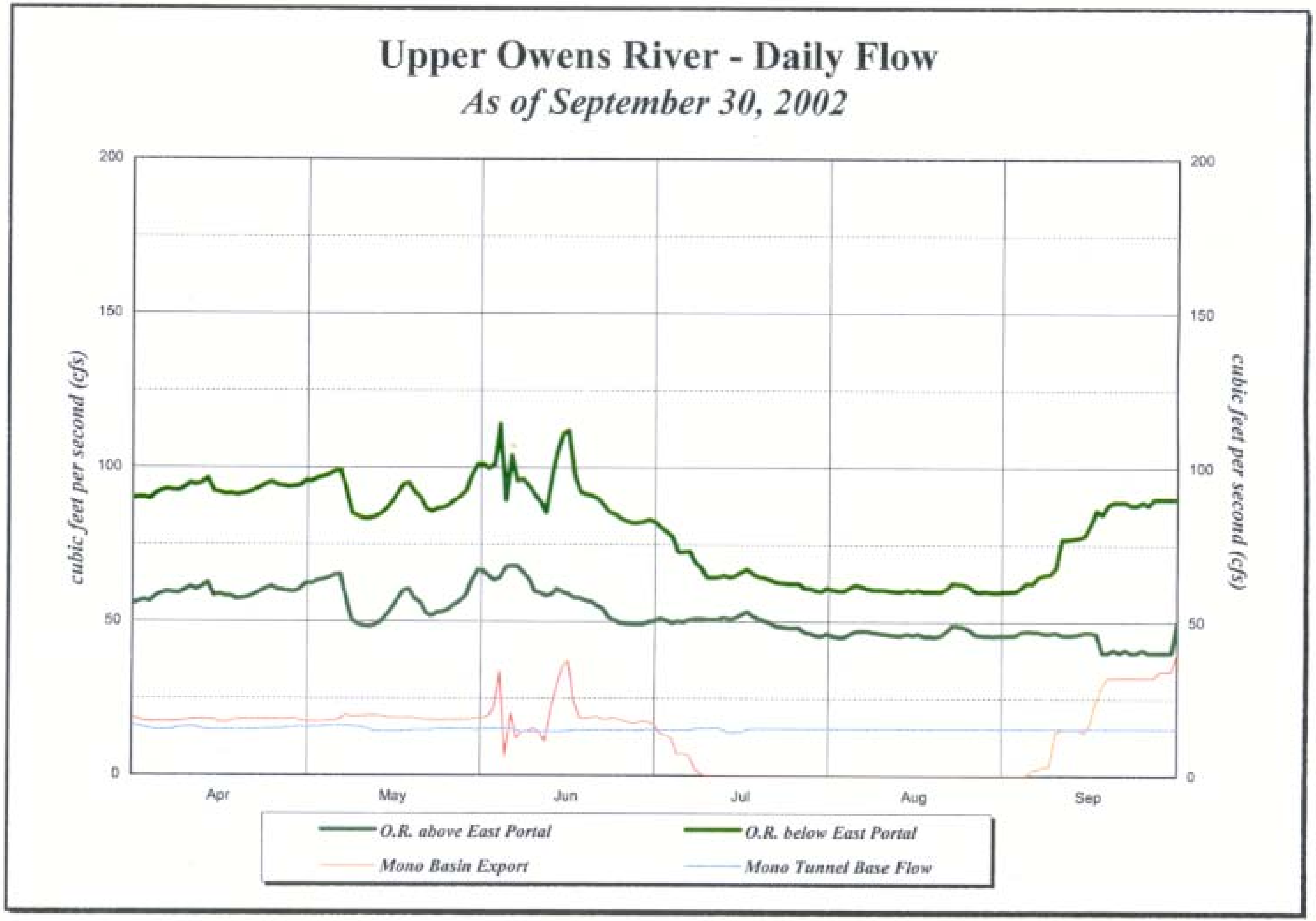


Mono Lake
Lee Vining
120
Lee Vining Creek
Diversion
Lee Vining Conduit
County Road
Culvert Crossing
Bottomlands
The Narrows
Gravel Mine
Creek
Diversion
Walker Creek
Walker Lake
Cain Ranch Headquarters
Rush Creek
Diversion
A. Ditch
Return Ditch
Former Creek Channel
Mono Gate 1
Diversion
Parker Creek
Parker Lake
June Lake Loop Road
Grant Lake reservoir
158
395
West Portal
Mono Craters Tunnel
Mono Craters
0
5,000
FEET
LEGEND
Highways
Improved roads
7,000' elevation

Figure 1



Upper Owens River - Daily Flow
As of September 30, 2002
200
150
100
50
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
O.R. above East Portal
O.R. below East Portal
Mono Basin Export
Mono Tunnel Base Flow

Figure 2

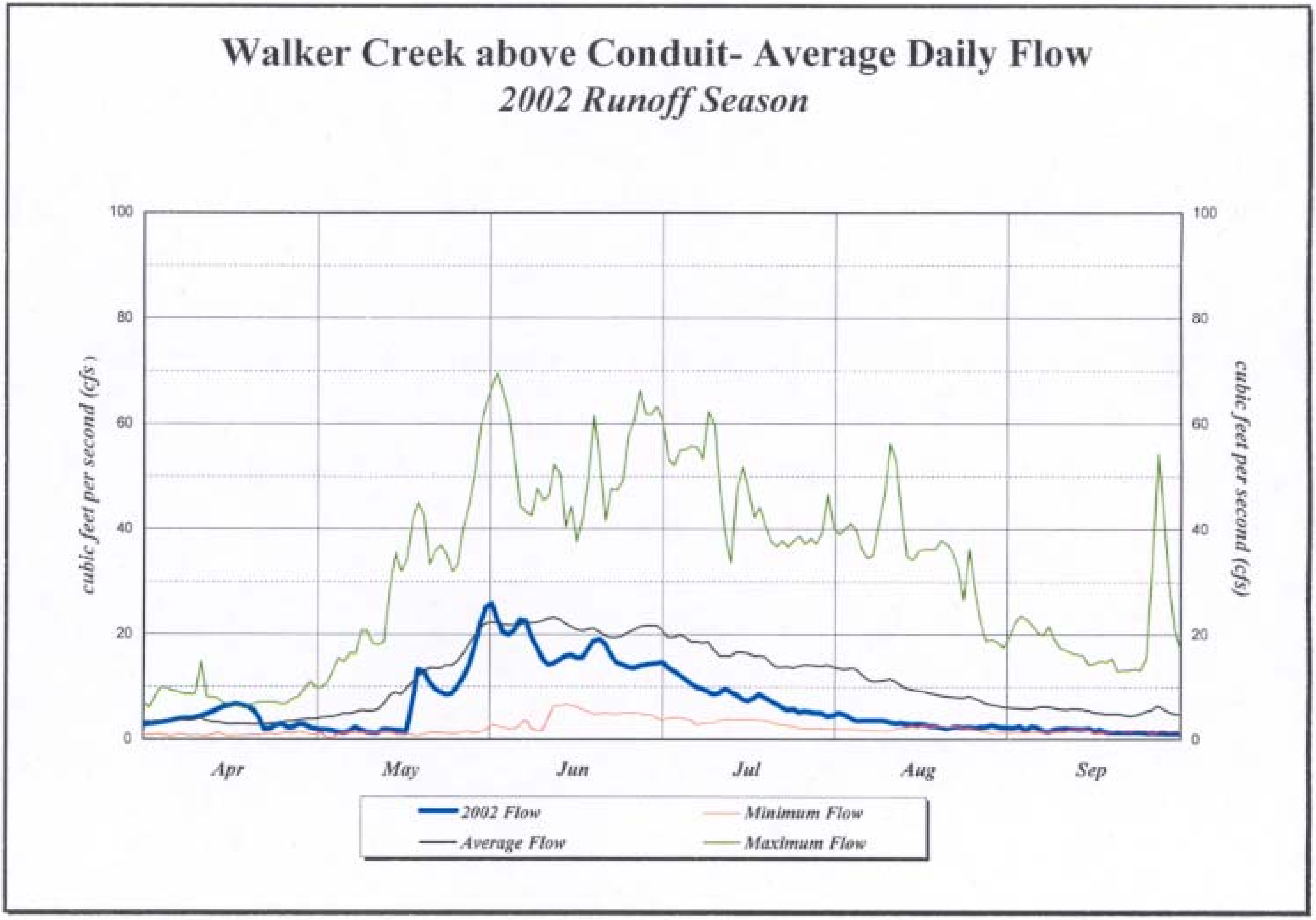

Walker Creek above Conduit- Average Daily Flow
2002 Runoff Season
cubic feet per second (cfs)
0
20
40
60
80
100
Apr
May
Jun
Jul
Aug
Sep
2002 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 3

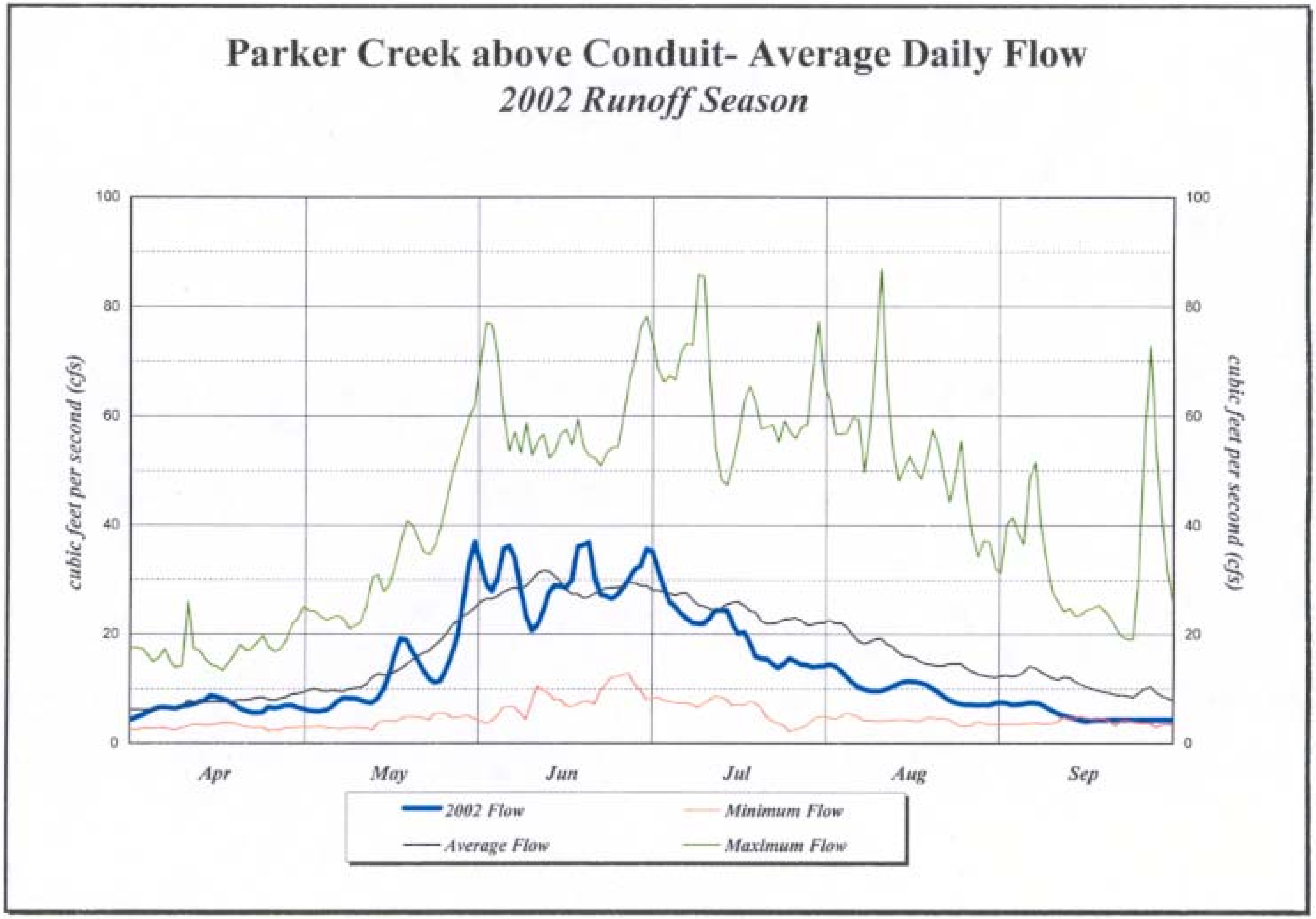
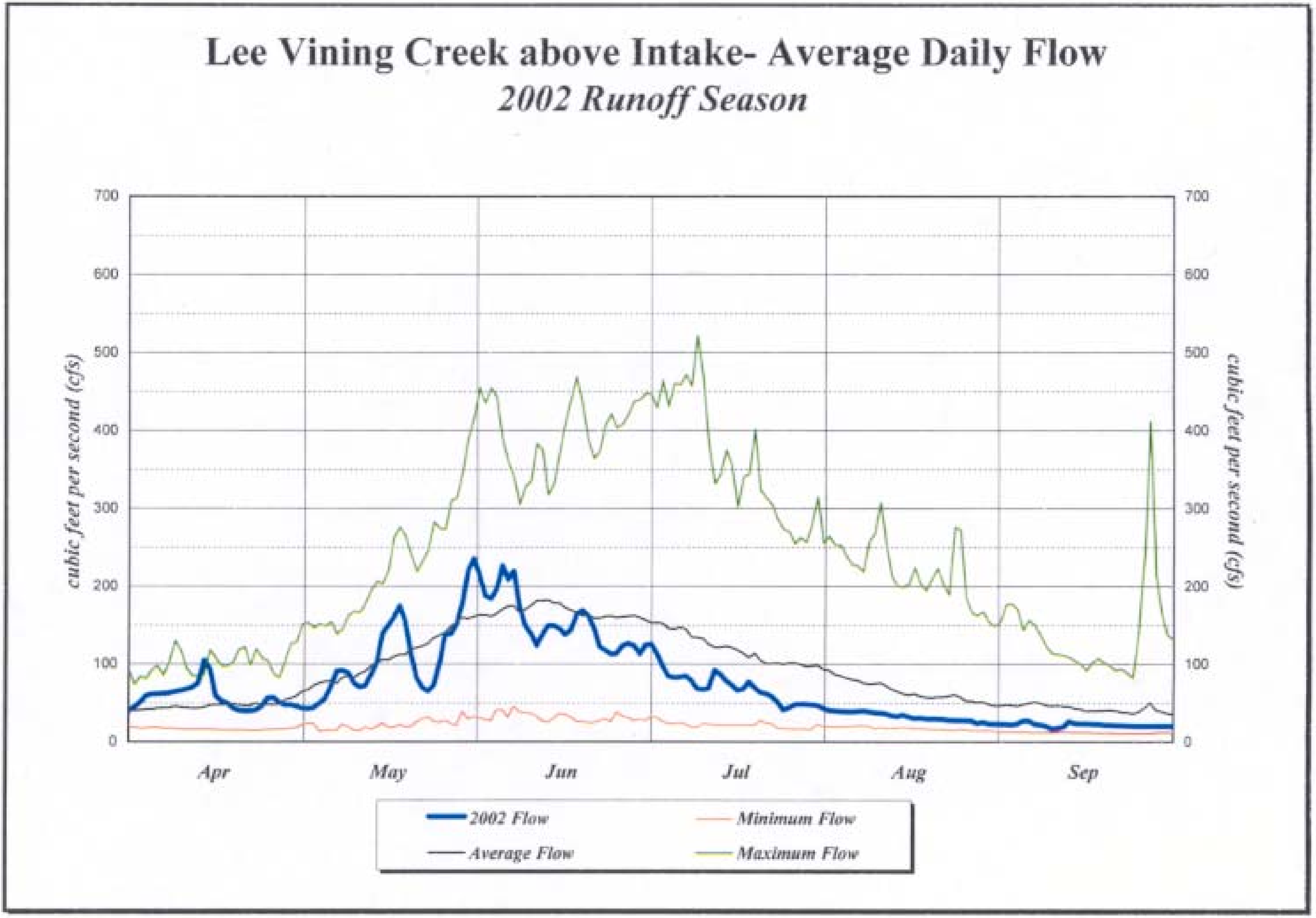

Parker Creek above Conduit- Average Daily Flow
2002 Runoff Season
cubic feet per second (cfs)
cubic feet per second (cfs)
100
80
60
40
20
0
Apr
May
Jun
Jul
Aug
Sep
2002 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 4



Lee Vining Creek above Intake- Average Daily Flow
2002 Runoff Season
700
600
500
400
300
200
100
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
2002 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 5

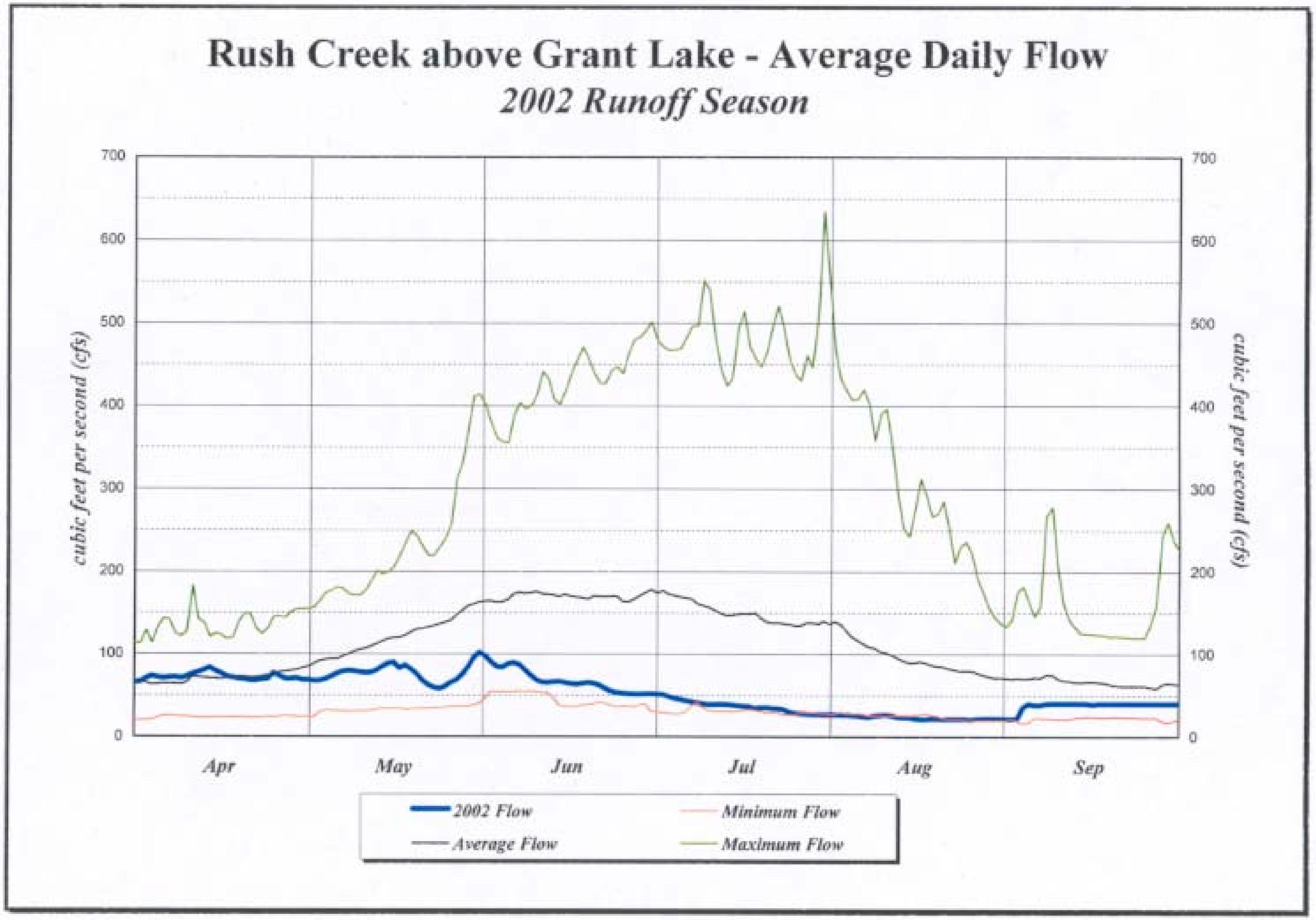
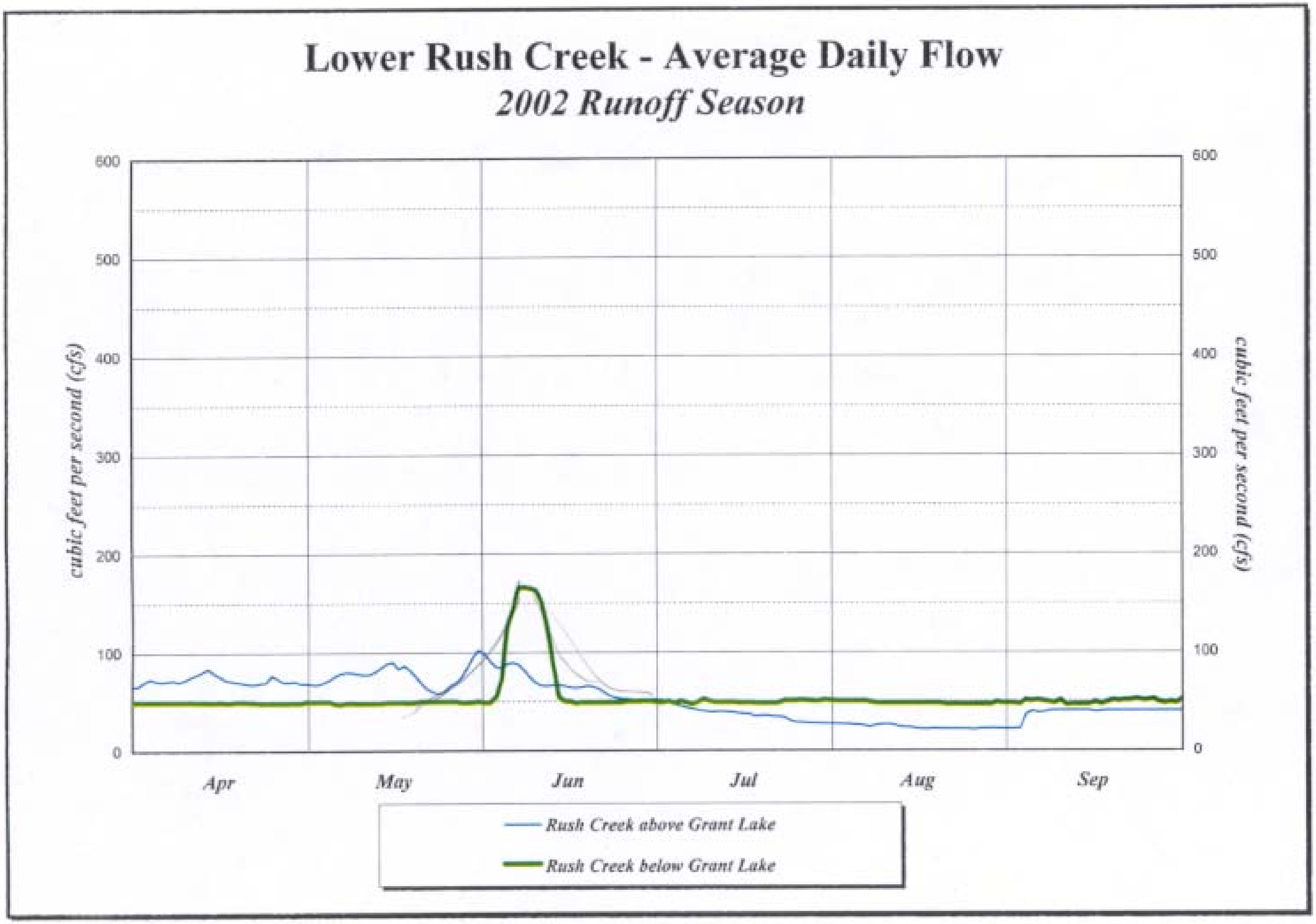

Rush Creek above Grant Lake - Average Daily Flow
2002 Runoff Season
cubic feet per second (cfs)
700
600
500
400
300
200
100
0
Apr
May
Jun
Jul
Aug
Sep
2002 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 6



Lower Rush Creek - Average Daily Flow
2002 Runoff Season
600
500
400
300
200
100
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
Rush Creek above Grant Lake
Rush Creek below Grant Lake

Figure 7

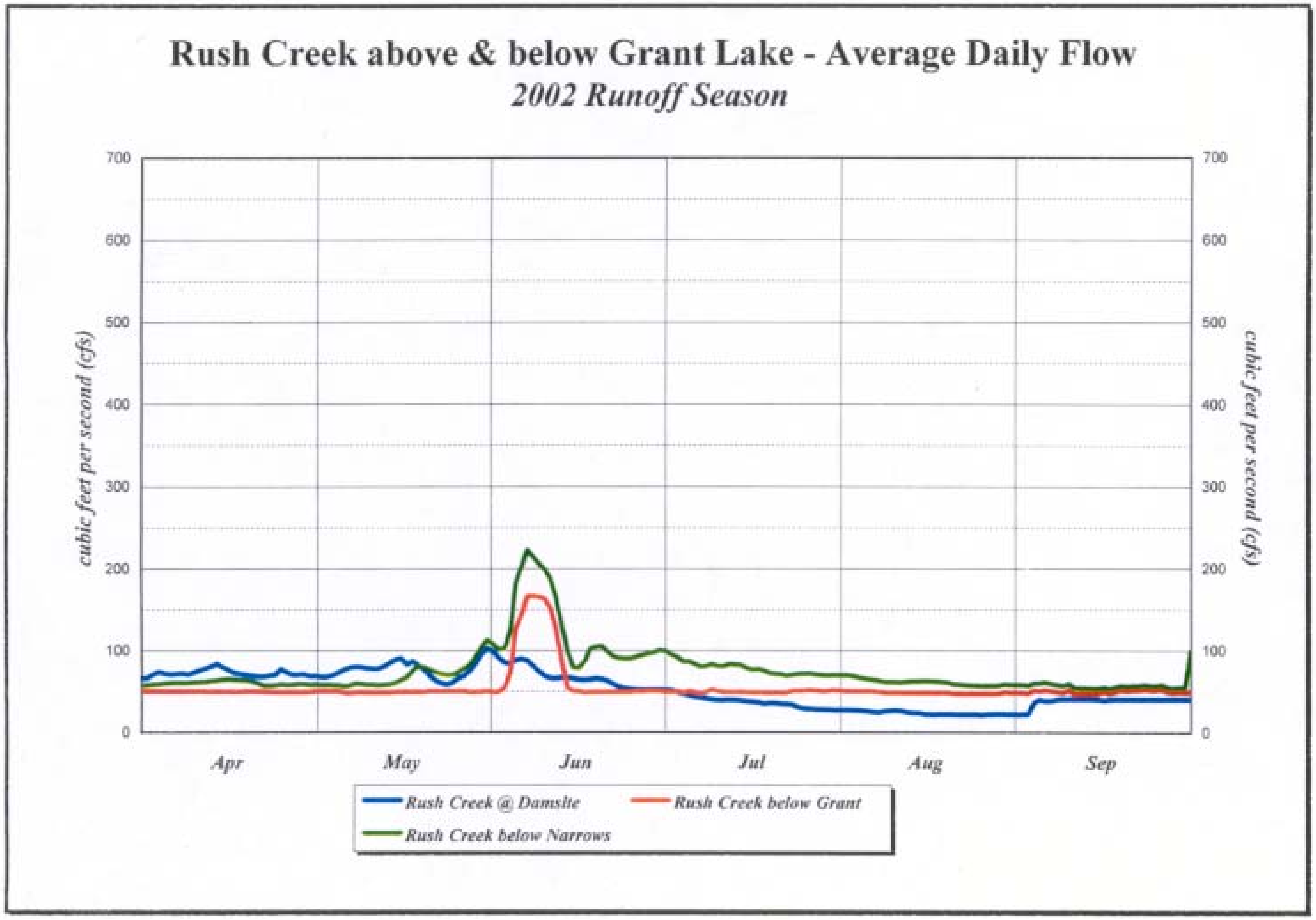
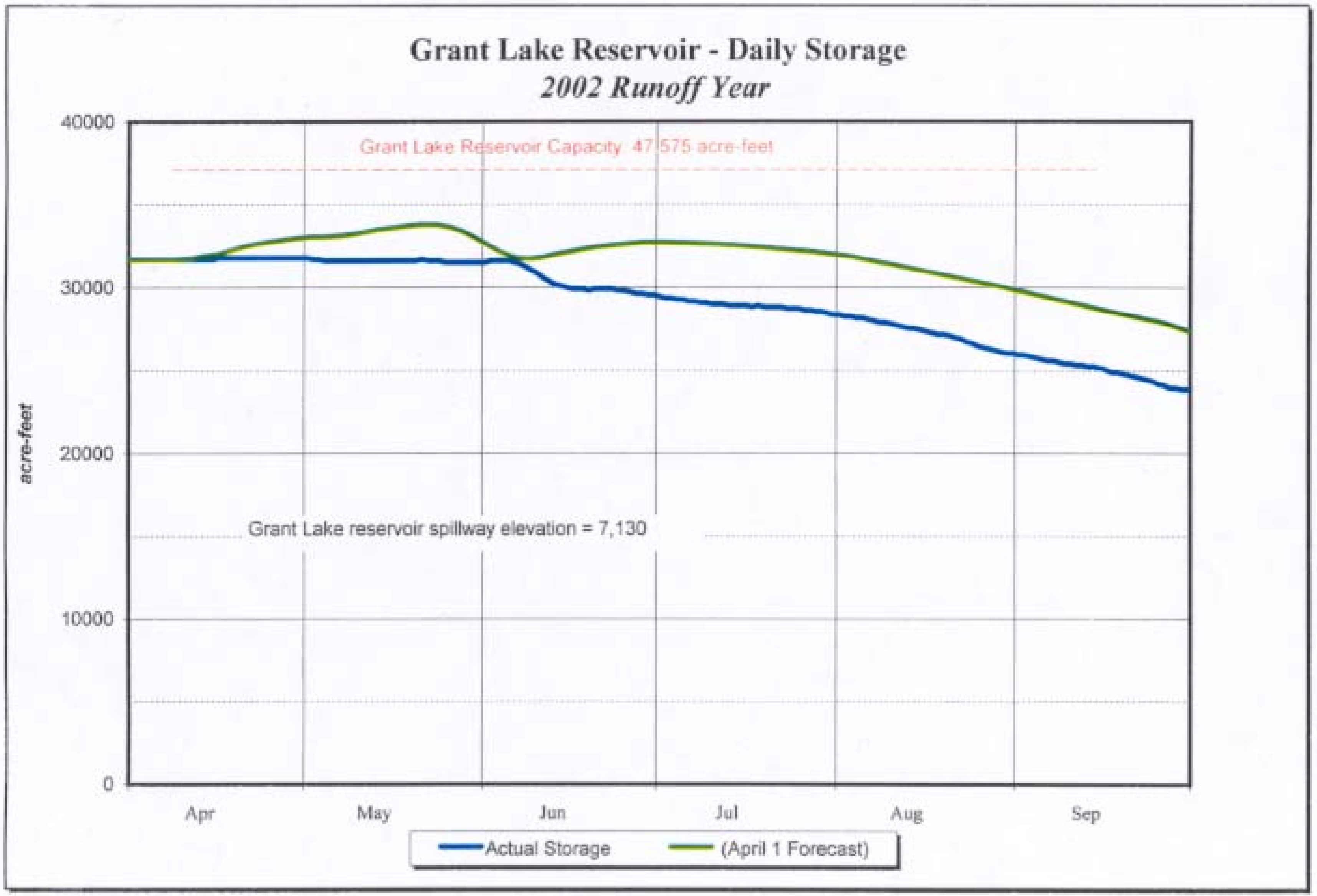

Rush Creek above & below Grant Lake - Average Daily Flow
2002 Runoff Season
700
600
500
400
300
200
100
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
Rush Creek @ Damsite
Rush Creek below Grant
Rush Creek below Narrows

Figure 8



Grant Lake Reservoir - Daily Storage
2002 Runoff Year
Grant Lake Reservoir Capacity 47,575 acre-feet
Grant Lake reservoir spillway elevation = 7,130
acre-feet
40000
30000
20000
10000
0
Apr
May
Jun
Jul
Aug
Sep
Actual Storage
(April 1 Forecast)

Figure 9

	2002												2003		
DAY	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
1								6382.2							
2				6382.5	6382.4										
3															
4							6382.4			6381.5			6381.7		
5									6381.8			6381.4			
6						6382.4									6382
7		6382.3	6382.4								6381.2				
8								6382							
9					6382.4										
10	6382.3									6381.4					
11							6382.4								
12									6381.7			6381.4			
13						6382.4								6381.8	6382
14											6381.4				
15					6382.4										
16								6382					6381.7		
17	6382.3									6381.4					
18				6382.4			6382.3								
19															
20									6381.6					6381.9	
21		6382.3	6382.4												
22								6381.9							
23					6382.4						6381.4				
24										6381.3					
25															
26				6382.4					6381.6						
27						6382.4									
28														6382	
29								6381.9							
30													6381.8		
31										6381.3					

Mono Lake Levels - RY 2002

Appendix 2 - Limnology

2002 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison, Sandra Roll, and John M. Melack

Marine Science Institute

University of California

Santa Barbara, CA 93106

Submitted: 15 April 2002

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EXECUTIVE SUMMARY

Limnological monitoring of the plankton dynamics in Mono Lake continued during 2002. To put the results from 2002 in context, Chapter 1 describes the seasonal plankton dynamics observed from 1979 through 2001, 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–present). In brief, long-term monitoring has shown that Mono Lake is highly productive compared to other temperate salt lakes, that this productivity is nitrogen-limited, and that year-to-year variation in the plankton dynamics has largely been determined by the complex interplay between varying climate 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.

Chapter 2 provides a detailed description of the laboratory and field methods employed.

Chapter 3 describes the results of our limnological monitoring program during 2002. Persistent chemical stratification (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 has continued the declined from 10.5 kg m^{-2} 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 (60-78µg chl *a* l^{-1}, February and March) and autumn (60-80 µg chl *a* l^{-1}, November). Annual estimates of lakewide primary production were 1,790 g C m^{-2} y^{-1}, about 70% more than the previous high estimate in 1988 during the breakdown of a 5-yr period of meromixis. Measured photosynthetic parameters were much higher than those predicted based on regressions established in 1991–92, and we conclude actual measurements are necessary to make reliable estimates of yearly productivity.

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, 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 x 10^6 m^{-2}), along with abundance of ovigerous females, was less than in the previous three years (3.0-4.2 x 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 $4.77 \times 10^6\ m^{-2}$.

In summary, weakening chemical stratification and increased mixed-layer nutrients and primary productivity indicate the impacts of meromixis on nutrient recycling have all but vanished. However, both integrative measures of the *Artemia* population suggest decreased secondary productivity for reasons that are not clear. In separate studies, R. Jellison is pursing development of an improved cohort model of *Artemia*, which when finished, will be used to examine these data. Given the snowpack conditions as of 1 March 2003, we would expect meromixis to break down completely in 2003 and the seasonal mixing regime return to one of monomixis.

ACKNOWLEDGEMENTS

Laboratory work was performed at the Sierra Nevada Aquatic Research Lab and University of California, Santa Barbara. Sandra Roll, Kimberly Rose, and Peter Kirchner assisted with field sampling and laboratory analyses. 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.

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 shimp population data. Meteorological data are collected continuously at a station on Paoha Island, while the other three components are assessed on eleven monthly surveys (every month except January). 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 2002 presented in Chapter 3. The relevant pages, tables, and figures for the specific elements of each of the four required components are given below.

	Text	Tables	Figures
Meteorological			
Wind Speed	28		84
Wind Direction	28		
Air Temperature	29		85
Incident Radiation	29		86
Humidity	29		87
Precipitation	29		88
Physical/Chemical			
Water Temperature	30	62	90
Transparency	35	66	96, 97
Underwater light	35		98
Dissolved Oxygen	36	67	99
Conductivity	31	63	91
Ammonium	38	68	100
Phosphate	38		
Plankton			
Chorophyll *a*	39	69	101
Primary production	47		108,109
Artemia Abundance	43	70	104
Artemia Instar distribution	41	73	103
Artemia Fecundity/Length	45, 51	77	
Artemia Reproductive parameters	45	78	105,111
Artemia Biomass	50		110

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CHAPTER 1
INTRODUCTION

Background

Saline lakes are widely recognized as highly productive aquatic habitats, which in addition to harboring unique 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 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 were employed during the 24-yr period, 1979–2002, and have yielded a standardized data set from which to analyze seasonal and year-to-year changes in the plankton. The limnological monitoring program for Mono Lake specifies eleven monthly surveys from 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, 1995b, 1996a, 1997, 1998b, 1999, 2000, 2001, 2002) 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 400 to 500 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 (ca. 30,000 individuals m^{-2}) and within the range seen from 1984–88, but decreased by late spring to 4,200 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 µ g 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 (21,000 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 lake levels, 1995–present

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 intermediate to that observed in 1993 (21,000 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.

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 (34,600 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 $brood^{-1}$).

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 (27,300 m^{-2}) was slightly lower than 1996 but similar to 1995 (24,400 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.

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 (27,300 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 $brood^{-1}$).

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 (32,200 m^{-2}), 1997 (27,300 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).

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^{-2} 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 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.

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^{-2} 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, 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 longterm 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 longterm 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.*

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 of increased vertical flux of ammonium due to deeper mixing into ammonium-rich monimolimnetic water. Annual production was greatest in 1988 (1,064 g C m^{-2} yr^{-1}) when the weakening of chemical stratification and eventual breakdown of meromixis in November resulted in large fluxes of ammonium into the euphotic zone.

The mean annual biomass of *Artemia* was estimated from instar-specific abundance and length-weight relationships for the period 1983–99. The mean annual biomass has varied from 5.34 to 17.6 g m^{-2} with a 16-yr mean of 9.8 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 current episode of meromixis. However, annual biomass increased in 1998, 1999, and 2000 to near the long-term mean.

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 the following peer-reviewed research publications by University of California, Santa Barbara (UCSB) researchers.

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., 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.)

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, 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, 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.

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

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

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.

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., 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.

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

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

Other related current research

A wide array of research is being conducted at Mono Lake and UCSB researchers are actively collaborating with several other projects. These include an NSF-funded microbial observatory at Mono Lake (J. Hollibaugh and S. Joye, Univ. Georgia; J. Zehr, UCSC), and NSF-funded study of viral dynamics (S. Jiang, UCI and G. Steward, U. Hawaii) and analysis of the effects of *Artemia* abundance on feeding and reproductive success of California Gulls (D. Winkler, Cornell; J. Jehl, Hubbs Sea-World Institute).

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 3 weeks of measurements and radio frequency telemetry is used to download the data weekly.

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 average photosynthetically available radiation (PAR, 400 to 700 nm, Li-Cor 192-S) and 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. Review and comparison of the 2002 Paoha precipitation data to Cain Ranch precipitation suggested sporadic malfunction of the Paoha tipping bucket and thus we present Cain Ranch precipitation (LADWP) here.

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 eleven monthly surveys from February through December. In 2002, ten monthly surveys were conducted from February through November. However, several attempted surveys in December were abandoned due to severe weather conditions and thus the final survey was not conducted until 6 January 2003. *Artemia*, temperature, conductivity, oxygen, ammonium, chlorophyll *a*, and Secchi depth were sampled on every survey.

Field Procedures

In situ profiles

Water temperature and conductivity were measured at eight buoyed, pelagic stations (2, 3, 4, 5, 6, 7, 8, and 12) (Figure 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 0.1-0.2 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

$$C_{25} = \frac{C_t}{1 + 0.02124(t-25) + 9.16\times10^{-5}(t-25)^2}$$

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:

$$\begin{aligned}\rho(t, C_{25}) = {} & 1.0034 + 1.335\times10^{-5}t - 6.20\times10^{-6}t^2 + 4.897\times10^{-4}C_{25} \\ & + 4.23\times10^{-6}C_{25}^2 - 1.35\times10^{-6}tC_{25}\end{aligned}.$$

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:

$$\rho_{25}(C) = 0.99986 + 5.2345\times10^{-4}C + 4.23\times10^{-6}C^2$$

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) (Figure 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, bouyed stations (Figure 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.

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.

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 (Milton Roy, model Spectronics 301), calibrated once a year by Milton Roy Company. 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 (Sequoia-Turner, model 450) which was calibrated against the spectrophotometer using fresh lettuce.

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 150 to 200 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 were collected for brood size and length analysis from seven buoyed stations (Stations 1, 2, 5, 6, 7, 8, and 11) with 20-m vertical net tows and kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females were 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 include).

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 Methods, Chapter 2).

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 9 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 1993). 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.

CHAPTER 3
RESULTS AND DISCUSSION

Mono Lake remained chemically stratified throughout 2002. The current episode of meromixis was initiated in 1995 when above normal runoff, coupled with reduced volume, resulted in the second largest annual lake level rise this century. The large influx of freshwater above saline lake water initiated a period of persistent chemical stratification or meromixis. Below average runoff from 1999 to 2002 have resulted in declining lake levels. Evaporative concentration of the surface mixed layer and deep mixing within the lake are weakening the strong chemical stratification initiated in 1995 and if this trend continues, meromixis will break down in late 2003. A previous episode of meromixis initiated by record runoff in 1982–83 ended 6 years later when the salinity of the mixolimnion (surface mixed layer) eventually became greater than that of the monimolimnion (bottom layer beneath chemocline) due to evaporative concentration and low inputs of freshwater.

Meteorological Data

Wind Speed and Direction

Mean daily wind speed varied from 0.7 – 9.3 m s^{-1} over the year, and averaged 3.2 m s^{-1} (Fig. 2). The daily maximum 10-min averaged wind speeds averaged 2.3 times mean daily wind speeds and the maximum recorded wind speed was 19.7 m s^{-1} on 9 November. The mean monthly wind speed was fairly constant (coefficient of variation, 15%) and only varied from 2.2 m s^{-1} in January to 3.5 m s^{-1} in September. Wind direction through the year was consistently from the southwest. The monthly vector-averaged wind direction was 239 degrees, and ranged from 90 – 264 degrees over the year. These wind speed and direction values are very similar to those observed during 2000 and 2001.

Air Temperature

Mean daily air temperature ranged from a minimum of –8°C on 29 January to a maximum of 26°C on 10 July (Fig. 3). Air temperatures ranged from 8°C to 26°C during the summer (June through August) and from –8°C to 7°C during the winter (December through February).

Incident Photosynthetically Available Radiation

Photosynthetically available radiation (400-700 nm) exhibits a regular sinusoidal curve. Values each year typically range from about ~20 Einsteins m^{-2} day^{-1} in mid-January and mid-December to ~65 Einsteins m^{-2} day^{-1} in mid-June (Fig. 4). Daily values that diverge from the curve indicate overcast or stormy days. During 2002, the annual mean was 39.9 Einsteins m^{-2} day^{-1}, with daily values ranging from 0.5 Einsteins m^{-2} day^{-1} on 31 December to 64.0 Einsteins m^{-2} day^{-1} on 22 June.

Relative Humidity and Precipitation

Mean daily relative humidity followed a general pattern of high values in January, decreasing to lows in May through August, and increasing through December. The lake experienced several brief periods of increased humidity over the year, particularly from 17-20 July and from 28 September to 10 October (Fig. 5). The yearly mean was 49.7%, with a maximum of 94.2% occurring on 25 December, and a minimum of 25.0% on 8 June (Fig. 5).

During 2002, annual precipitation, collected from the LADWP Cain Ranch meteorological station (see Methods), was 69.1 mm (Fig. 6). Total precipitation was lower than in 2001 (87.9 mm). The most rainy days occurred in December (9 days totaling 11.5 mm) and April (7 days totaling 6.3 mm), while the most precipitation fell in November (30.8 mm), owing to the two largest precipitation events of the year, on November 8 and 9 (13.9 mm and 17.2 mm, respectively). March and April also had a fair amount of rainfall (6.3 mm and 5.8 mm, respectively), while very little precipitation occurred during May through June (0.5 mm). This seasonal pattern is similar to that observed in 2001. 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 or other losses of falling snow.

Surface Elevation

In 2002, the surface elevation of Mono Lake rose 0.4 ft from the winter low of 6382.5 ft asl (USGS datum) in November 2001 to 6382.9 ft asl in early April (Fig. 7). Surface elevation remained at 6382.8 ft asl from mid-April to mid-July and then declined through early November to 6381.6 ft asl and rose slightly to 6381.8 ft asl by the end of December. Thus, a net annual decline of 0.8 ft in surface elevation occurred in 2002, similar to previous declines of 0.7 and 0.8 ft observed in 2000 and 2001, respectively.

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 freshwater inputs. The timing and magnitude of freshwater inputs, primarily precipitation and inflowing streams that mix into the upper portion of the water column, affect vertical mixing and thus the seasonal pattern of thermal stratification. The annual pattern of seasonal thermal stratification observed during 1990–94 is typical of large temperate lakes, with the lake being thermally mixed during holomixis in the late autumn through early winter. This pattern was altered during a previous episode of meromixis (1982-89) and similarly in the current episode of meromixis 1995–02; (Fig. 8, Table 1) due to vertical salinity gradients associated with ongoing meromixis.

Aside from the absence of a winter period of holomixis, the most notable difference in the thermal regime during 1996–02 compared to monomictic years is the presence of significant inverse thermal stratification at mid-depths (20–26 m). By November 2001, cooling of the monimolimnion had reduced the inverse thermal stratification to ca. 0.5 °C. In mid-February 2002, the upper water column was well-mixed with a temperature of ca. 2.2 °C, while below the mixolimnion the temperature increased to ca. 4.2 °C. Inverse thermal stratification remained through 2002, though the temperature in the monimolimnion decreased from 4.2 °C in February to ca. 3.7 ° in mid-July. Inverse thermal stratification was eliminated during summer months due to warming of the metalimnion, and temperatures in the monimolimnion also warmed slightly. By early January 2003, the mixolimnion was again well-mixed with a temperature ca. 3.6 °C and a slight inverse thermal stratification was present with temperatures ca. 4.0 °C below 28 m.

In February 2002, the temperature in the mixolimnion (2.2 °C) was warmer than in February 2001 (1.5 °C), but cooler than in February 2000 (3.3 °C). While the seasonal thermocline had formed by 13 March in 2001, it had not yet formed by 18 March 2002. In mid-April a thermocline at a depth of 9-11 m was present, 1-3 m deeper than the depth of the thermocline in March – May 2001. Epilimnetic temperatures were ca. 2.4 °C warmer in mid-April but ca. 3.7 °C cooler in May 2002 than in 2001. The seasonal thermocline deepened to ca. 12 m by mid-August, similar to 2001, and June through

September epilimnetic temperatures were similar in both years (18-22 °C). The epilimnion began to cool and deepen faster in the autumn of 2002 than in 2001, with October and November epilimnetic temperatures ca. 1-2 °C cooler. The thermocline was ca. 5 m deeper in mid-November 2002 than in 2001. By January 2003 the water column was isothermal at 3.6-4.0 °C above the chemocline at 29 m, with temperatures ca. 3 °C cooler than in 2001.

Conductivity and Salinity

Salinity, expressed as total dissolved solids, can be calculated from conductivity measurements corrected to a reference temperature (see Methods). Because total dissolved solids are conservative at the current salinities in Mono Lake, salinity decreases as the volume of the lake increases due to inputs of freshwater in excess of evaporative losses.

In 2002, conductivity of the mixolimnion decreased slightly from 81.4 mS cm^{-1} in February to 80.0-81.0 mS cm^{-1} in June due to spring runoff (Fig. 9, Table 2). Evaporative concentration through the second half of the year resulted in mixolimnetic conductivities increasing to 82.4-82.5 mS cm^{-1} (standardized to 25 °C) by early January 2003. The mixolimnetic salinity (TDS) therefore ranged from 78.9 to 79.0 g kg^{-1} (84.5-84.7 g l^{-1} at 25°C).

Monimolimnetic conductivities and salinities in 2002 exhibited a significant decrease from 85.4-85.7 mS cm^{-1} (82.7-83.1 g kg^{-1}) in February to 84.1-84.4 mS cm^{-1} (81.0-81.4 g kg^{-1}) in January 2003. While monimolimnetic conductivities and salinities have decreased slightly each year since the beginning of the current period of meromixis (from 90.3 mS cm^{-1} in December 1995), the decrease in 2002 was 1.5 times as large as observed during 2001, and 2.5 times as large as during each of the two years prior to

2001. This monimolimnetic freshening is indicative of mixing through the chemocline and the presence of subsurface freshwater inflows.

The chemocline was pushed downward ~3 m in April 2002 to 27-28 m. It remained at this depth until January 2003, when it again deepened to29-32 m (Table 2, Fig. 9). At this depth, 14% of the surface area of the lake and only 3% of its volume are beneath the chemocline.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows associated with a temperate climate and year-to-year climatic variation lead to complex patterns of seasonal density stratification. Much of the year-to-year variation in the plankton dynamics observed during the past two decades at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows.

As in previous meromictic years, density stratification was evident throughout the year in 2001 (Fig. 10, Table 3). Density of water below 28 m ranged from 1.072–1.076 g cm^{-3}, while minimum densities of 1.066-1.072 g cm^{-3} were recorded near the surface (< 4 m). This minimum density, occurring in July and August, was higher than observed during 2001 (1.065 g cm^{-3}) and reflects the higher salinity accompanying declining lake levels.

A comparison of the density differences between 2 and 28 m due to thermal versus chemical stratification indicates that chemical density stratification decreased significantly in 2002 (Fig. 11, Table 4). Annual peaks in chemical stratification increased each year from 1995 to 1998 (from 8.1 kg m^{-3} in August 1995 to 10.4 kg m^{-3} in July 1996, to 12.3 kg m^{-3} in July 1997, to 14.9 kg m^{-3} in August 1998), but have subsequently decreased due to evaporative concentration as the lake level declines. Annual peaks in chemical stratification for 2000 and 2001 were 10.6 and 8.9 kg m^{-3}, respectively. In 2002 the annual peak was 5.5 kg m^{-3}, occurring in mid-March, earlier than in 2001 (May–June) and earlier than in most years (July–August) owing to the lack of runoff after April 2002 (figure 7). Whereas in most meromictic years chemical stratification contributed much more than temperature to the overall midsummer density stratification, in 2002 the difference was markedly reduced (4.1 kg m^{-3} from chemical vs. 3.6 kg m^{-3} from thermal).

Summer thermal stratification regularly contributes 3.5 to 4.5 kg m^{-3} of density stratification between 2 and 28 m. During meromictic periods inverse thermal stratification early in the year results in a slight (~0.4 kg m^{-3}) lessening of overall vertical stratification. In 2002, this inverse thermal stratification occurred through June and may have enhanced mixing at the deep chemocline.

The decrease in the chemical contribution to density stratification is due to the decrease in the difference between the density near the surface and the density beneath the chemocline. It is also due in part to the deepening of the chemocline. Our analysis of density stratification compares relative densities between 2 and 28 m. In 2002 the chemocline deepened to 27-28 m in April (Fig. 9, Table 2), making this the first year that this analysis slightly underestimated the chemical contribution to density stratification. Densities at 28 m during the last half of 2002 (1.072-1.073) were slightly less than those deeper beneath the chemocline (1.074-1.075 at 32 m). We therefore included an additional plot of the density difference between 2 and 32 m to better represent the present state of density stratification in the lake (figure 12). The density difference between 2 and 32 m was equal to the density difference between 2 and 28 m until 2002. This year, total density stratification was greater at 32 m than at 28 m.

December conductivity profiles from 1994–2002 (Fig. 13) show that an overall decrease in chemical stratification occurred, resulting from an increase in mixolimnetic conductivities due to summer evaporative concentration of surface water while monimolimnetic conductivities decreased. The December chemical stratification was lower in 2002 than any other year since the onset of meromixis. The overall maximum density stratification due to temperature and salinity was 8.8 kg m^{-3}, a decrease from maximums of 12.0 kg m^{-3} and 14.1 kg m^{-3} in 2001 and 2000, respectively, and lower than the first year of the current episode of meromixis (1995) when it was 12.4 kg m^{-3}.

Transparency and Light Attenuation

In 2002, average lakewide transparencies as determined by Secchi depth were between 0.9-1.3 m during February-April (Fig. 14, Table 5). These are the lowest transparencies for this period of meromixis and reflect more phytoplankton during the spring bloom. Early season transparencies in 2001 were between 1.3-1.6 m. Mean secchi depth increased to 9.3 m in mid-June. This was the maximum transparency for the year, which was lower than in June 2001 (9.9 m), and higher than 2000 (7.1 m). 2002 had the earliest midsummer high during this period of meromixis. Mean August transparency (7.3 m) was similar to 1994, 1995, and 1997 (7.1 m, 7.9 m, 7.4 m, respectively).

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

Secchi depth decreased to 0.9 m by mid November 2002. The autumn decline was more rapid than any other year during this period of meromixis, and values for

September through November were, like the early season values, the lowest for this period of meromixis.

Reduced upward flux of nutrients accompanying meromixis reduces the annual autumn algal bloom during periods of meromixis. However, the autumn algal bloom has increased during each of the past three years presumably due to the observed autumn deepening of the mixed layer and the accompanying entrainment of ammonium-rich monimolimnetic water.

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 2002 was within the range observed during the past 22 years (Fig. 15).

The attenuation of PAR within the water column varies seasonally, primarily as a function of changes in algal biomass. In 2002, the depth of the euphotic zone, operationally defined as the depth at which only 1% of the surface insolation is present, varied from a low of 3.5 m in March to a high of 16–17 m in mid-July (Fig. 16). Although this annual pattern is within the previously observed range of monomictic years, 2002 had a very short period of deep attenuation (beneath 12 m), lasting only from mid-May through mid-July.

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 decline. 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 February 2002, dissolved oxygen concentrations in the upper water column ranged from 5.5 to 7.5 mg l^{-1} (Fig. 17, Table 6). The depth of the oxycline associated with persistent chemical stratification was 25-27 m, having deepened from 24–25 m in December 2001. The annual maximum concentrations of mixolimnetic oxygen occurred In February and April (6.6-7.5 mg l^{-1}), as concentrations were similar in these two months but higher than in March (5.6 mg l^{-1}). The annual maximum concentrations were lower than 2001 (9–10 mg l^{-1}) and 2000 (7.7-8.0 mg l^{-1}). In a pattern similar to 2000, mixolimnetic dissolved oxygen declined to midsummer values of 2.8-4.4 mg l^{-1}, increased to 2.5–5.5 mg l^{-1} during the October phytoplankton bloom, and decreased to 3.1-3.6 mg l^{-1} in November. By 6 January oxygen throughout the water column was less than 1.5 mg l^{-1}, indicating significant mixing of reduced species from the monimolimnion. Oxygen concentrations were generally lower than in 2000 throughout the year.

The anoxic zone (depth below which dissolved oxygen concentrations are <0.5 mg l^{-1}) varied between 14-16 m during the period of summer thermal stratification before deepening to 29-30 m due to autumn mixing in January 2003. While the absence of any winter period of holomixis continued to maintain anoxic conditions beneath the chemocline, the deepening of the chemocline has resulted in a much smaller portion of the lake (14% by area and 3% by volume) remaining anoxic throughout the year.

Nutrients (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 within the lake (Jellison *et al.* 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, ammonia 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 internal recycling of nitrogen.

During 2002, mixolimnetic ammonium concentrations in February and March (1.1-1.3 µM) were higher than in any year since 1995 (1.3 µM) (Fig.18, Table7). Concentrations decreased slightly to 0.7-0.9 µM during April and May. A large peak in ammonium occurred in June (10.7 µM) after which concentrations decreased to 1.0-3.0 µM from July through November. In January 2003, ammonium concentrations were mostly well-mixed at ca. 9.0-9.7 µM, while the concentration at 8 m was 13.4 µM.

Higher euphotic zone ammonium concentrations during June through August result from *Artemia* ammonium excretion and decreased algal uptake accompanying *Artemia* grazing and lower standing algal biomass. While this seasonal feature is observed during both meromictic and monomictic conditions, it is generally larger during monomictic periods. During meromictic conditions it is often reduced in magnitude and often only observed during one monthly sampling. During 2002, elevated ammonium concentrations were observed throughout the summer, and persisted through the autumn. While this may arise due to changes in any of the various sources and sinks, nitrogen limitation of photosynthetic activity may be assumed to have lessened during this period.

Ammonium concentrations in the monimolimnion varied through the season, but generally decreased. Ammonium at 35 m decreased from 1100 µM in February to 970 µM in January 2003. At 28 m, the concentration decreased substantially from 975 µM in February to ca. 200 µM in November, owing to the depression of the chemocline to 27-28 m. The present accumulation is much higher than that observed during the 1983–88 episode of meromixis when ammonium built up to ~600 µM (Jellison *et al*. 1989).

Soluble reactive phosphate concentrations remain several orders of magnitude above those that are saturating for phosphate uptake by phytoplankton. Thus, seasonal variation is not expected to significantly affect the plankton dynamics.

Phytoplankton (algal biomass and fluorescence)

The phytoplankton community, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation. During 2002, mixolimnetic concentrations varied from 60-78µg chl *a* l^{-1} during February and March, decreased to midsummer minimum values of ca. 2 µg chl *a* l^{-1}, and increased to ca. 60-80 µg chl *a* l^{-1} from November to early January 2003 (Fig. 19, Table 8). While midsummer chlorophyll *a* concentrations were similar to 2000 (1.4-2.0µg chl *a* l^{-1}) and 2001 (1-4µg chl *a* l^{-1}), early and late season concentrations were higher than any year during this period of meromixis. They were not as high as chlorophyll concentrations during algal blooms in monomictic years. The timing of both the spring and autumn blooms were similar to those observed in 2001.

Monimolimnetic (28 m) concentrations of chlorophyll *a* varied from 17 to 63 µg chl *a* l^{-1}, with higher concentrations occurring during the early and late season algal blooms. Because 28 m is well below the euphotic zone (Fig. 15), increased chlorophyll *a* at this depth is most likely due to sinking of algal cells from the euphotic zone, rather than an indication of a viable population.

Prominent mid-depth maxima in chlorophyll were observed throughout much of the period. However, chlorophyll *a* determinations are only made on a limited number of samples collected at discrete depths. *In situ* fluorescence profiles determined at 5–10 cm scales indicate strong vertical variation in biotic conditions.

A Seabird Seacat profiler equipped with a transmissometer, PAR sensor, and fluorometer was acquired and deployed on routine surveys beginning in July 2000. This has enabled a much better characterization of the vertical distribution of fluorescing and light absorbing particles than sampling with a Van Dorn bottle. Regressions of chlorophyll *a* determinations versus in situ fluorescence taken throughout the water column from July through December yielded a strong correlation and indicate the usefulness of fluorescence to characterize chlorophyll *a* distributions. However, there is a fair amount of scatter about the regression on any given day, and thus an accurate estimate of chlorophyll *a* requires depth and date specific comparisons to laboratory chlorophyll *a* extractions. Nevertheless, even without detailed comparisons, variations in fluorescence indicate complex vertical variation in the water column biotic properties.

Fluorescence profiles at station 6 give a detailed image of variation in the vertical structure of the phytoplankton community (Fig. 20). The development of the seasonal deep chlorophyll maximum was similar in timing to that observed in 2001. In mid-February, while near surface fluorescence was low in the upper 5 m, it was moderate and fairly uniform from 4-12 m, then decreased to the chemocline at 26 m. From May through September, prominent mid-depth peaks were noted in the oxycline/nutricline regions. The complex interplay between biogeochemical processing by micro-organisms and in situ light, oxygen, density, and nutrient gradients is a major focus of the NSF-funded Microbial Observatory at Mono Lake. These mid-depth peaks largely disappeared with autumn mixing during October through November.

Artemia Population Dynamics

Population Overview

The *Artemia* population in 2002 was similar in timing to 2000 and 2001, with fairly rapid development of the 1st generation and rapid decline of the adult population after mid-August. Two peaks in naupliar abundance occurred, the first in April (37,000 m^{-2}), and the second in June (66,000 m^{-2}). Both naupliar peaks were larger than the peak in 2001 (36,000 m^{-2}), and smaller than the peak in 2000 (93,000 m^{-2}). The peak in juvenile abundance (~9,000 m^{-2}) occurred in May and was similar to 2001 (8,600 m^{-2}), larger than 2000 (5000 m^{-2}), but much smaller than the annual peaks in 1999 (35,600 m^{-2}) or 1998 (29,135 m^{-2}). Ovoviviparous reproduction was highest in June (7% of females had ovoviviparous eggs) and was higher than occurred in either 2001 or 2000. Two peaks in adult abundances were also observed, occurring in June and August, with both abundances ca. 25,000 m^{-2}. The abundance of adults rapidly declined to 5000 m^{-2} in September and decreased to 10 m^{-2} by November.

Nauplii (Instars 1-7)

Hatching of over-wintering cysts typically becomes significant by late-February, as water temperatures warm after a cold dormancy period (Dana 1981), and continues through May. As in all previously sampled years, with the exception of 1989 when anoxic conditions following the breakdown of meromixis delayed the beginning of the spring hatch until the beginning of March, hatching had occurred by the first sampling date of 12 February 2002 (Fig. 21). The naupliar abundance on this sampling date was lower than February abundances in the two previous years, probably owing to the fact that sampling occurred 8-12 days earlier in 2002. Naupliar abundances increased to 37,000 m^{-2} in April, decreased to 18,000 m^{-2} in May, and increased to the annual peak in mean lakewide abundance of 66,000 m^{-2} in June (Table 9a). The peak in naupliar abundance was similar to 1998 and 1999 (64,400 m^{-2}, 60,600 m^{-}), slightly less than in 2000 (93,119 m^{-2}), and higher than observed in 2001 (36,000 m^{-2}) and the range recorded during 1991–1994 (13,000–35,000 m^{-2}). After June 2002, naupliar abundances decreased steadily to 3300 m^{-2} by August, and then continued to decrease through November.

Ovoviviparous second generation nauplii hatched from June through August of 2002 (Table 11a). Peak ovoviviparous hatching occurred in June, when ovoviviparously reproducing females comprised 7.0 percent of fecund females (Table 11c). The percent of ovoviviparous females was somewhat higher in 2002 compared to 2001 (5.8%) or 2000 (5%), but was lower than in previous years (8 % in 1999, 12% in 1998). This year the very large second peak in nauplii suggests that ovoviviparous reproduction resulted in recruitment into a large second generation of nauplii.

Nauplii were present in decreasing numbers in samples through November 2002. A lack of naupliar recruitment from July to September has been evident in past years, with naupliar instar stages (3-7) absent in *Artemia* samples (1984, 1987, 1989, 1990–91, 1996–98). This pattern was less pronounced in 1999, and has not occurred in the last three years. In 2002, all size classes were represented from May through November (Table 10). Naupliar abundances declined rapidly in the autumn. In 2000 and 2001, abundances of 2000-3000 m^{-2} continued through October, while in 2002, naupliar abundances declined to < 300 m^{-2} by October, and to < 100 m^{-2} by November.

Juveniles (Instars 8-11)

In 2002 the annual juvenile maximum occurred in May (8900 m^{-2}, Table 9a, Fig. 21) and was similar to the peak abundance in 2001 (8600 m^{-2}), higher than in 2000 (5017 m^{-2}), but lower than the range in peaks observed 1993–1999 (9700–32,200 m^{-2}). The timing of maximum abundance was similar to that observed in 2001, 2000, 1993-1994 and 1996-1997, but a month earlier than in 1998 and 1999. Juvenile abundance decreased to 495 m^{-2} in July, and increased to 986 m^{-2} in August. The existence of a second peak in juvenile abundance indicates that some recruitment into a second generation of juveniles occurred. After August, the abundance of juveniles decreased rapidly to 5 m^{-2} in November. The November mean abundance was lower than in the three years prior (80 m^{-2} , 83 m^{-2}, and 378 m^{-2} for 2001, 2000, and 1999, respectively).

Adults

In 2002, adult abundance increased to a peak of 24,900 m^{-2} in June (Fig. 21, Table 9a). This peak was a month earlier than in 2001, 2000, and 1999. Abundance then decreased to 21,850 m^{-2} in July and increased to a second peak of similar abundance (25,500 m^{-2}) in August. Both peaks were lower than the maximum in 2001, higher than in 2000, and at the low end of the range observed 1982 – 2002 (Figure 22). The peak in June was earlier than most peak abundances during the period 1982 – 2002, except 1986, 1988, and 1993. The maximum abundance of *Artemia* in the eastern sector of the lake (21,400 m^{-2}) occurred in June, before the maximum in the western sector (36,800 m^{-2} in August) (Table 9a). From June through September, adult abundances in the western sector were greater than abundances in the eastern sector.

Abundance decreased to 5000 m^{-2} in September and to < 80 m^{-2} by October, more rapidly than any other year on record. September abundance was the lowest for this month in the range of years from 1982 – 2002, and October abundance was higher only than 1997 (36 m^{-2}).

Analysis of long-term monitoring data of plankton dynamics reveals a 4-fold variation in summer peak abundance of adult brine shrimp. The summer population consists of overlapping generations of individuals, those hatched in spring from over-wintering cysts and those produced ovoviviparously during June-July. A persistent feature of the seasonal pattern of *Artemia* abundance is that during years with smaller or delayed spring generations much larger summer populations develop. This occurs despite relatively small year-to-year differences in ovoviviparous reproduction. Detailed stage-specific analysis indicates near cessation of development in early instars and increased mortality when algal biomass declines to below 1 μg chlorophyll a l^{-1}. During years with smaller or delayed first generations, algal biomass declines more slowly to these critical concentrations and adult recruitment is markedly enhanced.

The seasonal dynamics in 2002 exemplify this pattern. Chlorophyll a concentrations were very high in the spring (60 μg l^{-1} in March) and 1st generation naupliar development was early and high, with a peak of ca. 37,000 m^{-2} in mid-April. Adult abundances increased to 25,000 m^{-2} in June, ovoviviparous reproduction was relatively high (7%), indicating that food quality or quantity was good, and the second generation (and annual maximum) naupliar peak was high (see *Nauplii* discussion). However, by mid-June, during the development of 1st and 2nd instars of the 2nd generation, phytoplankton had been rapidly grazed to less than 1 μg l^{-1}, resulting in low recruitment into the juvenile and adult stages and high mortality and rapid decline of the 2nd generation.

Ovigerous females increased rapidly from zero on 13 May 2002 to a maximum of 5272 m^{-2} in mid-June (Fig. 23, Table 11a). The maximum abundance occurred a month later than most years (except 1998 and 1999), and was lower than in the three previous years (6500 m^{-2}, 6300 m^{-2}, 10,400 m^{-2} in 2001, 2000, and 1999, respectively). Ovigerous females decreased slightly to 4500 m^{-2} in July and August and then decreased rapidly to 572 m^{-2} in September and to zero by October. The percent ovigerity was 56% in June, and increased to 90% by September. The period of ovigerity was short in 2002, as ovigerous females appeared later and declined to zero earlier than in 2000 or 2001.

Ovoviviparity of adult females reached a peak of 7 % on 15 June, higher than 2001 (5.1%) or 2000 (4.2 %), but lower than the range observed during 1990–99 (8-70 %). The percent of ovoviviparous females decreased to 4.4 % in July and to zero by September (Fig. 23, Table 11c).

Mean female length ranged from 10.6 to 12.3 mm in 2002 (Table 12). The maximum length was higher than the range of maxima from 1996–01 (10.3 to 12 mm), and within the range of maxima during the period 1987–95 (11.6 to 13.7 mm). Mean female length increased to the annual maximum in September.. Shorter lengths of fecund females during the summers of 1996–99 reflect lower ambient algal concentrations. The large females observed in September 2002 and October 2001 most likely reflect increased chlorophyll *a* concentrations (9/2002: 5.1μg l^{-1}, 10/2001: 7.2 μg l^{-1}) compared to recent years (1.4 μg l^{-1} in 1999, 1.2 μg l^{-1} in 1998) (Table 8).

Mean brood size of ovigerous females in June 2002, when the first generation of *Artemia* matured, was 54 eggs brood^{-1}, higher than the brood size at maturation in 2001 (35 eggs brood^{-1} in July) but lower than in 2000 (68 eggs brood^{-1} in June). Maximum brood size (114 eggs brood^{-1}) occurred in September, while the early season maximum (June) was much lower (54 eggs brood^{-1}) (Table 12). Both maximum and June brood sizes in 2002 were higher than the maximum brood sizes in 2001 (89 eggs brood^{-1}), 2000 (110 eggs brood^{-1}),1999 (48 eggs brood^{-}1) and 1998 (50 eggs brood^{-1}). During the meromictic years 1984–1988 and 1995–2002, as well as 1991-92 and 1994, early summer brood sizes were moderate (20–70 eggs brood^{-1}). Peak brood size in 2002 occurred one to two months earlier than in1984–88 and 1991–94. From 1997-1999 the peak occurred in June, and in 1996 it occurred in May. Differences in brood size are largely related to algal abundance and individual size. Larger brood sizes in 2002 are therefore expected given the observed larger individuals and more algal biomass.

Artemia Summary Statistics, 1979-2001

Year to year variation in climate, hydrological conditions, vertical stratification, food availability, and possibly salinity have led to large 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 13, Fig. 24). 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. 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 is remarkably constant (14–20,000 m^{-2}). During 2000, Adult *Artemia* abundance was anomalously low, but in 2001 were within the range of data for most years. Abundance statistics for 2002 were again anomalously low, though slightly higher than 2000, with a mean of 11,600 m^{-2}, a median of 9955 m^{-2}, and a peak of 25500 m^{-2}. During most years, the seasonal distribution of adult abundance was 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 205 (24 July) to 230 (18 August) in the 23 years from 1979 to 2002 (Table 13, Fig. 25). 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 1986 an unusually large 1st generation shifted the seasonal temporal distribution much earlier to 9 July. During 2002, the overall temporal distribution of adults (19 July) was 9 days earlier than 2001, 23 days earlier than the long term mean (11 August) and earlier than any year since 1978, except for 1986.

Long-term integrative measures of productivity

Planktonic primary production

Photosynthetic activity as indicated by radiocarbon uptake measurements were conducted from 1982-2002. These measurements were discontinued in 1992. However, a significant fraction of the chlorophyll-specific variance in maximum (P_m^B) and light-limited uptake rates (α^B) is explained by temperature so estimates of primary production in subsequent years was made employing estimates of P_m^B and $\alpha^{B.}$ As 1989 and 1990 had elevated ammonia 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 1993), 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 are within the range reported in other studies. In 1995, rising lake levels and greater salinity stratification most likely reduced the vertical flux of nutrients and thus may have affected the photosynthetic rates, but previous regression analyses (Jellison and Melack 1993), 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 estimate of nutrient supply. Thus, we suggested the above regressions might explain most of the variance in photosynthetic rates and thus provide a reasonable alternative to frequent, costly field and laboratory measurements using radioactive tracers. 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. While photosynthetic parameters were not measured after 1992, other major factors determining primary production were measured throughout the year.

Concern over the ability of these regressions to represent the photosynthetic activity during changing nutrient regimes, led to the construction of new “photosynthetrons” (see Methods, Chapter 2) in 2001 and the resumption of actual measurements. Measured uptake rates in 2001 were much higher than would have been predicted by the 1991–92 regressions. The difference was so large that we do not think that previous estimates based estimated P_m^B and α^B can be deemed accurate and we no longer include them for comparison to measured rates.

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 now possible. Two typical P/I curve experiments are illustrate the increased accuracy (Fig. 26) afforded by the ability to incubate more samples. Chlorophyll-specific maximum carbon uptakes (P_m^B) rates ranged from 0.6 to 31 g C g Chl a^{-1} h^{-1}, while light-limited rates (α^B) ranged from 2.5 to 38 g C g Chl a^{-1} $Einst^{-1}$ m^2 (Fig. 27). Daily productivity ranged from ~1 to 14 g C m^{-2} d^{-1} and was above 5 C m^{-2} d^{-1} for the entire period from May through November except for briefly lower rates immediately after the *Artemia* population matured grazed the algal biomass down to low concentrations in late June. The highest period of productivity was during the autumn as both chlorophyll and ammonia increased. The estimated annual production was 1,790 g C m^{-2}. This is ~4 time higher than the previous measured rates during the 1980s episode of meromixis (270 to 523 g C m^{-2}) and 70% higher than the previous highest estimate of 1064 g C m^{-2} in 1988 (Table 14). 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. This year, an 8-yr period of meromixis is breaking down and significant amounts of ammonia were entrained into the mixed layer.

This annual rate is quite exceptional and regular monthly carbon uptake measurements are continuing as part of the monthly monitoring program. While high, the rates might be expected given the increase observed during 1988 during a similar but shorter period of meromixis began to break down. Also, in 2002 chlorophyll was about twice as high during the spring and 50% higher in the autumn compared to 1988. The current estimate arises from multiple chlorophyll-specific carbon uptake measurements taken throughout the year with high rates observed throughout May through October. There are no comparable long-term studies of algal production in other large, deep hypersaline lakes. Previous annual estimates of planktonic photosynthesis at Mono Lake ranged from 149–1063 g C m^{-2} yr^{-1} and 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 2002, *Artemia* biomass increased from ca. 0.007 g dry weight m^{-2} during the February survey to 17.1 g dry weight m^{-2} in mid-August before declining to near zero (0.02 g dry weight m^{-2}) in mid-November. The 2002 mean annual biomass of 4.9 g m^{-2} is almost 50% below the long-term mean of 9.7 g m^{-2}, and is lower than any year in the period 1983-2002 (Figure 27, Table 14). The lower annual biomass observed in 2002 results from low recruitment into the second generation of adults (see "Artemia Population Dynamics/*Adults*" above).

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 this year and in 1997, *Artemia* biomass has remained relatively constant since 1993 and was only slightly higher during 1990–92.

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction (Fig. 28, Table 14). In 2002, Total annual naupliar production (0.1×10^6 m^{-2}) was the same as in 2001 and 2000, and was higher than the period from 1996-1999. In contrast, 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}. While in general, cyst production was lower during years following the onset of meromixis and higher during the breakdown of meromixis and during monomictic period, cyst production has declined over the last 4 years, even as meromixis breaks down.

Comparison of 1980's and current (1995-present) meromictic events

The onset of meromixis in 1995, coupled with the management policy of restricting water diversions until an elevation of 6392 ft was reached, raised the possibility of an extended period of meromixis (Jellison et al. 1998) and reduced overall lake productivity. Although the impacts of meromixis on primary productivity lessened after only two years during the 1980s episode, this weakening of meromixis and its effects on nutrient recycling were due primarily to the evaporative concentration of the upper mixed-layer as freshwater inputs were low due to continued diversions and an extended drought. The current episode of meromixis was expected to last longer as diversions were to be restricted until the lake rose to 6392 ft and continually rising lake levels were expected to maintain meromixis. Indeed primary productivity was reduced during the first five years of the current episode (1995–1999) and impacts were noted on both *Artemia* and avian populations. However, normal or below runoff from 2000 to 2002 and warmer, windier, and drier weather conditions than the preceding four years have led to declining lake levels and a weakening of meromixis. This weakening of meromixis, in combination with a large buildup of ammonium in the monimolimnion, has led to increases in primary productivity similar to those observed during monomictic periods. Here, we directly compare several features of the 1980s and current episodes of meromixis.

Elevation

The lake elevations at the onset of meromixis were 6374.1 ft in 1983 and 6374.5 ft in 1995. In both cases, meromixis was initiated by large influxes of freshwater and a rapid rise (>3 ft yr^{-1}) in lake elevation (Fig. 29). During 1984 and 1985, following the onset of meromixis in 1983, lake level declined due to continued diversions, but rose again in 1986 due to higher snowmelt runoff. The onset of a prolonged drought in 1987 led to declining lake levels and evaporative concentration of the mixed layer until meromixis broke down in late 1988. The elevation at the end of meromixis was approximately 1 ft above the elevation at the onset of this meromictic period.

Unlike the 1980s meromictic event, lake elevation during the current period of meromixis continued to rise until 1999, after which it began a relatively gradual decline. At the end of 2001 the elevation of the lake was ca. 8 ft above the elevation at the onset of meromixis. The current lake elevation is 6381.8 ft, ~7 ft above the elevation at the onset, continuing a gradual decline relative to the previous period of meromixis.

Area and volume beneath chemocline

Although at any given time Mono Lake may be classified as being either monomictic or meromictic, this dichotomous classification does not capture the complexity of the annual mixing regime. The percent of the lake's surface area or volume which lies below the persistent chemocline under meromictic conditions may vary widely. Following the onset of meromixis in both the 1980s and 1990s episodes, the percent area and volume beneath the chemocline were similar, 55–57 % and 37–39 %, respectively (Fig. 30). The relative proportion of the lake beneath the chemocline decreased over time during both episodes of meromixis and thus the effects of meromixis lessened with time. In the 1990s episode, the continuing rise in lake level during 1996–98 resulted in little change in the relative proportion of the lake beneath the chemocline. However, once surface elevations began to lower in the fifth year of meromixis, winter deepening of the mixed-layer and chemocline occurred, and the trend of decreasing of the relative proportion of the lake beneath the chemocline resumed. By January 2003 the lake elevation had dropped 0.8 ft and the chemocline had deepened to 29-31 m, and the remaining portion of the lake beneath the chemocline was 14% of the area and only 3% of the volume (Fig. 31). After the 6th year of meromixis, the percent area and volume beneath the chemocline in the present episode were greater than at the time of turnover of the 1980's episode, but similar in slope. Because the surface area of the lake decreases as the lake level drops, the slope of the regression of the change in percent area beneath the chemocline steepened in January 2003, enhancing the decreasing trend.

Chemical stratification

The density difference due to salinity between 2 and 28 m at the onset of meromixis was 2.7 kg m^{-3} in 1983 and 4.0 kg m^{-3} in 1995. Initially, chemical stratification increased during both periods of meromixis, though the rise was more rapid in the 1980's event (Fig. 32). The maximum chemical stratification was similar in both episodes (15.5 kg m^{-3} in November 1984, and 15.0 kg m^{-3} in August 1998). Chemical stratification declined rapidly from 1986 to 1988 as the lake level dropped. By summer 1988, evaporative concentration had led to slight inverse chemical stratification (-0.1 kg m^{-3}) with warm, more saline water overlying colder, less saline water before holomixis in November 1988.

A more gradual decline in chemical stratification has been observed during the past four years of the current episode of meromixis. The density difference due to conductivity in January 2003 was 2.1 kg m^{-3}. Simple linear regressions of the trend of decreasing salinity stratification indicate a more rapid decrease in stratification during the 2001 and 2002 during the period of lake level declines due to evaporative concentration (Fig. 33). Unless high runoff and lake level rises occur during 2003, the current episode of meromixis will end in autumn 2003.

The expectation that meromixis will end in the next several years is significantly sooner than that predicted by previous analysis employing the hydrodynamic model, DYRESM (Jellison *et al*. 1998). Several factors account for all or part of this discrepancy. Subsequent to the DYRESM analysis, measurements of helium isotopes indicate the existence of less saline spring inputs to the monimolimnion. Boundary layer mixing is significant (MacIntyre & Jellison 2001) and may not be adequately described by DYRESM parameterization. Also, the warmer, drier, and windier meteorological conditions of the last three years lead to more rapid evaporative concentration of the mixed-layer. All these factors lessen the overall salinity stratification.

Surface ammonium

Under meromictic conditions annual variation in ammonium is attenuated (Jellison and Melack 1993a, Melack and Jellison 1998). During both periods of meromixis in Mono Lake, seasonal variation in ammonium in the surface waters was reduced relative to monomictic years, and mean ammonium concentrations at 2 m were low through the period (1.7 µM during the 1980's event and 1.2 µM during the current event) (Fig. 34). Annual peaks in surface ammonium during both episodes generally increased each year, owing to entrainment of high concentrations from beneath the chemocline into the mixing region. This increasing trend continued in 2002.

When meromixis ended in November 1988 and the lake turned over, a large pulse of ammonium was mixed into the upper water column, resulting in high mixed-layer ammonium concentrations (mean concentrations 18.8 µM from 1988 to 1989, compared to 7.8 µM from 1990 to 1994). These elevated concentrations continued through 1989. A similar increase in mixed-layer ammonium concentrations is expected at the breakdown of the current episode of meromixis.

Mixed-layer Chlorophyll a and Artemia

Chlorophyll *a* concentrations during the two meromictic events are quite similar (Fig. 35). The seasonal cycle of algal biomass in the surface waters was attenuated during the initial years of meromixis. Mean chlorophyll *a* concentrations during both periods declined relative to monomictic years (6.0 μg l^{-1} during 1983 to 1984 and 1995 to 1996 compared to 26.0 μg l^{-1} from 1989 to 1994). In both periods, however, recovery became evident in the third year after the onset of meromixis, though meromixis persisted. In 2001, seasonal concentrations were nearly identical to those that occurred immediately after the breakdown of the 1980s episode of meromixis. By the end of 2002, although the lake is currently still meromictic, chlorophyll concentrations have exceeded those of post-turnover in the 1980's episode of meromixis. These concentrations can be attributed to a longer period of meromixis leading to higher concentrations of ammonium (the limiting nutrient) accumulating beneath the chemocline, and more entrainment of these accumulated nutrients into the euphotic zone as the chemocline deepened. The result is decreased nutrient limitation of phytoplankton growth even before meromixis ends. Also, only a very small portion (3%) of the volume of the lake is beneath the persistent chemocline.

As discussed earlier in this (cf. "Long-term Integrative Measures of Productivity section) and previous reports, the effects of meromixis on the *Artemia* population is less than on primary production. Reduced food availability primarily manifests itself in lower annual cyst production and slightly delayed maturation of the spring *Artemia* population. While the *Artemia* population in 2002 was small and cyst production was low, these dynamics cannot be attributed to reduced food availability or quality. Affects of salinity may contribute to decreased abundances of *Artemia*, but inter-annual variability obscures affects due to changing salinity. The interactions between food availability and the timing of spring and summer generations appear to have a significant affect on inter-annual population variability.

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. 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. 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. 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. 1995. 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. 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., 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. 1998. 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. 1996. 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. 1995. 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. 1996. 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. 1998. 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.

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

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

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.

Table 1. Temperature at Station 6, February 2002 – January 2003 (°C)

Depth (m)	2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
	Dates										
1	3.08	3.1	9.25	11.63	18.51	-	22.36	18.17	14.02	-	-
2	2.41	3.03	9.25	11.44	18.62	21.72	22.34	17.93	14.08	8.79	3.56
3	2.35	3.02	8.78	11.57	19.04	21.44	21.9	17.81	14.1	8.8	3.67
4	2.29	3.01	8.62	11.59	19.2	21.39	21.52	17.77	14.16	8.75	3.74
5	2.16	3.01	8.4	11.22	18.47	21.42	21.3	17.74	14.2	8.69	3.74
6	2.18	3.01	7.87	11.12	17.55	21.42	21.05	17.71	14.21	8.68	3.72
7	2.19	3.01	7.58	11.02	17.03	21.43	20.97	17.68	14.32	8.68	3.73
8	2.2	3.01	7.1	10.73	16.51	21.57	20.91	17.69	14.32	8.68	3.74
9	2.21	3.02	6.78	9.84	15.74	20.73	20.8	17.69	14.24	8.67	3.75
10	2.2	3.02	5.29	9.15	14.28	19.12	20.59	17.82	14.28	8.67	3.76
11	2.17	3.02	4.99	8.26	12.58	16.39	20.09	17.71	14.31	8.67	3.64
12	2.09	3.02	4.82	7.47	10.79	12.9	16.9	17.65	14.27	8.67	3.58
13	2.09	3.04	4.49	7.01	9.65	11.3	13.24	17.38	14.23	8.68	3.58
14	2.11	3.05	4.31	6.2	8.54	9.5	10.43	15.06	14.06	8.68	3.57
15	2.11	3.06	4.05	5.54	6.73	8.45	8.43	11.68	13.63	8.71	3.58
16	2.12	3.1	4.02	4.94	5.73	7.34	7.26	9.47	12.68	8.79	3.61
17	2.12	3.11	3.91	4.69	5.46	5.81	5.93	7.54	9.08	8.81	3.58
18	2.11	3.14	3.88	4.34	5.1	5.15	5.57	6.14	7.35	8.84	3.59
19	2.05	3.11	3.74	4.14	4.7	4.94	5.07	5.46	6.2	8.81	3.56
20	2.01	2.9	3.3	4.02	4.61	4.59	4.86	5.01	5.87	8.78	3.58
21	1.95	2.75	3.19	3.84	4.45	4.39	4.65	4.74	5.38	8.73	3.6
22	1.93	2.68	3.2	3.64	4.02	4.27	4.44	4.64	4.97	8.34	3.65
23	1.93	2.64	3.14	3.48	3.97	4.08	4.24	4.41	4.61	8.15	3.67
24	1.96	2.64	3.2	3.35	3.93	3.89	4.09	4.14	4.22	7.88	3.68
25	1.92	2.58	3.06	3.35	3.8	3.83	4.01	4.11	4.12	7.15	3.69
26	1.97	2.66	3.09	3.38	3.63	3.85	3.96	3.97	4.02	6.32	3.66
27	3.08	2.69	3.1	3.41	3.56	3.76	3.88	3.86	3.93	5.34	3.67
28	3.89	2.98	3.07	3.41	3.57	3.73	3.78	3.84	3.89	4.84	3.7
29	4.13	3.3	3.35	3.47	3.62	3.68	3.76	3.83	3.85	4.42	3.97
30	4.18	3.79	3.49	3.6	3.69	3.71	3.77	3.83	3.85	4.24	4.04
31	4.2	4.01	3.67	3.76	3.71	3.69	3.78	3.82	3.84	4.05	4.12
32	4.21	4.1	3.84	3.8	3.73	3.7	3.77	3.82	3.84	4.07	4.15
33	4.23	4.16	3.98	3.84	3.75	3.71	3.77	3.81	3.83	3.98	4.09
34	4.23	4.2	4.03	3.88	3.76	3.72	3.78	3.81	3.84	3.92	4.04
35	4.23	4.2	4.12	3.89	3.78	3.73	3.78	3.81	3.84	3.92	4.01
36	4.24	4.22	4.16	3.9	3.79	3.73	3.79	3.81	3.85	3.92	4
37	-	4.23	-	3.94	3.8	-	-	3.82	3.85	3.91	3.98

Table 2. Conductivity (mS/cm at 25 °C) at Station 6, February 2002 – January 2003

Depth (m)	Dates 2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
1	80.88	81.15	81.07	80.55	80.01	-	81.54	82.44	82.37	-	-
2	81.02	81.17	81.07	80.66	80.51	81.33	81.59	82.44	82.44	82.57	82.35
3	81.19	81.17	80.98	80.94	80.76	81.29	81.76	82.47	82.49	82.58	82.39
4	81.22	81.17	80.99	80.99	81.01	81.33	81.81	82.46	82.56	82.56	82.40
5	81.28	81.17	81.06	80.94	81.25	81.36	81.88	82.47	82.61	82.55	82.40
6	81.32	81.17	81.03	81.05	81.22	81.39	81.91	82.47	82.64	82.55	82.40
7	81.32	81.17	80.85	81.06	81.36	81.41	82.04	82.48	82.68	82.54	82.41
8	81.33	81.17	80.99	81.07	81.30	81.52	82.07	82.54	82.66	82.55	82.43
9	81.33	81.17	81.01	81.07	81.26	81.23	82.11	82.60	82.66	82.55	82.43
10	81.32	81.18	80.75	81.06	80.89	81.51	82.04	82.68	82.70	82.55	82.44
11	81.34	81.18	80.96	81.03	80.86	80.98	81.66	82.64	82.70	82.55	82.44
12	81.35	81.18	81.08	81.00	80.86	81.01	81.24	82.65	82.69	82.54	82.44
13	81.35	81.18	81.15	80.98	81.07	80.94	81.19	82.28	82.65	82.55	82.44
14	81.36	81.18	81.05	81.05	81.05	80.85	81.04	81.89	82.51	82.55	82.44
15	81.36	81.20	81.06	81.11	80.92	81.08	80.92	81.40	82.56	82.56	82.44
16	81.37	81.21	81.19	81.12	81.29	81.17	81.12	81.29	81.84	82.59	82.46
17	81.37	81.22	81.15	81.14	81.35	81.37	81.45	81.30	81.92	82.60	82.45
18	81.37	81.22	81.22	81.13	81.29	81.70	81.41	81.62	81.88	82.61	82.47
19	81.37	81.28	81.21	81.20	81.51	81.79	81.68	81.81	82.07	82.62	82.46
20	81.39	81.31	81.22	81.21	81.58	81.85	81.89	81.80	82.17	82.63	82.47
21	81.38	81.42	81.78	81.27	81.61	82.06	81.94	81.92	82.24	82.62	82.48
22	81.39	81.45	81.81	81.27	81.81	82.14	81.95	82.16	82.21	82.74	82.50
23	81.40	81.49	81.83	81.41	81.92	82.25	82.08	82.26	82.11	82.72	82.50
24	81.41	81.55	81.92	81.58	82.00	82.47	82.15	82.38	82.40	82.82	82.52
25	81.42	81.75	82.08	81.80	82.03	82.62	82.28	82.64	82.67	82.79	82.52
26	81.50	82.14	82.26	82.19	82.20	82.88	82.61	82.89	83.17	82.90	82.54
27	85.42	83.19	82.52	82.73	82.57	83.23	82.93	83.33	83.51	83.17	82.58
28	85.48	85.42	83.39	82.90	82.94	83.53	83.36	83.54	83.76	83.41	82.58
29	85.46	85.77	85.53	83.54	83.25	84.24	83.78	83.74	84.00	83.46	82.90
30	85.54	85.82	85.59	84.47	84.10	84.64	83.92	83.86	84.08	83.45	83.07
31	85.61	85.93	85.69	84.82	84.45	84.82	84.07	84.02	84.16	83.56	83.65
32	85.65	85.90	85.79	84.86	84.59	84.90	84.21	84.12	84.15	83.56	84.11
33	85.68	85.89	85.79	84.88	84.65	84.95	84.26	84.15	84.14	83.57	84.14
34	85.70	85.89	85.80	84.92	84.67	85.00	84.28	84.16	84.11	83.66	84.19
35	85.71	85.90	85.83	84.93	84.73	85.00	84.28	84.19	84.09	83.69	84.24
36	85.73	85.92	85.84	84.96	84.77	84.99	84.29	84.21	84.07	83.67	84.31
37	-	85.92	-	84.98	84.81	-	-	84.21	84.05	83.68	84.38

Table 3. Density (g/cm3) at Station 6, February 2002 – January 2003 (°C)

	Dates										
Depth (m)	2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
1	1.0703	1.0706	1.0695	1.0683	1.0658	-	1.0662	1.0687	1.0698	-	-
2	1.0706	1.0707	1.0695	1.0685	1.0663	1.0662	1.0663	1.0688	1.0699	1.0713	1.0720
3	1.0708	1.0707	1.0695	1.0688	1.0665	1.0662	1.0666	1.0688	1.0700	1.0713	1.0720
4	1.0708	1.0707	1.0695	1.0689	1.0667	1.0663	1.0668	1.0688	1.0700	1.0713	1.0720
5	1.0709	1.0707	1.0696	1.0689	1.0672	1.0663	1.0670	1.0689	1.0701	1.0713	1.0720
6	1.0710	1.0707	1.0697	1.0690	1.0675	1.0664	1.0671	1.0689	1.0701	1.0713	1.0720
7	1.0710	1.0707	1.0696	1.0691	1.0678	1.0664	1.0673	1.0689	1.0701	1.0713	1.0720
8	1.0710	1.0707	1.0698	1.0692	1.0679	1.0665	1.0673	1.0690	1.0701	1.0713	1.0721
9	1.0710	1.0707	1.0699	1.0694	1.0681	1.0664	1.0674	1.0690	1.0701	1.0713	1.0721
10	1.0710	1.0707	1.0698	1.0695	1.0681	1.0673	1.0674	1.0691	1.0702	1.0713	1.0721
11	1.0710	1.0707	1.0701	1.0696	1.0685	1.0675	1.0671	1.0691	1.0702	1.0713	1.0721
12	1.0710	1.0707	1.0703	1.0698	1.0689	1.0686	1.0677	1.0691	1.0701	1.0713	1.0721
13	1.0710	1.0707	1.0704	1.0698	1.0694	1.0689	1.0687	1.0688	1.0701	1.0713	1.0721
14	1.0710	1.0707	1.0703	1.0700	1.0696	1.0692	1.0692	1.0690	1.0700	1.0713	1.0721
15	1.0710	1.0707	1.0704	1.0702	1.0698	1.0697	1.0695	1.0693	1.0702	1.0713	1.0721
16	1.0710	1.0707	1.0706	1.0703	1.0704	1.0700	1.0699	1.0697	1.0696	1.0714	1.0721
17	1.0710	1.0707	1.0705	1.0704	1.0705	1.0705	1.0706	1.0701	1.0705	1.0714	1.0721
18	1.0710	1.0707	1.0706	1.0704	1.0705	1.0710	1.0706	1.0707	1.0708	1.0714	1.0721
19	1.0710	1.0708	1.0706	1.0705	1.0708	1.0711	1.0710	1.0711	1.0712	1.0714	1.0721
20	1.0711	1.0708	1.0707	1.0706	1.0709	1.0712	1.0713	1.0711	1.0714	1.0714	1.0721
21	1.0711	1.0710	1.0714	1.0707	1.0710	1.0715	1.0713	1.0713	1.0716	1.0714	1.0721
22	1.0711	1.0710	1.0714	1.0707	1.0713	1.0716	1.0714	1.0716	1.0716	1.0716	1.0721
23	1.0711	1.0711	1.0714	1.0709	1.0714	1.0718	1.0716	1.0718	1.0715	1.0716	1.0721
24	1.0711	1.0712	1.0715	1.0711	1.0715	1.0721	1.0717	1.0719	1.0719	1.0718	1.0722
25	1.0711	1.0714	1.0717	1.0714	1.0716	1.0723	1.0718	1.0723	1.0723	1.0719	1.0722
26	1.0712	1.0719	1.0719	1.0718	1.0718	1.0726	1.0722	1.0726	1.0729	1.0722	1.0722
27	1.0757	1.0731	1.0723	1.0725	1.0722	1.0730	1.0726	1.0731	1.0733	1.0727	1.0722
28	1.0757	1.0757	1.0733	1.0727	1.0727	1.0734	1.0732	1.0734	1.0736	1.0731	1.0722
29	1.0756	1.0761	1.0758	1.0734	1.0731	1.0742	1.0737	1.0736	1.0739	1.0732	1.0726
30	1.0757	1.0761	1.0759	1.0745	1.0740	1.0747	1.0738	1.0737	1.0740	1.0732	1.0728
31	1.0758	1.0762	1.0760	1.0749	1.0745	1.0749	1.0740	1.0739	1.0741	1.0734	1.0734
32	1.0758	1.0761	1.0761	1.0749	1.0746	1.0750	1.0742	1.0741	1.0741	1.0733	1.0740
33	1.0759	1.0761	1.0760	1.0750	1.0747	1.0751	1.0742	1.0741	1.0741	1.0734	1.0740
34	1.0759	1.0761	1.0760	1.0750	1.0747	1.0751	1.0743	1.0741	1.0740	1.0735	1.0741
35	1.0759	1.0761	1.0761	1.0750	1.0748	1.0751	1.0743	1.0741	1.0740	1.0735	1.0742
36	1.0759	1.0762	1.0761	1.0751	1.0748	1.0751	1.0743	1.0742	1.0740	1.0735	1.0743
37	-	1.0762	-	1.0751	1.0749	-	-	1.0742	1.0740	1.0735	1.0743

Table 4. Temperature, conductivity, and density stratification (x 0.0001 g/cm3) at Station 6, February 2002 – January 2003

Date	Temperature		Conductivity		Density Difference due to		
	2 m	28 m	2 m	28 m	Temperature	Conductivity	Both
2-12	2.41	4.21	81.02	85.65	-2.5	55.1	52.5
3-18	3.03	4.10	81.44	85.90	-1.6	53.2	51.7
4-16	9.25	3.84	81.07	85.79	9.8	56.0	65.8
5-13	11.44	3.80	80.66	84.87	14.7	49.6	64.4
6-17	18.59	3.73	80.32	84.59	35.1	50.0	85.2
7-22	21.72	3.70	81.34	84.90	46.2	42.0	88.2
8-15	22.31	3.77	81.55	84.21	48.3	31.2	79.5
9-13	17.93	3.82	82.44	84.12	33.0	19.9	52.9
10-14	14.08	3.84	82.44	84.15	21.5	20.3	41.8
11-18	8.79	4.07	82.57	83.56	8.4	11.6	20.1
1-6	3.56	4.15	82.35	84.11	-0.9	20.9	20.1

Table 5. Secchi Depths (m), February 2002 – January 2003 (°C)

Station	Dates 2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
Western sector:											
1	1.10	1.10	1.00	1.00	9.25	10.20	7.50	4.00	1.10	0.85	-
2	1.00	1.10	1.10	-	10.10	9.80	7.50	2.60	1.50	0.85	-
3	1.10	1.20	1.30	1.80	9.25	8.50	7.75	2.20	1.40	0.90	0.80
4	1.20	1.10	0.90	1.30	9.50	9.00	8.00	2.20	1.40	0.85	0.80
5	1.10	1.00	0.95	1.30	9.40	7.00	7.60	2.30	1.00	0.90	0.85
6	1.00	1.10	1.20	1.30	9.25	6.25	7.70	2.30	1.50	0.85	0.90
Avg.	1.08	1.10	1.08	1.34	9.46	8.46	7.68	2.60	1.32	0.87	0.84
S.E.	0.03	0.03	0.06	0.13	0.14	0.64	0.08	0.29	0.09	0.01	0.02
n	6.00	6.00	6.00	5.00	6.00	6.00	6.00	6.00	6.00	6.00	4.00
Eastern sector:											
7	1.00	1.10	1.10	2.40	8.50	8.00	7.25	1.90	1.10	0.85	-
8	1.20	1.20	1.30	2.90	8.85	9.10	6.80	2.10	1.10	0.90	-
9	1.10	1.10	0.95	3.25	9.60	6.50	6.60	1.80	1.00	0.85	-
10	1.00	1.10	0.90	2.40	9.50	7.25	6.70	1.90	1.00	0.90	-
11	0.90	1.20	0.90	2.75	7.75	6.50	6.75	1.50	1.00	0.90	-
12	1.00	1.05	1.00	2.50	10.35	7.00	6.90	2.00	1.20	0.90	-
Avg.	1.03	1.13	1.03	2.70	9.09	7.39	6.83	1.87	1.07	0.88	-
S.E.	0.04	0.03	0.06	0.14	0.37	0.41	0.09	0.08	0.03	0.01	-
n	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	0.00
Total Lakewide											
Avg.	1.06	1.11	1.05	2.08	9.28	7.93	7.25	2.23	1.19	0.88	0.84
S.E.	0.03	0.02	0.04	0.23	0.20	0.40	0.14	0.18	0.06	0.01	0.02
n	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	4.00

*Stations 3, 4, 5, 6 sampled 4/16

Table 6. Dissolved oxygen (mg/l) at Station 6, February 2002 – January 2003

Depth (m)	2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
	Dates										
0	6.6	5.6	6.7	5.8	3.3	4.3	3.9	4.2	4.8	3.6	2.2
1	7.5	5.6	6.6	6.1	2.9	4.4	3.9	4.2	5.5	3.5	1.7
2	6.7	5.6	6.8	6.2	3.0	4.3	4.0	4.3	5.2	3.4	0.8
3	5.6	5.6	6.6	6.4	3.1	4.1	4.1	4.3	4.9	3.1	0.7
4	5.5	5.5	6.4	6.2	3.1	4.0	4.4	4.3	4.2	3.0	0.6
5	5.8	5.4	6.2	6.3	3.2	4.0	4.1	4.1	3.5	3.0	0.4
6	5.8	5.4	6.3	5.7	3.2	4.1	4.1	4.1	3.3	3.1	0.4
7	5.7	5.4	6.3	5.4	3.1	4.3	4.1	4.0	2.8	3.1	0.4
8	5.4	5.4	6.0	4.9	3.0	4.3	3.4	3.9	2.5	3.1	0.4
9	5.2	5.4	5.8	4.4	2.8	4.0	3.1	3.7	2.6	3.1	0.3
10	5.2	5.4	5.3	4.0	2.7	4.2	2.9	3.9	2.7	3.1	0.4
11	5.2	5.4	4.7	3.6	2.1	4.5	1.9	2.8	2.7	3.1	0.8
12	5.1	5.3	4.4	2.3	1.0	3.5	1.0	2.2	2.5	3.1	1.2
13	5.0	5.4	3.8	1.6	0.6	2.0	0.8	2.1	2.5	3.1	1.2
14	4.9	5.4	3.1	<0.5	0.6	1.3	<0.5	1.0	1.9	3.1	1.2
15	4.6	5.4	2.7	<0.5	<0.5	1.3	<0.5	<0.5	0.9	3.1	1.2
16	4.6	5.4	2.3	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	3.0	1.1
17	4.6	5.4	2.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.9	1.1
18	4.6	5.3	1.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.8	1.2
19	4.6	2.2	1.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.7	1.3
20	4.5	1.7	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.3	1.5
21	4.0	0.9	1.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.2	1.5
22	3.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.1
23	3.7	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.1
24	4.0	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.1
25	3.8	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
26	2.9	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6

Table 7. Ammonium (mg/m3) at Station 6, February 2002 – January 2003

Depth (m)	Dates 2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
1	-	-	-	-	-	-	-	-	-	-	-
2	1.1	1.3	0.7	0.9	10.7	3.1	2.0	1.4	3.0	1.3	9.7
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	1.0	1.2	0.9	1.0	9.2	3.3	1.0	1.2	3.0	1.0	13.4
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	1.5	-	-	-	-	-	-	-	-
11	-	-	-	1.2	-	-	-	-	-	-	-
12	0.8	1.6	1.2	1.4	8.9	2.7	6.2	1.8	3.9	1.2	9.0
13	-	-	-	1.8	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	1.2	1.2	4.8	9.3	22.5	5.6	0.9	24.5	7.5	1.2	9.3
17	-	-	-	-	-	-	-	-	-	-	-
18	1.1	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	30.4	7.6	12.6	31.0	53.1	66.6	67.8	52.6	63.8	5.7	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	36.5	15.6	76.7	93.6	94.0	116.4	105.2	113.0	98.5	52.8	-
25	-	-	-	-	-	-	-	-	-	-	-
26	5.0	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	975.65	207.37	63.34	300.46	187.35	313.05	453.85	560.43	335.25	210.25	-
29	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-
35	1107.32	1079.23	1080.69	1180.4	944.6	693.8	862.2	1029.2	747.4	792.8	973.1

Table 8. Chlorophyll a (mg/m3) at Station 6, February 2002 – January 2003

	Dates										
Depth (m)	2-12	3-18	4-16	5-13	6-17	7-22	8-15	9-13	10-14	11-18	1-6
1	-	-	-	-	-	-	-	-	-	-	-
2	63.8	59.4	20.8	22.2	0.5	1.8	1.6	5.1	34.8	81.1	63.4
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	78.0	59.4	37.8	29.3	1.1	1.5	2.8	9.6	32.2	79.4	60.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	52.0	-	-	-	-	-	-	-	-
11	-	-	-	43.0	-	-	-	-	-	-	-
12	77.9	60.4	55.9	50.7	1.0	4.4	2.1	10.1	26.2	79.5	62.2
13	-	-	-	43.8	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	70.0	57.7	64.0	28.4	40.8	63.6	58.1	27.8	30.2	80.3	62.5
17	-	-	-	-	-	-	-	-	-	-	-
18	74.7	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	74.5	63.1	60.9	23.6	20.0	20.3	21.3	38.4	23.0	78.3	65.8
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	67.3	48.9	43.3	22.1	15.3	18.7	22.9	22.1	23.5	43.5	64.5
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	40.1	35.0	50.2	23.7	17.4	23.1	24.3	23.9	23.4	33.1	63.3

Table 9a. Artemia lake and sector means, 2002.

	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 Mean:										
2/12	909	10	5	0	2	0	0	2	7	926
3/18	20,696	2	0	0	0	0	0	0	0	20,698
4/14*	36,881	0	0	0	0	0	0	0	0	36,881
5/13	18,312	8,884	1,689	0	926	0	0	926	2,614	29,809
6/15	66,237	5,446	15,520	255	4,118	4,668	349	9,390	24,910	96,593
7/19	9,968	495	15,740	54	1,623	4,240	196	6,113	21,853	32,316
8/16	2,425	986	19,940	312	1,093	4,131	57	5,594	25,533	28,944
9/17	1,559	205	4,329	25	60	547	0	632	4,962	6,725
10/16	218	27	64	0	15	0	0	15	79	324
11/14	96	5	7	0	3	0	0	3	10	111
Western Sector Mean:										
2/12	600	3	0	0	3	0	0	3	3	607
3/18	10,185	3	0	0	0	0	0	0	0	10,188
4/14*	43,823	0	0	0	0	0	0	0	0	43,823
5/13	10,453	3,870	882	0	657	0	0	657	1,539	15,862
6/15	56,123	7,726	19,021	242	4,266	4,668	215	9,390	28,411	92,260
7/19	6,492	590	20,309	81	2,790	4,856	161	7,887	28,196	35,278
8/16	2,267	1,315	29,537	443	1,422	5,312	81	7,257	36,794	40,376
9/17	1,858	265	5,513	47	50	805	0	902	6,415	8,538
10/16	148	27	33	0	7	0	0	7	40	215
11/14	60	7	7	0	7	0	0	7	13	80
Eastern Sector Mean:										
2/12	1,217	17	10	0	0	0	0	0	10	1,244
3/18	31,207	0	0	0	0	0	0	0	0	31,207
4/14*	29,940	0	0	0	0	0	0	0	0	29,940
5/13	26,171	13,897	2,495	0	1,194	0	0	1,194	3,689	43,756
6/15	76,352	3,166	12,019	268	3,971	4,668	483	9,390	21,409	100,925
7/19	13,444	399	11,171	27	456	3,625	231	4,339	15,510	29,353
8/16	2,582	657	10,342	181	765	2,951	34	3,930	14,272	17,512
9/17	1,261	144	3,146	3	70	289	0	362	3,508	4,913
10/16	288	27	94	0	23	0	0	23	118	433
11/14	131	3	7	0	0	0	0	0	7	141

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Stations 3, 4, 5, 6 were sampled 4/16

Table 9b. Standard errors of Artemia sector means (Table 9a), 2002.

	Instars 1-7	Instars 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:										
2/12	235	5	3	0	2	0	0	2	3	239
3/18	5,096	2	0	0	0	0	0	0	0	5,095
4/14*	7,728	0	0	0	0	0	0	0	0	7,728
5/13	2,890	2,317	476	0	287	0	0	287	743	5,636
6/15	6,896	1,226	1,720	111	595	762	170	1,076	2,347	8,244
7/19	2,161	119	2,285	30	459	655	57	944	2,999	3,926
8/16	361	264	3,506	133	293	714	41	1,090	4,079	4,278
9/17	190	47	692	14	17	98	0	104	756	795
10/16	39	7	18	0	5	0	0	5	22	57
11/14	30	3	4	0	2	0	0	2	4	30
SE of Western Sector Mean:										
2/12	252	3	0	0	3	0	0	3	3	253
3/18	3,724	3	0	0	0	0	0	0	0	3,723
4/14*	12,451	0	0	0	0	0	0	0	0	12,451
5/13	2,024	1,227	374	0	325	0	0	325	691	3,416
6/15	2,334	2,088	2,220	100	1,056	1,007	159	1,237	2,788	6,067
7/19	1,433	180	2,592	55	593	882	72	1,100	3,173	3,884
8/16	589	501	3,819	254	566	911	81	1,694	4,120	4,605
9/17	298	83	1,218	26	21	111	0	112	1,262	1,178
10/16	30	10	12	0	7	0	0	7	16	42
11/14	26	4	7	0	4	0	0	4	7	26
SE of Eastern Sector Mean:										
2/12	376	8	4	0	0	0	0	0	4	384
3/18	7,496	0	0	0	0	0	0	0	0	7,496
4/14*	9,406	0	0	0	0	0	0	0	0	9,406
5/13	2,821	3,473	773	0	477	0	0	477	1,220	7,090
6/15	12,763	419	1,786	211	658	1,241	308	1,887	3,400	15,961
7/19	3,695	162	2,810	27	177	980	92	1,206	3,663	7,017
8/16	466	113	1,629	79	119	924	26	1,118	2,347	2,650
9/17	186	37	249	3	28	56	0	74	281	274
10/16	61	11	31	0	6	0	0	6	36	88
11/14	52	3	4	0	0	0	0	0	4	53

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Stations 3, 4, 5, 6 were sampled 4/16

Table 9c. Percentage in different classes for Artemia sector means (Table 9a), 2002.

	Instars 1-7	Instars 8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Lakewide (%):										
2/12	98.2	1.1	0.5	0.0	100.0	0.0	0.0	0.2	0.8	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/14*	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/13	61.4	29.8	5.7	0.0	100.0	0.0	0.0	3.1	8.8	100.0
6/15	68.6	5.6	16.1	2.7	43.9	49.7	3.7	9.7	25.8	100.0
7/19	30.8	1.5	48.7	0.9	26.5	69.4	3.2	18.9	67.6	100.0
8/16	8.4	3.4	68.9	5.6	19.5	73.8	1.0	19.3	88.2	100.0
9/17	23.2	3.0	64.4	4.0	9.5	86.6	0.0	9.4	73.8	100.0
10/16	67.3	8.3	19.8	0.0	100.0	0.0	0.0	4.6	24.4	100.0
11/14	86.5	4.5	6.3	0.0	100.0	0.0	0.0	2.7	9.0	100.0
Western Sector (%):										
2/12	98.8	0.5	0.0	0.0	100.0	0.0	0.0	0.5	0.5	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/14*	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/13	65.9	24.4	5.6	0.0	100.0	0.0	0.0	4.1	9.7	100.0
6/15	60.8	8.4	20.6	2.6	45.4	49.7	2.3	10.2	30.8	100.0
7/19	18.4	1.7	57.6	1.0	35.4	61.6	2.0	22.4	79.9	100.0
8/16	5.6	3.3	73.2	6.1	19.6	73.2	1.1	18.0	91.1	100.0
9/17	21.8	3.1	64.6	5.2	5.5	89.2	0.0	10.6	75.1	100.0
10/16	68.8	12.6	15.3	0.0	100.0	0.0	0.0	3.3	18.6	100.0
11/14	75.0	8.8	8.8	0.0	100.0	0.0	0.0	8.8	16.3	100.0
Eastern Sector (%):										
2/12	97.8	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.8	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/14*	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/13	59.8	31.8	5.7	0.0	100.0	0.0	0.0	2.7	8.4	100.0
6/15	75.7	3.1	11.9	2.9	42.3	49.7	5.1	9.3	21.2	100.0
7/19	45.8	1.4	38.1	0.6	10.5	83.5	5.3	14.8	52.8	100.0
8/16	14.7	3.8	59.1	4.6	19.5	75.1	0.9	22.4	81.5	100.0
9/17	25.7	2.9	64.0	0.8	19.3	79.8	0.0	7.4	71.4	100.0
10/16	66.5	6.2	21.7	0.0	100.0	0.0	0.0	5.3	27.3	100.0
11/14	92.9	2.1	5.0	0.0	0.0	0.0	0.0	0.0	5.0	100.0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
The fem-?, e, c, n, percentages are of the total females
*Stations 3, 4, 5, 6 were sampled 4/16

Table 10. Lakewide Artemia instar analysis, 2002.

	Instars 1	2	3	4	5	6	7	8-11	adults	total
Mean:										
2/12	707	66	29	20	23	6	0	9	6	865
3/18	19,793	1,276	6	0	0	0	0	0	0	21,075
4/14*	7,485	19,954	5,542	293	0	0	0	0	0	33,274
5/13	2,196	3,087	3,254	3,133	2,443	2,041	2,794	7,692	2,604	29,244
6/15	49,416	2,851	46	46	161	460	1,472	6,991	22,558	84,001
7/19	2,964	831	808	1,069	719	615	333	377	19,882	27,597
8/16	1,512	586	23	23	80	69	115	1,219	29,468	33,096
9/17	210	216	264	267	219	224	149	135	4,544	6,229
10/16	3	9	9	46	40	37	63	26	78	310
11/14	37	14	9	14	20	11	6	3	11	126
Standard error of mean:										
2/12	306	30	13	9	12	4	0	6	4	375
3/18	6,111	419	6	0	0	0	0	0	0	6,517
4/14*	1,340	6,157	2,096	150	0	0	0	0	0	9,032
5/13	346	999	739	684	512	636	1,077	2,886	1,159	8,086
6/15	2,454	1,210	46	46	93	138	288	1,924	3,488	7,212
7/19	957	300	345	438	249	169	127	111	3,618	4,638
8/16	444	169	23	23	46	27	46	422	5,202	5,667
9/17	40	36	79	75	52	50	28	28	855	789
10/16	3	9	4	14	12	12	12	10	34	76
11/14	23	6	6	8	8	4	4	3	6	45
Percentage in different age classes:										
2/12	81.7	7.6	3.4	2.3	2.7	0.7	0.0	1.0	0.7	100.0
3/18	93.9	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/14*	22.5	60.0	16.7	0.9	0.0	0.0	0.0	0.0	0.0	100.0
5/13	7.5	10.6	11.1	10.7	8.4	7.0	9.6	26.3	8.9	100.0
6/15	58.8	3.4	0.1	0.1	0.2	0.5	1.8	8.3	26.9	100.0
7/19	10.7	3.0	2.9	3.9	2.6	2.2	1.2	1.4	72.0	100.0
8/16	4.6	1.8	0.1	0.1	0.2	0.2	0.3	3.7	89.0	100.0
9/17	3.4	3.5	4.2	4.3	3.5	3.6	2.4	2.2	72.9	100.0
10/16	1.0	2.9	2.9	14.8	12.9	11.9	20.3	8.4	25.2	100.0
11/14	29.4	11.1	7.1	11.1	15.9	8.7	4.8	2.4	8.7	100.0

*Stations 3, 4, 5, 6 were sampled 4/16

Table 11a. Artemia reproductive summary, lake and sector means, 2002.

			Adult Females			
	Total	Ovigery	e	?	c	n
Lakewide Mean:						
2/12	2	0	2	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	926	0	926	0	0	0
6/15	9,390	5,272	4,118	255	4,668	349
7/19	6,113	4,490	1,623	54	4,240	196
8/16	5,594	4,500	1,093	312	4,131	57
9/17	632	572	60	25	547	0
10/16	15	0	15	0	0	0
11/14	3	0	3	0	0	0
Western Sector Mean:						
2/12	3	0	3	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	657	0	657	0	0	0
6/15	9,390	5,124	4,266	242	4,668	215
7/19	7,887	5,097	2,790	81	4,856	161
8/16	7,257	5,835	1,422	443	5,312	81
9/17	902	852	50	47	805	0
10/16	7	0	7	0	0	0
11/14	7	0	7	0	0	0
Eastern Sector Mean:						
2/12	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	1,194	0	1,194	0	0	0
6/15	9,390	5,419	3,971	268	4,668	483
7/19	4,339	3,883	456	27	3,625	231
8/16	3,930	3,165	765	181	2,951	34
9/17	362	292	70	3	289	0
10/16	23	0	23	0	0	0
11/14	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Stations 3, 4, 5, 6 were sampled 4/16

Table 11b. Standard errors of Artemia reproductive summary (Table 11a), 2002

			Adult Females			
	Total	Ovigery	e	?	c	n
Standard Error of Lakewide Mean:						
2/12	2	0	2	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	287	0	287	0	0	0
6/15	1,076	903	595	111	762	170
7/19	944	689	459	30	655	57
8/16	1,090	847	293	133	714	41
9/17	104	105	17	14	98	0
10/16	5	0	5	0	0	0
11/14	2	0	2	0	0	0
Standard Error of Western Sector Mean:						
2/12	3	0	3	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	325	0	325	0	0	0
6/15	1,237	1,213	1,056	100	1,007	159
7/19	1,100	919	593	55	882	72
8/16	1,694	1,180	566	254	911	81
9/17	112	117	21	26	111	0
10/16	7	0	7	0	0	0
11/14	4	0	4	0	0	0
Standard Error of Eastern Sector Mean:						
2/12	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/14*	0	0	0	0	0	0
5/13	477	0	477	0	0	0
6/15	1,887	1,453	658	211	1,241	308
7/19	1,206	1,047	177	27	980	92
8/16	1,118	1,024	119	79	924	26
9/17	74	58	28	3	56	0
10/16	6	0	6	0	0	0
11/14	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Stations 3, 4, 5, 6 were sampled 4/16

Table 11c. Artemia percentages in different reproductive categories (Table 11a), 2002.

	Adult Females					
	Total	Ovig	e	?	c	n
Lakewide Mean (%):						
2/12	100.0	0.0	100.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/14*	0.0	0.0	0.0	0.0	0.0	0.0
5/13	100.0	0.0	100.0	0.0	0.0	0.0
6/15	100.0	56.1	43.9	4.8	93.0	7.0
7/19	100.0	73.5	26.5	1.2	95.6	4.4
8/16	100.0	80.4	19.5	6.9	98.6	1.4
9/17	100.0	90.5	9.5	4.4	100.0	0.0
10/16	100.0	0.0	100.0	0.0	0.0	0.0
11/14	100.0	0.0	100.0	0.0	0.0	0.0
Western Sector Mean (%):						
2/12	100.0	0.0	100.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/14*	0.0	0.0	0.0	0.0	0.0	0.0
5/13	100.0	0.0	100.0	0.0	0.0	0.0
6/15	100.0	54.6	45.4	4.7	95.6	4.4
7/19	100.0	64.6	35.4	1.6	96.8	3.2
8/16	100.0	80.4	19.6	7.6	98.5	1.5
9/17	100.0	94.5	5.5	5.5	100.0	0.0
10/16	100.0	0.0	100.0	0.0	0.0	0.0
11/14	100.0	0.0	100.0	0.0	0.0	0.0
Eastern Sector Mean (%):						
2/12	0.0	0.0	0.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/14*	0.0	0.0	0.0	0.0	0.0	0.0
5/13	100.0	0.0	100.0	0.0	0.0	0.0
6/15	100.0	57.7	42.3	4.9	90.6	9.4
7/19	100.0	89.5	10.5	0.7	94.0	6.0
8/16	100.0	80.5	19.5	5.7	98.9	1.1
9/17	100.0	80.7	19.3	1.0	100.0	0.0
10/16	100.0	0.0	100.0	0.0	0.0	0.0
11/14	0.0	0.0	0.0	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.
*Stations 3, 4, 5, 6 were sampled 4/16

Table 12. Artemia fecundity summary, 2002.

	#eggs/brood				female length		
	mean	SE	%cyst	%intended	mean	SE	n
Lakewide Mean:							
6/15	54.2	1.9	99.0	71.0	10.6	0.2	7
7/19	38.8	1.7	97.0	56.0	10.7	0.1	7
8/16	54.8	3.2	98.0	51.0	10.9	0.2	7
9/17	113.7	6.4	100.0	63.0	12.3	0.2	7
Western Sector Mean:							
6/15	53.2	3.4	100.0	63.0	10.5	0.3	4
7/19	38.1	1.8	100.0	62.0	10.6	0.2	4
8/16	51.0	1.0	100.0	51.0	10.6	0.2	4
9/17	108.4	6.9	100.0	70.0	12.2	0.2	4
Eastern Sector Mean:							
6/15	55.6	0.6	97.0	83.0	10.8	0.1	3
7/19	39.7	3.4	93.0	48.0	10.9	0.1	3
8/16	59.9	6.7	96.0	51.0	11.2	0.4	3
9/17	120.7	12.2	100.0	53.0	12.5	0.6	3

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

Table 13. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979–2002.

Year	Mean	Median	Peak	Centroid*
1979	14118	12286	31700	216
1980	14643	10202	40420	236
1981	32010	21103	101670	238
1982	36643	31457	105245	252
1983	17812	16314	39917	247
1984	17001	19261	40204	212
1985	18514	20231	33089	218
1986	14667	17305	32977	190
1987	23952	22621	54278	226
1988	27639	25505	71630	207
1989	36359	28962	92491	249
1990	20005	16775	34930	230
1991	18129	19319	34565	226
1992	19019	19595	34648	215
1993	15025	16684	26906	217
1994	16602	18816	29408	212
1995	15584	17215	24402	210
1996	17734	17842	34616	216
1997	14389	16372	27312	204
1998	19429	21235	33968	226
1999	20221	21547	38439	225
2000	10550	9080	22384	210
2001	20031	20037	38035	209
2002	11569	9955	25533	200

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

Table 14. Long-term Integrative Measures of Productivity: Annual Primary Production, *Artemia* biomass and egg production (see Chapter 2 for methods).

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** ($10^6\ m^{-2}$)
1983	523	9.3	0.2	4.8
1984	269	7.8	0.1	3.7
1985	399	7.8	0.2	4.6
1986	462	7.7	0.4	3.0
1987	371	12.5	0.2	6.4
1988	1064	15.2	0.2	4.7
1989	499	17.6	0.1	6.7
1990	641	11.0	1.0	6.1
1991	418	9.7	0.7	5.5
1992	435	10.2	0.3	5.8
1993	*na	8.9	0.3	6.3
1994	*na	8.7	0.2	5.6
1995	*na	8.4	0.4	4.9
1996	*na	8.2	0.0	3.6
1997	*na	5.3	0.0	2.5
1998	*na	8.0	0.0	2.8
1999	*na	8.9	0.0	4.2
2000	*na	8.2	0.1	4.0
2001	*na	8.8	0.1	3.0
2002	1790	4.9	0.1	2.5

*Carbon uptake measurements not conducted. Estimates in which photosynthetic parameters, (P_m^B) and (α^B), were estimated from regressions on previous measurements were deemed unreliable based on new analysis and measurements conducted in 2002

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, 2002.

Fig. 3. Daily air temperature; mean, maximum, and minimum, 2002.

Fig. 4. Daily photosynthetically available radiation, 2002.

Fig. 5. Mean daily relative humidity, 2002.

Fig. 6. Daily precipitation, 2002.

Fig. 7. Mono Lake surface elevation (ft asl), 1979–02, USGS datum.

Fig. 8. Temperature (°C) at station 6, 2002.

Fig. 9. Conductivity (mS cm^{-1} corrected to 25°C) at station 6, 2002.

Fig. 10. Density (kg m^{-3}) at station 6, 2002.

Fig. 11. Density difference (10^{-4} g cm^{-3}) between 2 and 28 m at station 6 due to temperature and chemical stratification from 1983 through 2002.

Fig.12 Density difference (10^{-4} g cm^{-3}) between 2 and 32 m at station 6 due to temperature and chemical stratification from 1983 through 2002.

Fig. 13. Winter salinity stratification, 1994–02.

Fig. 14. Mean lakewide Secchi depth (m), 1994–02. Error bars show standard errors of the lakewide estimate based on 12-20 stations.

Fig. 15. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–02.

Fig. 16. Light attenuation (% of surface) at station 6, 2002. Dots denote the dates and depths of samples.

Fig. 17. Dissolved oxygen concentration (mg O_2 l^{-1}) at station 6, 2002.

Fig. 18. Ammonium concentration (µM) at station 6, 2002. Dots denote the dates and depths of samples.

Fig. 19. Concentration of chlorophyll *a* (µg chl *a* l^{-1}) at station 6, 2002. Dots denote the dates and depths of samples.

Fig. 20. Seasonal fluorescence profiles at station 6, 2002.

Fig. 21. Lakewide *Artemia* abundance during 2002: nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).

Fig. 22. Reproductive characteristics of *Artemia* during 2002: 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. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1982–02 (see Methods). The mean relative error of the lakewide estimates is 20-25%.

Fig. 24. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–02. Values are based on interpolated daily abundances.

Fig. 25. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–02. Centroid is based on interpolated daily abundances of adult *Artemia*.

Fig. 26. Chlorophyll-specific uptake rates for May and September 2002 for samples collected from the surface mixed layer and the deep chlorophyll maximum.

Fig. 27 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}), 2002.

Fig. 28. Mean annual *Artemia* biomass, 1983–02. Data for the period 1982–99 estimated from instar-specific population data and previously derived weight-length relationships. In 2000–02, *Artemia* biomass was measured directly by determining dry weights of plankton tows.

Fig. 29. Annual *Artemia* reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–02.

Fig. 30. Changes in lake surface elevation from the height at the onset of meromixis during 1983–1989 and 1995–2002. Years of each meromictic event are overlayed. Surface elevations at the onset of meromixis were 6374.1 ft (1983) and 6374.5 ft (1995).

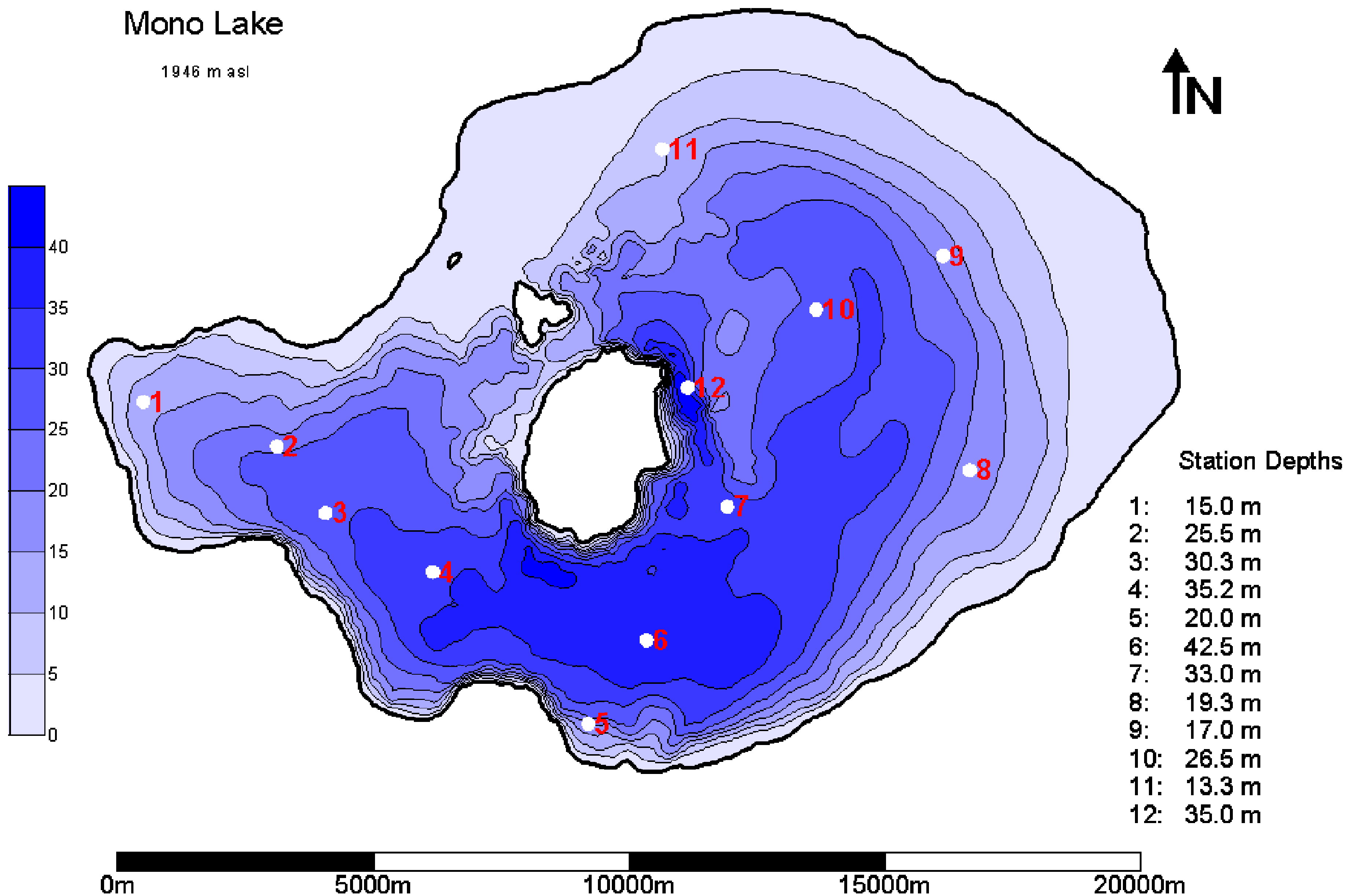
Fig. 31. Changes in percent area and volume of lake water beneath the chemocline during 1984–1988 and 1995–2002. Years of meromictic events are overlayed. Data are February values except in 2003, where they are from January.

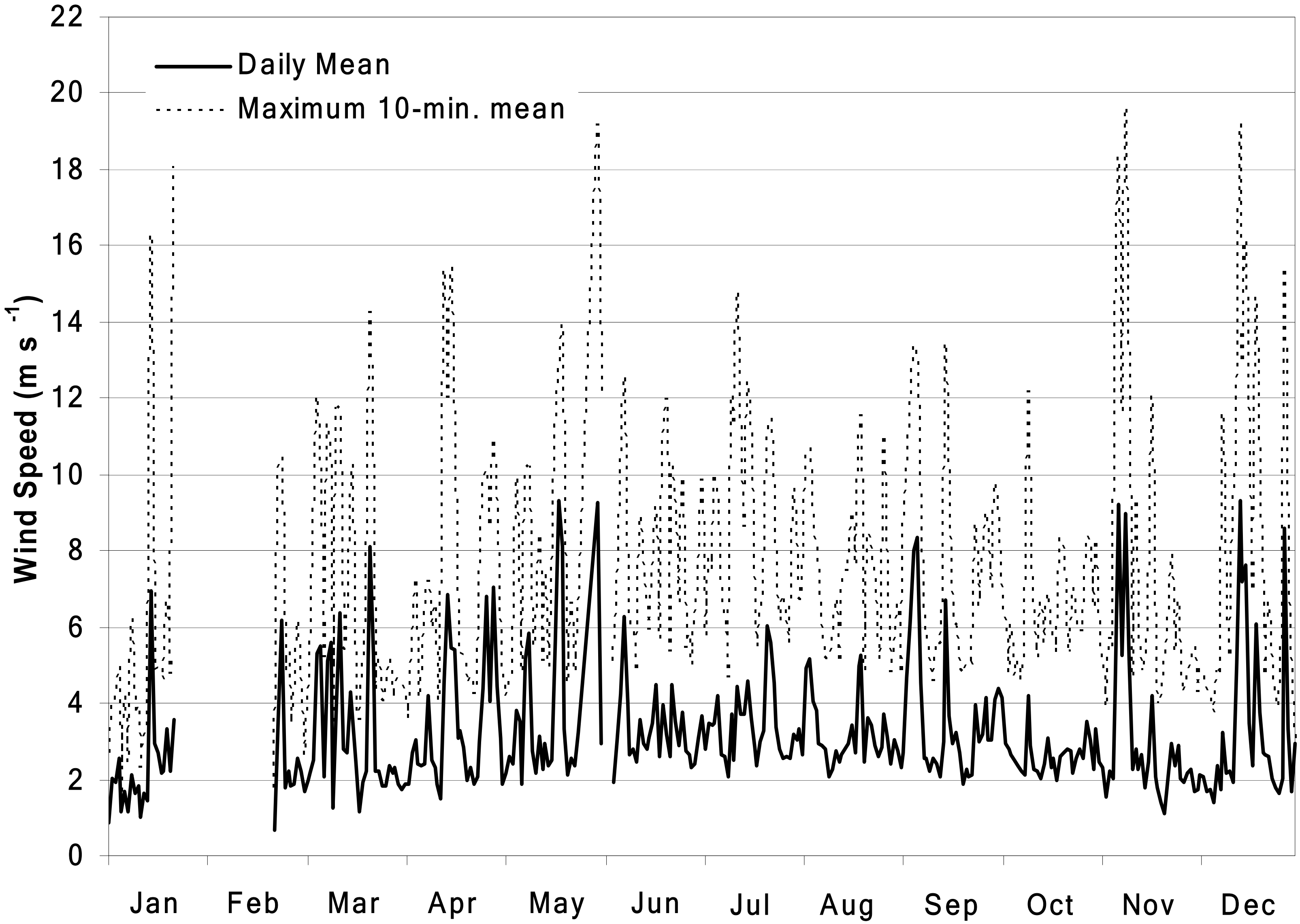
Fig. 32. Changes in the density difference due to salinity between 2 and 28 m during 1983–1989 and 1995–2002. Years of meromictic events are overlayed.

Fig. 33. Linear regression of the temporal trend of salinity stratification from 1998–2002, extending the regression line to zero salinity stratification (the density difference at which the lake should mix). Years of meromictic events are overlayed.

Fig. 34. Changes in ammonium (µM) at 2 m during 1983–1989 and 1995–2002. Years of meromictic events are overlayed.

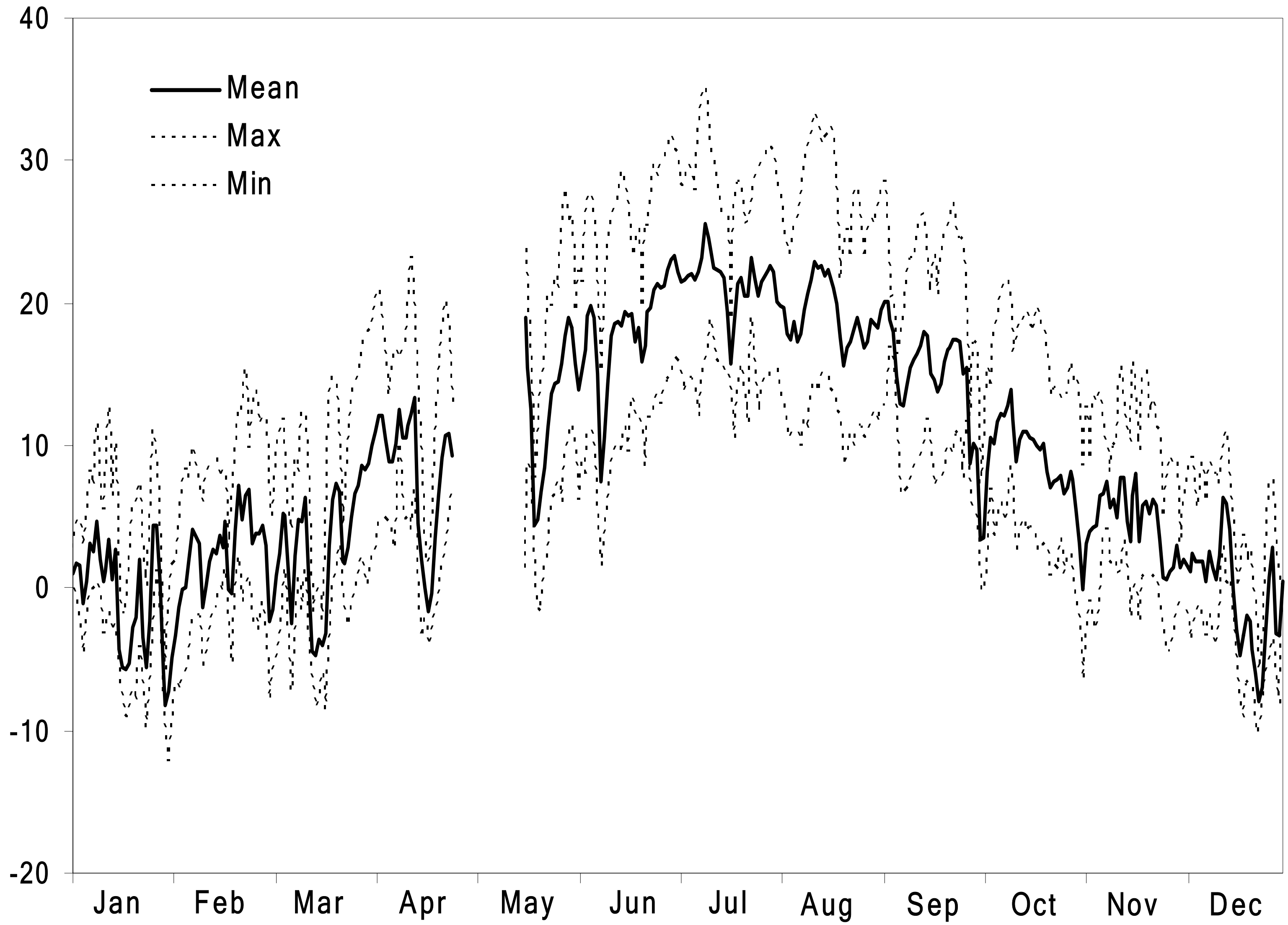
Fig. 35. Changes in algal biomass (µg l^{-1}) at 2 m during 1983–1989 and 1995–2002. Years of meromictic events are overlayed.


Mono Lake
1946 m asl
N
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
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
0m
5000m
10000m
15000m
20000m



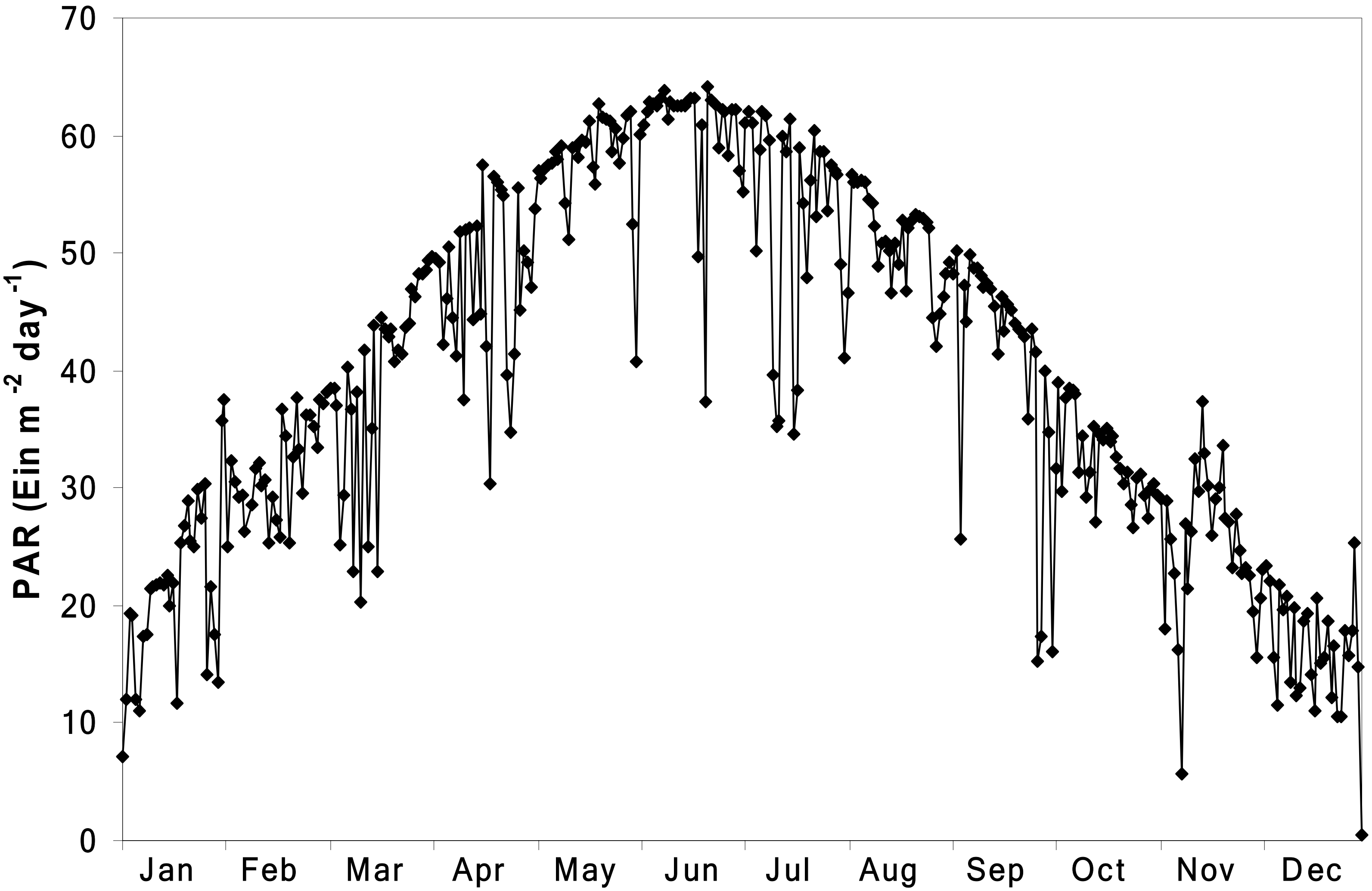
2002 Wind Speed

Figure 2



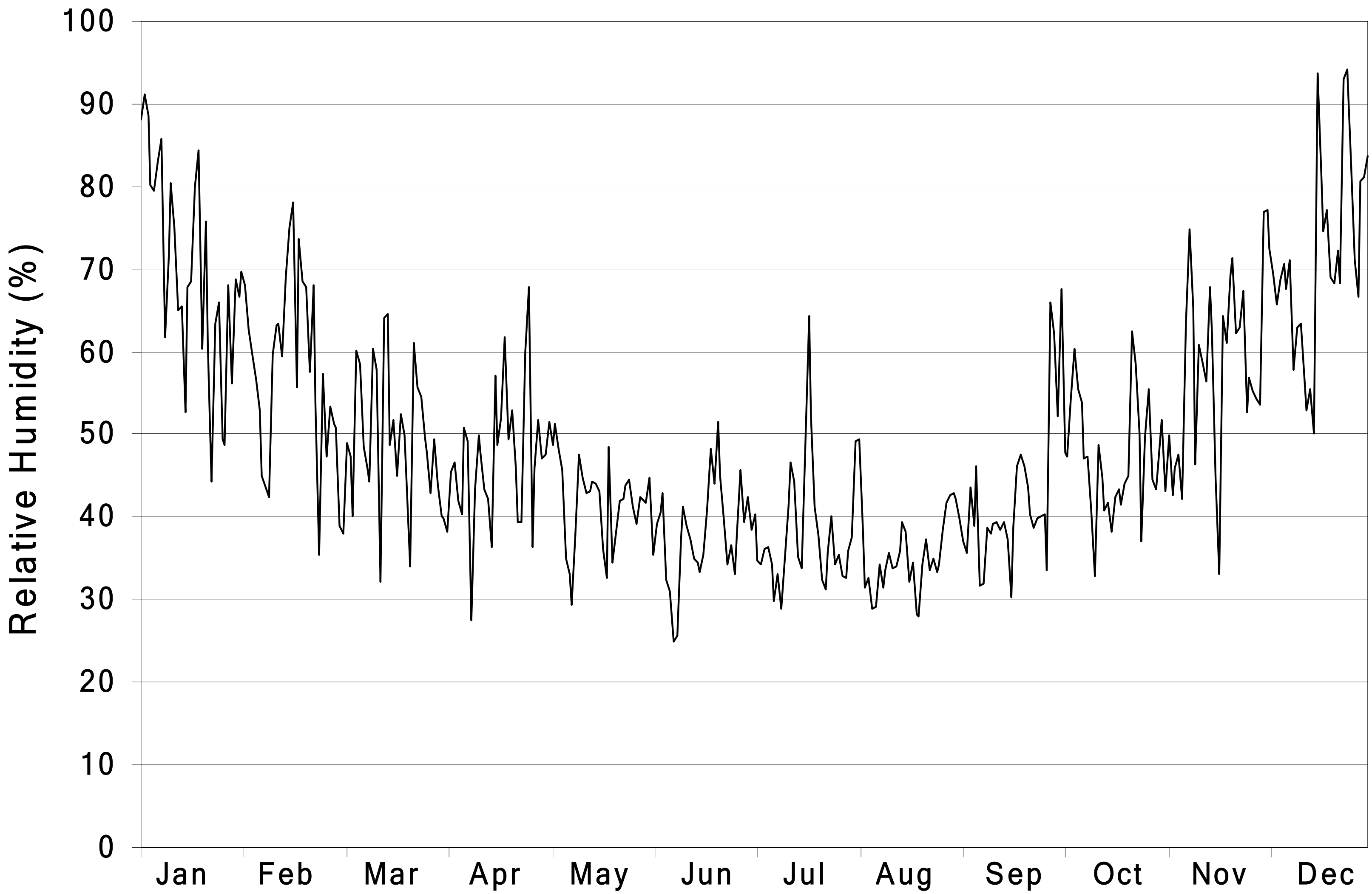
2002 Daily Air Temperature

Figure 3



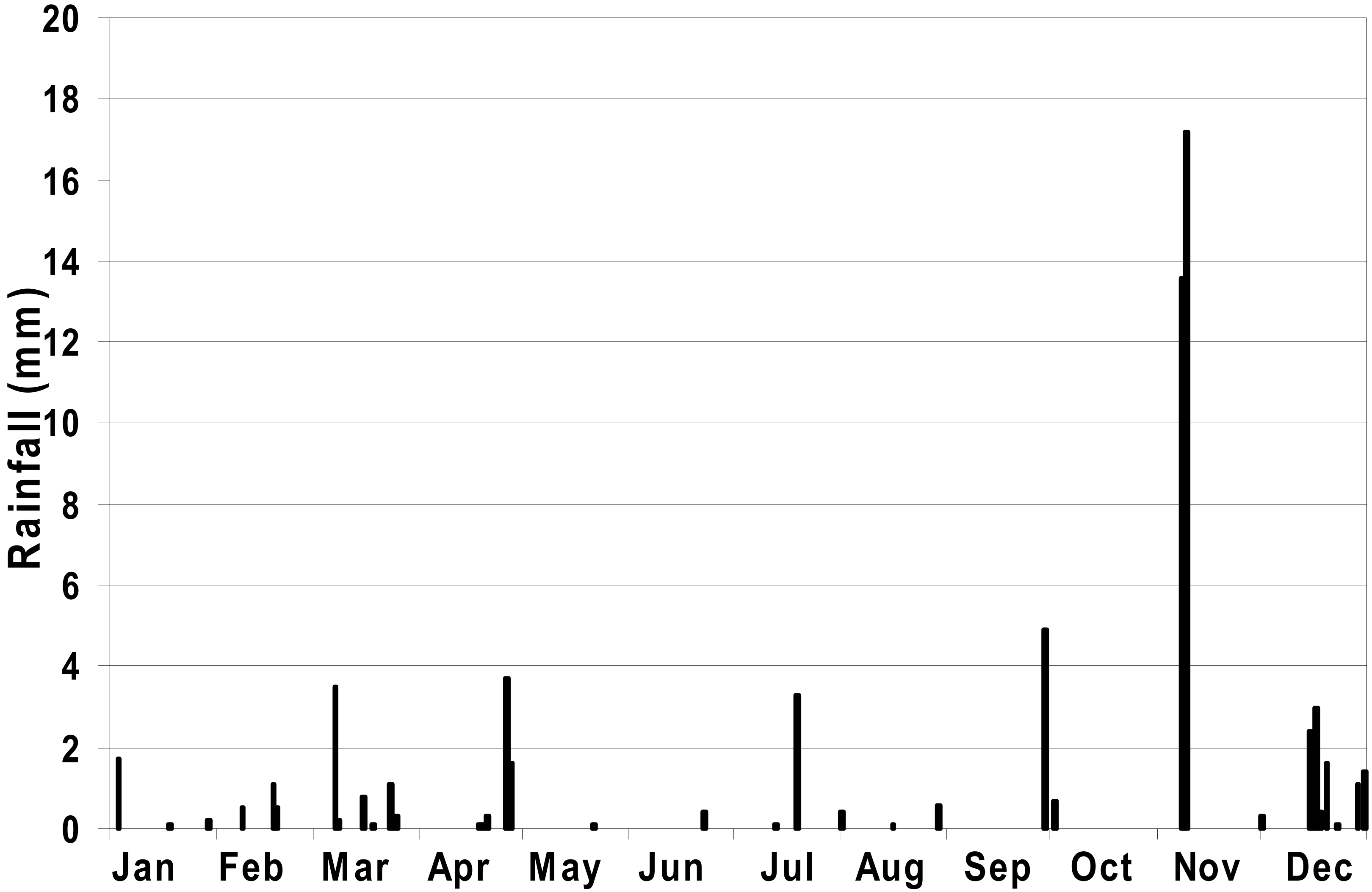
2002 Photosynthetically Available Radiation

Figure 4



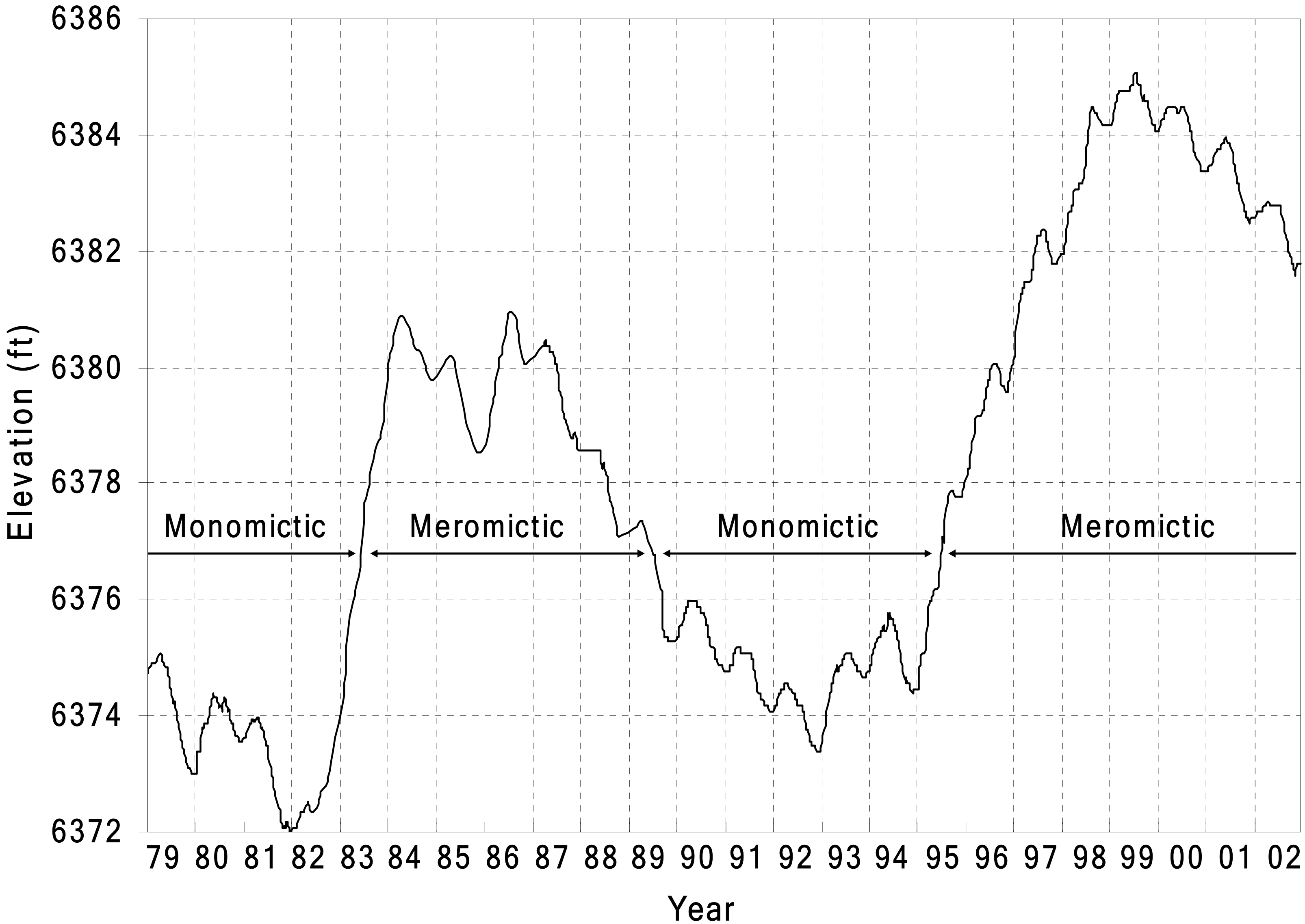
2002 Mean Daily Relative Humidity

Figure 5



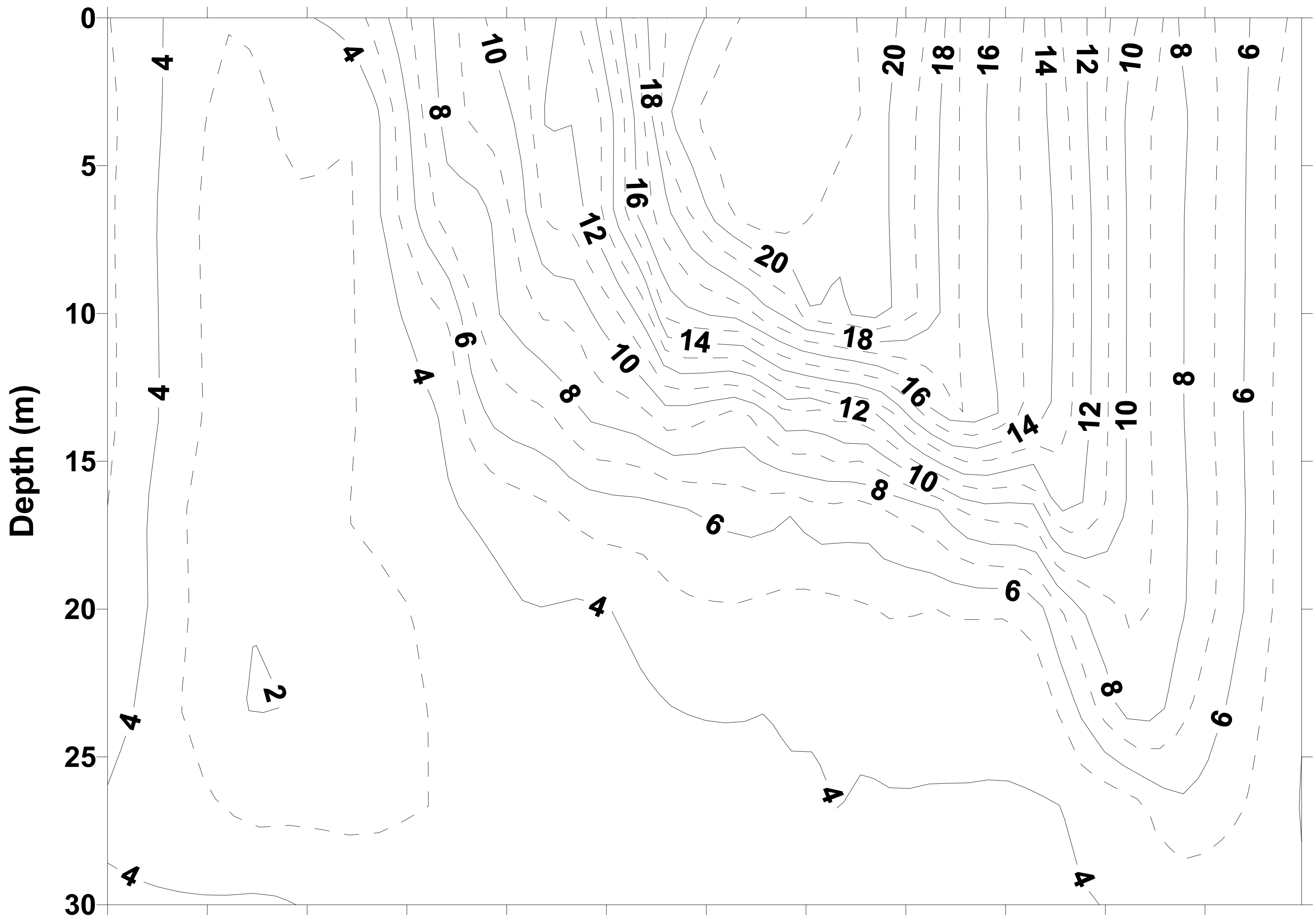
2002 Daily Precipitation

Figure 6



Mono Lake Surface Elevation

Figure 7

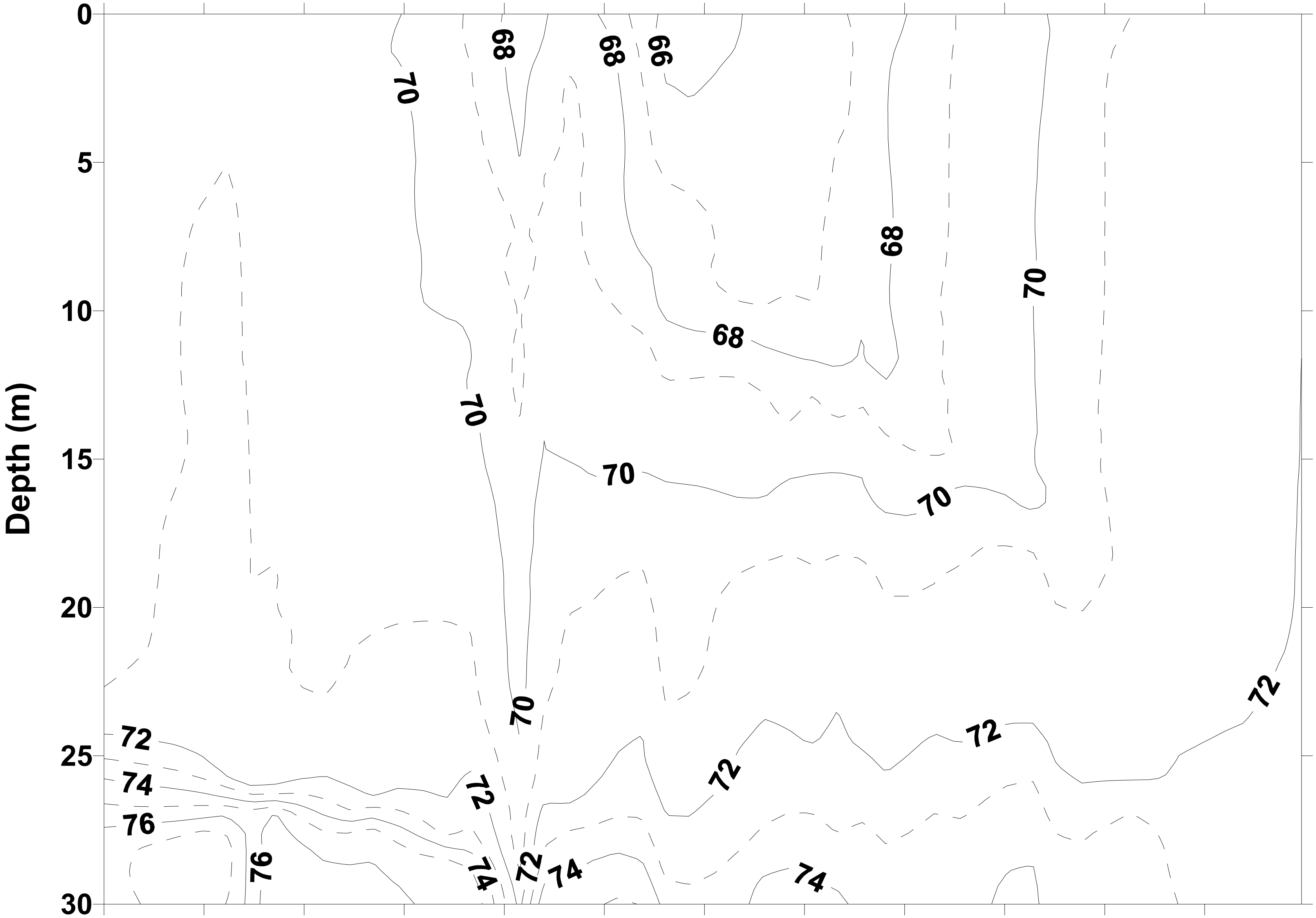


Temperature (°C) at Station 6, 2002

Figure 8

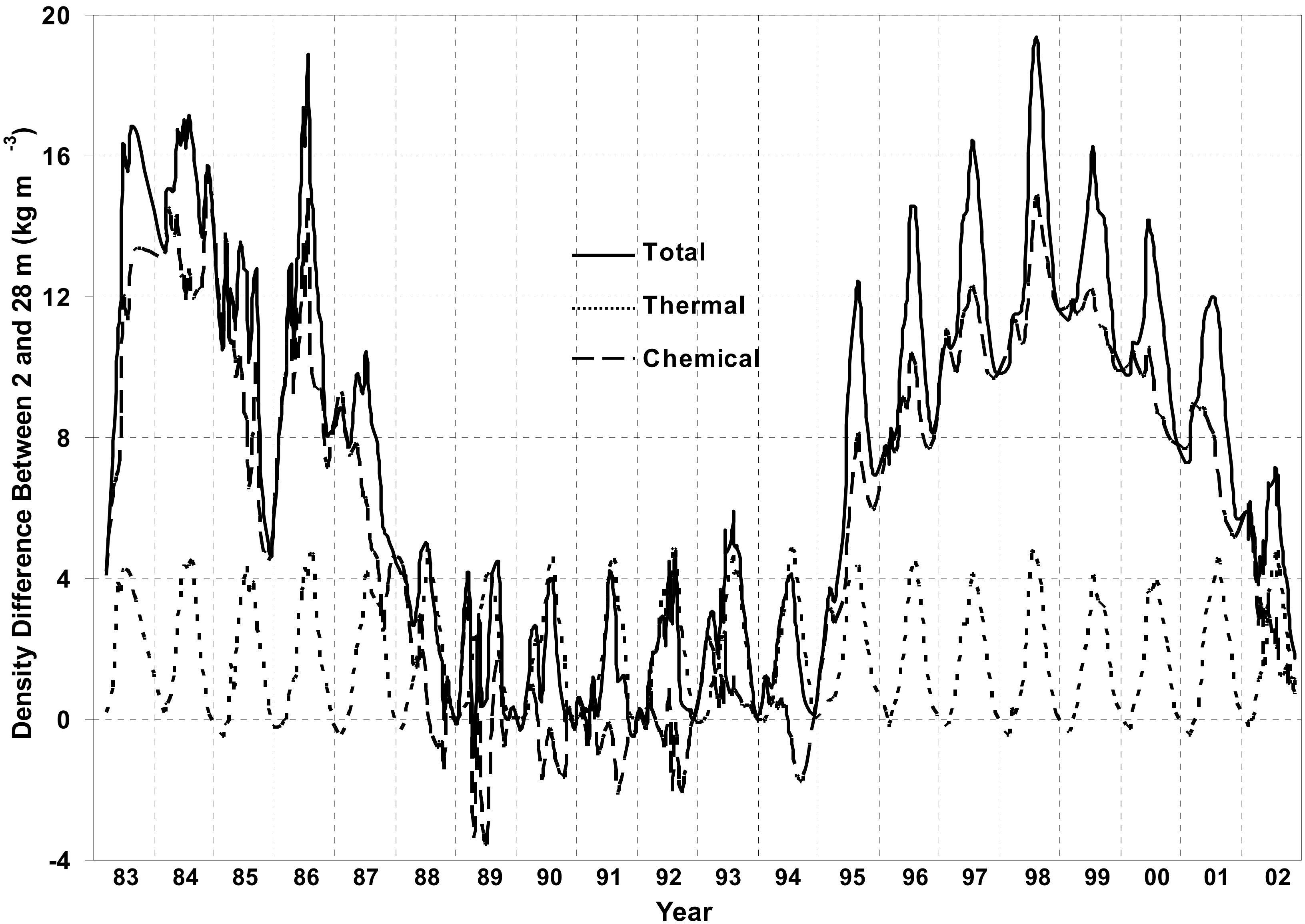
Conductivity (mS/cm) at Station 6, 2002

Figure 9



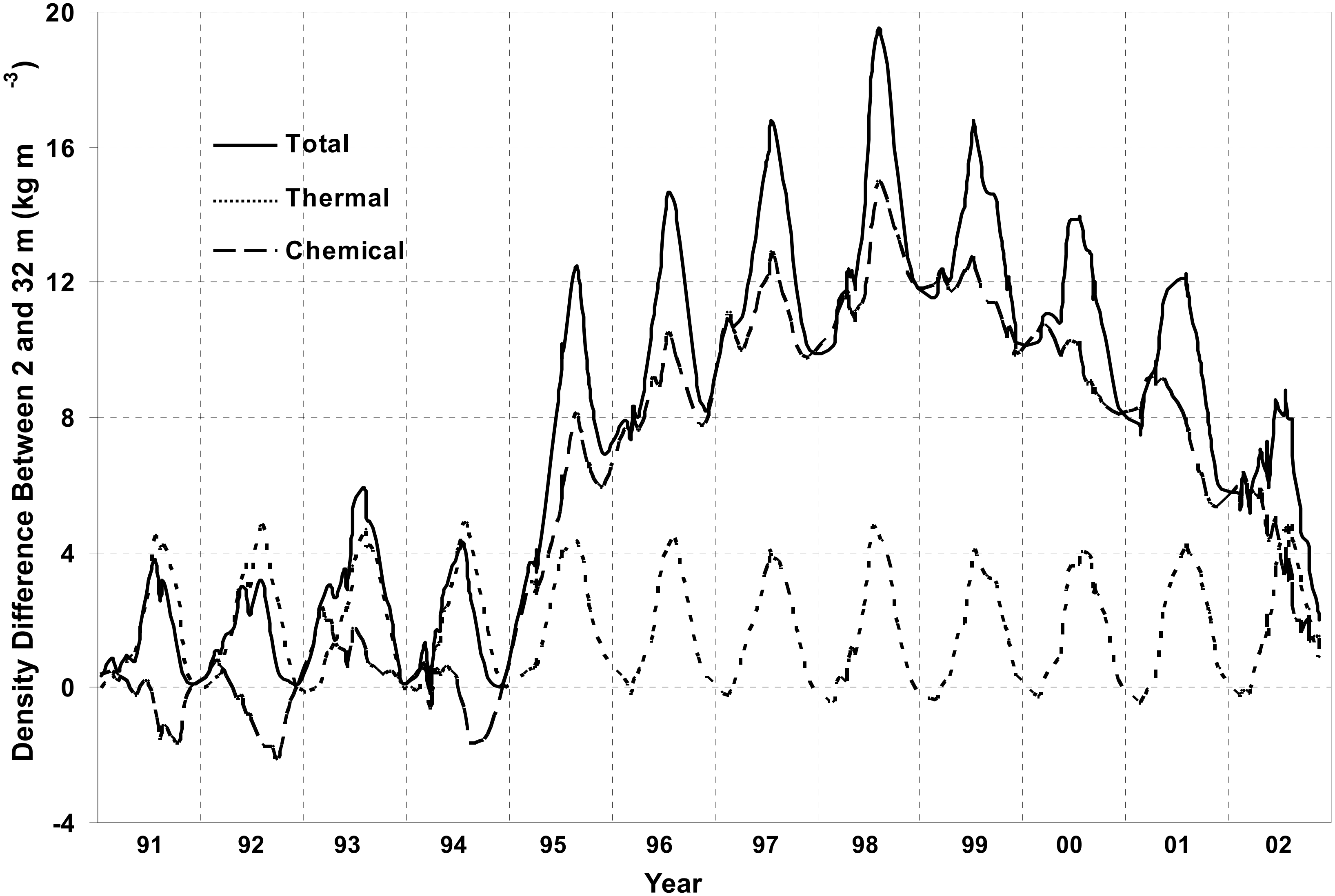
Excess Density (kg m) at Station 6, 2002

Figure 10



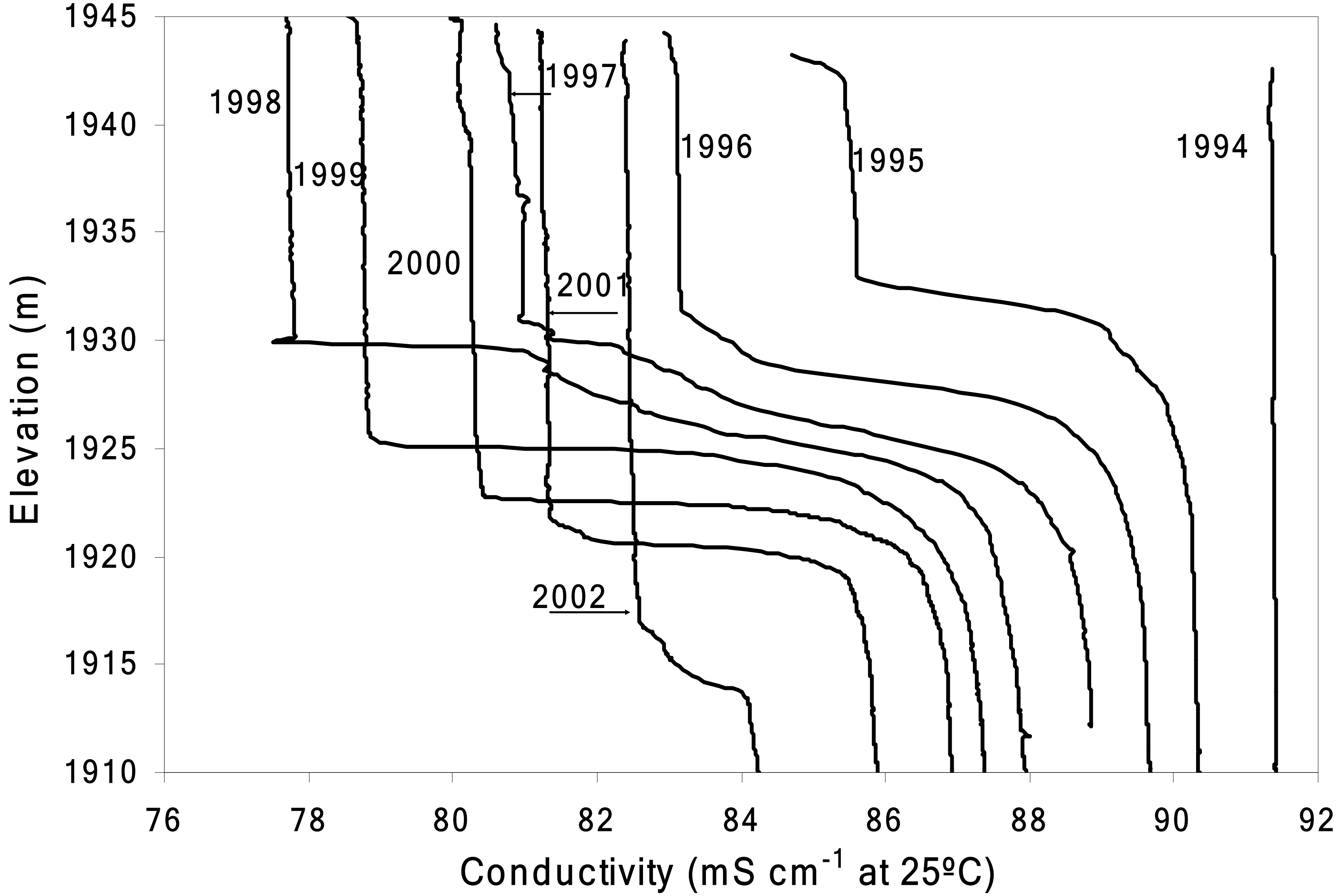
Density Stratification (2-28 m) 1983 - 2002

Figure 11



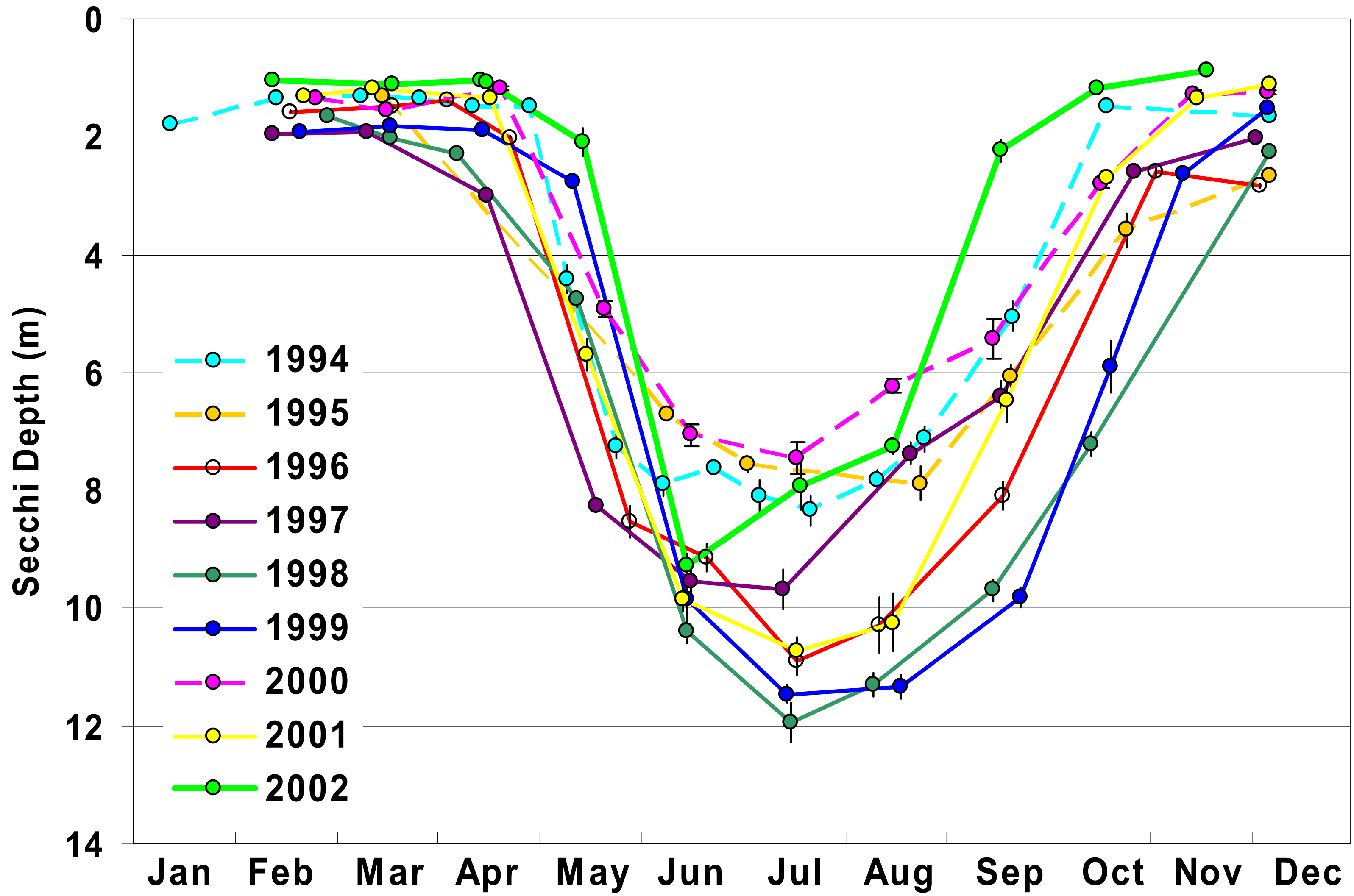
Density Stratification (2-32 m) 1991 - 2002

Figure 12



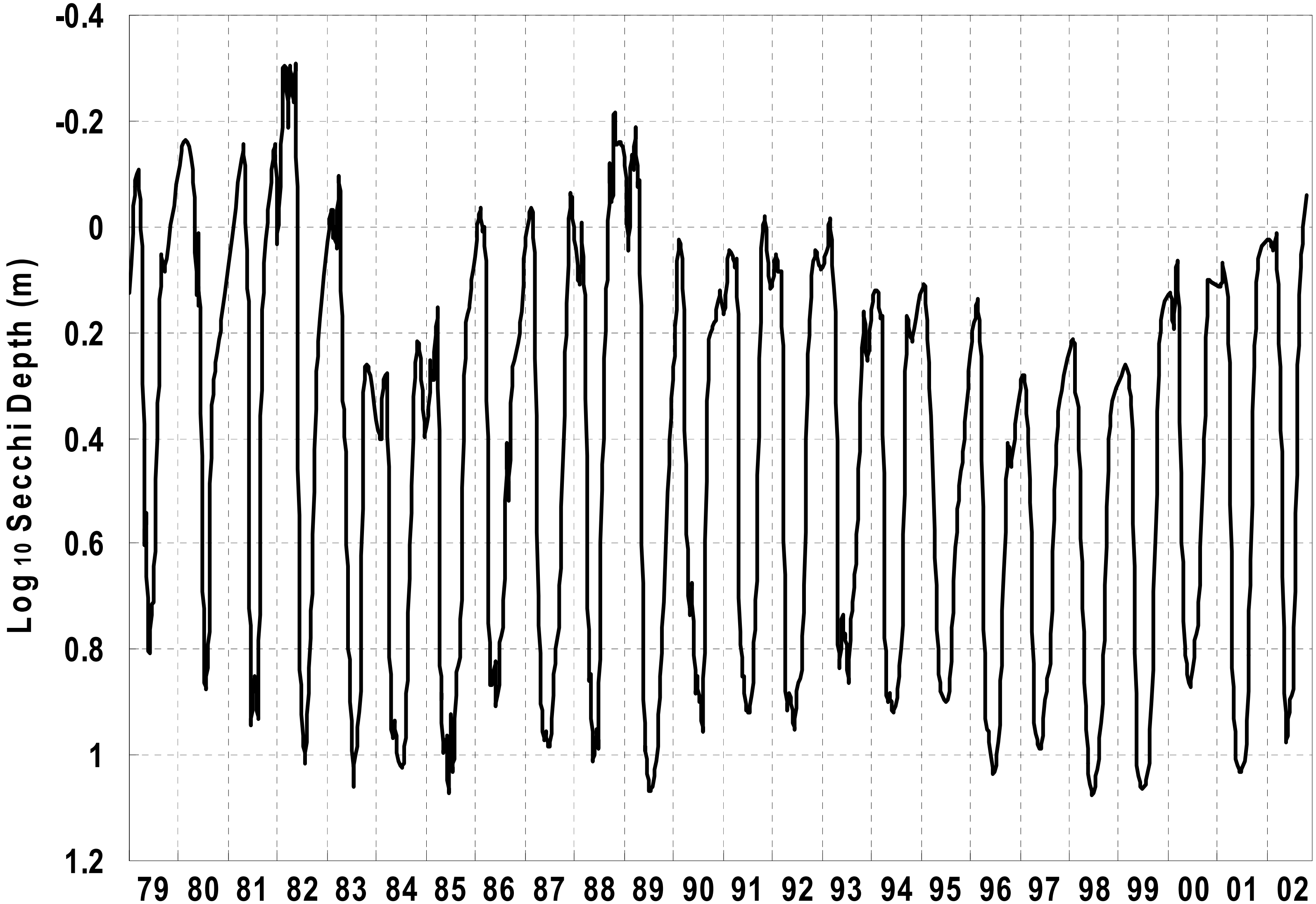
December Salinity Stratification at Mono Lake

Figure 13



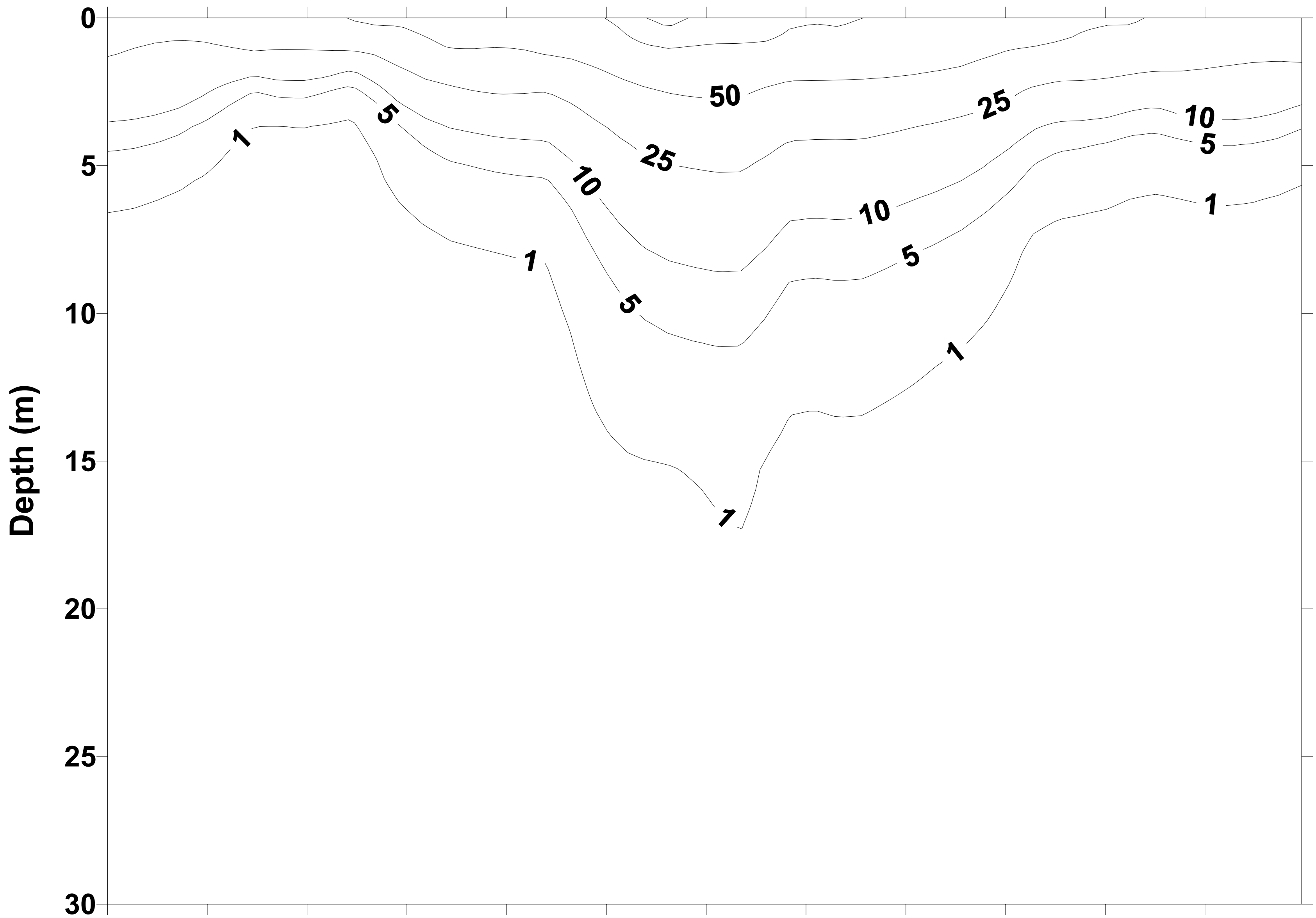
Mono Lake Transparency

Figure 14



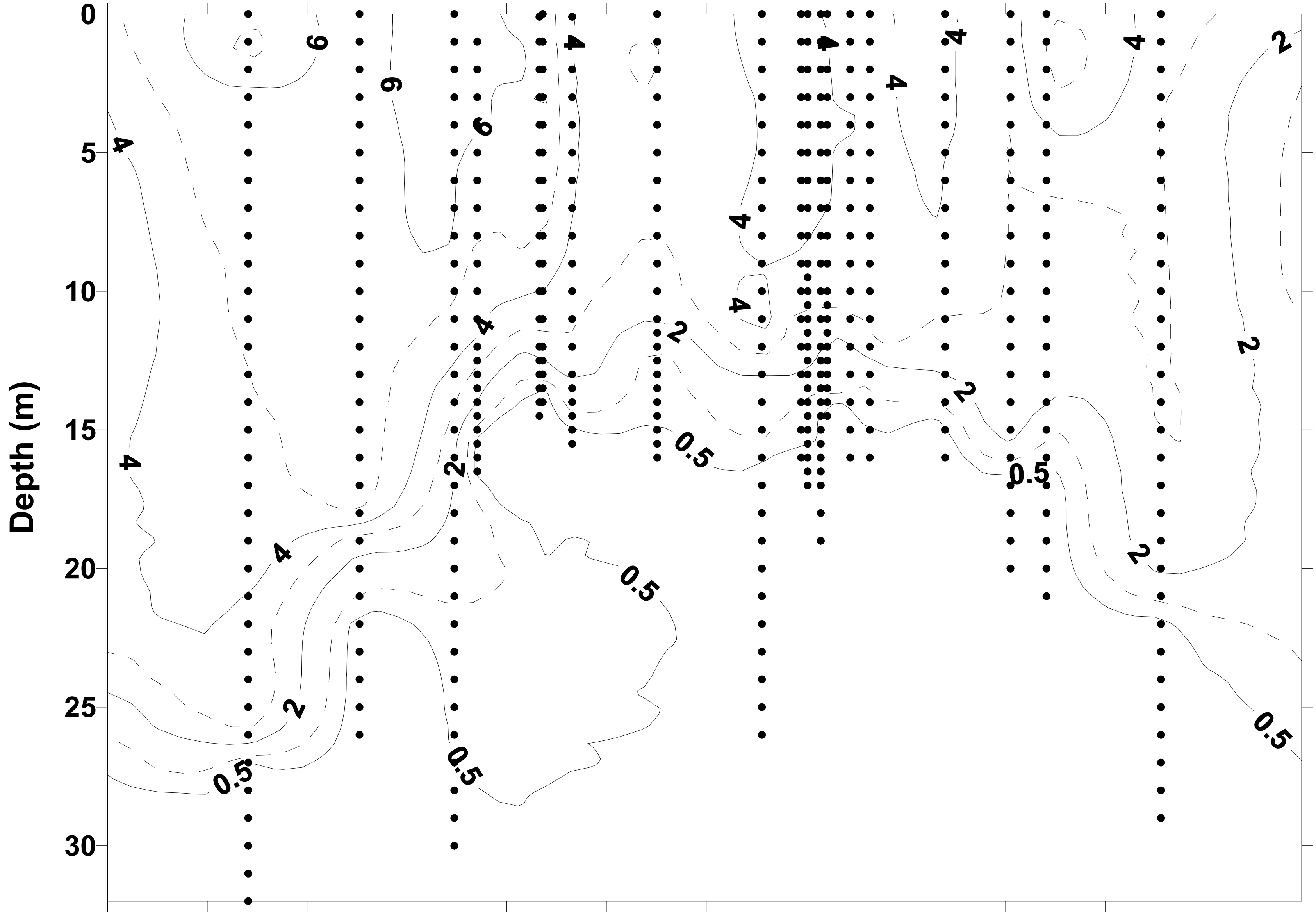
Transparency in Mono Lake

Figure 15



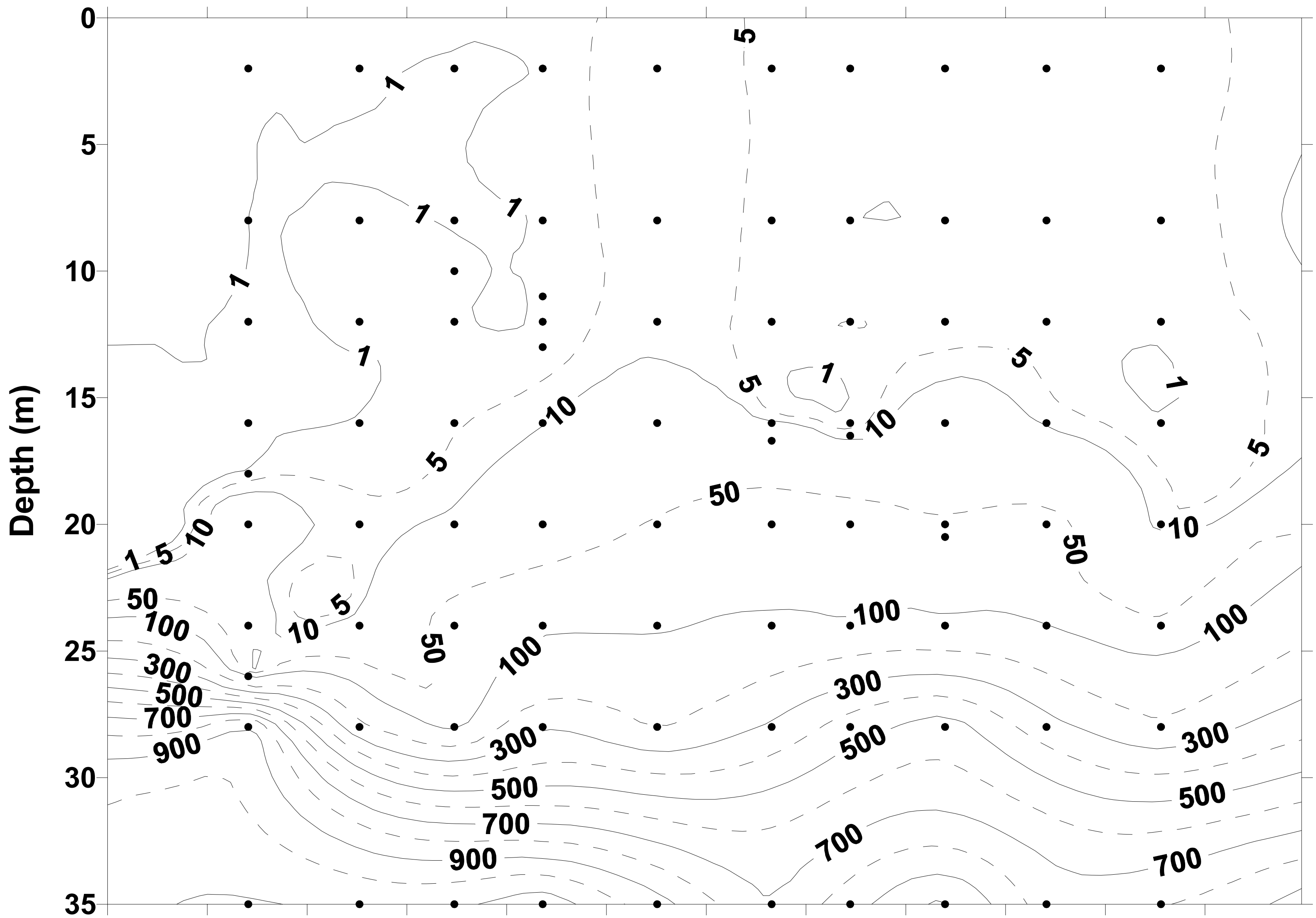
Light Attenuation (percent of surface) at Station 6, 2002

Figure 16



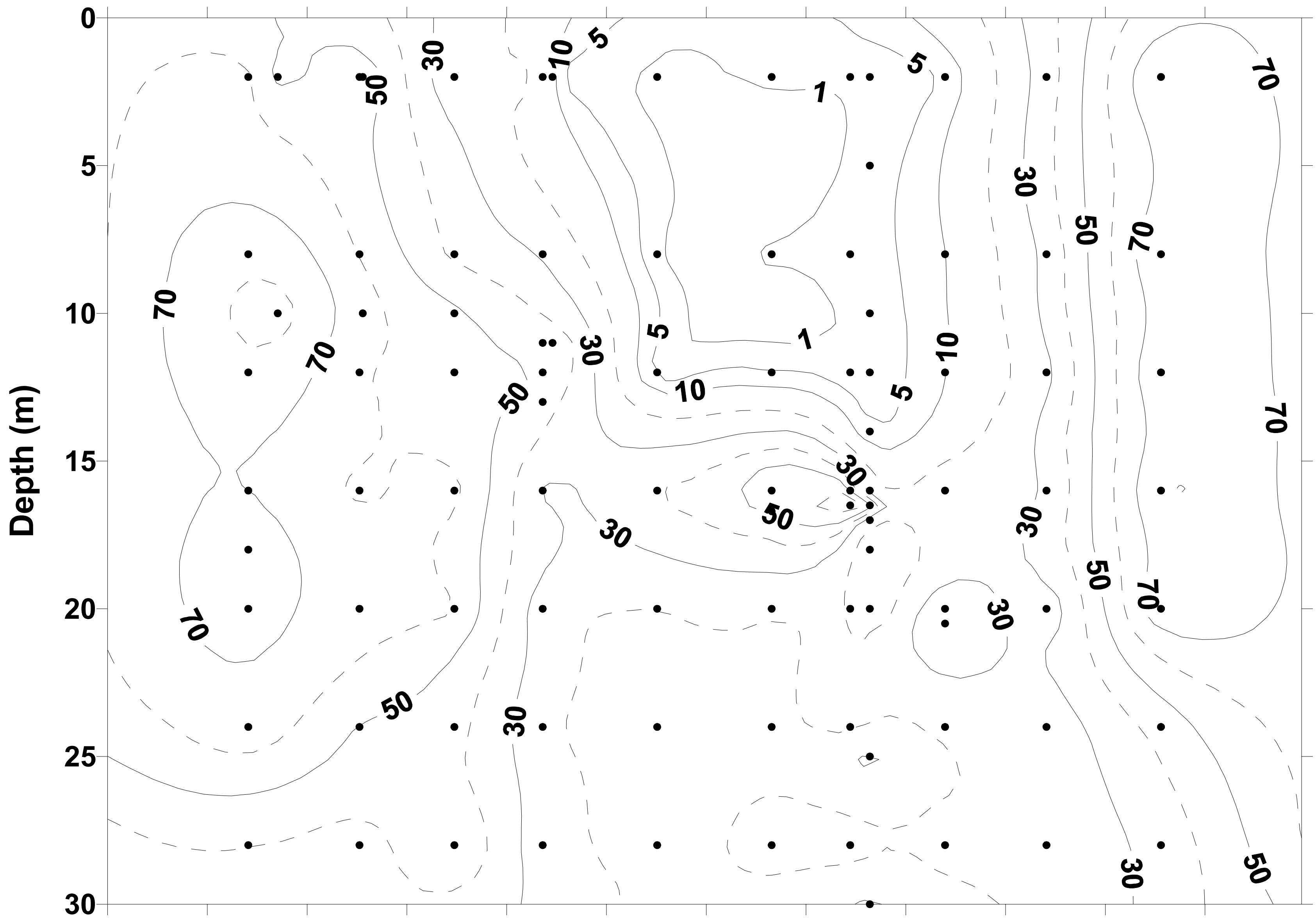
Dissolved Oxygen (mg/l) at Station 6, 2002

Figure 17



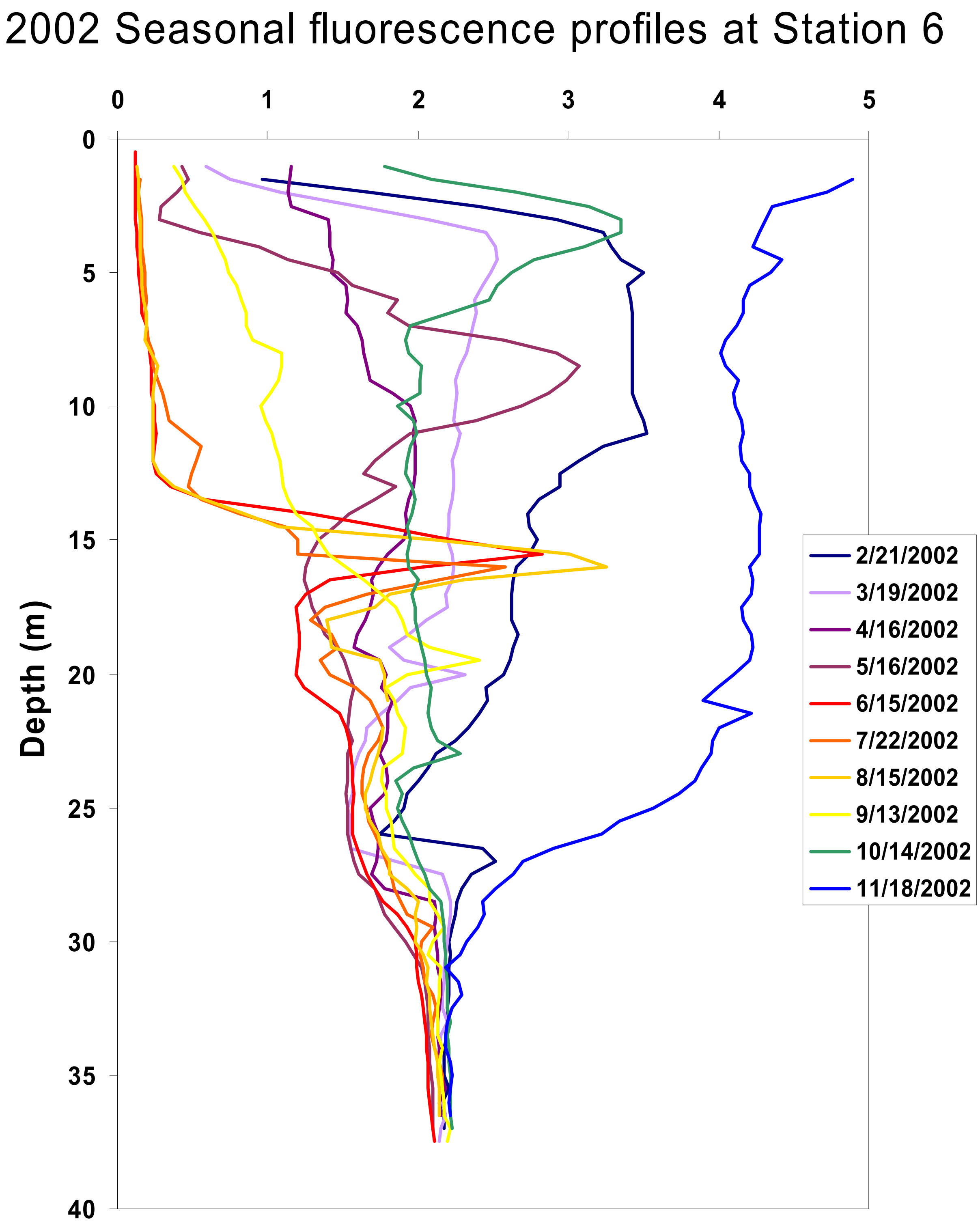
Ammonium (µM) at Station 6, 2002

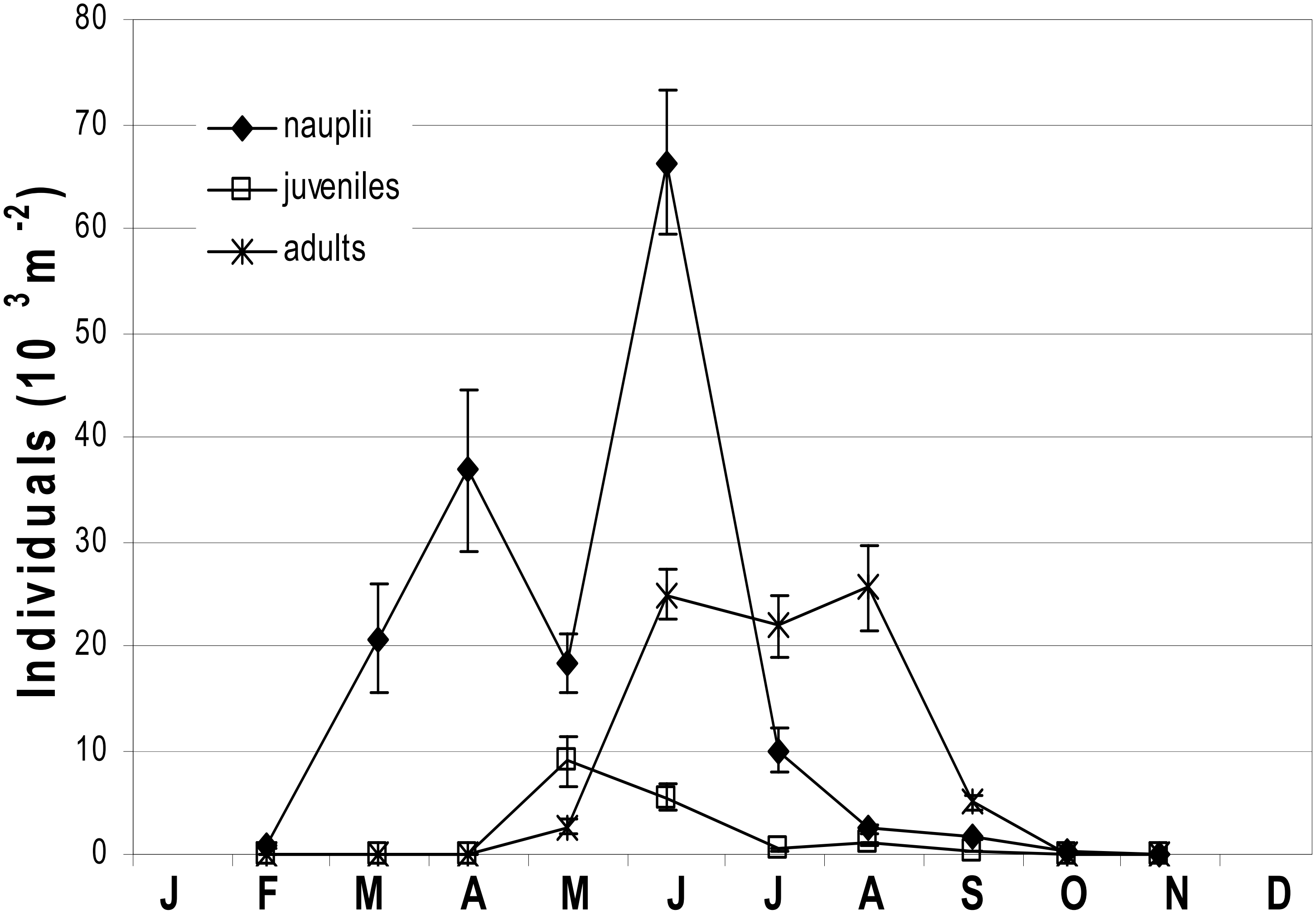
Figure 18



Chlorophyll a (µg/l) at Station 6, 2002

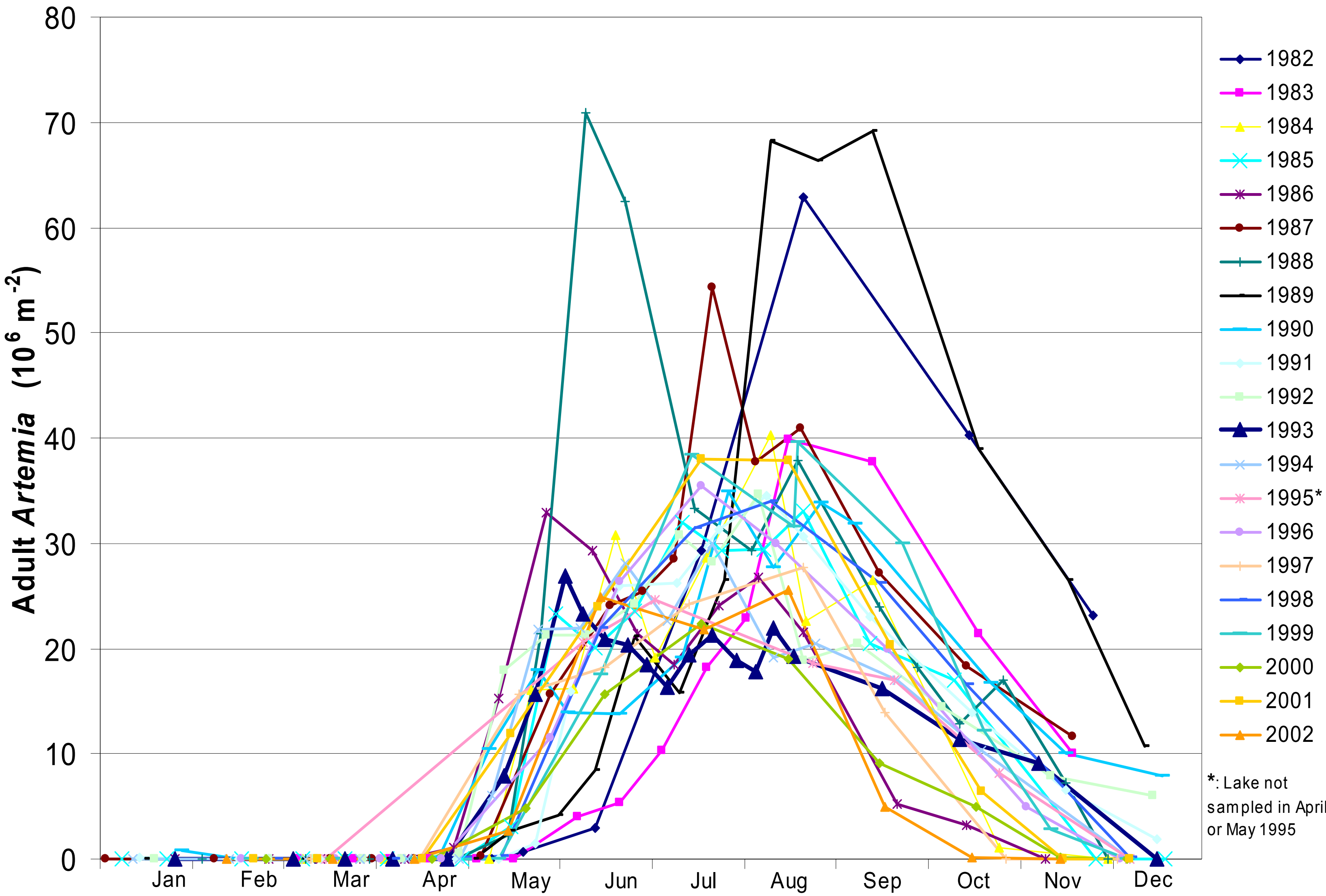
Figure 19


2002 Seasonal fluorescence profiles at Station 6
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
Depth (m)
2/21/2002
3/19/2002
4/16/2002
5/16/2002
6/15/2002
7/22/2002
8/15/2002
9/13/2002
10/14/2002
11/18/2002



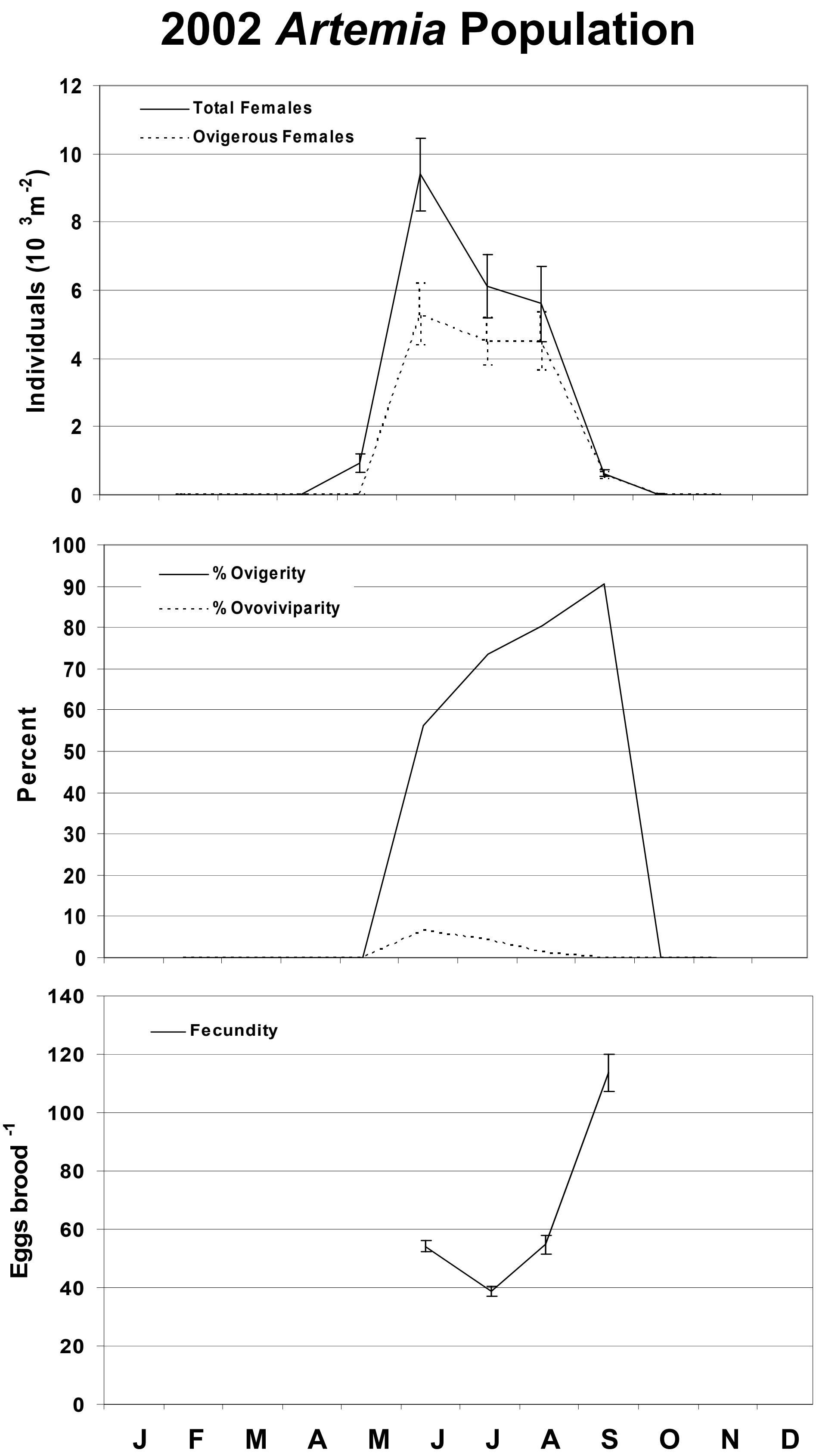
2002 *Artemia* Population

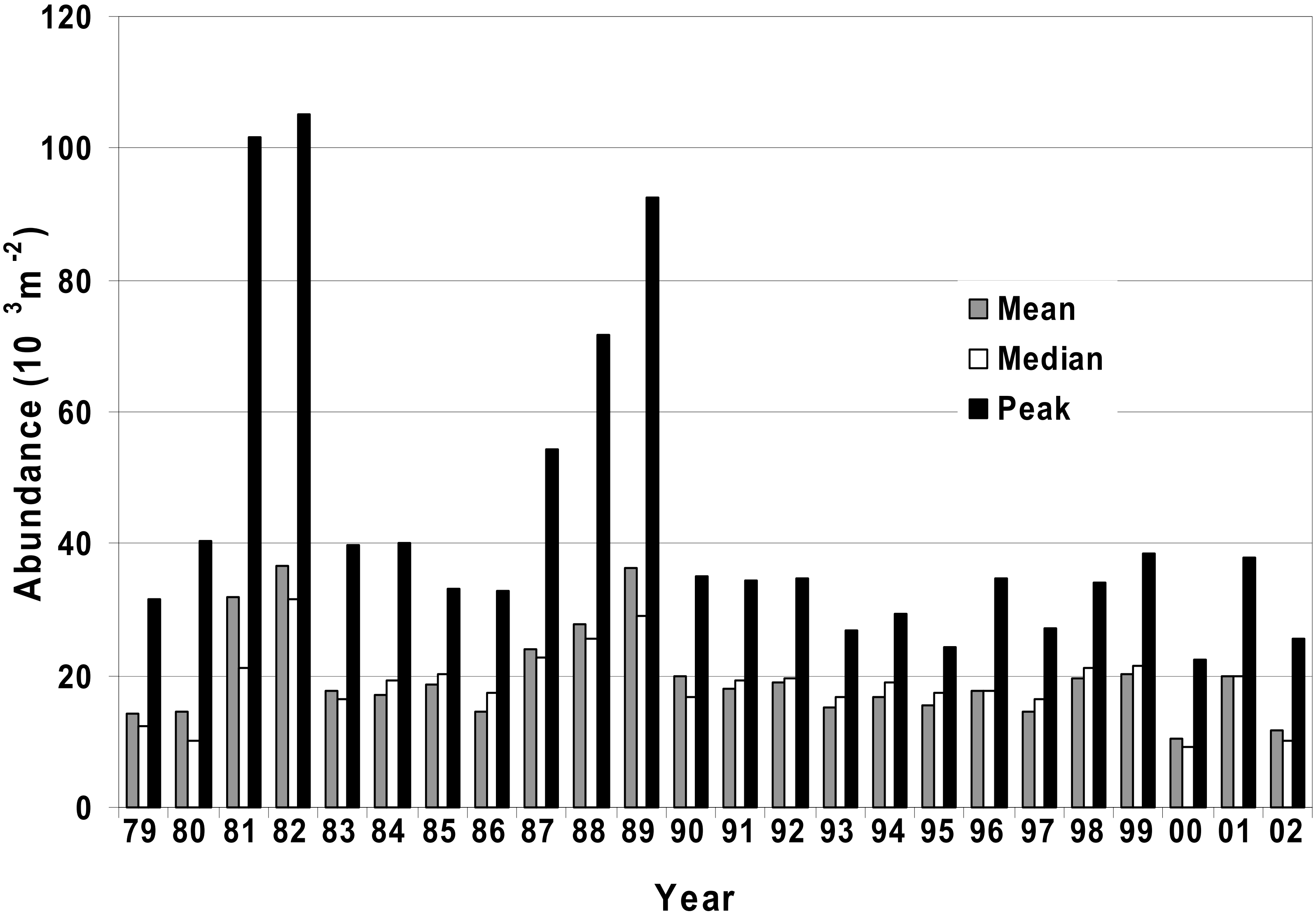
Figure 21



Adult *Artemia* Abundance

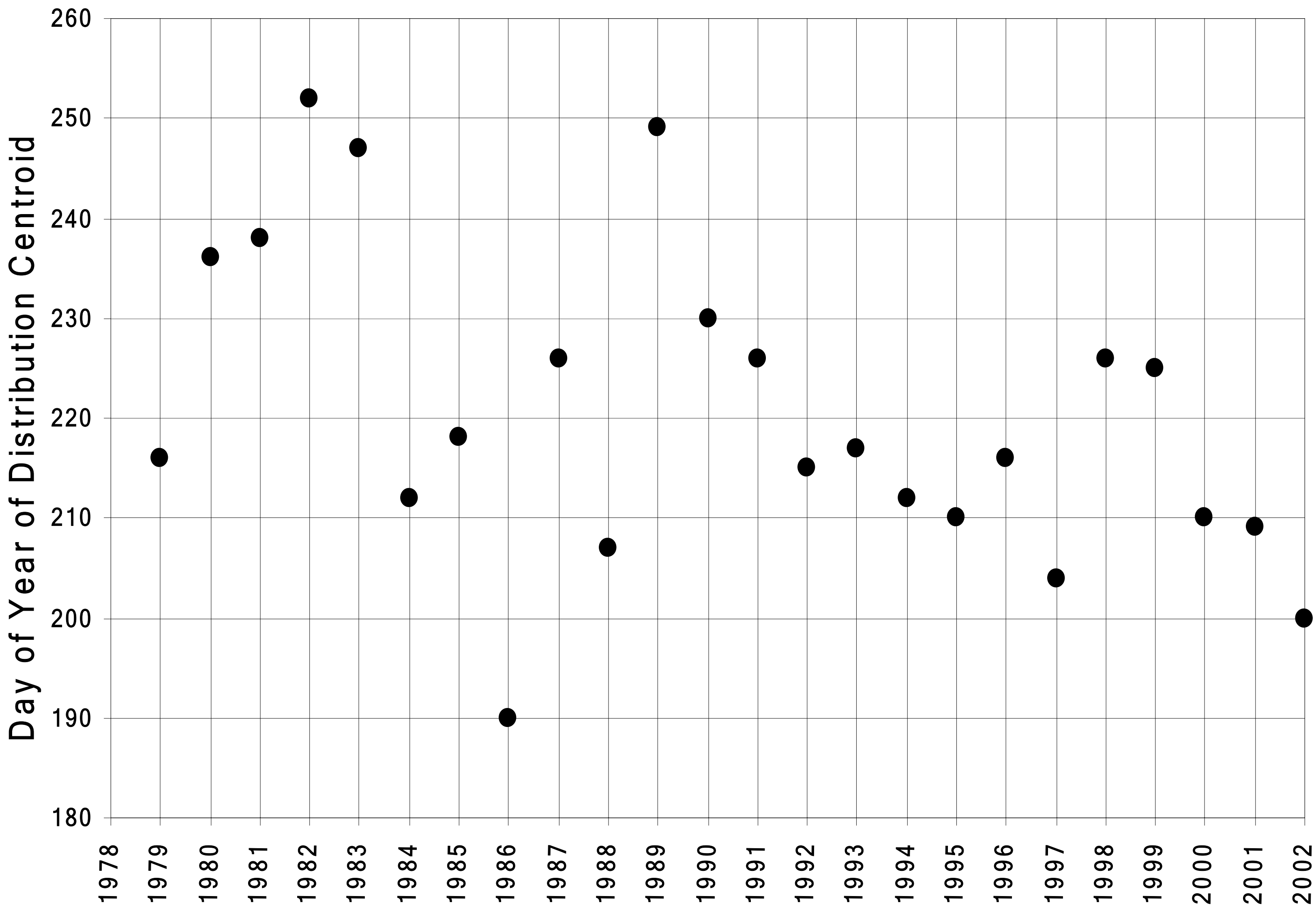
Figure 22


2002 *Artemia* Population
Total Females
Ovigerous Females
Individuals ($10^3 m^{-2}$)
12
10
8
6
4
2
0
% Ovigerity
% Ovoviviparity
Percent
100
90
80
70
60
50
40
30
20
10
0
Fecundity
Eggs brood $^{-1}$
140
120
100
80
60
40
20
0
J F M A M J J A S O N D



Adult *Artemia* Summary Statistics

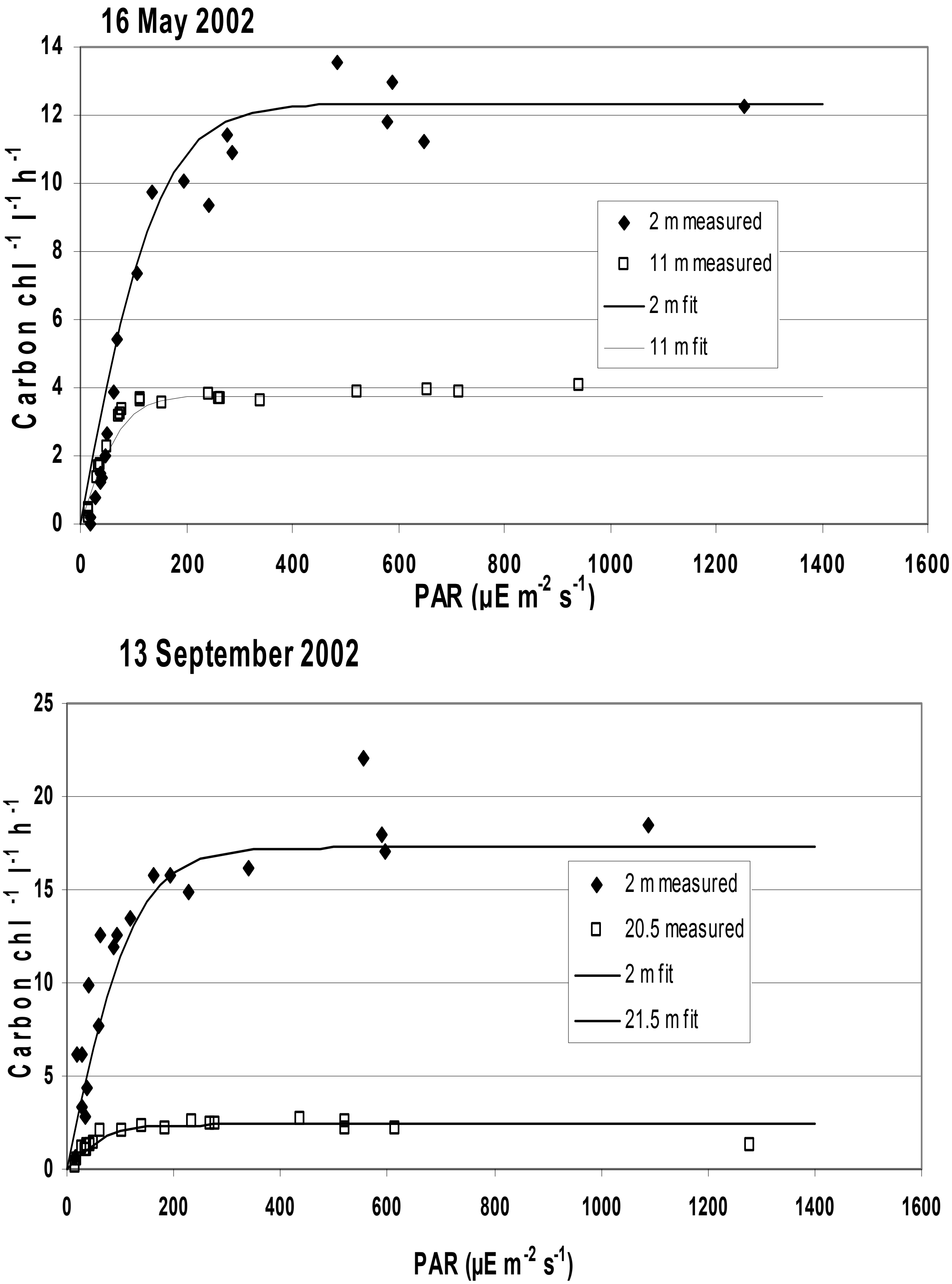
Figure 24



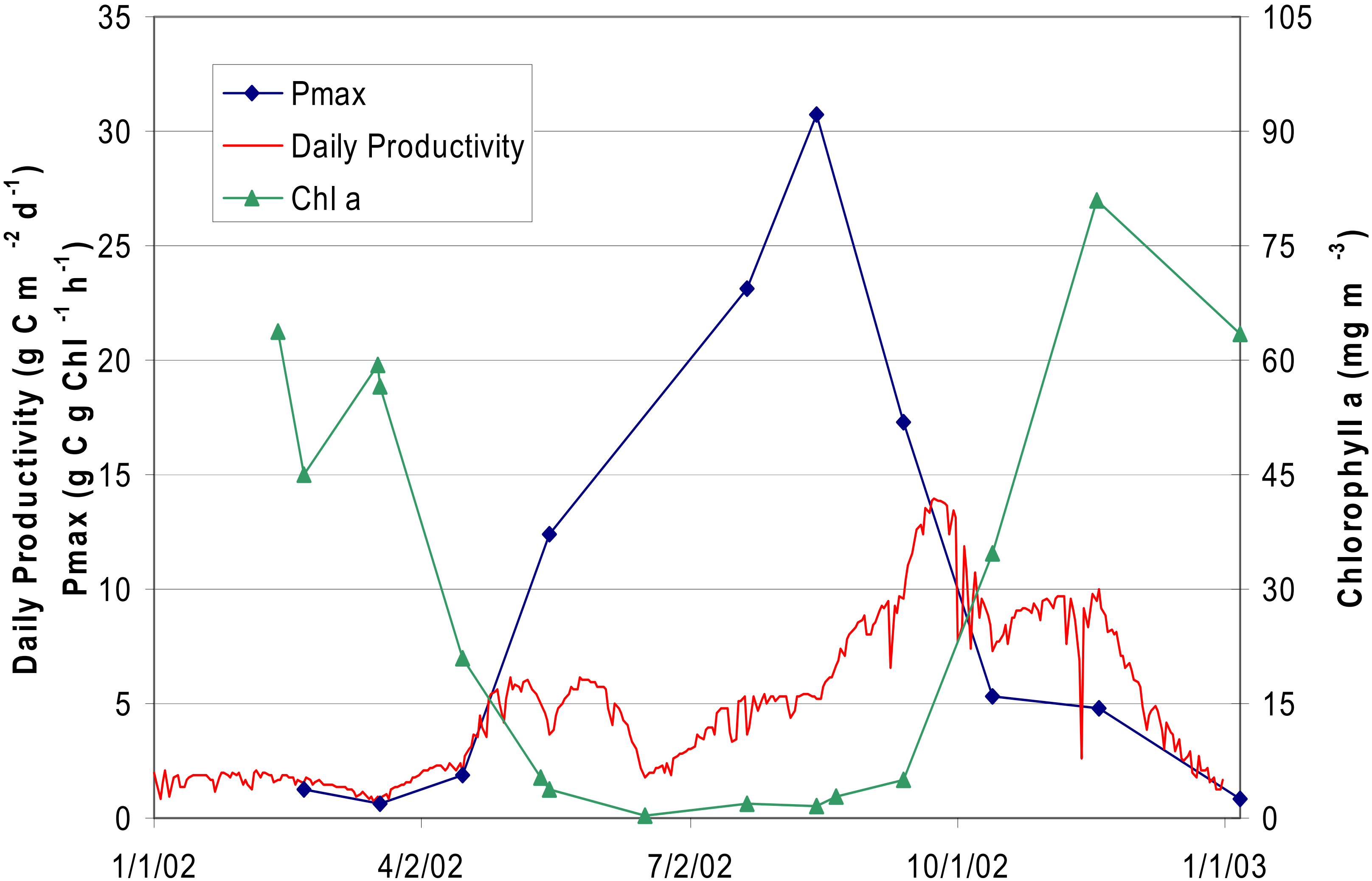
Adult *Artemia* Temporal Distribution

Figure 25

Figure 26

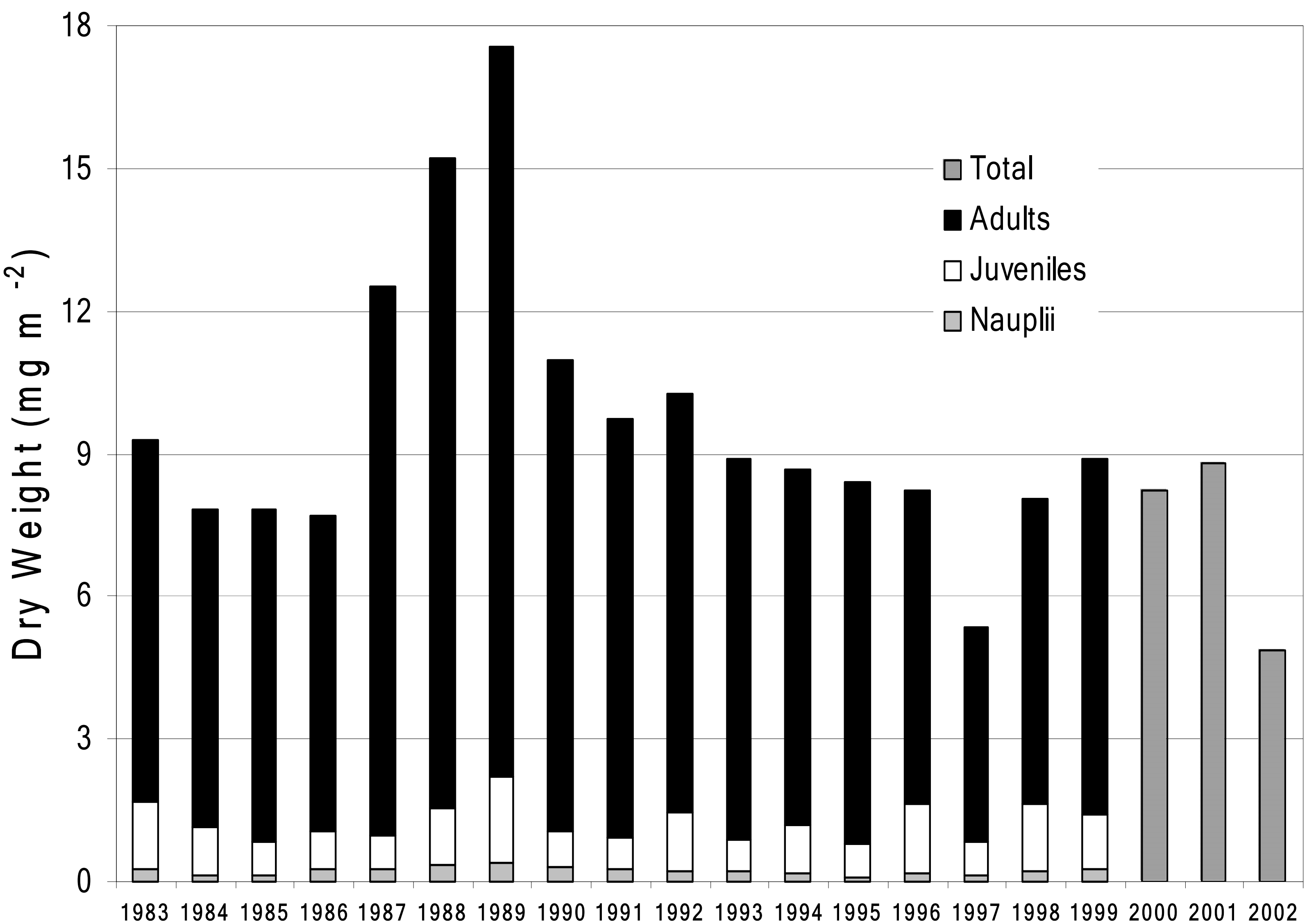


Photosynthetic Parameters



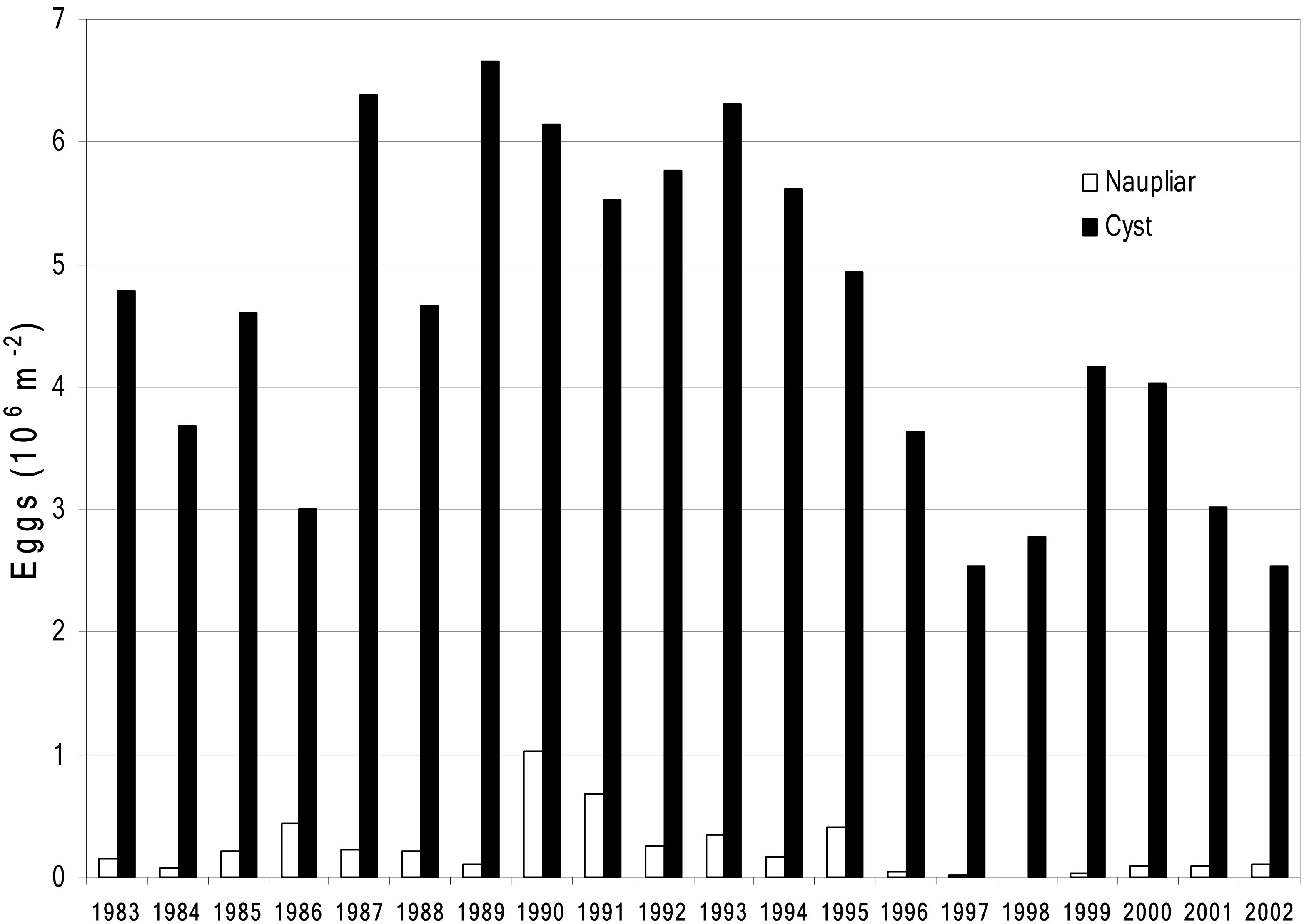
Primary Productivity

Figure 27



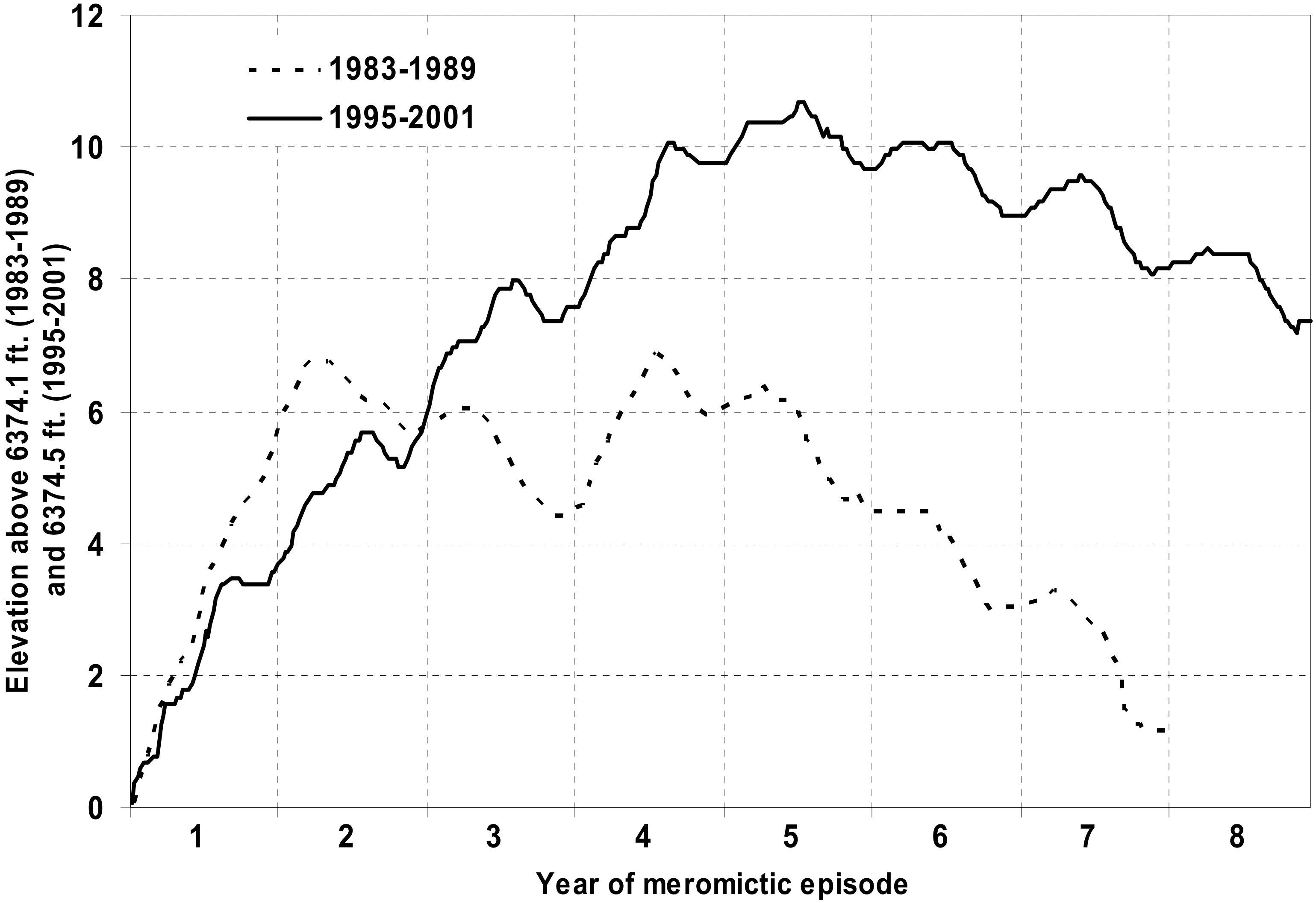
Mean Annual *Artemia* Biomass

Figure 28



Artemia Reproduction

Figure 29



Changes in Surface Elevation

Figure 30

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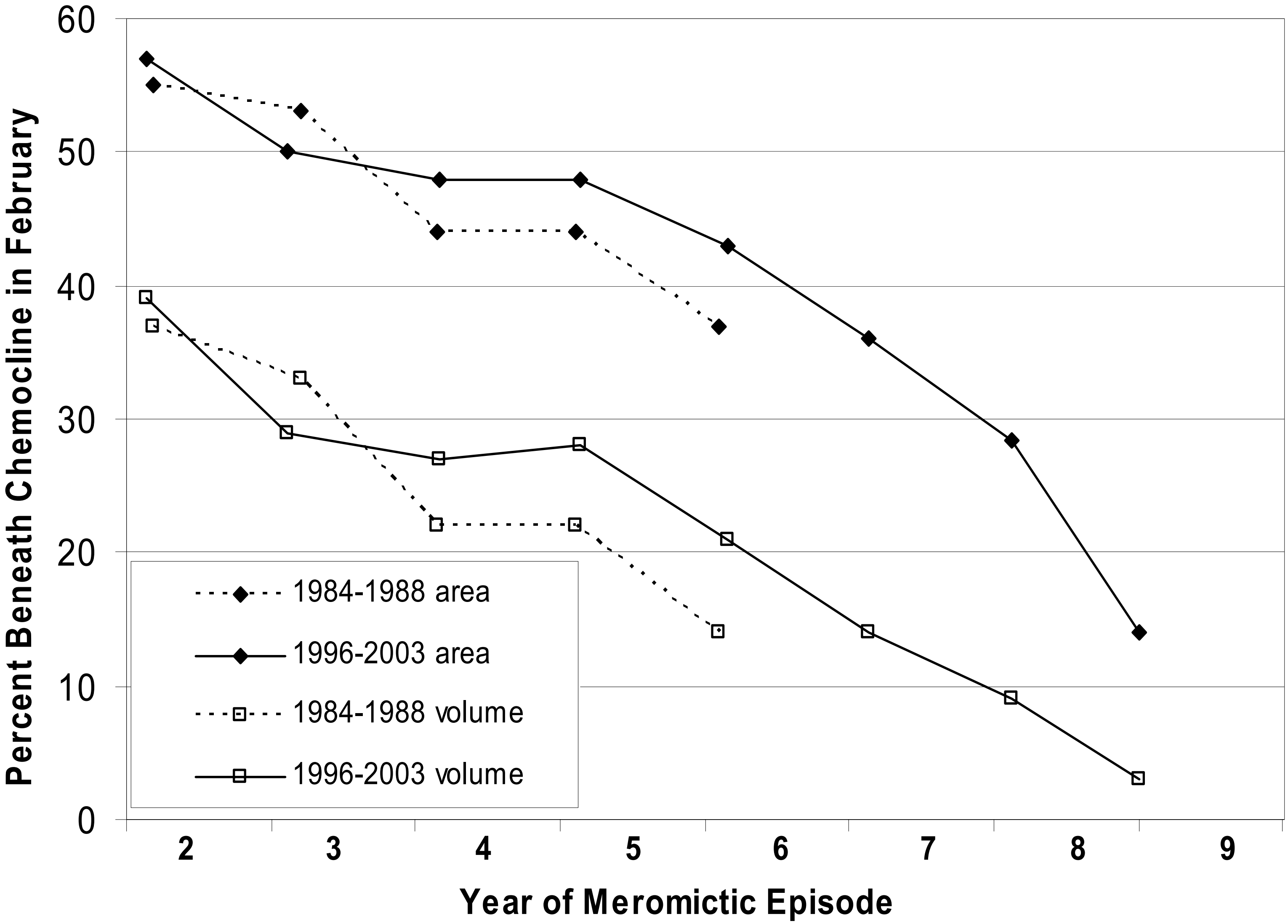
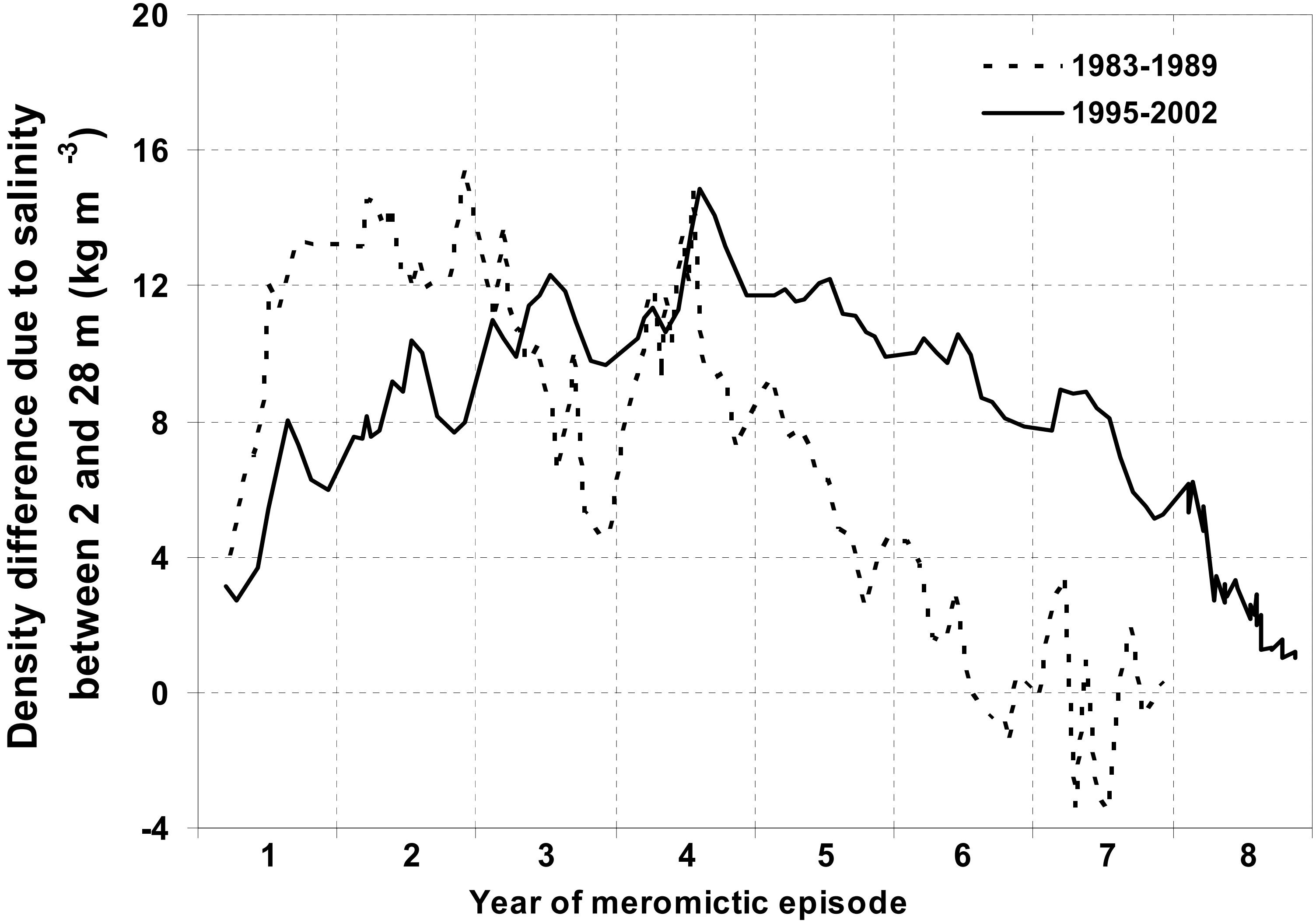


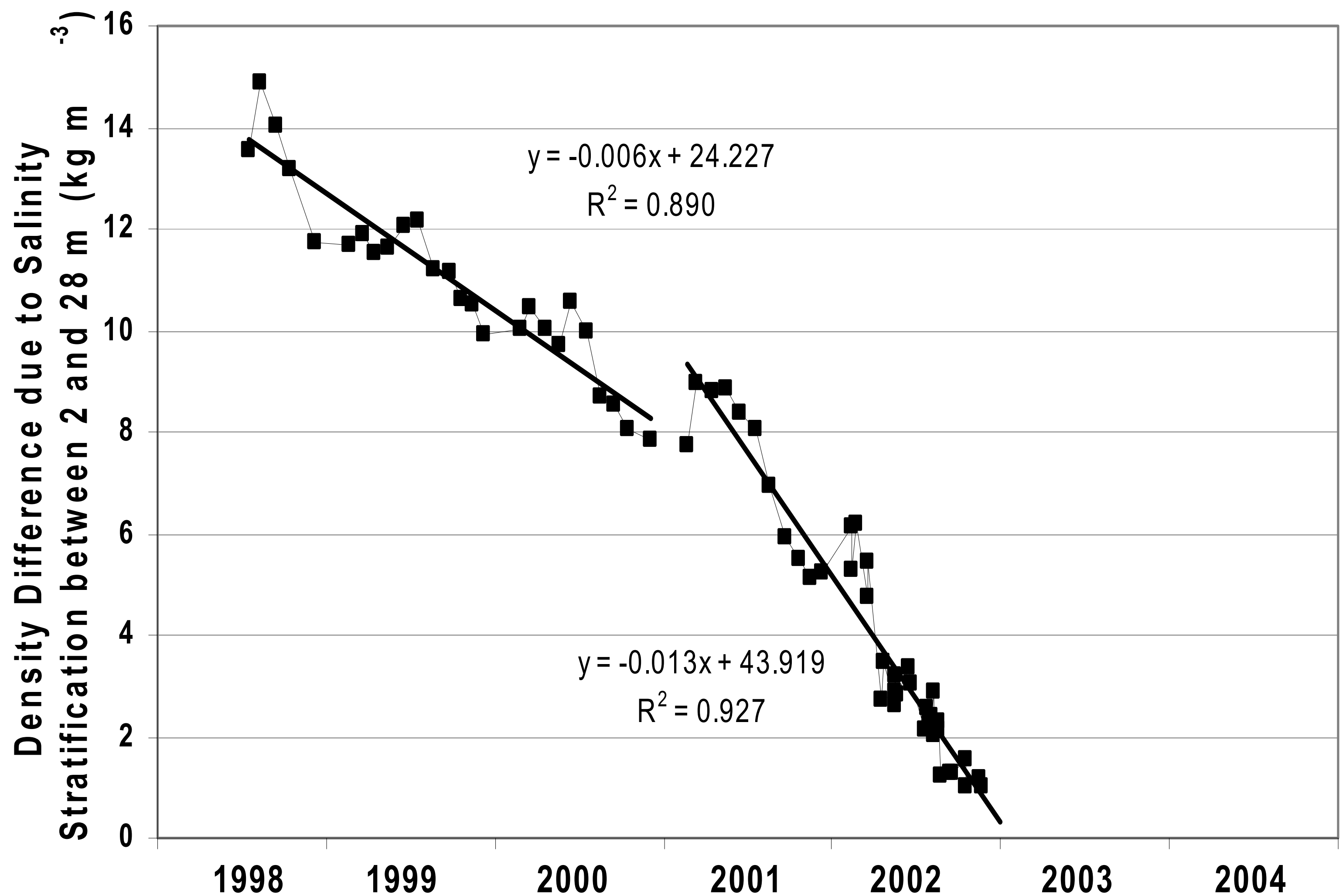
Changes in Percent Area and Volume beneath Chemocline

Figure 31



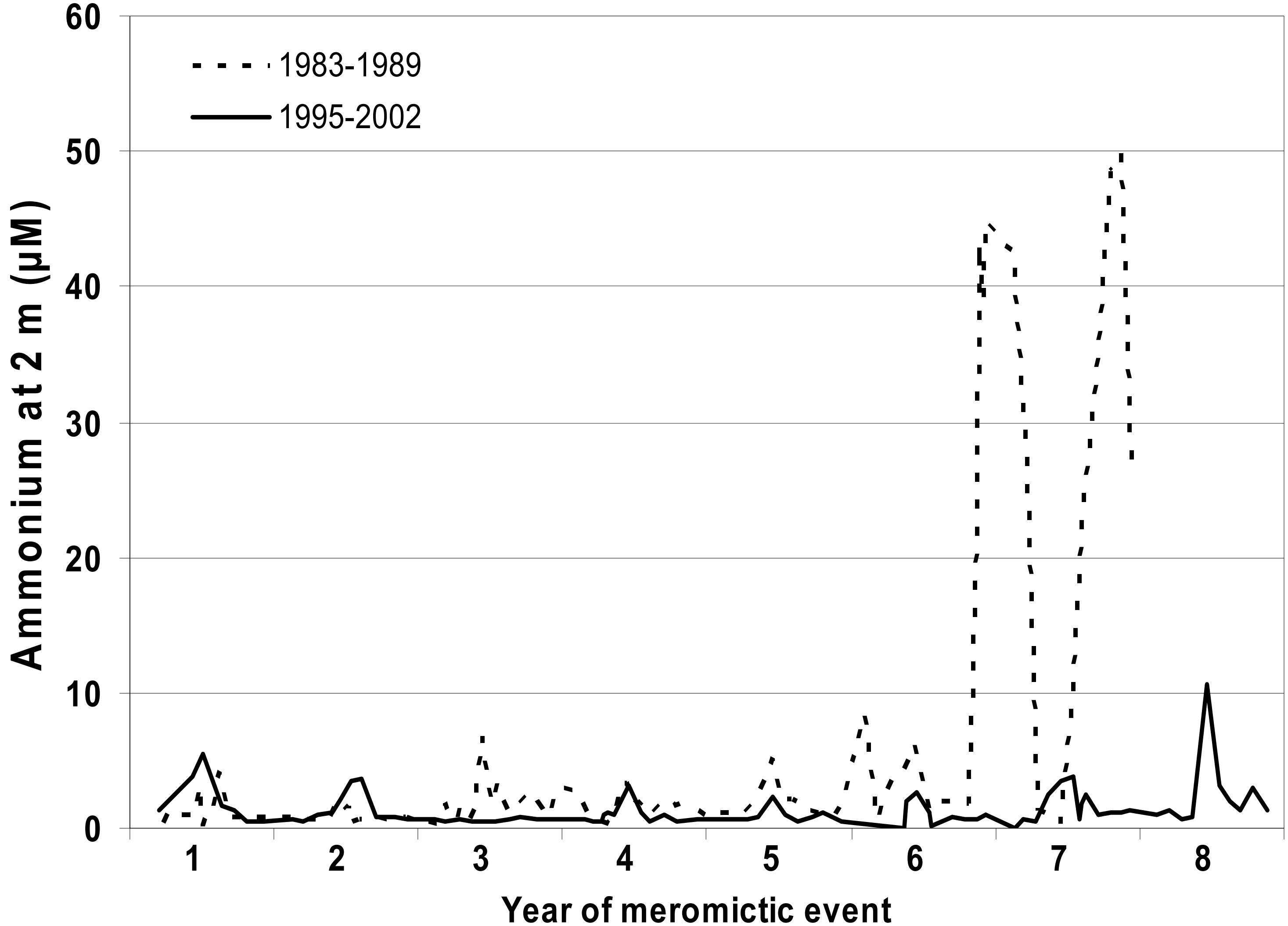
Changes in Salinity Stratification

Figure 32



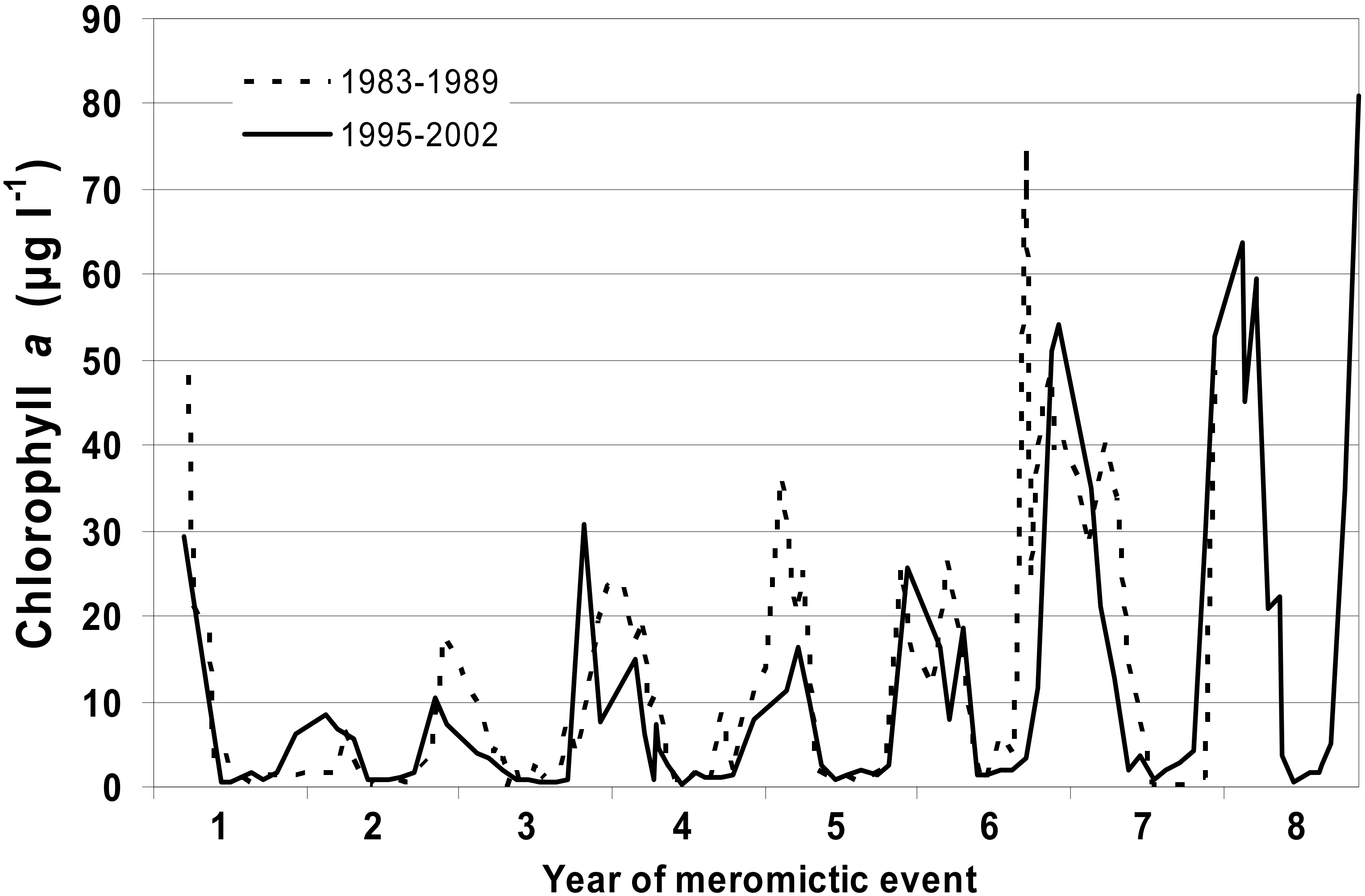
Temporal Trend of Salinity Stratification

Figure 33



Changes in Ammonium

Figure 34



Changes in Algal Biomass

Figure 35

Appendix 3 - Ornithology

2002 ANNUAL REPORT

MONO LAKE WATERFOWL POPULATION MONITORING

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
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BISHOP, CA 93514

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Executive Summary

Waterfowl populations were monitored in 2002 at Mono Lake, Crowley Reservoir, and Bridgeport Reservoir in compliance with State Water Resources Control Board Order 98-05. At Mono Lake, three summer ground counts and six fall aerial surveys for waterfowl were conducted. Three fall aerial surveys were conducted at Crowley and Bridgeport Reservoirs in order to provide data to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, or are specific to changes occurring at Mono Lake.

A total of ten waterfowl species were encountered at Mono Lake during summer surveys. The most frequently encountered waterfowl species during summer surveys was Gadwall, followed by Mallard, Cinnamon Teal and Northern Pintail. The Wilson Creek area attracted the greatest number of waterfowl throughout the summer survey season.

A minimum of 45 Gadwall, eight Mallard, and three Northern Pintail broods were detected during surveys. As was the case in 2001, the South Shore Lagoon, Wilson Creek, and Mill Creek areas supported the greatest number of waterfowl broods.

A total of 20 shorebird species were encountered during the summer surveys. Of the shorebird species that were detected throughout the summer, the most abundant breeding species was American Avocet. Other shorebird species for which evidence of breeding was detected include Wilson's Phalarope, Killdeer, Spotted Sandpiper, Snowy Plover and Long-billed Curlew. The Warm Springs and Sammann's Springs areas attracted the greatest number of shorebird species throughout the season.

A total of eleven waterfowl species were recorded at Mono Lake during fall aerial surveys. In terms of total detections, 25,351 waterfowl individuals were detected on the lake throughout the fall season, while 424 were detected at the Restoration Ponds. The peak number of waterfowl detected at Mono Lake was 7748 and occurred on the September 19 survey. At Mono Lake, the dominant species during fall migration were Northern Shovelers

and Ruddy Ducks. As was the case in 2001, the main areas of concentration of migrating Northern Shovelers were the Wilson Creek and Mill Creek deltas. The distribution of Ruddy Ducks was also similar to previous years, with the main areas of concentration occurring in the DeChambeau Embayment and Black Point areas. The Mill and/or Wilson Creek deltas accounted for 62% of all waterfowl detections throughout the entire fall period.

A total of 16 waterfowl species were recorded at Crowley Reservoir during fall aerial surveys. The peak number of waterfowl detected at Crowley Reservoir was 8153 individuals. The west shore of Crowley Reservoir (McGee Bay and Hilton Bay) held large numbers of waterfowl all season. Waterfowl in these two areas combined accounted for an average of 86% of all waterfowl detected at Crowley.

A total of 12 waterfowl species were recorded at Bridgeport Reservoir during fall aerial surveys. The West Bay area was the primary area of waterfowl concentration, accounting for an overall average of 90% of all waterfowl detected at this reservoir.

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

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population surveys and studies 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 Crowley and Bridgeport 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 2002. Three 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 18, 2002.

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INTRODUCTION

Waterfowl population monitoring is being conducted on an annual basis at Mono Lake in order to evaluate the response of waterfowl populations to restoration efforts in the Mono Basin watershed [State Water Resources Control Board Order Numbers 98-05 and 98-07 (Orders)]. The monitoring of waterfowl populations in the Mono Basin are expected to continue until at least the year 2014, or until the target lake level (6392 foot elevation) is reached and the lake cycles through a complete wet/dry cycle (LADWP 2000). 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 (and a subsequent decrease in the salinity of the lake), 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 passive restoration – proper flow management in the tributaries to achieve healthy, functional riparian systems, and decreased water diversions from the watershed that will result in increases in level of the lake.

Since waterfowl are migratory, their populations are influenced by factors on their wintering grounds, summering grounds, and along their migration route. In order to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, or are specific to changes occurring at Mono Lake, fall waterfowl surveys were also conducted at Crowley and Bridgeport Reservoirs.

All surveys were conducted by the author.

METHODS

Summer Ground Counts

Summer ground counts were conducted in order to document summer use by waterfowl and shorebird species of the Mono Lake shoreline, selected tributaries, and the freshwater restoration ponds. These ground surveys were conducted as area searches. Area searches were conducted by either transect surveys, or by making observations from a stationary point.

Three ground counts surveys were conducted at three to four week intervals beginning in early June. Three days were required to complete surveys of all areas. A summary of the ground count survey schedule is provided as Appendix 1. The locations surveyed were those identified in the Waterfowl Restoration Plan 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 Restoration Ponds (DEPO), and County Ponds (COPO). Areas surveyed during summer grounds counts are shown in Figure 1.

Transect surveys along the shoreline were conducted at South Tufa, South Shore Lagoons, Sammann's Spring, Warm Springs, Wilson Creek and Mill Creek sites. Transects surveys were conducted by walking at an average rate of approximately 2 km/hr. 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 or the flushing of waterfowl far ahead of the observer. In Lee Vining Creek, surveys of the creek channel were conducted by walking north 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 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 within 100 meters either side of the deltas were also recorded.

At the DeChambeau Creek delta, observations were taken from a stationary point at the end of the County Park. At this location, a spotting scope was used to scan the shoreline in the area indicated in Figure 1. Although the visibility of the shoreline to the east of the boardwalk was impaired by willows, this segment of the shoreline was not walked since the area is managed by the California State Parks and all efforts are made by this agency to keep the public on the boardwalk. Starting in 2003, this section of the shoreline will be walked, however, and a member of the Mono Lake Committee or other volunteer will remain at the end of the boardwalk to answer any questions the public may have about the ongoing survey.

At the DeChambeau Pond complex, observations were taken from a stationary point at each of the five ponds. At the County Ponds, observations were taken from a single location that allowed full viewing of both ponds. Observation points were selected as to provide a full view of each pond. The exact location of the observation point may change annually depending on vegetation growth. At the stationary observation points at the ponds, a minimum of 5 minutes was spent at each point.

All summer ground surveys were started 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 time spent surveying each area was recorded.

For every waterfowl and shorebird species encountered, the following were recorded based upon initial detection: the time of the observation, the habitat type the individual was using, and an activity code indicating how the bird, or birds, were using the habitat. If a waterfowl brood was detected, the size of the brood was recorded and the location of each brood was marked on an air photo while in the field. Each brood was also assigned to an age class based on plumage and body size (Gollop and Marshall 1954). Since the summer surveys were conducted at three-week intervals, any brood assigned to class I (which would include subclasses Ia, Ib, and Ic), using the Gollop and Marshall age classification scheme, would be a brood that hatched since a previous visit. This will allow for the determination of the minimum number of unique broods using Mono Lake wetland and shoreline habitats each year.

The habitat categories used follows the classification system found in the May 2000 Los Angeles Department of Water and Power report entitled "1999 Mono Basin Vegetation and Habitat Mapping". 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 as Appendix 2. Figures 2a – 2g are representative photos of these habitats. Two additional habitat types, open water (within 50 meters off-shore) and open water (>50 meters offshore), were used in order to more completely represent areas used by waterfowl and shorebirds. Although a ">50 meter" category was used, these observations will not be included in final calculations unless the presence of waterfowl off-shore is likely due to observer influence (e. g. the observer sees a that a female duck is leading her brood offshore and is continuing to swim away from shore).

The activity codes used were resting, foraging, flying over, nesting, brooding, sleeping, swimming, and other.

Fall Surveys

<u>Overview</u>

Aerial surveys were conducted in the fall at Mono Lake, Crowley Reservoir, and Bridgeport Reservoir. At Mono Lake, six surveys were conducted at two-week intervals beginning the first week of September and ending the middle of November. At Crowley and Bridgeport Reservoirs, three surveys were conducted, and were completed on the same day that Mono Lake surveys were done. The surveys at Crowley and Bridgeport Reservoir were conducted in conjunction with the second, fourth and sixth surveys of Mono Lake. A summary of the fall survey schedule is provided as Appendix 3.

Surveys of Mono Lake were started at approximately 0900 hrs and completed in approximately one and one-half hours. When all three water bodies were surveyed, Mono Lake was surveyed first, and the aerial surveys of both Bridgeport and Crowley were completed by 1200 hrs.

During initial flights, data were handwritten during the flight. During later flights, observations were recorded onto a handheld digital recorder, and then later transcribed.

Ground counts of the DeChambeau and County Pond complexes were conducted immediately after completion of the aerial flight. The protocol for the fall pond counts was the same as for the summer counts.

Mono Lake Aerial Surveys

Aerial surveys of Mono Lake consisted of a perimeter flight of the shoreline and fixed cross-lake transects. The shoreline was divided into 15 lakeshore segments. The segment boundaries are the same as those used by Jehl (2001) except for minor adjustments made in order to provide the observer with obvious landmarks that are seen easily from the air. The boundaries of the lakeshore segments are shown on a 2001 aerial photo as Figure 3 (2001 aerial image taken by A. K. Curtis, and processed by AirPhoto, USA). A description of the lakeshore segment boundaries and the four-letter code used for each area is provided as Appendix 4.

Under the proposed protocol (LADWP 2002), Mill and Wilson Creek were to be combined into one segment based on Jehl's experience while conducting surveys by boat in which birds would move between the two areas during the survey (Jehl 2001). Throughout the entire fall survey period, however, observations from these two areas were kept separate. Movement between areas (leading to the possibility of double-counting) was found to not be a problem when conducting the surveys by air, thus these two areas will continue to be treated separately during future surveys.

Eight cross-lake transects were established over the open water at Mono Lake. LADWP initially proposed to do four cross-lake transects, but felt that, given the uneven distribution of Ruddy Ducks and other species on the open water, four transects would not provide adequate coverage. The eight transects used for surveys were spaced at one-minute intervals and correspond to those used by Boyd and Jehl (1998) for conducting monitoring of Eared Grebes during fall migration (The location of each transect is provided as Appendix 5.

Each of the eight transects was further divided into two to four subsegments of approximate equal length (see Figure 3). The total length of each cross-lake transect was first determined from the 2001 aerial photo. These lengths were then divided into the appropriate number of subsections for a total of twenty-five subsegments of approximately 2 km each. This approach creates a grid-like sampling system that will allow for the evaluation of the spatial distribution of waterfowl on the open water. Since the airspeed and approximate length of each subsection was known, it was possible to use a stopwatch to determine the starting and stopping locations of each subsection when over open water.

Aerial surveys were conducted at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. The first survey was done in a Christen Husky while all subsequent surveys were done in a Cessna 172 XP. 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.

When conducting aerial surveys, the perimeter of the lake was flown first in a counterclockwise direction, starting in the Ranch Cove area. Perimeter surveys were conducted at approximately 250 meters from the shoreline. Cross-lake transects were flown immediately afterward, starting from the southernmost transect and proceeding north.

Crowley Reservoir Aerial Surveys

The shoreline of Crowley Reservoir was divided into seven segments (Figure 4). A description of the lakeshore segment boundaries and the four-letter code used for each can also be found in Appendix 4. Each survey began at the mouth of the Owens River (UPOW) and proceeded counterclockwise. The distance from shore, flight speed, and height aboveground were the same as at Mono Lake during most of each flight. On occasion, there were large numbers of fishermen on the water. This required the pilot to temporarily increase the height above ground during the flight in some areas of the lake.

Bridgeport Reservoir Aerial Surveys

The shoreline of Bridgeport was divided into three segments (Figure 5). Appendix 4 also contains a description of the lakeshore segment boundaries. 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 at Mono Lake. When flying over fisherman on the water, the pilot temporarily increased the height above ground.

Validation Counts

Ground validation counts were done at Mono Lake and Crowley Reservoir. Ground counts were conducted when flight conditions do not allow the identification of a large percentage of waterfowl encountered, or for confirmation of species or numbers present. During the ground validation counts an initial count of the total waterfowl present in an area was done. The researcher then recorded the number of individuals of each species present in the area. No attempt was made to count Ruddy Ducks at Mono Lake during ground validation counts.

Although not specifically required by the State Water Resources Control Board, ground validation counts were done at Crowley Reservoir as needed. At Crowley, validation counts were either done at the mouth of the Owens River or the west shore (McGee Bay and Hilton Bay). At the mouth of the Owens River, observations were made from an overlook to the west of the mouth of the Owens River. From this location, a count was done of the UPOW and LASP areas. Ground validation of the MCBA and HIBA areas was done by walking along the west shore from the Crowley Lake Fish Camp north.

Photo documentation

As required by the Orders, photo documentation of waterfowl habitats was done by taking photos of the shoreline from a helicopter. These photos were taken on September 18, 2002. Representative photos of each shoreline segment and the restoration ponds are found as Figures 6a - 6t.

In addition to the required photo documentation completed above, several permanent photo point locations were established on the ground. Photo point locations were established at Rush Creek, Lee Vining Creek, DeChambeau Creek, Mill Creek and Wilson Creek. Two stations per area were selected. These photos are not included in this report, but will be maintained in LADWP files. Due to time constraints, photo point locations (which are not required by the Orders) were not established in 2002 at the other key areas. This will be done in 2003.

Data Summary

<u>Summer ground counts</u>

Summer transect surveys - waterfowl

The number of waterfowl detected in each survey area during each visit can be found in Tables 1-3. A total of ten waterfowl species were encountered during summer surveys (Table 4). The most frequently encountered waterfowl species was Gadwall, followed by Mallard, Cinnamon Teal and Northern Pintail. Evidence of breeding in the area (presence of broods) was seen for all of these species except Cinnamon Teal. Ruddy Ducks, Redhead and Blue-winged Teal were also encountered in small numbers during all three surveys, however no evidence of breeding was detected for these species.

The Wilson Creek area attracted the greatest number of waterfowl throughout the season (Tables 1-3). Warm Springs and Sammann's Spring attracted fair numbers of waterfowl early in the season, but few in mid-summer. This pattern is consistent with that observed in 2001 (Jehl 2002).

Brood summary

A minimum of 45 Gadwall, eight Mallard, three Northern Pintail and eight American Coot unique broods were detected during surveys. The age class and size of each brood can be found in Table 5. The greatest number of unique waterfowl broods (15) was observed in the South Shore Lagoons area, followed by Wilson Creek and Mill Creek (Table

6). Although fair numbers of waterfowl were present in the Warm Springs and Sammann's Springs area early in the summer, only two broods were detected in Sammann's Springs. These findings are similar to those recorded during the surveys conducted the previous year (Jehl 2002). In terms of use by broods (defined as the total number of broods observed in each area during each visit over the entire survey period), the SSLA, WICR, and MICR were also the most heavily used (Table 7). No broods were detected in the South Tufa or Warm Springs areas. A total of seven American Coot broods were raised at the DeChambeau Ponds and one at the South Shore Lagoon area.

Summer transect surveys – shorebirds

A total of 20 shorebird species were encountered during the summer surveys. Of the shorebird species that were detected throughout the summer, the most abundant breeding species was American Avocet (Table 4). Other shorebird species for which evidence of breeding was detected include Wilson's Phalarope, Killdeer, Spotted Sandpiper, Snowy Plover and Long-billed Curlew. The Warm Springs and Sammann's Springs areas attracted the greatest number of shorebird species throughout the season (Tables 1-3).

Restoration Ponds

All five DeChambeau Ponds contained water all season. County Pond 2 was almost dry on the first visit, dry on the second, and then full on the third visit.

The American Coot was the most abundant breeding species at the DeChambeau Ponds, where a minimum of seven broods were raised. Two Gadwall broods were detected at DeChambeau Ponds, while one Gadwall and one Northern Pintail brood were seen at County Pond 1.

Fall Surveys

Mono Lake Aerial Surveys

A total of eleven waterfowl species were recorded at Mono Lake during fall aerial surveys (Table 8). The peak number of waterfowl detected at Mono Lake was 7748 and occurred on the September 19 survey (Table 9). This peak coincided with the peak at Crowley and Bridgeport Reservoirs (Table 9, Figure 7). At Mono Lake, the dominant species during fall migration were Northern Shovelers and Ruddy Ducks (Figure 8). The peak number of Northern Shovelers recorded was 4347 individuals and occurred on the second survey (19 September). The majority of Northern Shovelers using the lake were detected from early September to the first week of October in the Mill and/or Wilson Creek deltas (Tables 10 –15). These two areas also accounted for 62% of all detections throughout the entire fall period (Table 16), mostly due to the presence of the Northern Shovelers. Areas of secondary use were DeChambeau Creek delta and Sammann's Spring. By mid-October, fewer than 400 Northern Shovelers were present at the lake. The peak number of Ruddy Ducks (3757) occurred two weeks later (3 October) than that of Northern Shoveler. During this peak count, approximately 1/3 of the Ruddy Ducks counted were detected on the cross-lake transects. The majority of Ruddy Ducks detected on shoreline surveys were in the DEEM, BLPO, and WESH areas (Table 16). Field notes on the ground-truthing conducted at Mono Lake are provided as Appendix 6.

Ground Counts - Restoration Ponds

A total of 11 waterfowl species were detected at the DeChambeau and County Pond complexes during fall surveys (Tables 17 to 22). County Pond 2 was dry during the first three visits of the season. On the last three visits (from October 17 on), the pond was full, but the only ducks seen in this pond were decoys. The most frequently encountered species at DEPO were American Coots, followed by Gadwall. At COPO, Gadwall was the most abundant species.

Crowley Reservoir

A total of 16 waterfowl species were recorded at Crowley Reservoir during fall aerial surveys (Table 23). The peak number of waterfowl detected at Crowley Reservoir was 8153 individuals. Green-winged Teal was a dominant species throughout the season. Peak numbers of Green-winged Teal at Crowley Reservoir were detected mid-September (Figure 9). Peak numbers of Northern Pintail at Crowley Reservoir were also recorded during mid-September. Ruddy Ducks were the most abundant species in mid-October, while Mallards were most abundant mid-November. American Coots were very abundant all season at Crowley, and were the most abundant waterbird species at the reservoir through mid-October. The west shore of Crowley Reservoir (McGee Bay and Hilton Bay) held large numbers of waterfowl all season. Waterfowl in these two areas combined accounted for an average of 86% of all waterfowl detected at Crowley (Table 24). The Layton Springs and Upper Owens River area were the second largest areas of waterfowl concentration.

Bridgeport Reservoir

A total of 12 waterfowl species were recorded at Bridgeport Reservoir during fall aerial surveys (Table 25). The West Bay area was the primary area of waterfowl concentration, accounting for an overall average of 90% of all waterfowl detected at this reservoir (Table 26). Mallards, Northern Pintail, and Ruddy Ducks were the most abundant species in mid-September (Figure 10). Green-winged Teal were common at Bridgeport all season but peak numbers occurred mid-November. Mallards were codominate with Green-winged Teal in mid-October, while Green-winged Teal and Canada Geese were the most abundant species at this reservoir in mid-November.

Analysis of trend in waterfowl numbers

Simple linear regression analysis was used to evaluate the trend in peak waterfowl numbers detected at Mono Lake since 1996. This analysis was done only on counts excluding Ruddy Duck numbers. The regression equation was then tested using ANOVA to determine the significance of the regression, e.g. is the slope significantly different from zero (Zar 1996), indicating either a significant positive or negative trend in peak waterfowl numbers. The 1996 to 2001 data indicates a significant positive trend in peak waterfowl numbers ($p = 0.036$, $df = 1,4$). This data should be interpreted cautiously on a biological basis, though, due to the limited sample size. Addition of the 2002 data to the analysis did not change the outcome of the test ($p = 0.018$, $df = 1,5$). Figure 11 is graph of the regression line that illustrates the relationship of the peak number of waterfowl detected at Mono Lake over time (1996-2002).

DISCUSSION

Three waterfowl species (Gadwall, Mallard and Northern Pintail) were found to use the Mono Lake wetlands during the brooding period. Mallards, which have not been documented using Mono Lake wetlands or shorelines in previous monitoring reports, were the second most abundant in terms of the number of broods found during surveys in 2002. No Green-winged Teal broods were seen this year, although this species has nested in Lee Vining and Wilson Creeks (Heath, unpublished data) away from the immediate shoreline, and a female brooded young in the Lee Vining bottomlands in 2001 (House, unpublished data). The four other species present throughout the summer (Cinnamon Teal, Blue-winged Teal, Redhead, and Ruddy Ducks) could potentially breed in the Mono Basin, although broods were not detected in the areas surveyed in 2002. The total number of waterfowl broods detected in 2002 (56) is comparable to that reported in 2001 (55) for lakewide surveys. Since, unlike surveys conducted in 2001, the West Shore, Ranch Cove, and

Paoha Island (other areas where significant numbers of broods were detected) were not surveyed in 2002, it seems reasonable to conclude that the total number of broods using Mono Lake was greater in 2002 than in 2001. As was the case in the previous year, the Wilson Creek, Mill Creek and South Shore Lagoon area supported the greatest number of waterfowl broods.

Fall migration at Mono Lake was dominated by the presence of Northern Shovelers and Ruddy Ducks. As was the case in 2001, the main areas of concentration of migrating Northern Shovelers were the Wilson Creek and Mill Creek deltas. The distribution of Ruddy Ducks was also similar to previous years, with the main areas of concentration occurring in the DeChambeau Embayment and Black Point areas as well as the entire west shore. An analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996. Although this analysis of the short-term trend is intriguing, the variable nature of population data necessitates caution in the interpretation of short-term trends.

References

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.

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. 2000. 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). 1996. Mono Lake Waterfowl Population Monitoring Protocol. Prepared for the State Water Resources Control Board.

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

Table 1. Summer ground data, Survey 1 – May 20-22, 2002

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal						2	1					**3**
Cinnamon Teal			3		5	4	14				6	**32**
Gadwall	11	12	15	11	4	15	30	14	11	28	150	**301**
Green-winged Teal		3	2			3	3	1				**12**
Mallard	4	7	6		7	11	24	9	1	10	2	**81**
Northern Pintail			1		2	8	13	1		1		**26**
Northern Shoveler						4						**4**
Redhead	3			5	2					1	7	**18**
Ruddy Duck											10	**10**
Unidentified *Anas* sp.			4									**4**
Total waterfowl by area	**18**	**22**	**31**	**16**	**20**	**47**	**85**	**25**	**12**	**40**	**175**	**491**
Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		4	2		9	71	107	57	27		24	**301**
Black-bellied Plover						2						**2**
Black-necked Stilt						15	2				2	**19**
Dowitcher sp											2	**2**
Killdeer	5	9			1	1	5	4	10	4	8	**47**
Long-billed Curlew						1	2	1				**4**
Snowy Plover						5						**5**
Spotted Sandpiper	2	8									3	**13**
Willet						1						**1**
Wilson's Phalarope			2			126	169		2		6	**305**
Total shorebirds	**7**	**21**	**4**	**0**	**10**	**222**	**285**	**62**	**39**	**4**	**45**	**699**

Table 2. Summer ground data, Survey 2 – June 5-7, 2002

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal						2					2	**4**
Cinnamon Teal	1	2		8	4	1	1	1			4	**22**
Gadwall	4	5	6	6	7	1	24	44		16	128	**241**
Green-winged Teal	1	2	2		1			2				**8**
Lesser Scaup					1							**1**
Mallard	2	2	1		1		9	8		1	14	**38**
Northern Pintail	1				2		3	3				**9**
Redhead	4											**4**
Ruddy Duck				1			1					**2**
Unidentified *Anas* sp.										85		**85**
Total waterfowl	**13**	**11**	**9**	**15**	**16**	**4**	**38**	**58**	**0**	**102**	**148**	**414**
Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		4	35			188	109	51	57	1	8	**453**
Black-necked Stilt						7						**7**
Dowitcher sp.						2			2			**4**
Greater Yellowlegs						1	4					**5**
Killdeer	2	3	3		3	5	5		2	5	9	**37**
Lesser Yellowlegs						1						**1**
Long-billed Curlew							2	3				**5**
Snowy Plover						18	40					**58**
Spotted Sandpiper	22	9									2	**33**
We/Le Sandipiper							22					**22**
Western Sandpiper						7	26					**33**
Whimbrel							1					**1**
Willet						2						**2**
Wilson's Phalarope	425	2	8000			34	7	19	1		290	**8778**
Total shorebirds	**449**	**18**	**8038**	**0**	**3**	**265**	**216**	**73**	**62**	**6**	**309**	**9439**

Table 3. Summer ground data, Survey 3 – July 1-3, 2002

Waterfowl Species	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal											2	**2**
Cinnamon Teal	2						1				10	**13**
Gadwall	4		6	2	2		2	7		18	18	**59**
Mallard						4	3	6		9	1	**23**
Northern Pintail				2				1			1	**4**
Redhead										3	2	**5**
Ruddy Duck										10		**10**
Unidentified *Anas* sp.			1									**1**
Total waterfowl	**6**	**0**	**7**	**4**	**2**	**4**	**6**	**14**	**0**	**40**	**34**	**117**

Table 3, continued. Summer ground data, Survey 3 – July 1-3, 2002

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet			22			495	359	114	68		25	**1083**
Baird's Sandpiper						4						**4**
Black-necked Stilt										5		**5**
Dowitcher sp							12					**12**
Greater Yellowlegs					3	5						**8**
Killdeer	2	21	3		5	10	11	3	2	11	10	**78**
Least Sandpiper		8				17	26		3			**54**
Long-billed Curlew		1						5				**6**
Long-billed Dowitcher						7	1					**8**
Marbled Godwit						2	1					**3**
Phalarope sp.			5				2750	1070			48	**3873**
Red-necked Phalarope							372	141		65		**578**
Short-billed Dowitcher								1				**1**
Snowy Plover						1	10					**11**
Solitary Sandpiper									1			**1**
Spotted Sandpiper	7	8					1			8		**24**
We/Le Sandipiper						73	18					**91**
Western Sandpiper						17	68					**85**
Willet							6	25				**31**
Wilson's Phalarope	183	1				1	1309	26		14	5	**1539**
Total shorebirds	**192**	**39**	**30**	**0**	**8**	**632**	**4944**	**1385**	**74**	**103**	**88**	**7495**

Table 4. Summary of ground count data for Mono Lake, 2002

Waterfowl species	Survey 1	Survey 2	Survey 3
Blue-winged Teal	3	4	2
Cinnamon Teal	32	22	13
Gadwall	301	241	59
Green-winged Teal	12	8	
Lesser Scaup		1	
Mallard	81	38	23
Northern Pintail	26	9	4
Northern Shoveler	4		
Redhead	18	4	5
Ruddy Duck	10	2	10
Unidentified *Anas* sp.	4	85	1

Shorebirds	Survey 1	Survey 2	Survey 3
American Avocet	301	453	1083
Baird's Sandpiper			4
Black-bellied Plover	2		
Black-necked Stilt	19	7	5
Dowitcher sp.	2	4	12
Greater Yellowlegs		5	8
Killdeer	47	37	78
Least Sandpiper			54
Lesser Yellowlegs		1	
Long-billed Curlew	4	5	6
Long-billed Dowitcher			8
Marbled Godwit			3
Phalarope sp.			3873
Red-necked Phalarope			578
Short-billed Dowitcher			1
Snowy Plover	5	58	11
Spotted Sandpiper	13	33	24
Solitary Sandpiper			1
We/Le Sandpiper		22	91
Western Sandpiper		33	85
Whimbrel		1	
Willet	1	2	31
Wilson's Phalarope	305	8778	1539

Table 5. Brood data

Date	Location	Species	Age Class	Brood size
June 5, 2002	COPO	Northern Pintail	IA	2
June 6, 2002	SSLA	Mallard	IA	4
June 6, 2002	SSLA	Mallard	IA	4
June 7, 2002	RUCR	Mallard	III	2
July 1, 2002	DECR	Gadwall	IA	10
July 1, 2002	DEPO	American Coot		2
July 1, 2002	DEPO	American Coot		4
July 1, 2002	DEPO	American Coot		1
July 1, 2002	DEPO	American Coot		7
July 1, 2002	DEPO	Gadwall	IB	11
July 1, 2002	LVCR	Gadwall	IB	12
July 1, 2002	LVCR	Gadwall	IB	7
July 1, 2002	MICR	Gadwall	IIA	4
July 1, 2002	MICR	Mallard	IA	3
July 1, 2002	WICR	Gadwall	IIA	5
July 1, 2002	WICR	Gadwall	1A	6
July 2, 2002	RUCR	Mallard	III	8
July 2, 2002	SSLA	American Coot		4
July 2, 2002	SSLA	Gadwall	IA	10
July 2, 2002	SSLA	Gadwall	IB	6
July 2, 2002	SSLA	Gadwall	IB	8
July 2, 2002	SSLA	Gadwall	IA	2
July 2, 2002	SSLA	Gadwall	IA	8
July 2, 2002	SSLA	Mallard	IIB	4
July 2, 2002	SSLA	Mallard	IA	4
July 2, 2002	SSLA	Mallard	IIB	3
July 2, 2002	SSLA	Northern Pintail	II B	3
July 3, 2002	SASP	Gadwall	IIB	10
July 3, 2002	SASP	Mallard	IC	15
July 22, 2002	COPO	Gadwall	IIA	3
July 22, 2002	COPO	Gadwall	IA	11
July 22, 2002	DECR	*Anas* sp.	II	6
July 22, 2002	DECR	Gadwall	IIA	8
July 22, 2002	DECR	Gadwall	IB	6
July 22, 2002	DECR	Gadwall	IC	5
July 22, 2002	DECR	Gadwall	IA	5
July 22, 2002	DECR	Gadwall	IB	7
July 22, 2002	DECR	Gadwall	IB	10
July 22, 2002	DEPO	American Coot		2
July 22, 2002	DEPO	American Coot		4
July 22, 2002	DEPO	American Coot		4
July 22, 2002	DEPO	American Coot		3
July 22, 2002	DEPO	American Coot		4
July 22, 2002	DEPO	American Coot		2
July 22, 2002	DEPO	American Coot		5
July 22, 2002	DEPO	American Coot		2
July 22, 2002	DEPO	Gadwall	IC	5
July 22, 2002	DEPO	Gadwall	IIA OR IIB	11
July 22, 2002	DEPO	Northern Pintail	Flying	1
July 22, 2002	LVCR	Gadwall	IB	10

Table 5 Cont.				
July 22, 2002	LVCR	Gadwall	IA	9
July 22, 2002	LVCR	Gadwall	IA	7
July 22, 2002	LVCR	Gadwall	II	8
July 22, 2002	MICR	Gadwall	IC	6
July 22, 2002	MICR	Gadwall	IC	6
July 22, 2002	MICR	Gadwall	IB	7
July 22, 2002	MICR	Gadwall	IA	7
July 22, 2002	MICR	Gadwall	IB	6
July 22, 2002	MICR	Gadwall	IIB	5
July 22, 2002	MICR	Gadwall	IA	8
July 22, 2002	MICR	Gadwall	II	3
July 22, 2002	MICR	Mallard	IA	4
July 22, 2002	WICR	Gadwall	I	10
July 22, 2002	WICR	Gadwall	IB	12
July 22, 2002	WICR	Gadwall	IB	12
July 22, 2002	WICR	Gadwall	IA	9
July 22, 2002	WICR	Gadwall	IA	10
July 22, 2002	WICR	Gadwall	IC	11
July 22, 2002	WICR	Gadwall	IA	8
July 22, 2002	WICR	Gadwall	IC	9
July 22, 2002	WICR	Gadwall	IC	24
July 22, 2002	WICR	Mallard	II	4
July 22, 2002	WICR	Northern Pintail	IIC	3
July 23, 2002	SSLA	American Coot		2
July 23, 2002	SSLA	Gadwall	IA	8
July 23, 2002	SSLA	Gadwall	IA	8
July 23, 2002	SSLA	Gadwall	IB	9
July 23, 2002	SSLA	Gadwall	II	9
July 23, 2002	SSLA	Gadwall	III	10
July 23, 2002	SSLA	Gadwall	IC	4
July 23, 2002	SSLA	Mallard	IC	4

Table 6. Summary of brood data

Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total unique broods
Survey 1		2			1			2				5
Survey 2	2		1	1			2	8		2	2	18
Survey 3	3		5	1	1			5		7	11	33
Unique broods per area	5	2	6	2	2	0	2	15	0	9	13	56

Table 7. Total number of broods present in each area on each visit

Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR
Survey 1		2			1			2			
Survey 2	2	1	1	1			2	10		2	2
Survey 3	4		7	3	2			7		9	12
Total broods detected	6	3	8	4	3	0	2	19	0	11	14
American Coot broods				7				1			

Table 8. Summary of fall aerial survey counts – Mono Lake

Species	5 Sept	19 Sept	3 Oct	17 Oct	31 Oct	14 Nov
American Wigeon	0	10	0	4	5	0
Bufflehead			1	0	0	0
Canada Goose			12	0	5	34
Cinnamon Teal	105	4	0	0	0	0
Gadwall	650	52	2	0	0	5
Green-winged Teal	50	60	154	277	245	203
Mallard	85	35	39	80	357	39
Northern Pintail			15	5	0	6
Northern Shoveler	3540	4347	2492	355	3	0
Redhead	0	9	0	0	0	0
Ruddy Duck	110	3101	3757	2782	1106	646
Unidentified *Anas* sp.	100	130	95	80	25	238
Unidentified diving ducks						12
American Coot	0	17	41	36	7	164

Table 9. Total waterfowl individuals detected during aerial surveys

Waterbody	5 Sept	19 Sept	3 Oct	17 Oct	31 Oct	14 Nov
Mono	4640	7731	6531	3619	1746	1084
Crowley		8153		5202		5614
Bridgeport		3052		1142		1531

Table 10. Mono Lake - fall aerial survey, 5 September, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	**Total**
Species																	
Cinnamon Teal	5								100								105
Gadwall	120		450								80						650
Green-winged Teal									50								50
Mallard									85								85
Northern Shoveler				10							3500			30			3540
Ruddy Duck																110	110
Unidentified *Anas* sp.				45										55			100
Total	**125**	**0**	**450**	**55**	**0**	**0**	**0**	**0**	**235**	**0**	**3580**	**0**	**0**	**85**	**0**	**110**	**4640**

Table 11. Mono Lake - fall aerial survey, 19 September, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	**Total**
Species																	
American Wigeon									4						6		10
Cinnamon Teal					1		3										4
Gadwall				10							20	10	10	2			52
Green-winged Teal	15			35	10												60
Mallard	9			5	8						1		10		2		35
Northern Shoveler				40					7	3500		800					4347
Redhead				9													9
Ruddy Duck								1500	600		30					971	3101
Unidentified										65	40		25				130
Total Waterfowl	**24**	**0**	**0**	**99**	**19**	**0**	**3**	**1500**	**611**	**3565**	**91**	**810**	**45**	**2**	**8**	**971**	**7748**
American Coot																17	17

Table 12. Mono Lake - fall aerial survey, 3 October, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	Total
Species																	
Bufflehead															1		1
Canada Goose				12													12
Gadwall										2							2
Green-winged Teal				45	22					45		30		12			154
Mallard					8			3				25	2	1			39
Northern Pintail				6								5	1			3	15
Northern Shoveler	250							12		1900	300	30					2492
Ruddy Duck		90						328		30	500	200	1230	35	17	1327	3757
Unidentified *Anas* sp.	50			45													95
Total Waterfowl	**300**	**90**	**0**	**108**	**30**	**0**	**0**	**343**	**0**	**1977**	**800**	**290**	**1233**	**48**	**18**	**1330**	**6567**
American Coot																41	41

Table 13. Mono Lake - fall aerial survey, 17 October, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	Total
Species																	
American Wigeon																4	4
Green-winged Teal			2	65								135		75			277
Mallard				45				22				4	9				80
Northern Pintail										5							5
Northern Shoveler				5						350							355
Ruddy Duck	51	21	1					363	781	9	22	7	187	215	292	833	2782
Unidentified *Anas* sp.										15		65					80
Total Waterfowl	**51**	**21**	**3**	**115**	**0**	**0**	**0**	**385**	**781**	**379**	**22**	**211**	**196**	**290**	**292**	**837**	**3583**
American Coot				27												9	36

Table 14. Mono Lake - fall aerial survey, 31 October, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	Total
Species																	
American Wigeon																5	5
Canada Goose												5					5
Green-winged Teal					10							115		120			245
Mallard	18			275	30			12	4	2		16					357
Northern Shoveler														3			3
Ruddy Duck	164	46	6					68	22		41		175	124		460	1106
Unidentified *Anas* sp.				25													25
Total Waterfowl	**182**	**46**	**6**	**300**	**40**	**0**	**0**	**80**	**26**	**2**	**41**	**136**	**175**	**247**	**0**	**465**	**1746**
American Coot								4								3	7

Table 15. Mono Lake - fall aerial survey, 14 November, 2002

Lakeshore segment	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO	Cross-lake	Total
Species																	
American Wigeon																	0
Bufflehead														1			1
Canada Goose				8			4			8		14					34
Cinnamon Teal																	0
Gadwall														5			5
Green-winged Teal										123				80			203
Mallard					18			12					1	8			39
Northern Pintail														6			6
Northern Shoveler																	0
Redhead																	0
Ruddy Duck	42	36	1					2	72	33			16	94	72	278	646
Unidentified *Anas* sp.			3	15										120			138
Unidentified diving				12													12
Total Waterfowl	**42**	**36**	**4**	**35**	**18**	**0**	**4**	**14**	**72**	**164**	**0**	**14**	**17**	**314**	**72**	**278**	**1084**
American Coot	35		12											75	8	34	164

Table 16. Percentage of all waterfowl detections during fall surveys by lakeshore segment – Mono Lake

Survey area	Waterfowl, exclusive of Ruddy Ducks	Ruddy Ducks only
RUCR	4.5	2.3
SOTU	0.0	1.7
SSLA	4.4	0.1
SASP	7.1	0.0
WASP	1.0	0.0
NESH	0.0	0.0
BRCR	0.1	0.0
DEEM	0.6	19.8
BLPO	2.4	12.9
WICR	24.1	0.6
MICR	38.1	5.2
DECR	12.0	1.8
WESH	0.6	14.1
LVCR	5.0	4.1
RACO	0.1	3.3
Cross-lake	0.1	34.0

Table 17. Mono Lake – Fall pond survey, 5 September, 2002

	DeChambeau Ponds					County Ponds		Total
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	
American Coot	18	30	15	7		3		73
Blue-winged Teal						1		1
Cinnamon Teal	3				6	4		13
Gadwall			5	8	5	65		83
Green-winged Teal					1			1
Mallard				1		5		6
Northern Pintail						10		10
Northern Shoveler	1							1
Ruddy Duck		5	2	4				11

Table 18. Mono Lake – Fall pond survey, 19 September, 2002

	DeChambeau Ponds					County Ponds		Total
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	
American Coot	10	46	12			4		72
Blue-winged Teal								
Cinnamon Teal		3				3		6
Gadwall		3		26	12	6		47
Green-winged Teal					3	4		7
Mallard				1		12		13
Northern Pintail						2		2
Northern Shoveler						2		2
Pied-billed Grebe		1	1					2
Ring-necked Duck				1				1
Ruddy Duck		4	6	4				14

Table 19. Mono Lake – Fall pond survey, 3 October, 2002

	DeChambeau Ponds					County Ponds		
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**Total**
American Coot	25	50	12					87
American Wigeon				4		3		7
Cinnamon Teal	1			2		1		4
Gadwall	1			35		71		107
Mallard						4		4
Northern Pintail						3		3
Ruddy Duck	2	2						4

Table 20. Mono Lake – Fall pond survey, 17 October, 2002

	DeChambeau Ponds					County Ponds		
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**Total**
American Coot	17	73		8		8		106
American Wigeon						4		4
Eared Grebe	1			5	2			8
Gadwall	1				1	17		19
Mallard						2		2
Pied-billed Grebe					1			1
Ruddy Duck		2	1					3

Table 21. Mono Lake – Fall pond survey, 31 October, 2002

	DeChambeau Ponds					County Ponds		
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**Total**
American Coot	23	40		47		11		121
Common Goldeneye		1						1
Eared Grebe				1				1
Gadwall	1							1
Northern Shoveler						1		1
Pied-billed Grebe	1	1						2
Ruddy Duck		1		3		3		7
Wood Duck						1		1

Table 22. Mono Lake – Fall pond survey, 14 November, 2002

	DeChambeau Ponds					County Ponds		
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**Total**
American Coot	8	20		47		11		86
American Wigeon				10				10
Bufflehead		1						1
Common Goldeneye						1		1
Gadwall						2		2
Northern Shoveler				1				1
Ring-necked Duck				2				2
Ruddy Duck				2		3		5
Wood Duck		2						2

Table 23. Summary of fall aerial survey counts – Crowley Reservoir

Species		19 Sept		17 Oct		14 Nov
American Wigeon		15		53		0
Bufflehead				62		257
Canada Goose		80		23		65
Cinnamon Teal		2		4		0
Common Mergenser						14
Gadwall		313		77		52
Greater Scuap						6
Greater White-fronted Goose				8		0
Green-winged Teal		3580		1075		1223
Lesser Scaup						195
Mallard		80		213		2353
Northern Pintail		2550		1225		20
Northern Shoveler		443		50		40
Redhead		4		20		3
Ring-necked Duck				35		131
Ruddy Duck		481		1600		788
Unidentified *Anas*		605		757		408
Unidentified diving ducks						60
American Coot		2901		3413		1377

Table 24. Percentage of all waterfowl detections during fall surveys by lakeshore segment – Crowley Reservoir

Survey area	All waterfowl
UPOW	3.0
SAPO	0.1
NOSH	1.8
MCBA	72.6
HIBA	13.6
CHCL	1.2
LASP	7.7

Table 25. Summary of fall aerial survey counts – Bridgeport Reservoir

Species		19 Sept		3 Oct		14 Nov
Bufflehead				42		52
Canada Goose		75		7		550
Cinnamon Teal		5		0		0
Gadwall		181		0		0
Green-winged Teal		305		355		630
Lesser Scaup				2		0
Mallard		645		293		129
Northern Pintail		469		0		0
Northern Shoveler		205		36		12
Redhead		0		0		9
Ring-necked Duck				60		0
Ruddy Duck		440		295		2
Unidentified		727		54		147
American Coot		514		93		25

Table 26. Percentage of all waterfowl detections during fall surveys by lakeshore segment – Bridgeport Reservoir

Survey area	All waterfowl
North Arm	2.5
West Bay	89.9
East shore	7.6

Figure 1. Summer ground survey areas

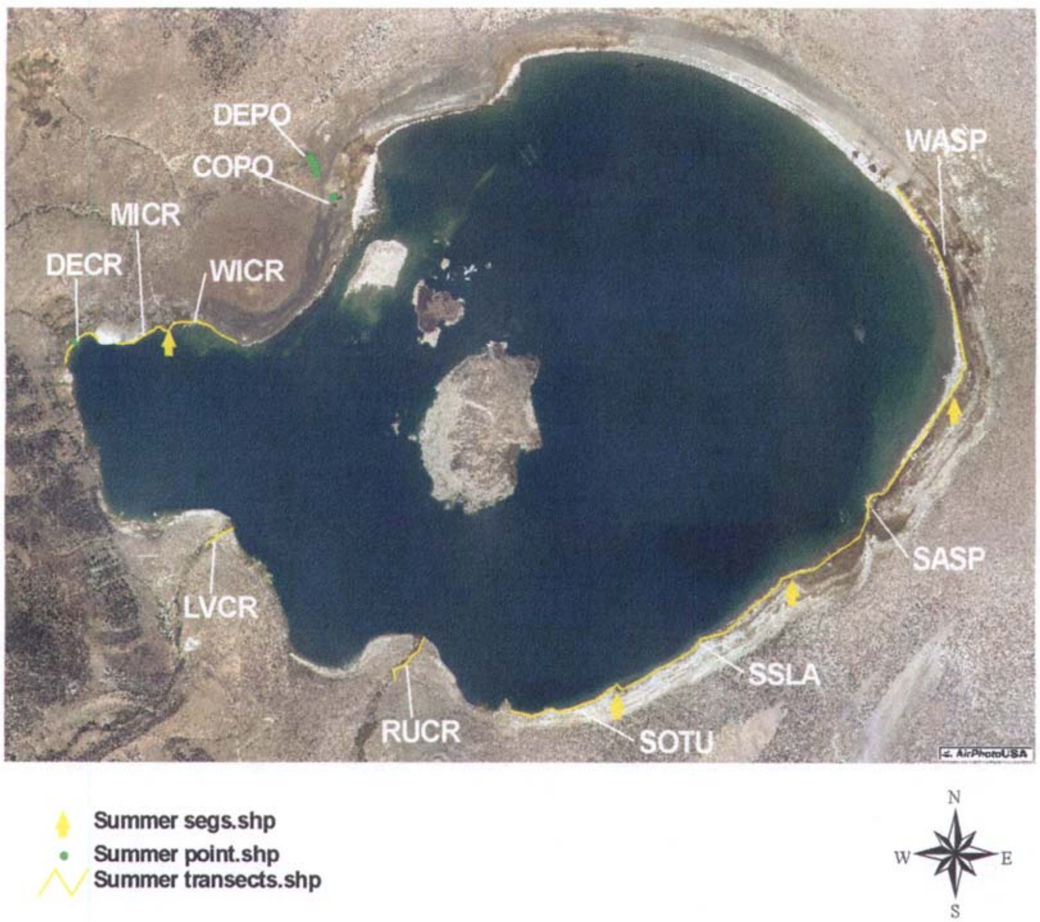

Figure 2a. Wet meadow habitat (Wilson Creek)

Figure 2b. Dry meadow habitat (near Black Point)

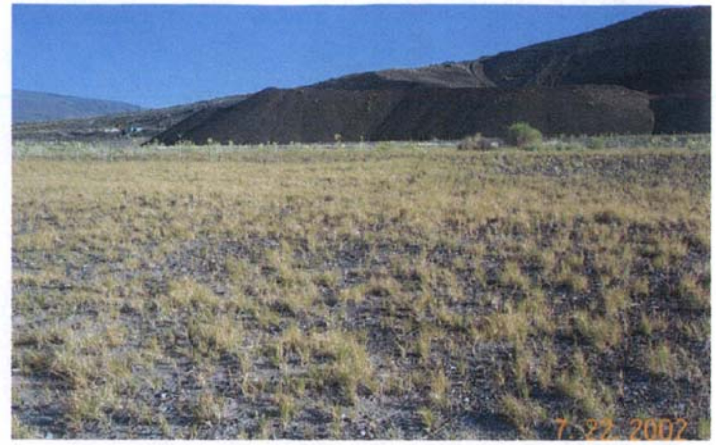

Figure 2c. Brackish Lagoon (Warm Springs)

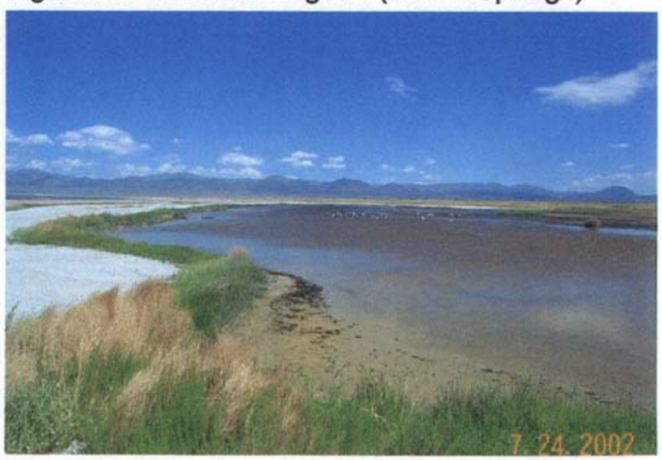

Figure 2d. Hypersaline Lagoon

Figure 2e. Freshwater pond, marsh, and adjacent Great Basin scrub habitats

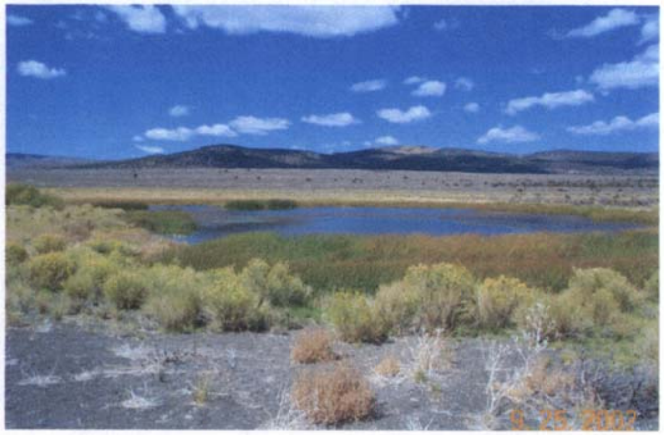

Figure 2f. Riparian Scrub (Wilson Creek)

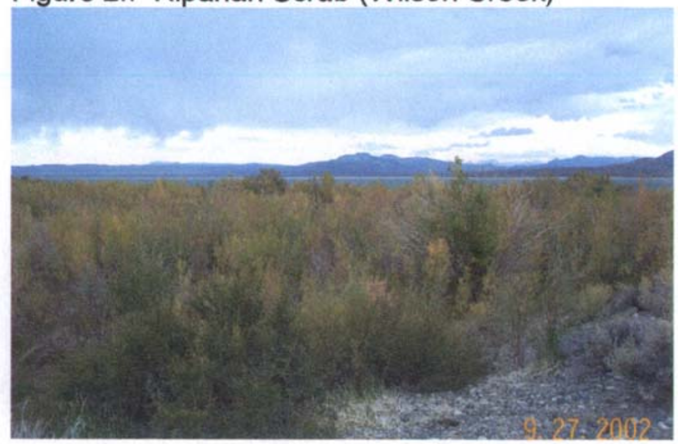

Figure 2g. Riparian forest and freshwater stream habitats

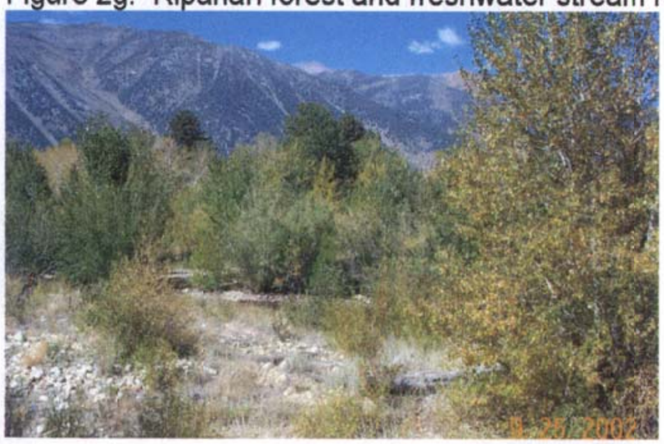

Figure 3. Lakeshore segments, segment boundaries, and cross-lake transects used for fall aerial surveys of Mono Lake

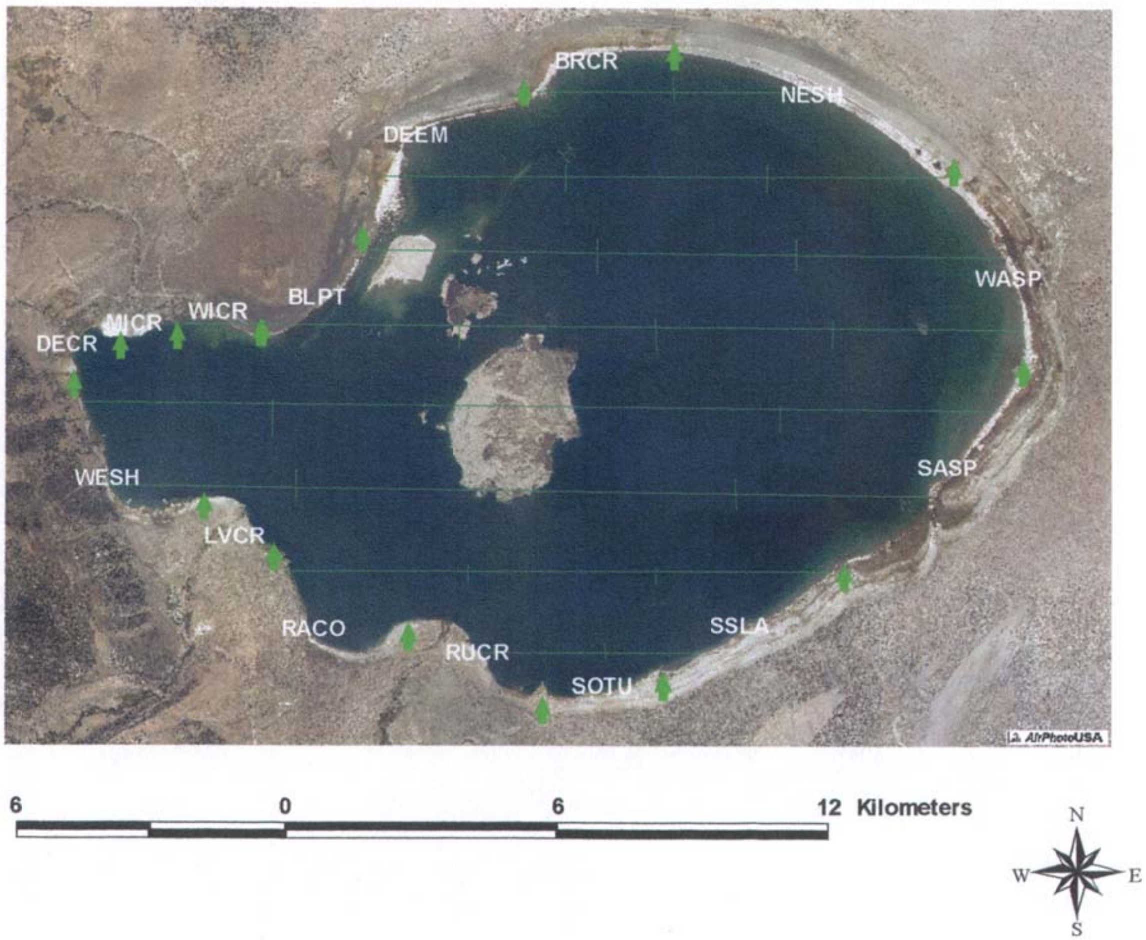

Figure 4. Lakeshore segments and segment boundaries used for fall aerial surveys of Crowley Reservoir

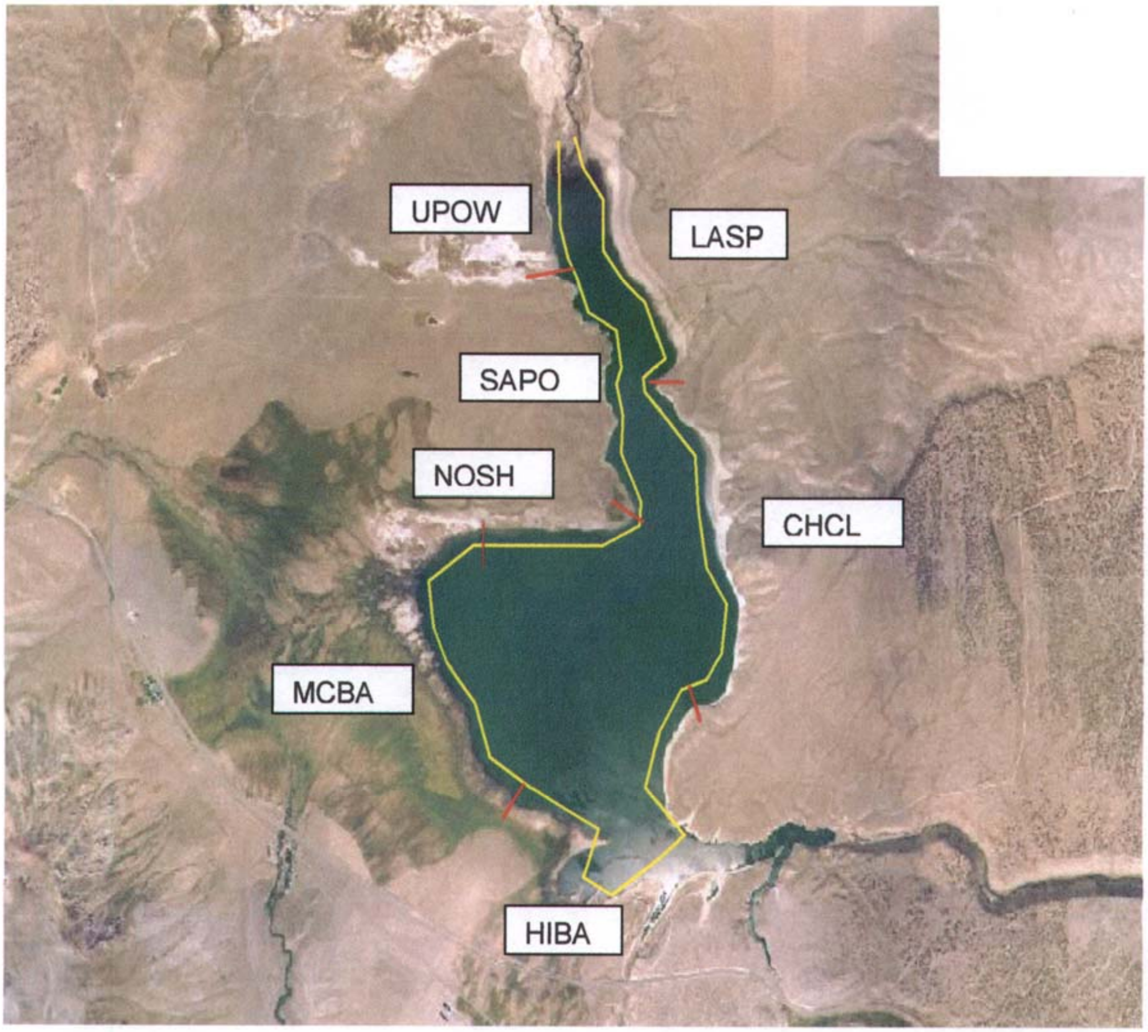

Figure 5. Lakeshore segments and segment boundaries used for fall aerial surveys of Bridgeport Reservoir

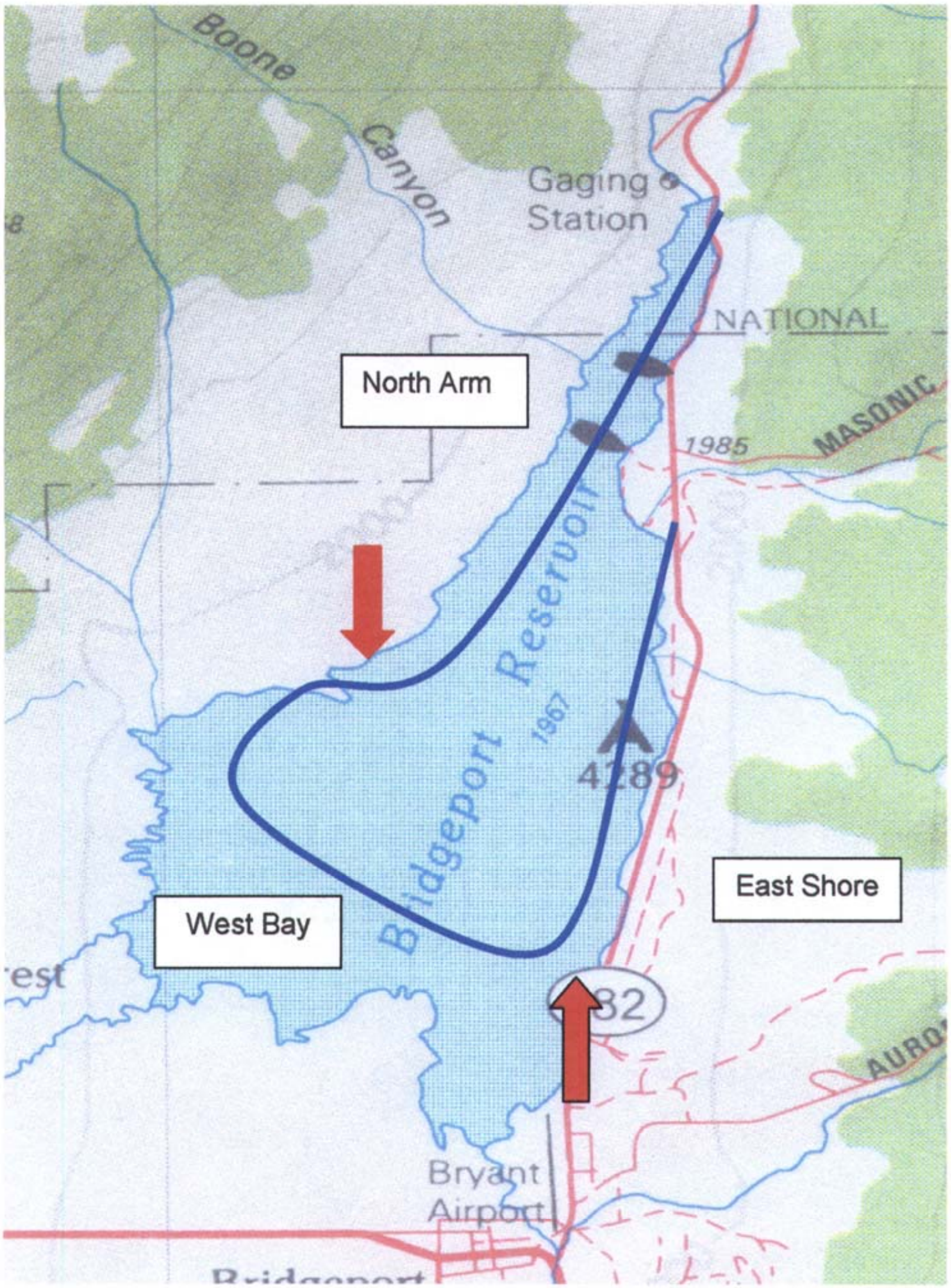

Figure 6a. Rush Creek bottomlands and delta

Figure 6b. South Tufa shoreline

Figure 6c. South shore lagoon seasonal ponds

Figure 6d. Brackish lagoon at west end of South Shore lagoon area

Figure 6e. Sand Flat Spring in SSLA

Figure 6f. Overview of Sammann's Spring area

Figure 6g. Freshwater ponds and brackish lagoons in SASP

Figure 6h. Overview of Warm Springs area with brackish lagoon on right

Figure 6i. Northeast shore

Figure 6j. Bridgeport Creek area

Figure 6k. DeChambeau Embayment

Figure 6l. Black Point shoreline

Figure 6m. Overview of Mill and Wilson Creek areas

Figure 6n. DeChambeau Creek area (east of boardwalk)

Figure 6o. West Shore

Figure 6p. Lee Vining Creek bottomlands and delta

Figure 6q. Ranch Cove shoreline

Figure 6r. DeChambeau Restoration ponds 1 and 2

Figure 6s. DeChambeau Restoration Pond 5

Figure 6t. County Ponds 1 and 2

Figure 7. Total waterfowl detected at each waterbody during aerial surveys

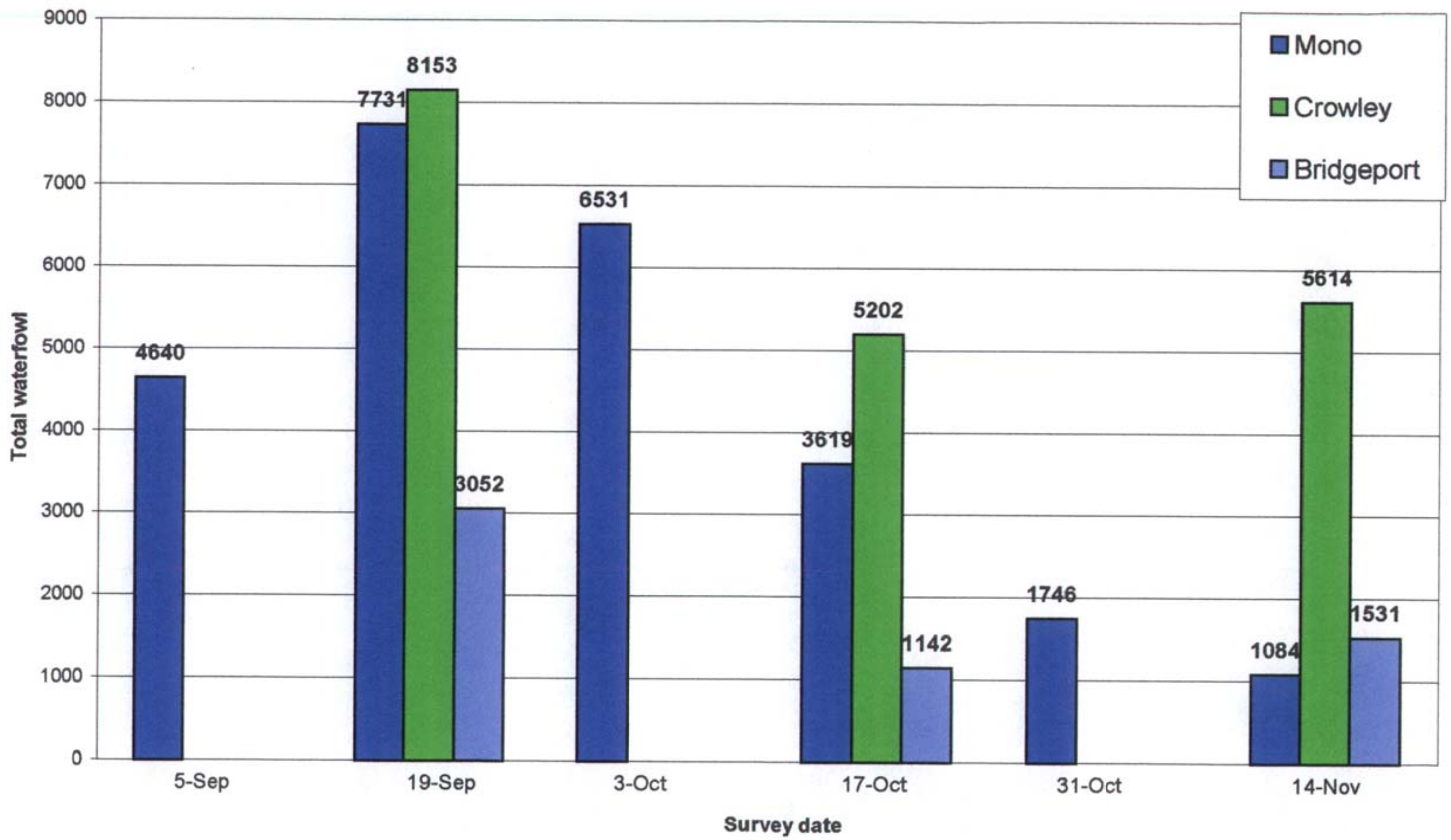

Figure 8. Timing and peak numbers of dominant species at Mono Lake

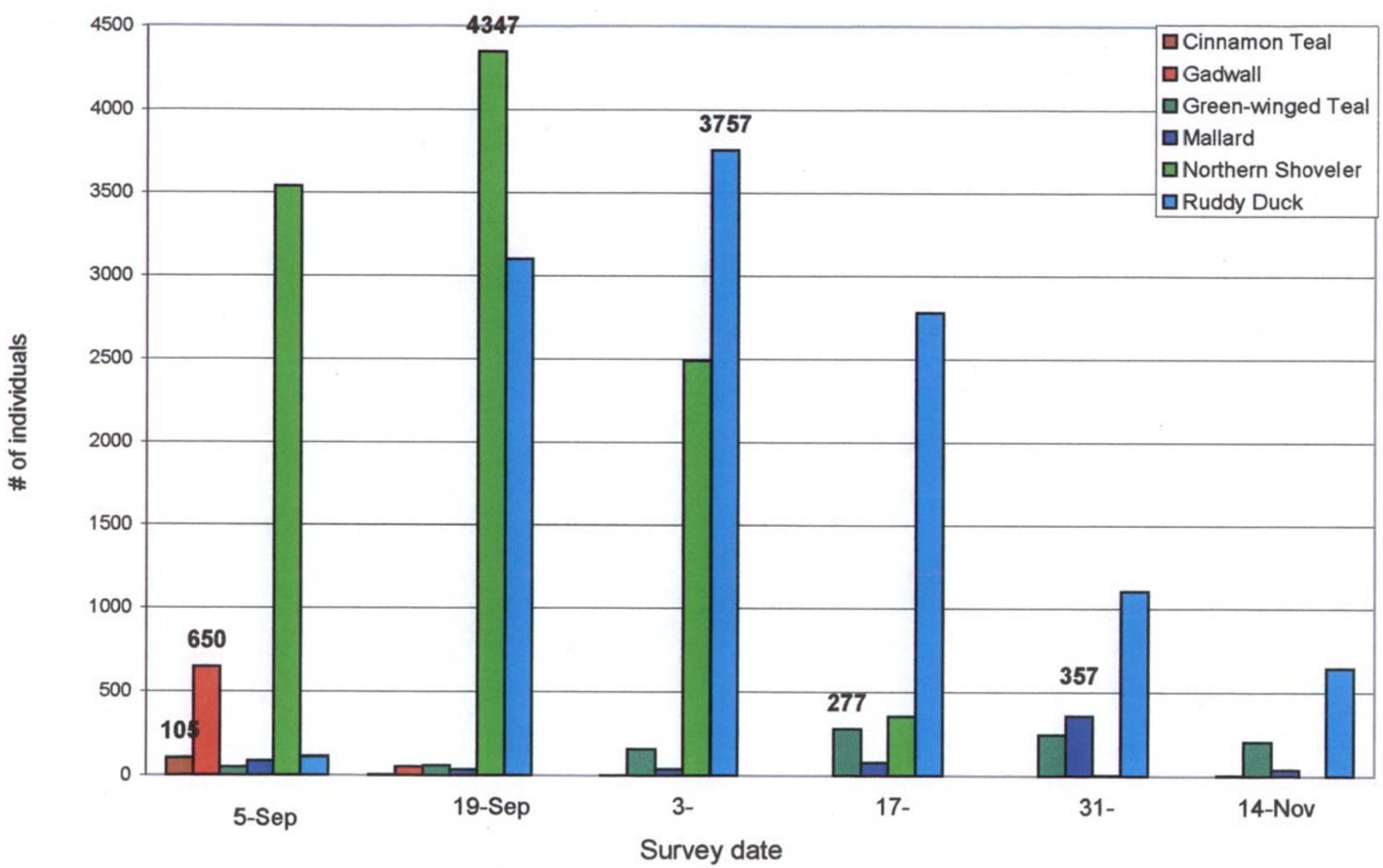

Figure 9. Timing and peak numbers of dominant species at Crowley Reservoir

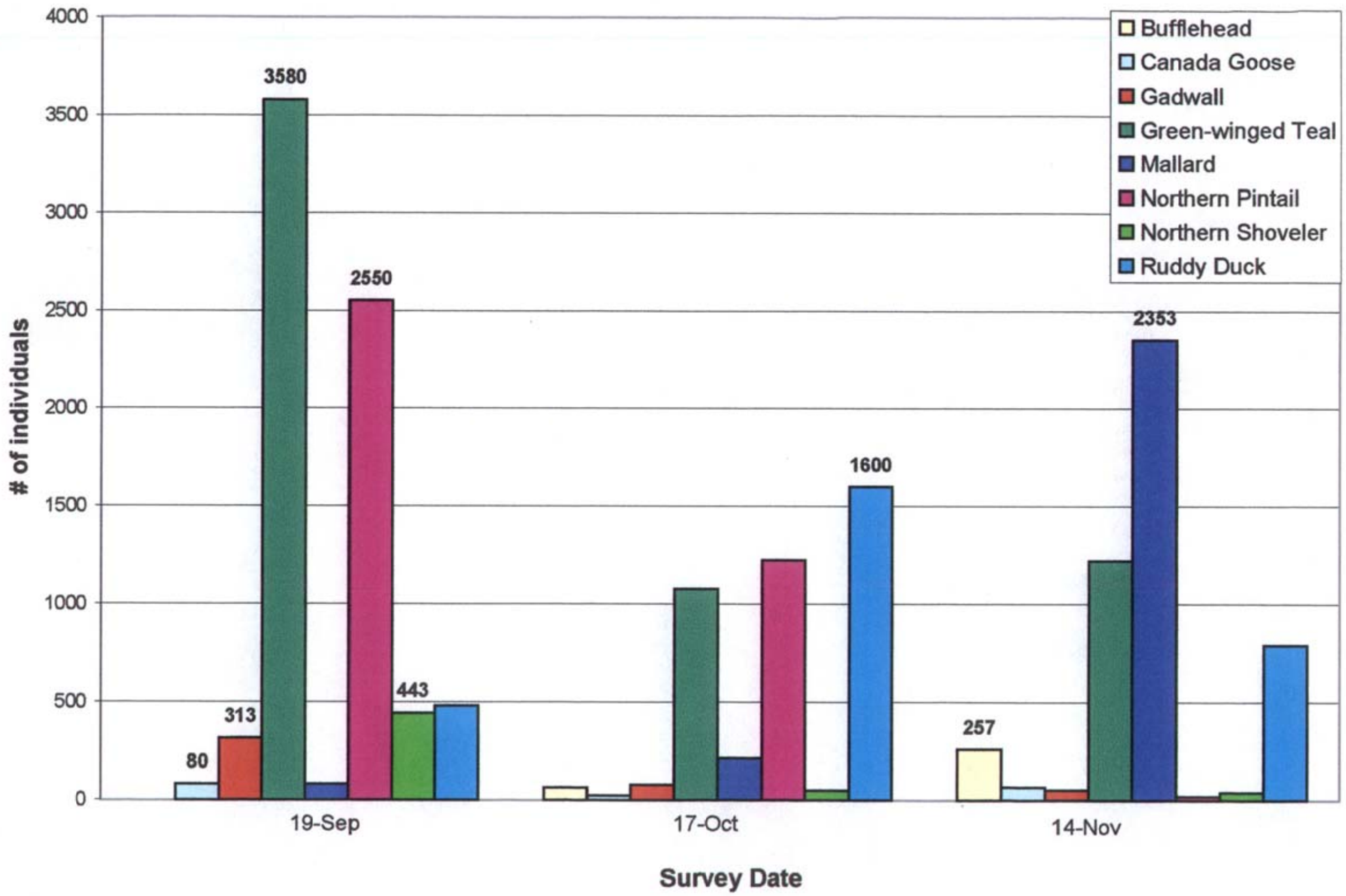

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Figure 10. Timing and peak numbers of dominant species at Bridgeport Reservoir

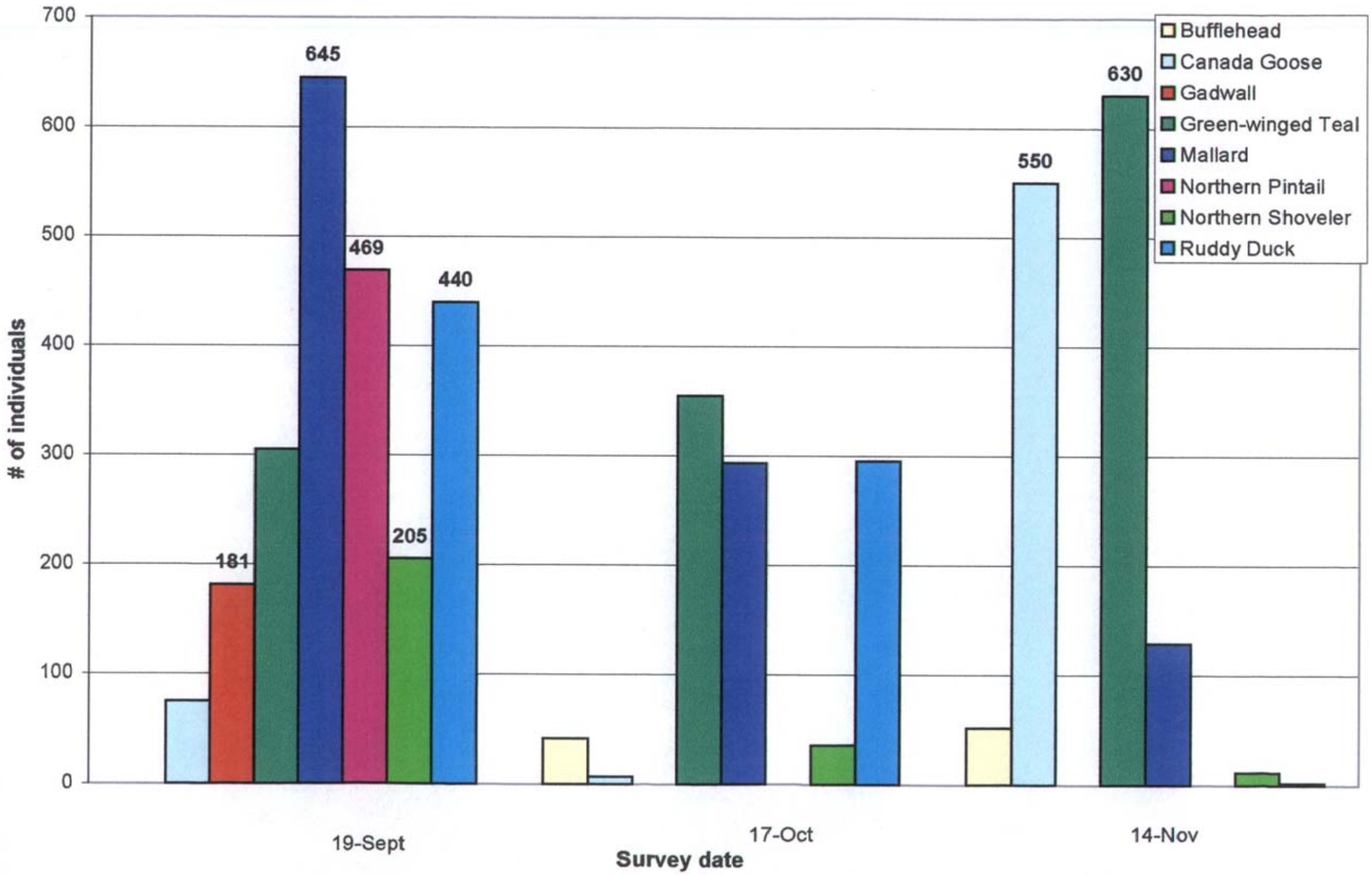
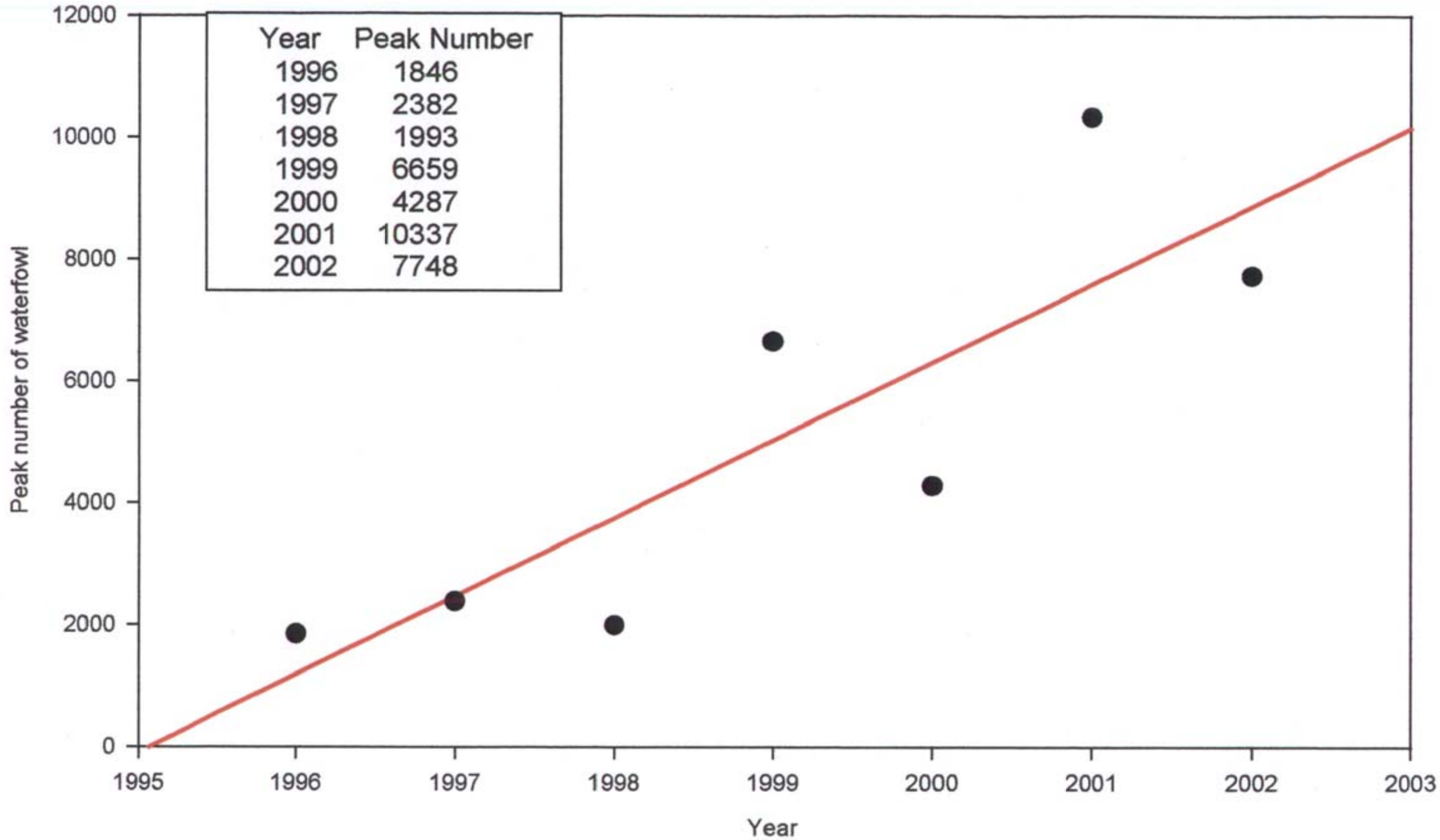


Figure 11. Trend in peak waterfowl numbers (not including Ruddy Ducks) at Mono Lake, 1996-2002



Appendix 1. Summer ground count survey dates (Mono Lake)

Survey number	1	2	3
Dates	May 21-22	June 5-7	July1-3

Appendix 2. 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 3. Fall aerial survey dates

Survey Number	1	2	3	4	5	6
Mono Lake	5 Sept	19 Sept	3 Oct	17 Oct	31 Oct	14 Nov
Bridgeport Reservoir		19 Sept		17 Oct		14 Nov
Crowley Reservoir		19 Sept		17 Oct		14 Nov

Appendix 4. Description of lakeshore segment boundaries

Mono Lake

a. Rush Creek Delta (RUCR) – extends from above segment to the South Tufa formation
b. South Tufa (SOTU) – South Shore Tufa formation to Sand Flat Springs
c. South Shore Lagoons (SSLA) – from Sand Flat Springs to southwest edge of wetland vegetation associated with Sammann's Spring
d. Sammann's Springs (SASP) – from above ending location to halfway to Warm Springs
e. Warm Springs (WASP) – halfway between Sammann's Spring and Warm Springs to northeast edge of existing wetland vegetation of Warm Springs
f. North Shore (NESH) – from above ending location to the first set of springs on the north shore (VRJ Spring)
g. Bridgeport Creek (BRCR) – from VRJ Spring on the north shore to Bridgeport Creek (equivalent to Black Point East segment used by Jehl (2001)
h. DeChambeau Embayment (DEEM) – from the first set of springs on north shore to the south end of DeChambeau embayment
i. Black Point (BLPT) – south end of DeChambeau embayment to the west side of Black Point
j. Wilson Creek (WICR)– west edge of Black Point to the west of Wilson Creek delta
k. Mill Creek (MICR) – east edge of Mill Creek delta to west edge of old Mill Creek delta
l. DeChambeau Creek (DECR) – west edge of Mill Creek delta to the south end of the wetland vegetation of DeChambeau Creek area
m. West Shore (WESH) – from above ending location to Lee Vining Spring

Appendix 4, cont.

n. Lee Vining Delta (LVCR) – east edge of Lee Vining Spring to just north of Dove Tufa towers
o. Ranch Cove (RACO) – Dove Tufa towers to the west edge of the Rush Creek delta area

Bridgeport Reservoir

a. North Arm – from Rainbow Point to the dam
b. West bay – the western arm from Rainbow Point to approximately the airport
c. East shore – the east shore from the airport to the campground area

Crowley Reservoir

a. Upper Owens River (UPOW) – from North Landing to the mouth of the Owens River
b. Sandy Point (SAPO) – from North Landing to Sandy Point
c. North Shore (NOSH) – from Sandy Point to the fence line
d. McGee Bay (MGBA) – from Sandy Point to approximately the southeast border of the irrigated pasture on the west shore of the lake
e. Hilton Bay (HIBA) – Hilton Creek to the beginning of Chalk Cliffs
f. Chalk Cliffs (CHCL) – the east shore from the southern end of Chalk Cliffs to Alligator Point
g. Layton Springs (LASP) – from Alligator Point north, excluding the mouth of the Owens River

Appendix 5. Cross-lake transect positions

Cross-lake transect number	Latitude
1	37° 57'00"
2	37° 58'00"
3	37° 59'00"
4	38° 00'00"
5	38° 01'00"
6	38° 02'00"
7	38° 03'00"
8	38° 04'00"

Appendix 6. Ground verification field notes – Mono Lake

19 September 2002
I ground-truthed the DeChambeau Creek area. Ground-truthing was done about 4 hours after the flight. In flight I estimated that there were approximately 800 Northern Shovelers. On the ground I counted a total of approximately 745 ducks. The following is a summary of a comparison between the aerial count and the ground count of this area.

Species	Air	Ground
Northern Shoveler	800	715
Gadwall	0	18
Mallard	0	9
Green-winged Teal	0	1
Northern Pintail	0	2
Total	800	745

3 October 2002
I first attempted to ground-truth the Mill-Wilson Creek area, but after DFG had flown over it several times, all of the ducks were well off-shore. I then ground-truthed the Rush Creek area. This was done about 4 hours after the flight.

Species	Air	Ground
Northern Shoveler	250	325
Gadwall	0	2
Unidentified	50	0
Total	300	327

17 October 2002
I ground-truthed the County Park area from the end of the boardwalk because I felt that the count from the air was not satisfactory.

Species	Air	Ground
Canada Goose		5
American Wigeon		9
Mallard	4	50
Northern Shoveler		42
Green-winged Teal	135	84
Gadwall	0	
Northern Pintail		3
Unidentified	65	10
Total	204	203

COMMENTS ON MONO LAKE WATERFOWL MONITORING PROGRAM

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Background

The waterfowl monitoring program at Mono Lake was initiated in 1995 in accordance with a ruling by the State Water Quality Control Board. This program formalized the gathering of information that had been on-going since 1980 as an adjunct to studies of the dominant bird species at Mono Lake. The main goals were:

1. To obtain quantitative data on the size and timing of waterfowl migration, by species, in the Mono Basin, principally at Mono Lake and the fringing freshwater ponds.

2. To obtain comparative data for Crowley Lake and Bridgeport Reservoir to determine the relative importance of each site, and

3. To determine the importance of Mono Lake to breeding waterfowl.

The results from 1995 through 2001 were presented in a series of Hubbs Sea World Research Institute Technical Reports (96-261, 99-289,98-279,99-288,2000-299, 2001-311, 2002-330).

Background.-- *This section is provided in response to the "Context of Review" information requested by the Mono Lake Committee.*

Regular censuses began in 1995. Previous experience (my studies began in 1980 under support from National Geographic Society and in 1981 LADWP), including scores of days in small boats over the entire lake had provided information about the distribution and timing of the waterfowl migrations. It was known, for example, that the distribution of *dabbling ducks* was tied to the distribution of fresh water sources and associated marshes. (Ruddy Ducks will be discussed separately). Since dabblers do not normally occur on the open lake, except when disturbed by hunting, I found it most efficient to conduct censuses by small boat. I cruised along the entire shoreline of the lake, as close to shore as depth conditions allowed, and counted and identified all ducks. Censuses began in the early morning and were completed in one day, if weather conditions allowed. The method:

1. Allowed relatively close approach, so that ducks could usually be identified to species, and numbers could be determined accurately.

2. Allowed me to make observations on the behavior and ecology of individual species, and to go ashore, as necessary, to examine ecological conditions (e.g., salinity, distribution of hypopycnal conditions, food plants) that influenced distribution.

3. Provided important information on the distribution and success of breeding waterfowl. It also allowed me to capture and band ducks for further studies on their health (see below) and movements, and feeding habits.

I als censused ducks (and other waterbirds) at the lakeshore ponds, usually in the evening (1800-2000), when they become more active. To make these counts I simply walked the perimeter of a pond or counted birds from a high vantage point.

I did not use aerial censuses originally because I felt they would be less efficient (confirmed by later studies; see annual reports), more costly, and involve the additional risk of flights over open water. Later, however, I did use aerial censusing to gather comparative data from Crowley Lake and Bridgeport Reservoirs. These lakes attract numerous waterfowl of many species but are not easily censused from shore (there is no access to the North Side of Bridgeport Reservoir, for example) or by boat (both are full of aquatic plants that are fine food for ducks but clog propellers and make boating difficult). At the same time, I also made an aerial count of

Mono Lake, to obtain data to compare with those gathered at other lakes and by boat survey.

In subsequent years, as funding was available, I used aerial surveys occasionally in fall. They were most useful in November, when boating conditions might be least favorable. In my experience they provided satisfactory information on the numbers of dabbling ducks (that is, within censusing error, the numbers detected by boat or plane were similar). Their main advantage was that they could be conducted in a short time (Mono Lake could be censused in about an hour and in decent weather all three lakes could be censused in a morning). Further, the entire periphery of Mono Lake could be observed (this was more difficult by boat because of the extreme shallow conditions at Warm Springs). The general results of the comparative surveys showed, as expected, that Mono Lake usually held far fewer ducks than the freshwater lakes but that the species assemblages differed by lake. For example, at Mono Lake Shovelers and Ruddy Ducks are dominant, and although a large diversity of species can be recorded each year, many species are very scarce and are recorded only once or twice.

However, aerial surveys have drawbacks:

Ducks are more wary of planes than boats and take flight at greater distances, making identification to species difficult or impossible, so that many ducks must be counted as “unidentified”. This problem was complicated by harsh sun angles on some flight.

At the same time, the plane is moving at 80-100 mph, which requires the observer to make a rapid judgment concerning the number of birds encountered (since they are usually flying away very fast). There is no chance for a recount, as can be done from a boat when the birds circle around, and thus accuracy is inherently less.

Because disturbed ducks tend to move long distances to undisturbed areas, there is some possibility of double counting. (The same problem exists for boat surveys, but is less extreme.)

More important is that aerial surveys cannot provide reliable information on breeding waterfowl, as it is impossible to see tiny ducklings from the air or, when they grow, to determine the size of the brood accurately. This problem cannot be fully alleviated by shore-based observations because the lake is too big to study all critical areas and access to many areas is too difficult by foot (some Gadwall, for example, nest on Paoha Island and could only be detected by boat work).

Ruddy Ducks

The Ruddy Duck is the most numerous duck on the lake for much of the fall, with numbers into the low thousands from late September into November or later. Much important information about its biology and distribution at that season has been obtained but remains to be analyzed (Jehl unpubl.).

Ruddies are hard to census because the timing of their occurrence coincides with that of the Eared Grebes, which are so numerous (up to 1.5 million) that a few thousand Ruddies become almost undetectable in the mob. Aerial surveys are of little help times because Ruddies cannot be reliably separated from grebes from above, so that the number detected from planes is a small and variable fraction of numbers that are actually present. (A recent suggestion that they might be separated by video-photography is unlikely, because that technique relies on color differences, which are minor).

A further problem is that Ruddies, unlike dabbling ducks, are not tied to fresh water or the shoreline but occur farther offshore, making it impossible to census them accurately from shore (worse, they concentrate in areas that are inaccessible by foot).

Finally, unlike dabbling ducks, Ruddies do not fly as a plane approaches but dive and disappear before they can be counted. .

The only technique that can produce a valid index to their abundance is to approach them by boat, at which time many tend to run over the water leaving long and obvious splash trails, and then following up with counts as the birds settle down and diving birds re-surface. To use this technique, however, requires experience in knowing their requirements, daily movement patterns, food habits, and major distribution (Jehl unpayable.).

The proposed survey plan

The proposal developed by D. House is based on the current census methods but substitutes aerial surveys and ground-truthing for boat work. It clearly states the purpose of the plan and will meet most of its requirements as regards dabbling ducks. However, it will not provide the depth of information on Ruddy ducks or breeding waterfowl that has been available in the past. A few comments:.

A. Summer ground counts. Ground counts may be useful, but have the disadvantage of scaring ducks with small broods into hiding (and thus undetectability). The most useful data on breeding waterfowl will come from mid-July onward, after the Gadwall have hatched and moved to the lake, and are best gathered by boat observations on the lake.

B. Fall aerial surveys. The timing is fine, although it would be useful to start in late August to get the early flight of Cinnamon Teal and Shovelers. The protocol needs adjustment. Because the ducks are tied to the shore, most will be detected by a single observer on the shore side of the aircraft. However, many will fly offshore before the plane arrives and will not be detectable by the observer, though they will be obvious to the pilot, who will rightly be concerned with collisions. Pilots have often called my attention to birds that would otherwise be missed and are an important source of information.

Cross-lake transects have little value. There are no dabbling ducks offshore, and the proposed routes shown in Figure 1 will not encounter the main concentration of Ruddies (and any that might be along those routes will disappear among the grebes). One might also ask the purpose of a route that would cross Paoha Island.

Note that the proposed protocol is to count ducks on one side of the plane without regard to distance. Let us suppose that there were lots of ducks offshore that would be encountered on the transects. How, then, would the counts numbers be extrapolated to obtain some index to offshore populations? Not possible as presented. All you can get is presence/absence data, which are not useful. These transects can be eliminated in favor of programs that will provide useful information on Ruddies.

C. Ground validation counts. Useful in principle, but the devil is in the details. Once you fly over an area the birds will move. There is no assurance that they will return to the spot they left, or even if they will return to Mono Lake. Some may move to Crowley or Grant Lake. Therefore, you don't really know what you are comparing. What is the "reduced" lag time. If you fly a census in the AM, return to Mammoth, get in a car and drive to ML, the lag is still hours. There is no control on what has happened in the meantime. And October is hunting season, when birds are constantly disturbed by gunshots. This idea needs to be rethought. Also, because bird move, the idea of placing buoys is not practical. (I did this to no avail in 1981; the birds avoided them). There are adequate natural physical features (tufa, springs) to mark areas.

Responses to specific question posed by LADWP, based on the information presented above and the annual reports submitted.

1. *Will the proposed aerial counts provide a useful index of waterfowl numbers*?

Yes, if numbers of dabbling ducks is all that is needed. The plan does not address the specific requirements and censuses challenges associated with Ruddy Duck distribution.
The current plan also lacks some attributes of boat-based studies, as it will not provide as detailed information on (1) the abundance of individual species, and (2) the status of breeding duck populations. Further, boat studies also offer the possibility of getting additional information at no extra cost, by capturing and banding birds for health studies (an undiagnosed foot disease affects nearly all local Gadwall) and determining food habits (via scat samples).

2. *Will the proposed aerial counts provide a useful index of waterfowl habitat use.*

Yes, for dabbling ducks, although I wonder why further information is needed at this point. Use and distribution have been established over a range of lake elevations since 1995 and will not change until the distribution of fresh water sources changes. Habitat for dabbling ducks can be assessed from aerial photos of freshwater springs/marshes. Habitat use by Ruddies must be determined by boat.

3. *Can the proposed aerial counts be compared to the boat counts of previous years.*

Yes, for dabbling ducks, as shown by the similar numbers obtained from boat and plane counts in past years. Of course, as in any long term study, there may be a problem associated with different observers. Observer A may see a group as 50, when B sees it as 90. That is not unusual and may lead to consistent bias. However, because duck numbers are usually so small that I would expect no significant differences, except when flocks run into the low hundreds or greater.

Aerial counts will not obtain data comparable to boat counts for Ruddy Ducks.

Other

Several requirements in the recovery plan are mentioned in passing in the LADWP proposal. My experience shows that these are either poorly-conceived or irrelevant to management and restoration issues. For example, I have failed to detect (and no one has yet shown) any biological value to the prescribed burning program (and other waterfowl professionals are also critical of the technique; see Kruse and Bowen, J. Wildl. Manage 60:233-246, 1996). Also, the study of time budgets has been addressed as fully as possible given the circumstances at Mono Lake. These activities should be terminated in favor of programs *with specific goals and measurable outcomes* that will enhance the resources of the lake. Further comments can be found in the annual reports.

Review of Mono Lake Waterfowl Population Monitoring Protocol

Robert L. McKernan
Director
San Bernardino County Museum

1 October 2002

Generally, I found Debbie House's monitoring protocol to be complete and the methods proposed will provide the necessary data to evaluate the response of waterfowl populations to restoration efforts in the Mono Basin. However, survey frequencies could be increased in some situations to obtain a higher level of confidence (e.g., breeding waterfowl counts).

Summer Ground Counts

Obviously, ground counts are the most applicable way to discern breeding waterfowl numbers and assess landscape use. Depending on vegetation conditions (dense versus sparse), delectability of breeding waterfowl can be problematic. To obtain ample confidence through ground counts to establish breeding utilization by waterfowl species within the restoration area, the greater the survey frequency during the breeding period is always better. Although, I realize that there can be budgetary limitations, three ground counts proposed might not provide enough information to reasonably establish benefits of the restored areas for breeding waterfowl.

Fall Surveys

The protocol proposed by D. House appears to constitute a feasible coverage of Mono Lake. The coverage of the lake on each flight will provide a good index of waterbird numbers both temporally and spatially. While one observer will be adequate to assess waterbird abundances on the lake during each flight, two observers are usually better to lend to greater coverage of the flight tracks over water. Simply, having one observer viewing out of the left

side, while another viewing out of the right side of the aircraft provides greater coverage. Constant flight speed can be tedious to establish and maintain during each flight relative to conditions, etc., although, if sustained, an approximate speed of 130 kilometers is reasonable. If during each flight an average altitude of 60 meters can be maintained, preferably lower, above the deck, then I believe you will maximize identification of all bird species. Generally dividing the lake surface/shoreline into segments or blocks will provide an excellent way to establish spatial use of waterfowl and with segments make it easy to apply a -statistic to these data.

My research between 1983 and 1999 at the Salton Sea clearly indicated that aerial surveys are far superior to boat counts to establish indices on large lakes for waterbird use within and among years. While boats also can establish similar indices for relative abundance of waterbirds, boats cannot provide the efficiency as aerial surveys can in a shorter amount of time.

In addition, some ornithologists question whether waterbird avoidance behaviors (e.g., diving or taking flight) are greater when counting via aircraft, my twenty-year + experience at Salton Sea has observed the contrary. When assessing differences between aircraft counts against boat counts, I found that greater numbers of waterbirds are more likely to dive or fly when approached by boat than aircraft. Although, both methods do create disturbances for rafting waterbirds flocks, aircraft counts reduce the avoidance behavior of waterbirds, than boat counts.

There has been some question regarding previous multiple year waterbird counts conducted via a boat by Joe Jehl, and concerns relative to how comparable aerial counts will be with past boat count data sets. Obviously both methods, boat and aircraft provide an index for waterbird

populations within and among years. These two methods provide trend data for bird species occurrences on Mono Lake and spatial use by waterbird at Mono Lake. I believe that comparisons or integration of the two data sets to establish population trends at Mono Lake will be comparable, as they are both estimates for establishing waterbird usage during determined periods at Mono Lake.

<u>Validation Counts</u>

I found at Salton Sea that validation counts are an important component for comparative purposes that add confidence to aerial counts. Although all validation counts at Salton Sea where conducted by boat because of time-constraints, shoreline subsampling purposed by D. House seems to be a good measure. I believe that instead of placing buoys out to determine subsample areas, UTM coordinates can be established which can serve the same need.

<u>Aerial Counts and Waterbird ID</u>

Various questions arise with regards to identification at the species level of waterbird when conducting aerial counts. I found that there are various consequences of aerial counts that can be relatively controlled if appropriate foresight is used in designing and formalizing an aerial count strategy:

- **The altitude of the aircraft over the water (±60meters)**
- **Speed of the aircraft over the water (±120 kilometers)**
- **Time of each flight relative to sun angles (0800 to 1200)**
- **Avoidance of inclement weather which can cultivate high winds and create aggravated wave actions.**

- **During all aerial counts utilizing a cassette recorder with a microphone to record all data entries, so the observer(s) is always visually scanning the water surface.**

Certain species of waterbirds can create a challenge for the observer with minimal experience. However, these challenges can be overcome through a basic understanding of waterbird identification and flights prior to the commencement of the standardized counts. During my aerial counts at Salton Sea I found that certain species of waterbirds are more tedious to identify because of their similar colorations (plumage), but are identifiable with care and experience. Examples of two species are Ruddy Duck (*Oxyura jamaicensis*) versus Eared Grebe (*Podiceps nigricollis*). Based on conditions, these two species can appear similar on the water surface from the air. However, separation of the Ruddy Duck and Eared Grebe can be made, based on the large headed appearance of the Ruddy Duck, the Ruddy Duck's elongated appearance(stifftail) compared to the Eared Grebe, and the dorsal coloration of the Ruddy Duck, which appears to have greater contrast (brown) with the water surface than the darker Eared Grebe.

6 August 2002
Dave Shuford

Memo: re. Proposed Revision of the Mono Lake Waterfowl Monitoring Protocol

To: Heidi Hopkins, Steve McBain, and Brian White

This memo is in response to a request, at the end of a conference call among Heidi Hopkins, Steve McBain, Brian White, and me on 31 July 2002, to commit to writing concerns I had about the proposed change in the waterfowl survey protocol at Mono Lake. My comments are given in light of having recently read an earlier version and a June 2002 version of the document titled "Mono Lake Waterfowl Population Monitoring Protocol" prepared by Debbie House, a 19 June 2002 memo on "Mono Basin Waterfowl Population Monitoring" from Debbie House to Brian White, a 2 July 2002 letter titled "Proposal for Modification to the Waterfowl Plan" from Thomas Erb (LADWP) to Edward Anton (SWRCB), and a 6 September 2001 letter from Graham Smith (USFWS) to Brian White in which he commented on the 2001 report on waterfowl surveys at Mono Lake. Thus, I offer the following comments:

Adequate Review of the Proposed Change in Protocol

Although the letter from Mr. Erb to Mr. Anton indicates that the Mono Lake Committee and I reviewed the proposed waterfowl survey protocol, it does not indicate that I expressed serious reservations with some aspects of the proposed protocol that seemed to warrant additional review by waterfowl experts familiar with waterfowl survey protocols in general, with the biological and logistical constraints of conducting such surveys at Mono Lake and nearby reservoirs, and with knowledge of study design and issues of standardization of protocols for obtaining data on long-term population trends of birds. Although many of my comments were incorporated in the revised protocol dated June 2002, the main issue of switching from a primary method of surveying waterfowl at Mono Lake heavily reliant on boat surveys supplemented by less frequent aerial surveys to one totally reliant on aerial surveys (with some ground truthing) has not been addressed to my satisfaction. I do not have any problems with aerial surveys per se as I have used them extensively to survey shorebirds and other waterbirds in California and I know that they are used as a primary survey method by U.S. Fish and Wildlife and California Dept. of Fish and Game to conduct waterfowl surveys. The real question, though, is whether it is advisable to make a major switch in the survey protocols after seven years of data collection and whether data collected by the new protocol will be easily comparable to that collected by the old one. In this regard, it should noted that in the letter from Graham Smith (referenced above), in which he commented upon the 2001 waterfowl report authored by Joseph R. Jehl, Jr., he states that "the approach seems very reasonable given the purpose of the work" and "I believe you are doing a very good job of documenting waterfowl usage at Mono Lake." Although he did make suggestions for improving estimates of Ruddy Duck numbers, he did not suggest a major switch in survey methods. In an attempt to resolve the issue of whether a switch to the primary use of aerial surveys is warranted, I recommend the following:

(1) **Additional Review** – it would be very beneficial to obtain additional review of the proposed protocol. Formal *written* comments should be obtained from Joseph R. Jehl, Jr., who has conducted most of the waterfowl surveys since 1995, one of the waterfowl biologists (Roderick Drewien, Fritz Reid, Thomas Ratcliff) who authored the original Mono Lake waterfowl plan, and other experts that LADWP has informally asked to comment on waterfowl survey methods (Graham Smith, Robert McKernan).

(2) **Context of Review** – the type of review that is requested should be explicit, and all experts should be asked the same questions. As we all agree that aerial surveys are used widely to survey waterfowl, we do not need to ask experts about the validity of using this technique. To my mind the primary question the reviewers should address is whether given seven years of prior data collection on waterfowl at Mono Lake that emphasized boat surveys whether it would now be advisable to switch to a method emphasizing aerial surveys. Reviewers should be provided with a summary of the number of surveys conducted, the method used, and the dates on which they were conducted for all years since surveys began in 1995. Dr. Jehl, in particular, should be asked why he chose to emphasize boat over aerial surveys and what advantages and disadvantages he sees to using these methods *at Mono Lake*. It would be valuable for other reviewers to know his response when evaluating the proposed change in protocol, particularly if

there were valid reasons why Dr. Jehl rejected aerial surveys as the primary survey method. My understanding of the original justification for a limited number of aerial surveys was for use in comparing waterfowl numbers at Mono Lake, Bridgeport Reservoir, and Crowley Lake all on the same day.

Such a review would assure all parties that all the right questions were asked regardless of whether the majority opinion expressed is to endorse the switch to a protocol dominated by aerial surveys or to retain one emphasizing boat surveys.

Additional Comments on the Revised (June 2002) Protocol

The following are some less important suggestions for improvement of the suggested waterfowl protocol:

(1) *Dechambeau Creek mouth* – the protocol calls for a ground survey of waterfowl near the Dechambeau Creek mouth from a fixed point at the platform at the end of the boardwalk at the county park. As the protocol for other ground surveys at other sites at the lake calls for walking particular stretches of shoreline, I suggest that the same be done at Dechambeau Creek. This seems particularly warranted as the view from the end of the boardwalk is somewhat obstructed by tufa towers and/or willows and viewing conditions may change with additional growth of vegetation or changes in lake level.

(2) *Validation counts (ground truthing)* – the current protocol calls for some validation (ground truthing) counts for the aerial surveys conducted at Mono Lake, Bridgeport Reservoir, and Crowley Lake. My observation, though, is that there is no standardization of these counts across the three sites and the frequency may not be adequate for the intended purpose (to ensure that the aerial surveys provide a good index of waterfowl present and to ensure that adequate data on the ratio of ducks at each site is obtained). The present protocol calls for at least one validation count at Mono Lake each October, "as necessary" at Bridgeport, and does not specific frequency at Crowley Lake. I would recommend that such surveys be conducted a minimum of at least twice per fall at each site and additionally on any aerial survey on which there is a high ratio (say >30%) of unidentified ducks. It is important to obtain the ratios of the various species of ducks as these may change with an increase in lake level and corresponding drop in salinity at Mono Lake. Iit would also be important to know if the ratios just change at Mono (suggesting this reflects lake level/salinity changes there) or if they also change at the other reservoirs (suggesting these changes reflect other factors affecting the populations on a broader scale).

(3) Buoys at Mono Lake – the protocol suggests placement of buoys to Mono Lake so that validation ground counts can start and end at the same place that the aerial surveys do. It seems that buoys would be unnecessary if the ground observers simply use GPS units to determine the locations of the boundaries between survey segments.

I would be glad to discuss any of these, or any other, matters pertaining to the waterfowl surveys with any of the interested parties.

Sincerely,

Dave Shuford

Appendix 5 - Robert McKernan Curriculum Vitae

CURRICULUM VITAE

Robert L. McKernan
Biological Science Section
San Bernardino County Museum
2024 Orange Tree Lane
Redlands, CA 92373

Education

9/77 – 6/80 M.S. Zoology Program, Arizona State University, Tempe, Arizona.
9/70 – 5/75 B.S. Zoology, California State Polytechnic University, Pomona, California

Professional Experience

June 2002 – Director, San Bernardino County Museum.
Responsibilities include supervision of all staff and daily operations at the main museum and historic sites, col1aboration with County Administration regarding activities, personnel resolution, management or budgetary appropriations, interfacing with affiliate groups and community regarding the museum's mission, short and long term planning regarding the museum's mission. In addition, continued ornithological research at Salton Sea and water bird population assessments at inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrant throughout the deserts of the southwest U.S.

September 2001 – June 2002 – Interim Director, San Bernardino County Museum
Responsibilities include supervision of all staff and daily operations at the main museum and historic sites, collaboration with County Administration regarding activities, personnel resolution, management or budgetary appropriations, interfacing with affiliate groups and community regarding the museum's mission, short and long term planning regarding the museum's mission. In addition, continued ornithological research at Salton Sea and water bird populations assessments at inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrants throughout the deserts of the southwest U.S.

March 2000 – September 2001 – Supervising Curator, San Bernardino County Museum
Responsibilities include supervision of all professional staff, curatorial policy, collaboration with museum administration regarding curatorial activities, personnel resolution, management or budgetary appropriations for curatorial activities, short and long term planning for curatorial sections. Overseeing all research activities at SBCM. In addition, continued ornithological research at Salton Sea and water bird populations assessments at Inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrants throughout the deserts of the southwest U.S.

1997 to 2001 – Senior Curator of Biological Sciences at San Bernardino County Museum
Duties include oversight of an biological collections and exhibit. Implement collection care policies, curatorial activities, management or professional personnel, develop and conduct collection-based research, oversee loans, visiting researchers, and collaboration with research associates. Additional duties include management of approximately one million dollars annually in contract and grant funding for biological field studies. Field studies activities include development of study design, methodologies, data analysis, develop and monitor "Section" budget, generation of peer review publication from field studies research, and management of field personnel: 40 biologists. In addition, continued ornithological research at Salton Sea and water bird populations assessments at inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrants throughout the deserts of the southwestern U.S.

1994 – 1997 – Curator of Biological Sciences at San Bernardino County Museum.
Responsibilities include oversight and collection management of all biological collections, exhibits, implement collection policies, curatorial activities, management of biological personnel, conduct collection based research, oversee loans and visiting researchers. Duties also included management of contracts and grants annually to conduct biological field studies in the southwest U.S. Responsibilities for field studies included RFP development, study design, methodology development, develop and monitor "Section" budget, data analysis, generation or peer reviewed publications, and management of all field personnel. In addition, continued ornithological research at Salton Sea and water bird populations assessments at inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrants throughout the deserts of the southwest U.S.

1990 to 1994 -Assistant Curator of Biological Sciences at San Bernardino County Museum
Duties included collection management of all biological collections, implement collection policies, curatorial activities, management of research personnel, conduct collection based research, oversee loans and visiting researchers. Responsibilities al~o included management of contracts and grants annually for the purpose of conducting biological field studies in the southwest U.S. Additional responsibilities included RFP development, study design, methodology development, develop and monitor "Section" budget, data analysis, and generation of technical reports.

1988 to 1990 – Research Biologist for University of California, Riverside Integrated Natural Resources Program
Project leader and collaborator on biological research conducted in southwestern North America. Studies included ecology, habitat affinities, community associations, and racial identification various vertebrate taxa through portion of the California and Arizona. In addition, continued ornithological research at Salton Sea and water bird populations assessments at inland lakes in southern California. Also continued research regarding migratory behavior of Neotropic avian migrants throughout the deserts of the southwest U.S.

1980 to 1988 – Senior Research Ornithologist/Asst. Curator at Los Angeles Natural History Museum
Research various aspects of avian ecology, behavior, and systematics in North America and Mexico. Additional duties included collection management activities, preparation of museum specimens, supervision of research and field staff, data analysis, and manuscript development. Responsibilities included securing funding for research related to avian collections and field research. Developed state-of-the-art methodologies for studying nocturnal and diurnal movements, both migratory and local, for waterbirds and Passerines in the southwest U.S.

1982 to 1992 – Contract Research Ornithologist for Hubbs-Sea World Research Institute, San Diego
Co-principle investigator for long term population studies of waterbird species in the southwestern U.S. Collection and preparation of avian specimens to determine food and habitat needs in hyper saline environments.

1980 to 1982 – Research Ornithologist for the U.S. Forest Service
Developed habitat relationship criteria for Western North America avian species.

1977 to 1980 – Collection Manager for Birds and Mammals at Department of Zoology Museum, Arizona State University, Tempe AZ
Collection management, oversee loans, oversee use of collections by graduate and undergraduate students and visiting researchers. Accessioning, preparations, and conservation care of museum specimens. Maintained computerized database of collection holding.

1975 to 1977 – Biologist/Ornithologist for U.S. Bureau of Land Management
Inventory birds, mamma1s, and vegetation in the desert of California. Determine population attributes, collected and prepared voucher specimens for the California Desert Plan. Principal investigator for Colorado Desert wetland and thicket study to identified important haunts for bird species. Also unit leader for the Saline Valley area for California Desert Plan.

Professional Organizations

Society for the Preservation of Natural History Collections
Western Field Ornithologist (Past President 1991-1994)
American Ornithologist' Union
Association of Field Ornithologist
Cooper Ornithological Society
Wilson Ornithological Society
Southwestern Naturalist
American Society of Mammalogists
Ecological Society of America
Waterbird Society

Publications, Technical Reports, and Chaired Seminars

Over 100 technical reports, publications and 10 chaired seminars

Invited Keynote speaker to American Association for the Advancement of Science Annual Meeting, Los Angeles, CA 1985. Advances in research technology and the study or bird migration (waterbirds and songbirds)

Twenty-years as Sub-regional editor (Riverside County) for North American Birds.

Primary Literature Published in the Past Five Years

McKernan, R.L. and E.A. Cardiff. “in press” The patterns of migration for two sibling species, *Empidonax difficilis* and *Empidonax occidentalis* in California Condor

McKernan, R.L. and E.A. Cardiff. "in press” Utilization of desert playas by migratory and wintering waterbirds.

Jehl, J.R. Jr., and R.L. McKernan, 2002. Biology and migration of the Eared Grebe at the Salton Sea. Hydrobiologia 473:245-253.

McKernan, R.L. and J. Jehl, Jr., in-prep. An eighteen-year assessment of Winter relative abundance and spatial use of the Salton Sea by selected waterbirds.

McKernan, R.L. and J. Jehl, Jr. in-prep. Ruddy Duck wintering biology at the Salton Sea.

Shuford, D.W.N. Warnock, and R.L. McKernan in press. Patterns of shorebird use of the Salton Sea, Califomia. Cooper Ornithological Society Symposium Ecology and Conservation of the Avifauna of the Salton Trough.

Braden, G. T., R. L. McKernan, and S. M. Powell 1997 Effects of nest parasitism by the brown-headed cowbird on nesting success of the California gnatcatcher.
Condor 99(4): 858-865.
Braden, G. T., R. L. McKernan, and S. M. Powell. 1997. Association of within-territory vegetation characteristics and fitness components of California Gnatcatchers.
Auk 114(4) 601-609

McKernan, R. L., E. A. Cardiff, and M. S. Crook. 1996. Breeding Bird Study: Palo Verde-Ironwood I. Journal of Field Ornithology, Vol. 67.

McKernan, R. L., E. A. Cardiff, and M. S. Crook. 1996. Breeding Bird Study: Palo Verde-Ironwood II. Journal of Field Ornithology, Vol. 67.

McKernan, R. L., E. A. Cardiff, and M. S. Crook. 1996. Breeding Bird Study: Palo Verde-Ironwood III. Journal of Field Ornithology, Vol. 67.

McKernan, R. L., E. A. Cardiff, and M. S. Crook. 1996. Breeding Bird Study: Palo Verde-Ironwood IV. Journal of Field Ornithology, Vol. 67.

Selected Gray Literature Technical Reports

Braden, G. T. and R. L. McKernan. 2000. A data based survey protocol and quantitative description of suitable habitat for the endangered San Bemardino Kangaroo Rat (*Dipodomys merriami parvus*). Biology Section, San Bemardino County Museum Redlands, CA. June, 35 pp.

Braden, G. T. and R. L. McKernan. 1999. Possible effect of low level nest parasitism by the Brown-headed Cowbird (*Molothrus ater*) on the nest success of the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) at sites monitored by the San Bernardino County Museum: A data review, progress report, and power's analysis. Report submitted to the U. S. Bureau of Reclamation, Lower Colorado River Region, Boulder City, Nevada, by the San Bernardino County Museum Biological Sciences Section, Redlands, California. December, 21 pp.

Braden, G. T. and R. L. McKernan. 1998. Nest stages, vocalizations, and survey protocols for the Southwestern Willow Flycatcher (*Empidonax: traillii extrimus*). Final Report submitted to the U. S. Bureau of Reclamation, Lower Colorado River Region, Boulder City, Nevada, by the San Bernardino County Museum Biological Sciences Section, Redlands, California. October, 36 pp.

Braden, G. T. and R. L. McKernan. 1998. Observations on nest cycles, vocalization rates, the probability of detection, and survey protocols for the Southwestern Willow Flycatcher (*Empidonax: traillii extrimus*). Report submitted to the U. S. Bureau of Reclamation, Lower Colorado River Region, Boulder City, Nevada, by the San Bernardino County Museum Biological Sciences Section. Redlands, California. March, 38pp.

Braden, G. T., R. L. McKernan, S. Love, and S. Powell. 1995. Nesting biology of the Coastal California Gnatcatcher (*Polioptila californica californica*) in western Riverside County: 1993-1994. San Bernardino County report to the Metropolitan Water District. 29pp.