May 9, 2017

Ms. Barbara Evoy
Deputy Director
Division of Water Rights
State Water Resources Control Board
1001 I Street, 14th Floor
Sacramento, California 95814

Dear Ms. Evoy:

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

Pursuant to the State Water Resources Control Board 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's (LADWP) Mono Basin Water Right License Nos. 10191 and 10192, enclosed is a compact disc (CD) containing a submittal, "Compliance Reporting May 2017", which contains the following four reports required by the Orders. The reports are as follows:

- Mono Basin Operations: Runoff Year (RY) 2016-17 and Planned Operations for RY 2017-18
- Mono Basin Fisheries Monitoring Report: Rush, Lee Vining, Parker, and Walker Creeks for RY 2016-17
- Stream Monitoring Report RY 2016-17
- Mono Lake Waterfowl and Limnology Monitoring Reports for RY 2016-17

In addition to these reports, the submittal also includes Section 1: the RY 2016-17 Status of Restoration Compliance Report, which summarizes the status of LADWP's compliance activities in the Mono Basin to date and planned activities for the upcoming runoff year.

The filing of these reports, along with the restoration and monitoring performed by LADWP in the Mono Basin, fulfills LADWP's requirements for RY 2016-17, as set forth in Decision 1631 and the Orders.

Electronic copies of the Compliance Reporting May 2017 submittal on CD will be provided to the interested parties listed on the enclosed distribution list. Hard copies of the submittal will be provided upon request.

If you have any questions, please contact Mr. Peter N. Tonthat, Civil Engineering Associate, at (213) 367-1792.

Sincerely,

FOR AC

Anselmo G. Collins
Director of Water Operations

PNT:jem
Enclosures
c/enc: Mr. Peter N. Tonthat

Mono Basin Distribution List
Runoff Year 2016-17

Ms. Barbara Evoy Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Ms. Lisa Cutting Mono Lake Committee P.O. Box 29 Lee Vining, California 93541
Ms. Amanda Montgomery Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Board of Supervisors Mono County P.O. Box 715 Bridgeport, California 93517
Mr. Scott McFarland Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Dr. Mark Drew California Trout Inc. P.O. Box 3442 Mammoth Lakes, CA 93546
Dr. William Trush Humboldt State University River Institute c/o Dept of Environmental Science & Mgmt 1 Harpst Street Arcata, CA 95521-8299	Mr. Richard Roos-Collins Water and Power Law Group 2140 Shattuck Avenue, Ste. 801 Berkeley, CA 94704-1229
Mr. Ross Taylor 1254 Quail Run Court McKinleyville, CA 95519	Mr. Marshall S. Rudolph Mono County Counsel P.O. Box 2415 Mammoth Lakes, CA 93546
Mr. Jon C. Regelbrugge USDA Forest Service P.O. Box 148 Mammoth Lakes, CA 93546	Mr. Steve Parmenter Department of Fish and Wildlife 787 North Main Street, Suite 220 Bishop, CA 93514
Ms. Tamara Sasaki California Department of Parks and Recreation P.O. Box 266 Tahoma, CA 96142	Mr. Doug Smith Grant Lake Reservoir Marina P.O. Box 21 June Lake, CA 93529
Mr. Matthew Green State Parks 3415 Hot Springs Rd. Markleeville, CA 96120	

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

COMPLIANCE REPORTING

Mono Basin Operations
Fisheries Monitoring
Stream Monitoring
Waterfowl & Limnology Monitoring

May 2017
Los Angeles Department of Water and Power

CONTENTS

Section 1

Status of Restoration Compliance Report

Status of Restoration Compliance Report (SORC)

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

May 2017

Los Angeles Department of Water and Power

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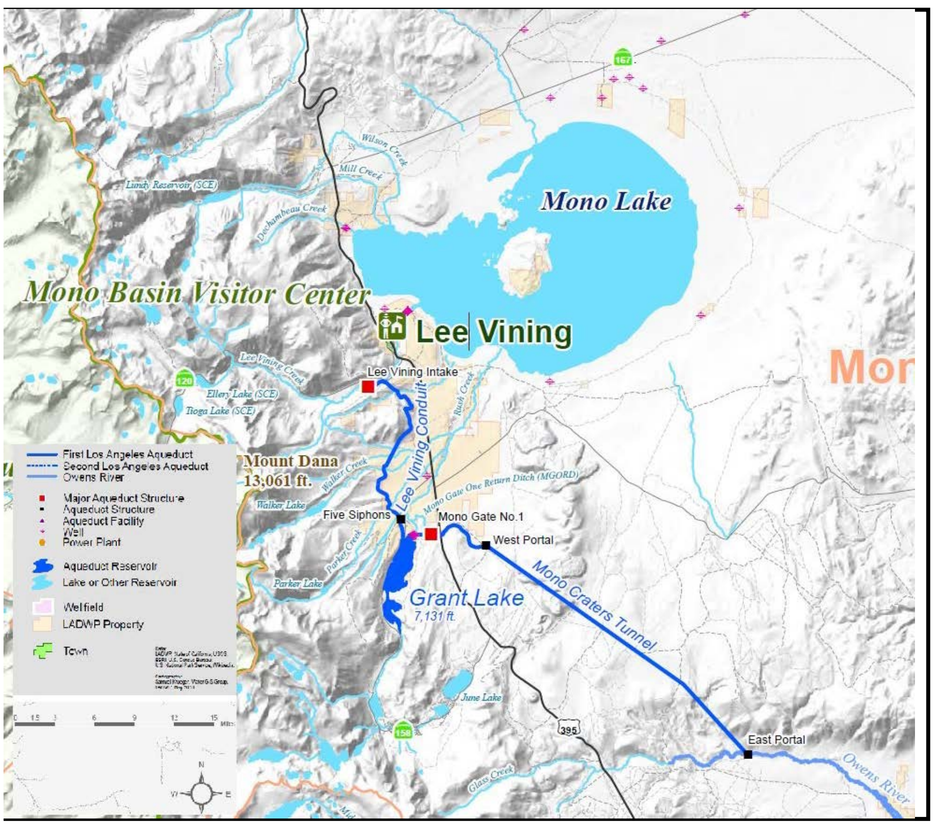
Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1631 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 monitor stream flows, and to restore and monitor the fisheries, stream channels, and waterfowl habitat. This chapter includes the Status of Restoration Compliance Report, which summarizes the status of LADWP compliance activities in the Mono Basin to date. It is expected that the Water Board will amend LADWP's water rights license. Following SWRCB adoption of the amended license, the new requirements will be reflected in future SORC Reports.

Figure 1: Map of Mono Basin showing major Streams and LADWP facilities.



Status of Restoration Compliance Report

This document was first submitted as draft to the interested parties on April 1, 2017. It was developed to include a 21 day review period during which LADWP will review and address comments submitted by the interested parties. Following the 21 day review period, LADWP will finalize it as part of the May 2017 Status of Restoration Compliance Report as below.

Status of Restoration Compliance Report
State Water Resource Control Board Decision 1631 and Order Nos. 98-05 & 98-07

The Status of Restoration Compliance Report ("SORC Report") is organized into the following sections:

1. **Introduction** – Description of the SORC Report
2. **Definitions** – Explanations of what each category represents
3. **Updates from Previous SORC Report** – Changes over the past year
4. **Plans for the Upcoming Runoff Year** – Planned activities for the upcoming year
5. **Requirements** – Categories of the entire list of LADWP's requirements in the Mono Basin
6. **Completion Plans** – Long term plans for completing all requirements
7. **Ongoing Items Definitions** – Ongoing activities necessary for LADWP operations in the Mono Basin.

1. Introduction:

The SORC Report details the status of the Los Angeles Department of Water and Power's (LADWP) restoration requirements in the Mono Basin as outlined by the State Water Resources Control Board (SWRCB) Decision 1631 and Order Numbers 98-05 and 98-07, and any subsequent decision letters distributed by the SWRCB. This initial structure and content of the SORC report was cooperatively prepared by LADWP and the Mono Lake Committee (MLC) through an extensive series of staff discussions and a workshop held in the Mono Basin in August 2005. LADWP and MLC believe this report represents the most thorough and complete listing of Mono Basin restoration requirements and their current status available in a unified document. These requirements are categorized as ongoing, complete, in progress, incomplete or deferred as defined below in Section 2. The final section of the SORC Report details how LADWP plans to proceed with those items not listed as ongoing or completed (i.e. items in progress, incomplete, and/or deferred).

The SORC Report will be submitted by LADWP to SWRCB as part of the annual Compliance Reporting. By April 1 each year, LADWP will update and submit a draft SORC Report to the interested parties. Within 21 days of the draft submission, LADWP will accept comments on the draft SORC Report from the interested parties. Then, LADWP will finalize the SORC Report, incorporating and/or responding to comments. The final SORC Report will then be included into the final Compliance Reporting to SWRCB by May 15 of each year.

It is expected that the Water Board will amend LADWP's current water rights license following a CEQA analysis of proposed actions related to the Mono Basin settlement agreement. The new requirements are expected to take effect immediately after the Water Board issues an order, and those new requirements will be reflected in future SORC Reports. Any items no longer relevant under the new order will be moved to a new category "Eliminated" in the SORC. The new SORC will show both a new numbering system for all active items as well as the old numbering system for cross reference. Once agreement is reached on the items in the "eliminated" category, those items as well as the old numbering will no longer be shown in future SORC Reports.

2. Definitions:

Below are the definitions of the categories where each requirement has been grouped.

A. Ongoing — Items that are current and require continuous action (e.g. Maintain road closures in floodplains of Rush and Lee Vining Creeks)

B. Complete — Items that have been finalized (e.g. Rehabilitation of the Rush Creek Return Ditch)

C. In-Progress — Items started and not yet finalized because of time or the timeline extends into the future (e.g. Waterfowl monitoring and reporting)

D. Incomplete — Items not yet started or not complete because plans for completion not finalized.

E. Deferred — Items placed on hold which need input from the Stream Scientists and/or SWRCB before plans commence (e.g. Prescribed burn program)

3. Updates from Previous SORC Report:

Since the last SORC Report of May 15, 2016, the report is updated as follows:

- Section 4, Plans for the Upcoming Runoff Year, has been updated to cover Runoff Year 2017-2018 (RY 2017-18).

4. Plans for the Upcoming Runoff Year:

During the upcoming runoff year, RY2017-18, LADWP plans to:

1. Continue with all requirements listed under Category A – Ongoing Items, as needed based on the runoff year.
2. Continue Category C – In-Progress Items C17 "Sediment Bypass for Parker Creek". Sediment bypass will continue in the next non-Dry RY.
3. Continue Category C – In-Progress Items C18 "Sediment Bypass for Walker Creek". Sediment bypass will continue in the next non-Dry RY.

5. Requirements:

This section lists and categorizes the individual requirements based on the status of each item. The requirements are derived from SWRCB Decision 1631, and/or Order Nos. 98-05 and 98-07, and/or any subsequent decision letters distributed by SWRCB. The requirements are either described in the cited section of the order and/or are described in the cited page of the specified plan and/or document (Stream Plan, Waterfowl Plan, GLOMP, etc.) that the Order references, and/or detailed in the SWRCB letter. Plans for completing in-progress, incomplete, and deferred items are further explained in Section 6, Completion Plans. Finally, plans for those items described as ongoing are detailed in Section 7, Ongoing Items Description.

<u>Category A – Ongoing Items</u>

1. Maintain road closures in floodplains of Rush and Lee Vining Creeks – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

2. Base flow releases – *Stream Management*
   Order 98-05 order 2.a.; GLOMP p. 2, table A

3. Low winter flow releases – *Stream Management*
   Order 98-05 order 2.b.

4. Annual operations plan – *Stream Management*
   Order 98-05 order 3; GLOMP p. 103, 104

5. Notification of failure to meet required flows – *Stream Management*
   Order 98-05 order 3

6. Grant operations and storage targets – *Stream Management*
   Order 98-05 order 1.a.; Decision 1631 order 1; GLOMP p. 84

7. Amount and pattern of export releases to the Upper Owens River – *Stream Management*
   Order 98-05 order 2; Decision 1631 order 7; GLOMP p. 84, 85

8. Diversion targets from streams – *Stream Management*
   Order 98-05 order 2; GLOMP p. 85

9. Export amounts dependent on Mono Lake level – *Stream Management*
   Decision 1631 order 6

10. Year type designation and guidelines – *Stream Management*
    Order 98-05 order 2; Decision 1631 order 3; GLOMP p. 87-96

11. Dry and wet cycle contingencies for stream restoration flows and base flows – *Stream Management*

Order 98-05 order 2; GLOMP p. 97

12. Deviations from Grant Lake Operation Management Plan (GLOMP) – *Stream Management*
    Order 98-05 order 2; GLOMP p. 98, 99

13. Ramping rates – *Stream Management*
    Order 98-05 order 2; Decision 1631 order 2; GLOMP p. 90-96

14. Stream restoration flows and channel maintenance flows – *Stream Management*
    Order 98-05 order 1.a.

15. Salt Cedar eradication – *Waterfowl*
    Order 98-05 order 4.e.; Waterfowl Plan p. 27

16. Aerial photography every five years or following an extreme wet year event – *Monitoring*
    Order 98-05 order 1.b; Stream Plan p. 103

17. Make basic data available to public – *Monitoring*
    Order 98-05 order 1.b as revised by Order 98-07; Order 98-07 order 1.b(2); Stream Plan p. 110

18. Operation of Lee Vining sediment bypass – Stream Facility Modifications
    Order 98-05 order 2

19. Operation of the Rush Creek augmentation from the Lee Vining Conduit when necessary – *Stream Management*
    Order 98-05 order 2

20. Make data from all existing Mono Basin data collection facilities available on an internet web site on a same-day basis – *Stream Management*
    Order 98-05 order 2.c

<u>Category B – Completed Items</u>

1. Placement by helicopters of large woody debris into Rush Creek, completed fall 1999 – *Stream Work*
   Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

2. Placement by helicopters of large woody debris into Lee Vining Creek, completed fall 1999 – *Stream Work*
   Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

3. Rewater Rush Creek side channels in reach 3A, completed fall 1999 – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 68-71

4. Rewater Rush Creek side channel in reach 3B, completed fall 1999 with changes (see LADWP annual Compliance Reporting, May 2000) – *Stream Work*

Order 98-05 order 1; Stream Plan p. 68-71

5. Rewater Rush Creek side channel in reach 3D, completed fall 2002 with changes (see LADWP annual Compliance Reporting, May 2003) – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 68-71

6. Revegetate approximately 250 Jeffrey Pine trees on Lee Vining Creek, completed in 2000 – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

7. Revegetate willows on Walker Creek. No planting necessary in judgment of LADWP and MLC as area revegetated rapidly without intervention – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

8. Revegetate willows on Parker Creek. No planting necessary in judgment of LADWP and MLC as area revegetated rapidly without intervention – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

9. Limitations on vehicular access in Rush and Lee Vining Creek floodplains, completed fall 2003 – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 78-80

10. Removal of bags of spawning gravel, completed fall 2003 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 85, 86

11. Removal of limiter logs, completed 1996 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 86

12. Removal of Parker Plug, completed by California Department of Transportation 2000 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 87

13. Sediment bypass facility for Lee Vining Creek, completed winter 2005 – *Stream Facility Modifications*
    Order 98-05 order 1.f.

14. Flood flow contingency measures, completed by California Department of Transportation's Highway 395 improvements in 2002 – *Stream Management*
    Order 98-05 order 1; Stream Plan p. 76

15. Stream monitoring site selection, completed 1997 – *Monitoring*
    Order 98-05 order 2; Stream Plan p. 109

16. Waterfowl and limnology consultants, completed 2004 – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27-29

17. Status report on interim restoration in Mono Basin, completed 2006 – *Other*

Decision 1631 order 8.d (3)

18. Cultural resources investigation and treatment plan report to SWRCB, completed 1996 – *Other*
    Decision 1631 order 9, 10

19. Revegetate or assess the need to revegetate Rush Creek side channels in reach 3A five years after rewatering, assessed annually and reported in May 2006 Monitoring Report – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 71-75

20. Revegetate or assess the need to revegetate Rush Creek side channels in reach 3B five years after rewatering, assessed annually and reported in May 2006 Monitoring Report – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 71-75

21. Revegetate or assess the need to revegetate Rush Creek side channel in reach 3D and reported in May 2008 Monitoring Report – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 71-75

22. Rewater Rush Creek side channel 11 in reach 4C. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Waterfowl*
    Order 98-05 order 4.a., order 4.d.; Waterfowl Plan p. 22

23. Rewater Rush Creek side channel 14 in reach 4C. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered complete in 2008. – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 68-71

24. Revegetate or assess the need to revegetate Rush Creek side channel 11 in reach 4C for five years following rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Waterfowl*
    Order 98-05 order 4.a., order 4.d.; Waterfowl Plan p. 22

25. Revegetate or assess the need to revegetate Rush Creek side channel 14 in reach 4C for five years after rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 68-71

26. LADWP and MLC were to cooperatively revegetate pine trees on areas of Rush Creek and Lee Vining Creek including disturbed, interfluve, and upper terrace sites

targeted from reach 3B through 5A on Rush Creek. In 2005, remaining suitable areas were assessed resulting in a map showing those areas where planting pine trees may be successful and would add to habitat complexity. LADWP and MLC investigated locations suitable for planting by LADWP and MLC staff and volunteers. Acceptable Jeffrey Pine seedlings were procured by LADWP and were planted by MLC and volunteers on all available suitable sites. This item is considered complete and is moved to Category B "Completed Items." However, MLC may continue to water these seedlings. MLC may also plant cottonwoods with volunteers as opportunities arise – Stream Work Order 98-05 order 1; Stream Plan p. 71-75

27. Rewater Rush Creek side channel 8 in reach 4B, completed March 2007 – *Waterfowl.* The further rewatering of Rush Creek side channel complex 8 in reach 4B was deferred by the Stream Scientists. Final review is being conducted by McBain and Trush. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists and SWRCB has approved the plan *Order 98-05 order 4.a., order 4.d; Waterfowl Plan p. 22*

28. Rehabilitation of the Rush Creek Return Ditch, completed 2002 – *Stream Facility Modifications.* Since then, vegetation growth has slightly reduced ditch capacity. To restore maximum capacity of 380 cfs, the return ditch embankments were raised.
Order 98-05 order 1, order 1.c.; Stream Plan p. 85, appendix III

<u>Category C – In-Progress Items</u>

1. Placement by hand crews of large woody debris into Rush Creek on an opportunistic basis based on stream monitoring team recommendations – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

2. Placement by hand crews of large woody debris into Lee Vining Creek on an opportunistic basis based on stream monitoring team recommendations – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

3. Grazing moratorium for 10 years, assessed annually and status reported in May 2009 Monitoring Report. Grazing moratorium to continue until further notice. – *Stream Management*
Order 98-05 order 1; Stream Plan p. 83

4. Grant Lake Operation Management Plan (GLOMP) preparation for revisions – *Stream Management*
Order 98-05 order 2; GLOMP p. 103, 104

5. Waterfowl project funding – *Waterfowl*
Order 98-05 order 4.b.

6. Salt Cedar eradication reporting– *Waterfowl*

Order 98-05 order 4.e.; Waterfowl Plan p. 27

7. Stream monitoring team to perform duties – *Monitoring*
   Order 98-05 order 1.b as revised by Order 98-07

8. Stream monitoring reporting to the SWRCB – *Monitoring*
   Order 98-05 order 1.b as revised by Order 98-07; Order 98-07 order 1.b(2); Stream Plan p. 110

9. Development, approval, and finalization of stream monitoring termination criteria for Walker and Parker Creeks – *Monitoring Order 98-07*

10. Development, approval, and finalization of stream monitoring termination criteria for Lee Vining and Rush Creeks – *Monitoring*
    Order 98-07

11. Hydrology monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27

12. Lake limnology and secondary producers monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27, 28

13. Riparian and Lake fringing wetland vegetation monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27, 28

14. Waterfowl monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 28; LADWP's 2004 "Mono Lake Waterfowl Population Monitoring Protocol" submitted to SWRCB on October 6, 2004

15. Testing the physical capability for Rush Creek augmentation up to 150 cfs from the Lee Vining Conduit through the 5-Siphon Bypass facility – *Stream Management*
    Order 98-05 order 2; GLOMP p. 82, 83

16. Evaluation of the effects on Lee Vining Creek of Rush Creek augmentation for diversions up to 150 cfs through the Lee Vining Conduit – *Monitoring*
    Order 98-05 order 1.b.

17. Sediment bypass for Parker Creek – *Stream Facility Modifications*
    Order 98-05 order 1.f.

18. Sediment bypass for Walker Creek – *Stream Facility Modifications*
    Order 98-05 order 1.f.

<u>Category D – Incomplete Items</u>

None

Category E – Deferred Items

1. Recommend an Arizona Crossing or a complete road closure at the County Road Lee Vining Creek, if and when Mono County plans to take action – *Stream Work Order 98-05 order 1; Stream Plan p. 78-80*

2. Fish screens on all irrigation diversions – *Stream Facility Modifications Order 98-05 order 1; Stream Plan p. 84*

3. Prescribed burn program – *Waterfowl Order 98-05 order 4.b.(3)c.; Waterfowl Plan p. 25, 26*

4. Rewatering of Rush Creek side channel 1A in reach 4A.– *Stream Work Order 98-05 order 1; Stream Plan p. 68-71*

5. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 1A in reach 4A – *Stream Work; Order 98-05 order 1; Stream Plan p. 68-71*

6. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 4Bii in reach 4B. – Stream Work Order 98-05 order 1; Stream Plan p. 68-71

7. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 8 in reach 4B.

8. Stream monitoring for 8-10 years to inform peak flow evaluation and recommendations including the need for a Grant Lake Reservoir Outlet – *Monitoring Order 98-05 order 1.b as revised by Order 98-07*

6. Completion Plans:

The following descriptions detail how LADWP plans to fulfill SWRCB requirements in the Mono Basin for each item above not categorized as complete or ongoing. This section will be reviewed annually by LADWP for revisions to reflect progress towards completion.

Category C – In-Progress Items

Item C1 – During walking surveys, large woody debris will be placed into Rush Creek and will continue to be done on an opportunistic basis based on recommendations made by the Monitoring Team. This item will remain "In-Progress" until the Monitoring Team indicates that no further work is required. At that time, this item will be considered complete and will be moved to Category B "Completed Items".

Item C2 – During walking surveys, large woody debris will be placed into Lee Vining Creek and will continue to be done on an opportunistic basis based on recommendations made by the Monitoring Team. This item will remain "In-Progress" until the Monitoring Team indicates that no further work is required. At that time, this item will be considered complete and will be moved to Category B "Completed Items".

Item C3 – The grazing moratorium in the Mono Basin was in effect until 2009. At this time LADWP does not intend to allow grazing on its lands in the Mono Basin and will continue the moratorium in 2017. This item will remain in the Category C "In Progress".

Item C4 – The Grant Lake Operation Management Plan (GLOMP) includes instructions to "review for revisions" every five years until Mono Lake reaches 6,391 feet above mean sea level. Although no revisions have been finalized to date, the plan was continuously under review. GLOMP is expected to be revised and replaced with "Mono Basin Operations Plan" (MBOP) after the SWRCB amends LADWP Water Rights licenses. This item will remain in Category C "In-Progress Items" until the final operation/management plan is approved by SWRCB. It is expected that a final plan will be developed after the Water Board order. Once the plan is approved, this item will be considered complete and will be moved to Category B "Completed Items".

Item C5 – LADWP is to make available a total of $275,000 for waterfowl restoration activities in the Mono Basin. This money was to be used by the USFS if they requested the funds by December 31, 2004. Afterwards, any remaining funds are to be made available to any party wishing to do waterfowl restoration in the Mono Basin after SWRCB review. USFS has requested funds for a project estimated at $100,000. MLC has requested that the remainder of the funds be applied toward the total cost of the Mill Creek Return Ditch upgrade which would provide benefits for waterfowl habitat. The Mill Creek Return Ditch rehabilitation is a component of a Federal Energy Regulatory Commission (FERC) settlement agreement. These funds will continue to be budgeted by LADWP until such a time that they have been utilized. Currently, this money has been tentatively been included in the Settlement Agreement as part of Administrative of Monitoring Accounts to be administered by a Monitoring Administration Team (MAT). Once the full $275,000 has been utilized, this item will be considered complete and will be moved to Category B "Completed Items".

Item C6 – Progress of the salt cedar eradication efforts is reported in the annual reports following the vegetation monitoring efforts. This was reported in the May 2016 Monitoring Report. This item will continue to be in progress until notice from SWRCB is received that LADWP's obligation for this in the Mono Basin is complete. Once this notice is received, this item will be moved to Category B "Completed Items".

Item C7 – The stream monitoring team continues to perform their required duties in the Mono Basin. This item will continue to be in progress until notice from SWRCB is received that LADWP's obligation for funding and managing the monitoring team in the Mono Basin is complete. Once this notice is received, this item will be moved to

Category B “Completed Items”, and LADWP will implement an appropriate monitoring program for the vegetation, stream morphology waterfowl, and fisheries.

Item C8 – Progress of the restoration efforts is reported in the annual reports. This item will continue to be in progress until notice from SWRCB is received that LADWP’s obligation for this in the Mono Basin is complete. Once this notice is received, this item will be moved to Category B “Completed Items”.

Item C9 – The Stream Scientists have submitted final recommendations for termination criteria on Walker and Parker Creeks in 2007 to the SWRCB. There has been no decision from SWRCB. Once the termination criteria are finalized by the Stream Scientists and approved by SWRCB, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C10 – The Stream Scientists have submitted final recommendations for termination criteria on Lee Vining and Rush Creeks in 2007 to the SWRCB. There has been no decision from SWRCB. Once approved by SWRCB, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C11 – LADWP will continue to monitor and report on the hydrology of the Mono Basin including regular Mono Lake elevation readings, stream flows, and spring surveys until SWRCB approves that all or portions of the hydrology monitoring is no longer required. Once this occurs, all or portions of this item will be considered complete and will be moved to Category B “Completed Items”. Any portions of this requirement that are deemed to be ongoing by the SWRCB will be moved to Category A “Ongoing Items”.

Item C12 – LADWP will continue to monitor and report on the Mono Lake limnology and secondary producers until SWRCB approves that limnological monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C13 – LADWP will continue to monitor and report on the vegetation status in riparian and lake fringing wetland habitats, which is done every 5 years until SWRCB approves that vegetation monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C14 – LADWP will continue to monitor and report on the waterfowl populations in the Mono Basin until SWRCB approves that waterfowl monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C15 – Testing augmentation of Rush Creek flows with water from Lee Vining Creek through the use of the Lee Vining Conduit is possible and can occur as needed as demonstrated during peak runoff in June 2005. The augmentation has been tested up to 100 cfs and the orders call for maximum augmentation to be 150 cfs. This will only be possible if adequate runoff is available in Lee Vining Creek after the peak operation is complete. Once augmentation is successfully tested through 150 cfs, this item will be moved to Category B “Completed Items”.

Item C16 – Evaluation of the effects of Rush Creek augmentation on Lee Vining Creek needs to be completed to cover diversions up to 150 cfs. Once the evaluation is completed, this item will be moved to Category B “Completed Items”.

Item C17 – Sediment bypass for Parker Creek is now in trial implementation stage. Once a plan is finalized by SWRCB and becomes part of LADWP’s operation plans, this item will be moved to Category A “Ongoing Items”.

Item C18 – Sediment bypass for Walker Creek is now in trial implementation stage. Once a plan is finalized by SWRCB and becomes part of LADWP’s operation plans, this item will be moved to Category A “Ongoing Items”.

Category D – Incomplete Items

None

Category E – Deferred Items

Item E1 – Pending further action by Mono County to improve the county road crossing at Lee Vining Creek, LADWP will write a letter to Mono County recommending an Arizona crossing at that point. Once LADWP writes this letter, or the parties agree that this is unnecessary; this item will be moved to Category B “Completed Items”.

Item E2 – LADWP was to place fish screens on all of its irrigation diversions in the Mono Basin. Subsequently LADWP ended all irrigation practices and hence does not need to install fish screens. If at a later date LADWP resumes irrigation, fish screens will be installed and this item will be moved to Category A “Ongoing Items”.

Item E3 – LADWP began a prescribed burn program with limited success. LADWP requested to remove this item from the requirements and the SWRCB instead ruled that the prescribed burn program will be deferred until Mono Lake reaches 6,391 ft. Once Mono Lake reaches 6,391 ft. LADWP will reassess the prescribed burn. Based on results from the assessment, LADWP will either reinstate the program or request relief from the SWRCB from this requirement. If LADWP reinstates the program this item will be moved to Category C “In-Progress Items”, however if LADWP requests, and is granted relief from this SWRCB requirement, this item will be moved to Category B “Completed Items”.

Item E4 - Rewatering of Rush Creek side channel 1A in reach 4A. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel and was awaiting final decision by SWRCB. This item was approved by SWRCB and was therefore considered completed in 2008. Further work on Channel 1A was to be considered in the future if deemed appropriate. In 2014, as part of the pending new license, it has been included to be done in the future. Until the

SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E5 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 1A in reach 4A will occur for five years following rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel and was awaiting final decision by SWRCB. This item was approved by SWRCB and was therefore considered completed in 2008. In 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E6 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 4Bii in reach 4B five years following rewatering (2007) occurred in the summer of 2012. The results from the assessment following the fifth year after rewatering was reported in Section 4 of the 2013 report. The final assessment concluded that satisfactory revegetation has occurred through natural processes and was considered complete and was moved to Category B "Completed Items". However, in 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E7 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 8 in reach 4B five years following rewatering (2007) occurred in the summer of 2012. The results from the assessment following the fifth year after rewatering were reported in Section 4 of the 2013 report. The final assessment concluded that satisfactory revegetation has occurred through natural processes and was considered complete and was moved to Category B "Completed Items". However, in 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E8 – The stream monitoring team is to evaluate the restoration program after "no less than 8 years and no more than 10 years" from the commencement of the restoration program. This evaluation is to cover the need for a Grant Lake outlet, Rush Creek augmentation, and the prescribed stream flow regime. According to SWRCB Order Nos. 98-05 and 98-07, evaluation of LADWP's facilities to adequately provide proper flows to Rush Creek "*shall take place after two data gathering cycles but no less than 8 years nor more than 10 years after the monitoring program begins*". The Monitoring Team submitted final recommendation, on April 30, 2010. LADWP had 120 days after receiving the recommendation from the monitoring team to determine whether to implement the recommendation of the monitoring team. On July 28, 2010, LADWP submitted a Feasibility Report evaluating the recommendations. In September 2013, LADWP entered into a Settlement Agreement with the Stakeholders and this Agreement is pending SWRCB's approval via an amended Water Rights license. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

7. Ongoing Items Description:

See Section 5 for references where each requirement originates.

Category A – Ongoing Items

Item A1 – *Road closures*. Periodically LADWP personnel will visit all road closures performed by LADWP in accordance with SWRCB Order No. 98-05, Order 1, in the Lower Rush and Lee Vining Creek areas to assess their effectiveness. Where evidence exists that a road closure is ineffective, LADWP will improve the road closures through means such as additional barriers.

Item A2 – *Base flow releases*. LADWP normally will control flow releases from its facilities into Lower Rush, Parker, Walker, and Lee Vining Creeks according to agreed upon flow rate requirements as set forth in the SWRCB Decision 1631, Order Nos. 98-05 and Order 98-07, the Grant Lake Operations Management Plan, and any subsequent operations plans and decisions made by the SWRCB.

Item A3 – *Low winter flow releases*. Per the California Department of Fish and Wildlife recommendations, and SWRCB Order No. 98-05, order 2.b., LADWP will maintain winter flows into Lower Rush Creek below 70 cfs in order to avoid harming the Rush Creek fishery.

Item A4 – *Annual operations plan*. Per SWRCB Order No. 98-05, order 3, LADWP will distribute an annual operations plan covering its proposed water diversions and releases in the Mono Basin. Presently the requirement is to distribute this plan to the SWRCB and all interested parties by May 15 of each year.

Item A5 – *Notification of failure to meet flow requirements*. Per SWRCB Order No. 98-05, order 3, and SWRCB Decision 1631, order 4, if at the beginning of the runoff year, for any reason, LADWP believes it cannot meet SWRCB flow requirements, LADWP will provide a written explanation to the Chief of the Division of Water Rights by May 1, along with an explanation of the flows that will be provided. If unanticipated events prevent LADWP from meeting SWRCB Order No. 98-05 Stream Restoration Flow requirements, LADWP will notify the Chief of the Division of Water Rights within 20 days and provide a written explanation of why the requirement was not met. LADWP will provide 72 hours notice and an explanation as soon as reasonably possible for violation of SWRCB Decision 1631 minimum instream flow requirements.

Item A6 – *Grant storage targets*. LADWP will operate its Mono Basin facilities to maintain a target storage elevation in Grant Lake Reservoir between 30,000 and 35,000 acre-feet at the beginning and end of the runoff year. LADWP shall seek to have 40,000 acre-feet in Grant Reservoir on April 1 each year at the beginning of wet and extreme wet years.

Item A7 – *Export release patterns to the Upper Owens River*. Per SWRCB Decision 1631, order 7, and SWRCB Order No. 98-05, order 2, LADWP will make exports from the Mono Basin to the Upper Owens River in a manner that will not have a combined flow rate below East Portal above 250 cfs. LADWP will perform ramping of exports at 20% or 10 cfs, whichever is greater, on the ascending limb, and 10% or 10 cfs, whichever is greater, on the descending limb of the hydrograph as measured at the Upper Owens River.

Item A8 – *Diversion targets from streams*. Per the 1996 GLOMP, diversion targets for exports from the Mono Basin will be divided between Rush, Lee Vining, Parker and Walker Creeks in the following manner. During all years except dry and extremely wet years, LADWP will seek to divert one-third to one-half of the export amount from Lee Vining Creek, with the remaining water coming from Rush Creek. Only during dry years when 16,000 acre-feet of export is permitted, LADWP will seek to divert from Parker and Walker Creeks. During extremely wet years, all exports will come from diversions off of Rush Creek. Parker and Walker Creeks are expected to be flow through after the SWRCB approves the Settlement Agreement and amends LADWP Water Rights licenses.

Item A9 – *Export amounts dependent on Mono Lake level*. LADWP export amounts follow those ordered by SWRCB Decision 1631, order 2.

Item A10 – *Year type designation and guidelines*. Per SWRCB Decision 1631, order 4, SWRCB Order No. 98-05, and GLOMP, LADWP will perform runoff year forecasts for the Mono Basin with preliminary forecasts being conducted on February 1, March 1, and April 1, with the forecast being finalized on or around May 1 if necessary. LADWP developed a draft May 1 forecast methodology without a need for May snow surveys. When Gem Pass snow pillow measures show an increase in water content between April 1 and May 1, the percentage change experienced by the pillow will be applied to all of the April 1st snow course survey measurements used in calculating the runoff. A slight adjustment to the calculation may be made for dry years. Additionally, the May 1st forecast will have measured April values.

Item A11 – *Dry and wet cycle contingencies for stream restoration flows and base flows*. During consecutive dry years LADWP will release channel maintenance flows (CMF) every other year. The CMF will commence in the second consecutive dry year The channel maintenance flows for Rush Creek will be 100 cfs for five days, and for Lee Vining Creek it will be 75 cfs for five days. Ramping rates will be 10 cfs per day. The occurrence of a year type other than a dry year will terminate the dry year cycle. During consecutive wet years, LADWP will increase base flows above the minimum flow rate every other year. The increased base flows will commence in the second consecutive wet year. The occurrence of a year type other than a wet year will terminate the wet year cycle.

Item A12 – *Deviations from Grant Lake Operation Management Plan (GLOMP)*. LADWP must maintain operational flexibility to adjust or react to unpredictable circumstances.

Item A13 – *Ramping rates*. LADWP will continue to operate its Mono Basin facilities in order to provide SWRCB ramping flow requirements for Lee Vining, Parker, Walker, and Rush Creeks.

Item A14 – *Stream restoration flows and channel maintenance flows*. LADWP will continue to operate its Mono Basin facilities in order to provide peak flow requirements for Lee Vining, Parker, Walker, and Rush Creeks.

Item A15 – *Salt Cedar eradication*. LADWP will continue assisting in a Mono Basin wide effort to eradicate Salt Cedar (*Tamarisk*), and will continue to report on these efforts.

Item A16 – *Aerial Photography.* LADWP will capture aerial and/or satellite imagery of the Mono Basin (Stream Plan, 1" = 6,000' scale; SWRCB Order No. 98-05, Section 6.4.6(4), 1:6,000 scale) every five years or following an extreme wet year event, which resets the five year clock.

Item A17 – *Make basic data available to public*. Per SWRCB Order 98-05, Order 1.b., as revised by SWRCB Order No. 98-07, order 1.b(2), LADWP will continue to make all basic monitoring data available to the public.

Item A18 – *Operation of Lee Vining sediment bypass*. In order to bypass sediment past the Lee Vining diversion facility, LADWP will operate the Lee Vining Conduit control gate to assist with ramping flows towards peak with the intention of having it be in the completely open position while peak flows are passing the diversion facility. After peak flows have passed the facility, the Lee Vining Conduit control gate will slowly close assisting with ramping flows back down towards base flow condition.

Item A19 – *Operation of the Rush Creek augmentation from the Lee Vining Conduit when necessary*. At times when peak flow requirements in Rush Creek exceed facility capacities, and Grant Lake Reservoir is not spilling, LADWP will operate the Lee Vining Conduit 5-Siphon Bypass to bring water from Lee Vining Creek to Rush Creek to augment flows to the required levels.

Item A20 – Data from existing Mono Basin data collection facilities is available on a same-day basis on the LADWP.com internet web site. The data collection and reporting works, as with any other system, can experience periodic short term communication problems and/or technical difficulties, which may result in incorrect readings. LADWP will continue to monitor the data posting on a daily basis and will work to troubleshoot and correct problems as soon as possible. LADWP will continue to improve the data collection, computer, and communication systems as new technology(ies) become available.

Section 2

Mono Basin Operations

Section 2

Mono Basin Operations

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

May 2017

Los Angeles Department of Water and Power

Table of Contents **Page No.**

I. Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1631 and Order Nos. 98-05 and 98-07 (Orders), the Los Angeles Department of Water and Power (LADWP) undertakes certain activities in the Mono Basin in compliance with the terms and conditions of its water right licenses 10191 and 10192. In addition to restoration and monitoring activities covered in this report, LADWP also reports on certain required operational activities.

II. Summary of Mono Basin RY 2016-17 Operations

A. Rush Creek

The runoff from Rush Creek was approximately 45,791 AF which amounts to the total water delivered to GLR's 'Damsite'. The highest flow of 188 cfs occurred on June 4, 2016.

Rush Creek flows below 'the Narrows', which consist of Rush Creek releases (Return Ditch, Spill, and 5-Siphons augmentation) combined with Parker and Walker Creek flows, had an approximate total of 53,453 AF. This flow terminated into Mono Lake.

RY 2016 was forecasted as a DRY-NORMAL I year type and as such, following Guideline 'B', Rush Creek peak flow was maintained at 200 cfs for 7 days from June 14, 2016 to June 20, 2016.

1. Rush Creek Augmentation

To meet high flow targets for lower Rush Creek, LADWP at times must employ facilities in addition to the Mono Gate One Return Ditch (MGORD) which has a 380 cfs capacity limit. During wetter years, LADWP utilizes one or both of its additional facilities to release higher peak flows. These facilities include the 5-Siphons bypass, which can release up to 100 cfs from Lee Vining Creek, and the GLR Spillway which can release large reservoir spills into lower Rush Creek during the wetter years.

<u>5-Siphons Bypass</u>
RY 2016 was forecasted as a DRY-NORMAL I year type. In accordance with Guideline 'B', peak flows in Rush Creek was set at 200 cfs for 7 days. The MGORD, at a max capacity of 380 cfs, was able to accommodate the prescribed peak flows therefore 5-Siphons were not utilized.

<u>Grant Reservoir Spill</u>
Grant did not spill during RY 2016.

B. Lee Vining Creek

RY 2016 was forecasted as a DRY-NORMAL I year type and as such, following Guideline 'B', peak flow was allowed to pass through the diversion facility from May 25, 2016 to June 21, 2016.

Lee Vining Creek had its highest flow on June 8, 2016 at 256 cfs. Total runoff for the year was approximately 44,231 AF.

C. Dry Cycle Channel Maintenance Flows

RY2016 was forecasted as a DRY-NORMAL I year type, therefore dry cycle channel maintenance flows (CMF) were not required in accordance with the GLOMP.

D. Parker and Walker Creeks

Parker and Walker were operated as pass through for RY2016.

Parker Creek had its highest flow on June 8, 2016 at 47 cfs. Total runoff for the year was approximately 8,045 AF.

Walker Creek had its highest flow on June 13, 2016 at 29 cfs. Total runoff for the year was approximately 5,184 AF.

E. Grant Lake Reservoir

Grant Lake began the runoff year at approximately 15,991 AF (7,096.0 ft AMSL). The reservoir did not spill during the RY. Final storage volume by the end of the RY of March 31, 2017 was approximately 30,546 AF (7,113.67 ft AMSL).

F. Exports during RY 2016-17

During RY2016, Mono Lake elevations were within the 6,377 ft – 6,380 ft range, allowing for up to 4,500 AF of exports per D1631. LADWP exported 4,439 AF total from the Mono Basin, which is slightly below the allowed 4,500 AF.

G. Mono Lake Elevations during RY 2016-17

In RY2016, Mono Lake elevations were as shown in the following table. The Lake elevation was at 6,378.11 ft AMSL at the beginning of the runoff year, and ended the runoff year at 6,378.30 ft AMSL, an increase of 0.19 ft.

RY 2016-17 Mono Lake Elevation Readings

April 1, 2016	6,378.11
May 1, 2016	6,378.19
June 1, 2016	6,378.20
July 1, 2016	6,378.32
August 1, 2016	6,378.03
September 1, 2016	6,377.67
October 1, 2016	6,377.35
November 1, 2016	6,377.16
December 1, 2016	6,377.31

January 1, 2017	6,377.47
February 1, 2017	6,377.81
March 1, 2017	6,378.13
April 1, 2017	6,378.30

III. Proposed Mono Basin Operations Plan RY 2017-18

A. Forecast for RY 2017-18

The Mono Basin's April 1st forecast for Runoff Year (RY) 2017 for April to March period is 238,800 acre-feet (AF), or 200 percent of average using the 1966-2015 long term mean of 119,103 AF (**Attachment 2**). This value puts the year type within the 'EXTREME WET' category and operations shall be in accordance with the requirements of SWRCB D1631/Order 98-05 and Guideline 'G' of the Grant Lake Operations Management Plan (GLOMP). See **Attachment 3**.

B. Rush Creek

1. Rush Creek Base Flow

Base flows will follow Order No. 98-05 minimum requirements of 68 cubic feet per second (cfs) from April 1 to September 30, 2017. After peak flow operations, Rush Creek base flows will follow Guideline G until March 31, 2018.

If Grant Lake inflow is less than the dry year base flow and/or if Grant Lake storage drops below 11,500 AF, base flow requirements for a dry year under Guideline A applies.

2. Rush Creek Peak Flow

Peak flows will be timed with Grant Lake spill to achieve and maintain 500 cfs for 5 days followed by 400 cfs for 10 days. Peak flow operations may be reduced or eliminated if Grant Lake storage drops below 11,500 AF in accordance with Section 1.a.(1) of Order 98-05. Ramping rate shall be at 10% change ascending and descending, or 10 cfs, whichever is greater. The expected magnitude and timing of the peak flows in Rush Creek at Dam Site were generated by the Mono Basin Operations Model (MBOM), the results of which are shown below:

Predicted magnitude and timing of peak flows		
Creek	**Magnitude**	**Timing**
Rush	418 cfs	June 1, 2017

3. Rush Creek Augmentation

In wetter years where peak flow requirements may exceed the Mono Gate One Return Ditch (MGORD) or Grant Outlet pipe maximum design capacities, LADWP utilizes one or both of its additional facilities to release the higher peak flows. These facilities include the 5-Siphons bypass, which can release as tested 100 cfs from Lee Vining Creek, and the GLR Spillway, which can release large reservoir spills into lower Rush Creek during the wetter years.

<u>5-Siphons Bypass</u>

Grant Reservoir is expected to spill, therefore the 5-Siphons will not be utilized for augmentation.

<u>Grant Reservoir Spill</u>

According to the MBOM run, Grant Reservoir is expected to spill beginning mid-June 2017. The MGORD operations will be timed with Reservoir spill to try to meet the required peak flows.

C. Lee Vining Creek

1. Lee Vining Creek Base Flow

Lee Vining Creek will be operated as pass through in accordance with Guideline ‘G’.

2. Lee Vining Creek Peak Flow

Lee Vining Creek will be operated as pass through in accordance with Guideline ‘G’.

D. Dry Cycle Channel Maintenance Flows

Because RY2017 is forecasted to be an EXTREME WET year, dry cycle channel maintenance flows will not be required in accordance with the GLOMP.

E. Parker and Walker Creeks

Parker and Walker Creek facilities will be operated as pass through in accordance with Guideline ‘G’

F. Grant Lake Reservoir

Grant Lake Reservoir (GLR) storage volume was 30,546 AF, corresponding to a surface elevation of 7113.7 feet above mean sea level (AMSL) at the start of the runoff year. Using the closest available representative historical inflow data (1983 runoff year at 196 percent of normal), and above specified flows, GLR is projected to spill as shown in **Attachment 4**. Forecasted scenarios will be relatively close only if this year’s hydrology turns out to be similar to the hydrology of the selected historical runoff year. Operations are subject to change with variations in actual hydrology during the upcoming runoff year.

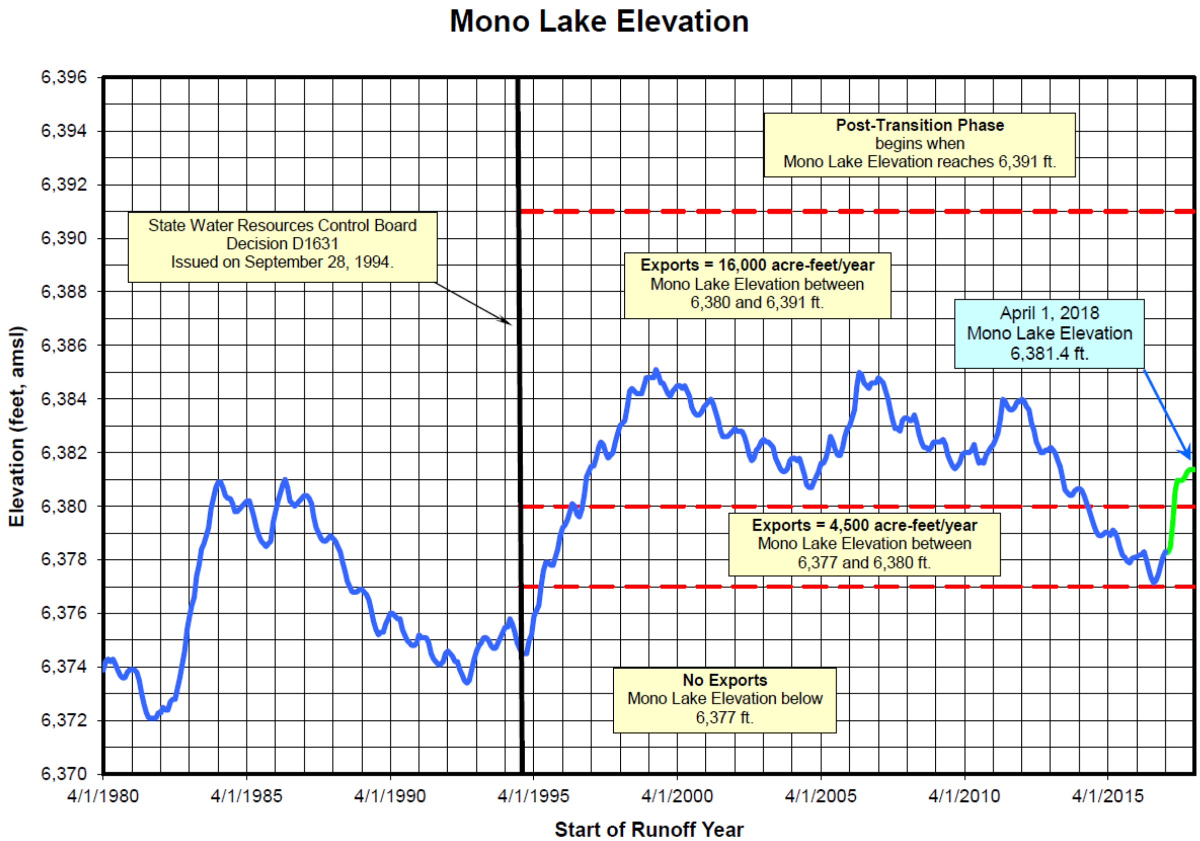
G. Planned Exports for RY 2017-18

Mono Lake level reading conducted on April 1, 2017 indicated that the lake’s surface water elevation was at 6,378.30 ft AMSL, well within the 6,377 ft – 6,380 ft range, thereby allowing for 4,500 AF of exports per the SWRCB Decision 1631. LADWP plans to conduct export operations in the later part of the runoff year.

H. Expected Mono Lake Elevations during RY 2017-18

Mono Lake began this runoff year at 6,378.30 ft AMSL where it is forecasted to increase and end the runoff year at approximately 6,381.4 ft AMSL (**Attachment 1**).

ATTACHMENTS


Mono Lake Elevation
6,396
6,394
6,392
6,390
6,388
6,386
6,384
6,382
6,380
6,378
6,376
6,374
6,372
6,370
Elevation (feet, amsl)
Post-Transition Phase begins when Mono Lake Elevation reaches 6,391 ft.
State Water Resources Control Board Decision D1631 Issued on September 28, 1994.
Exports = 16,000 acre-feet/year Mono Lake Elevation between 6,380 and 6,391 ft.
April 1, 2018 Mono Lake Elevation 6,381.4 ft.
Exports = 4,500 acre-feet/year Mono Lake Elevation between 6,377 and 6,380 ft.
No Exports Mono Lake Elevation below 6,377 ft.
4/1/1980
4/1/1985
4/1/1990
4/1/1995
4/1/2000
4/1/2005
4/1/2010
4/1/2015
Start of Runoff Year

Attachment 2

2017 EASTERN SIERRA RUNOFF FORECAST
April 1, 2017

APRIL THROUGH SEPTEMBER RUNOFF

	MOST PROBABLE VALUE (Acre-feet)	MOST PROBABLE VALUE (% of Avg.)	REASONABLE MAXIMUM (% of Avg.)	REASONABLE MINIMUM (% of Avg.)	LONG-TERM MEAN (1966 - 2015) (Acre-feet)
MONO BASIN:	**211,200**	**210%**	218%	201%	100,782
OWENS RIVER BASIN:	**643,000**	**216%**	227%	205%	298,151

APRIL THROUGH MARCH RUNOFF

	MOST PROBABLE VALUE (Acre-feet)	MOST PROBABLE VALUE (% of Avg.)	REASONABLE MAXIMUM (% of Avg.)	REASONABLE MINIMUM (% of Avg.)	LONG-TERM MEAN (1966 - 2015) (Acre-feet)
MONO BASIN:	**238,800**	**200%**	211%	190%	119,103
OWENS RIVER BASIN:	**801,900**	**197%**	208%	187%	406,185

NOTE - Owens River Basin includes Long, Round and Owens Valleys (not incl Laws Area)

MOST PROBABLE - That runoff which is expected if median precipitation occurs after the forecast date.

REASONABLE MAXIMUM - That runoff which is expected to occur if precipitation subsequent to the forecast is equal to the amount which is exceeded on the average once in 10 years.

REASONABLE MINIMUM - That runoff which is expected to occur if precipitation subsequent to the forecast is equal to the amount which is exceeded on the average 9 out of 10 years.

Mono Basin Operations, Guideline G

Year Type:………………………………..………………………………. EXTREME WET
Forecasted Runoff in acre-feet...…………………………………………. > 195,400

Lower Rush Creek

Base Flows:

	April	May–Aug	Sep-Mar
Flow (cfs)	80	150	100

Minimum base flows are 68 cfs for Apr-Sep and 52 cfs for Oct-Mar, or the inflow to Grant Lake, whichever is less (flows listed above are for Mono Lake maintenance water). However, if Grant Lake inflow is less than the dry year base flow requirements under Guideline A, dry year requirements apply. If Grant Lake storage drops below 11,500 acre-feet (7,089.4' elevation), base flow requirements for a dry-year under Guideline A also apply (D-1631, p 197-198).

Peak Flows: - 500 cfs for 5 days followed by 400 cfs for 10 days (see augmentation).

Ramping: - Begin ramping on June 1st (rule of thumb). Note peak operations will take 38 days, so timing this with peak flows in P/W Creeks, with fish movement, and cottonwood germination is beneficial. If augmenting, begin ramping as Lee Vining Creek peaks.
- 10 percent daily change during ascending and descending limbs, or 10-cfs, whichever is greater.

Lee Vining Creek

Base Flows: - Flow-through conditions.

Peak Flows: - Flow-through conditions.

Ramping: - None, unless augmenting Rush Creek. In such case, ramp flows with 20 percent daily change during ascending and 15 percent during descending limbs, or 10-cfs, whichever is greater.

Diversions: - None, unless augmenting Rush Creek. If augmenting Rush Creek, begin 14 days after peak flow in Lee Vining Creek and resume flow-through conditions after completion of augmentation.

Augmentation: - If not spilling Grant Lake, augment flows in Rush Creek with up to 150-cfs from Lee Vining for 5 days followed by up to 50-cfs for10 days. This should begin 14 days after peak flow in Lee Vining.

Parker and Walker Creeks

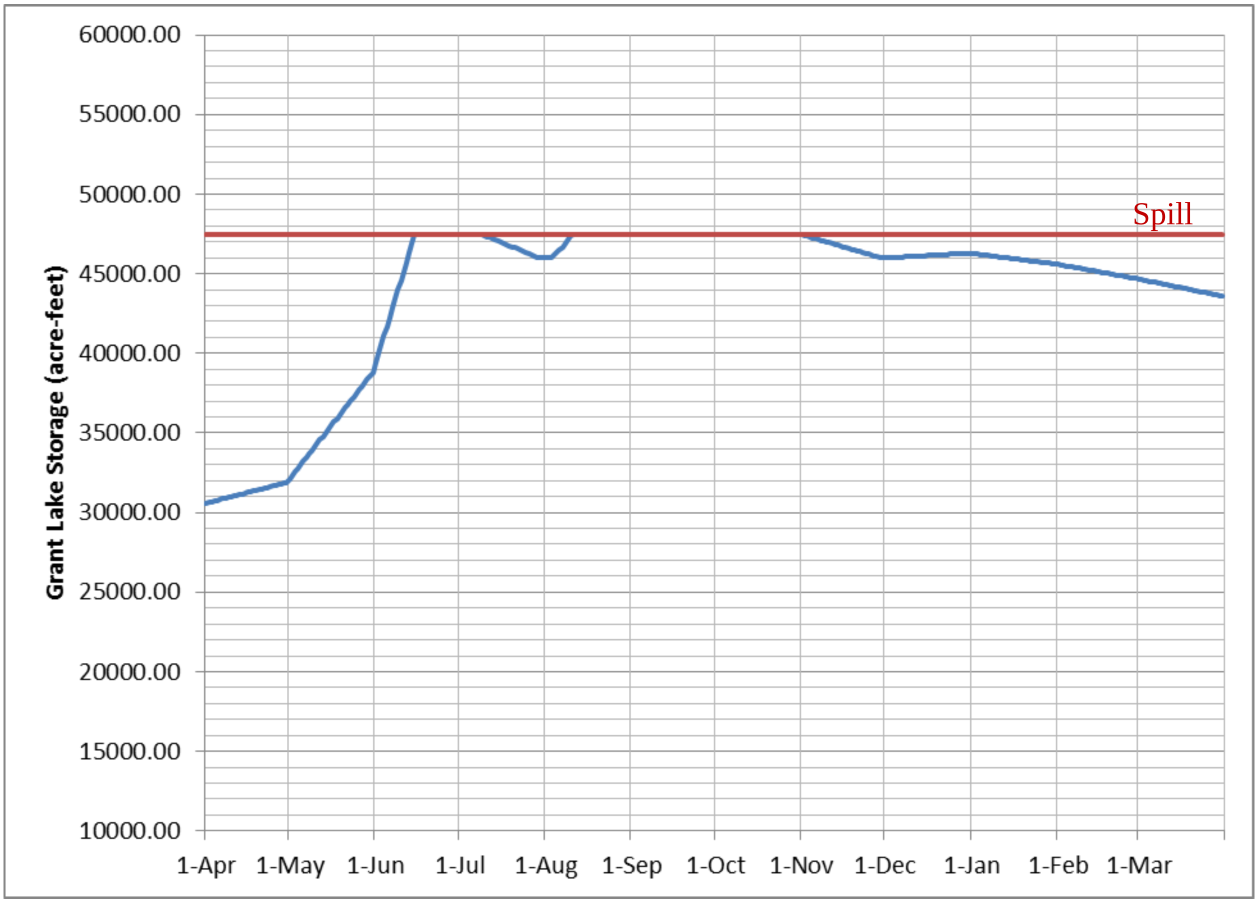
Flow-through conditions for entire year.

Exports

4,500 acre-feet scenario – Maintain 6 cfs export throughout the year.
16,000 acre-feet scenario – Maintain 23 cfs export except during peak flow operations in lower Rush Creek. During this time, exports should be zero.

Attachment 4

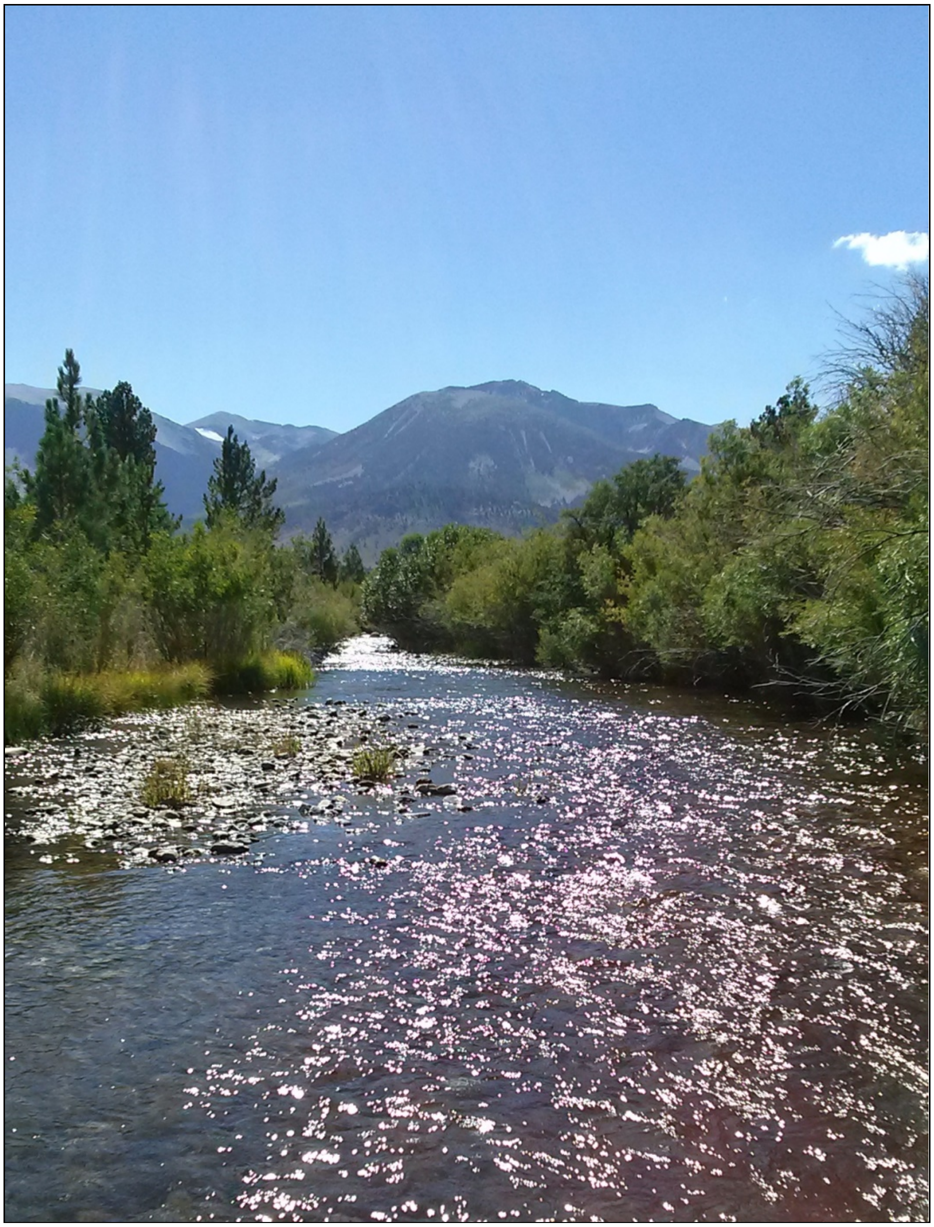
RY 2017/18 Grant Lake Reservoir Storage Projection Using 1983 (196% Year) Inflow



Section 3

Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks 2016-17

Mono Basin Fisheries Monitoring Report
Rush, Lee Vining, and Walker Creeks
2016



Prepared by Ross Taylor and Associates for

Los Angeles Department of Water and Power's Annual Compliance Report to the State Water Resources Control Board

Date: April 15, 2017

Table of Contents

Executive Summary

This report presents results of the 20th year of trout population monitoring for Rush, Lee Vining, and Walker Creeks pursuant to SWRCB's Water Right Decision 1631 (D1631) and the eighteenth year following SWRCB Orders #98-05 and #98-07. This report provides the trout population data collected between September 13th and 23rd 2016 as mandated by the Orders and the Settlement Agreement.

The 2016 runoff year (RY) was 74% of normal and classified a "Dry-Normal 1" runoff year (RY) type, as measured on April 1st. RY 2016 was a departure from four consecutive Dry runoff years (RY 2015 was 25% of normal, RY 2014 was 48% of normal, RY 2013 was 66% of normal and RY 2012 was 55% of normal). Annual electrofishing mark-recapture monitoring was conducted in three sections of Rush Creek and in the main channel section of Lee Vining Creek. Multiple-pass depletion electrofishing was conducted in the Lee Vining Creek side channel and in Walker Creek. These data were used to generate population estimates, density estimates, standing crop estimates, condition factors, relative stock densities, and growth rates and apparent survival rates from PIT tag recaptures.

Population Estimates

The Upper Rush section supported an estimated 146 age-0 Brown Trout in 2016 compared to 647 age-0 fish in 2015. This section supported an estimated 55 Brown Trout 125-199 mm in length in 2016 compared to 297 fish in 2015. In 2016, Upper Rush supported an estimated 110 Brown Trout ≥200 mm in length compared to an estimate of 117 fish in 2015. Between 2012 and 2016, the Upper Rush total Brown Trout population estimate dropped from 3,564 fish to 311 fish, a 91% decline.

The Bottomlands section supported an estimated 146 age-0 Brown Trout in 2016 versus 465 age-0 fish in 2015. This section supported an estimated 46 Brown Trout 125-199 mm in length in 2016 compared to 96 fish in 2015. The Bottomlands section supported an estimated 38 Brown Trout ≥200 mm in 2016 compared to 62 trout in 2015. Between 2012 and 2016, the Bottomlands total Brown Trout population estimate dropped from 1,402 fish to 230 fish, an 84% decline.

The MGORD section of Rush Creek supported an estimated 13 Brown Trout 125-199 mm in 2016 (versus 237 in 2014) and an estimated 286 Brown Trout ≥200 mm in 2016 (versus 555 in 2014). In 2016, total catch numbers were the lowest ever for two electrofishing passes within the MGORD. Between 2012 and 2016, the catch dropped from 575 fish (average of two passes) to 116 fish (average of two passes), an 80% decline.

Lee Vining Creek's main channel section supported an estimated 118 age-0 Brown Trout in 2016, compared to an estimated 251 age-0 fish in 2015. This section supported an estimated 150 Brown Trout 125-199 mm in length in 2016 compared to 192 fish in 2015. Lee Vining Creek's main channel supported an estimated 50 Brown Trout ≥200 mm in 2016 versus 55 fish in 2015. Between 2012 and 2016, the total Brown Trout population estimate dropped from 797 fish to 318 fish, a 60% decline.

A total of seven Rainbow Trout were captured in Lee Vining Creek's main channel making up approximately 2% of the total trout catch in 2016. No age-0 Rainbow Trout (<125 mm) and no Rainbow Trout in the 125-199 mm size class were captured during the 2016 sampling. The 2016 estimate for Rainbow Trout ≥200 mm in length was seven fish versus nine fish in 2015.

The 2016 age-0 Brown Trout estimate for Walker Creek was 292 fish. The 2016 population estimate for Brown Trout in the 125-199 mm size class equaled 70 trout. Brown Trout ≥200 mm in length accounted for 5% of the total catch in 2016 and the population estimate for this size class was 17 Brown Trout. The largest Brown Trout captured in Walker Creek in 2016 was 271 mm in length.

In the Lee Vining Creek side channel, 12 Brown Trout were captured in four electrofishing passes during the 2016 sampling. The estimates equaled the catch numbers for each size class: <125 mm = two fish; 125-199 mm = seven fish; and ≥200 mm= three fish. No Rainbow Trout were captured in the side channel in 2016. This was the eighth consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the sixth consecutive year the no age-1+ Rainbow Trout were captured.

Densities of Age-0 Trout

Age-0 Brown Trout density estimates (numbers per hectare) decreased in both the Upper Rush and Bottomlands sections of Rush Creek in 2016 when compared to the 2015 values. In 2016, the Upper Rush section's estimated density of age-0 Brown Trout was 439 fish/ha and the Bottomlands section's estimated density of age-0 Brown Trout equaled 458 fish/ha. In Walker Creek, the 2016 density estimate of age-0 Brown Trout was 6,578 fish/ha (a 93% increase from 2015).

The 2016 age-0 Brown Trout density estimate in the main channel of Lee Vining Creek was 873 fish/ha. In 2016, two age-0 Brown Trout were captured in the Lee Vining Creek side channel.

Densities of Age-1 and older (aka Age-1+) Trout

Age-1 and older Brown Trout density estimates (numbers per hectare) decreased in both the Upper Rush and Bottomlands sections of Rush Creek in 2016 when compared to the 2015 values. In 2016, the Upper Rush section's estimated density of age-1+ Brown Trout was 496 fish/ha and the Bottomlands section's estimated density of age-1+ Brown Trout equaled 245 fish/ha. In Walker Creek, the 2016 density estimate of age-1+ Brown Trout was 1,960 fish/ha.

The 2016 age-1+ Brown Trout density estimate in the main channel of Lee Vining Creek was 1,479 fish/ha. In 2016, the Lee Vining Creek side channel's density estimate of age-1 and older Brown Trout was 430 fish/ha.

Standing Crop Estimates

The estimated standing crop for Brown Trout in the Upper Rush section was 62 kg/ha in 2016, the lowest value for this section in 18 years. The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 34 kg/ha in 2016, the lowest value for this section in nine years of sampling.

The estimated standing crop for Brown Trout in Walker Creek was 172 kg/ha in 2016 and was the fifth highest value recorded in Walker Creek over the 18-year sample period.

The Lee Vining Creek main channel in 2016 produced a total estimated standing crop of 113 kg/ha for both Rainbow and Brown Trout. The 2016 Brown Trout standing crop estimate was 105 kg/ha and the Rainbow Trout standing crop estimate was 8 kg/ha.

The Lee Vining Creek side channel produced a total Brown Trout standing crop estimate of 31 kg/ha in 2016. No Rainbow Trout were captured in the side channel in 2016 and none have been sampled in the side channel for six consecutive years (2011-2016).

Condition Factors

Condition factors of Brown Trout 150 to 250 mm in length in 2016 decreased in two sections (Bottomlands and Walker) from 2015's values and increased in four sections from 2015's values (MGORD, Upper Rush, Lee Vining side channel, and Lee Vining main channel). In 2016, three sections (MGORD, Upper Rush, and Lee Vining Side Channel) had Brown Trout condition factors ≥1.00.

Relative Stock Densities (RSD)

In the Upper Rush section, the 2016 RSD-225 of 28 was the highest value for this section since 2010's value of 34. This increase in the RSD-225 value was most likely influenced by the overall low numbers of fish along with poor age-0 recruitment during the previous years, leading to low numbers of age-1 and older fish in the 150-224 mm size class. The RSD-300 value was 3 in 2016, back up to the same value as 2010's.

In the Bottomlands section of Rush Creek, the RSD-225 for 2016 was 21, a slight drop from 2015's value of 23. As in the Upper Rush section, low numbers of age-1 and older trout affected the Bottomlands RSD-225 value. In 2016, only 14 Brown Trout ≥225 mm in length were captured (Table 14). The RSD-300 value was 5 in 2016, based on the capture of three Brown Trout ≥300 mm, of which two were >400 mm.

In the MGORD, the RSD-225 value increased from 72 in 2015 to 74 in 2016; this was the third consecutive increase since the low value of 42 in 2013. In 2016, the RSD-300 value was 21, a slight decrease from a value of 25 in 2015. The RSD-375 value in 2016 was 11, the highest this has been since the 2001 season. Although the total catch of Brown Trout in the MGORD during the 2016 season was lowest ever (116 fish average for two electrofishing passes), 38 trout ≥300 mm in length were caught, including 20 fish ≥375 mm in length.

RSD values in Lee Vining Creek were generated for the main channel combined with the side channel and for the main channel only. The RSD-225 values for the main/side combined and main-only equaled 14 for 2016, an increase compared to the 2015 value. For a third straight year, no trout greater than 300 mm in length were captured in Lee Vining Creek.

Introduction

This report presents results of the 20th year of trout population monitoring for Rush, Lee Vining, and Walker Creeks pursuant to SWRCB's Water Right Decision 1631 (D1631) and the eighteenth year following SWRCB Orders #98-05 and #98-07. Order 98-07 stated that the monitoring team would develop and implement a means for counting or evaluating the number, weights, lengths and ages of trout present in various reaches of Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. This report provides trout population data collected in 2016 as mandated by the Orders and the Settlement Agreement.

Study Area

Between September 13th and 23rd, 2016, Los Angeles Department of Water and Power (LADWP) staff , Ross Taylor (the SWRCB fisheries scientist) and two consultants from Stantec Engineering conducted the annual fisheries monitoring surveys in six reaches along Rush, Lee Vining, and Walker Creeks in the Mono Lake Basin. The six reaches were similar in length to those which have been sampled between 2009 and 2015 (Figure 1). Aerial photographs of the 2016 sampling reaches can be found in Appendix A.

Hydrology

The 2016 runoff year (RY) was 74% of normal and classified a "Dry-Normal 1" runoff year (RY) type, as measured on April 1st. RY 2016 was a departure from four consecutive Dry runoff years (RY 2015 was 25% of normal, RY 2014 was 48% of normal, RY 2013 was 66% of normal and RY 2012 was 55% of normal). Under the existing SWRCB orders, a Dry-Normal 1 prescribes a peak release of 200 cfs for seven days in Rush Creek, followed by baseflows of 47 cfs from April 1 through September 30, and 44 cfs from October 1 through March 31. In Lee Vining Creek, the existing SWRCB orders require that the primary peak flow is passed downstream. The SRF summer baseflow to Lee Vining Creek below LADWP's point of diversion was 54 cfs or to pass all the flow if less than 54 cfs.

Streamflow discharges in Rush Creek at Dam Site (located upstream of Grant Lake Reservoir) were irregular throughout 2016 due to SCE's operations (blue line on Figure 2). Flows released to Rush Creek downstream of Grant Lake Reservoir (Rush at MGORD) followed the SRF Dry-Normal 1 prescription with the winter baseflow until late March, followed a by spring bench of approximately 50 cfs, then a 200 cfs peak for seven days, and a down-ramp to summer baseflows of approximately 50 cfs (red line on Figure 2). Accretions from Parker and Walker creeks resulted in flow fluctuations through the spring and summer, and a peak of 255 cfs in Rush Creek below the Narrows on June 13th (green line on Figure 2).

In 2016, three distinct peaks occurred in Lee Vining Creek – May 14th, June 8th, and June 22nd (Figure 3). As required by the SRFs, LADWP passed the primary peak of 257 cfs on June 8th. Starting in late July, the irregularities between the "Above and Below" Intake flows were due to recording errors, not actual flow differences (Figure 3).

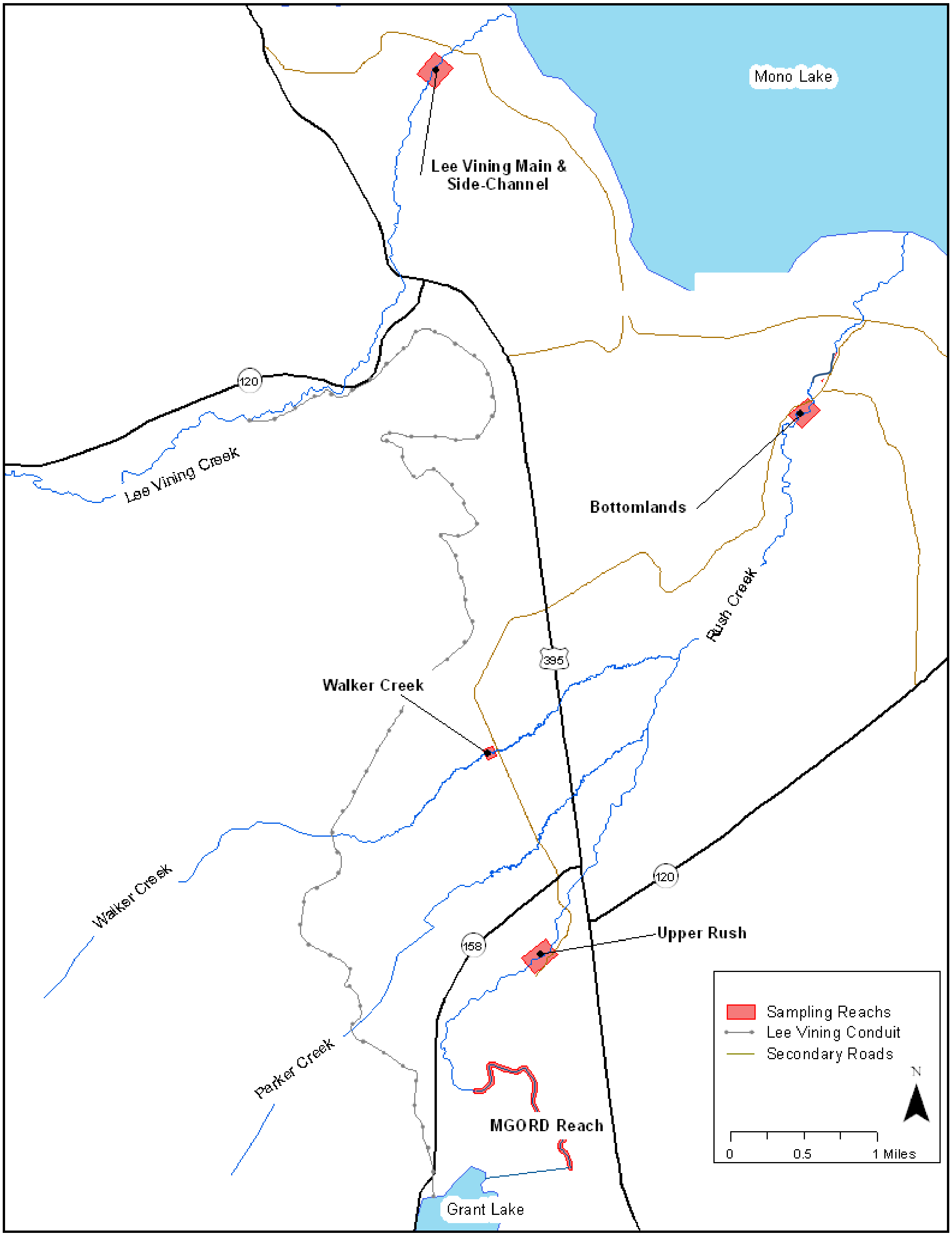


Figure 1. Annual fisheries sampling sites within Mono Basin study area, September 2016.

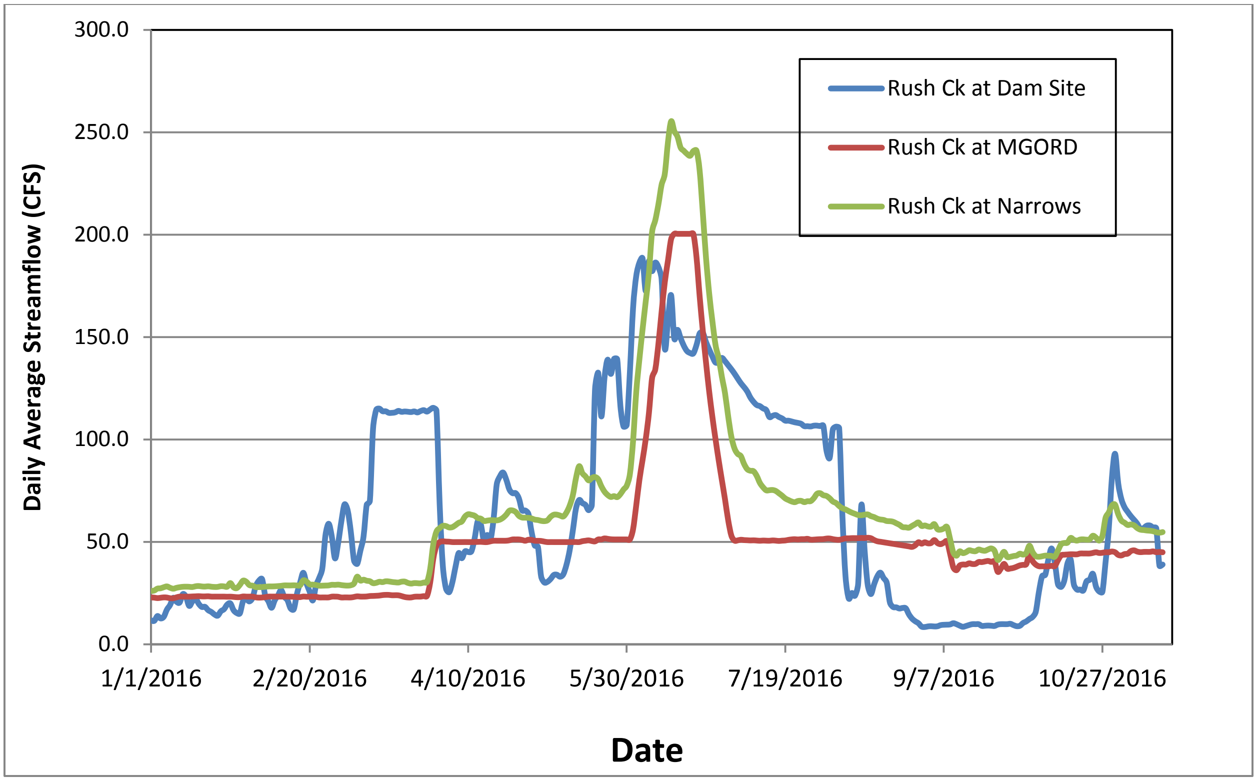


Figure 2. Rush Creek hydrographs between January 1st and November 15th of 2016.

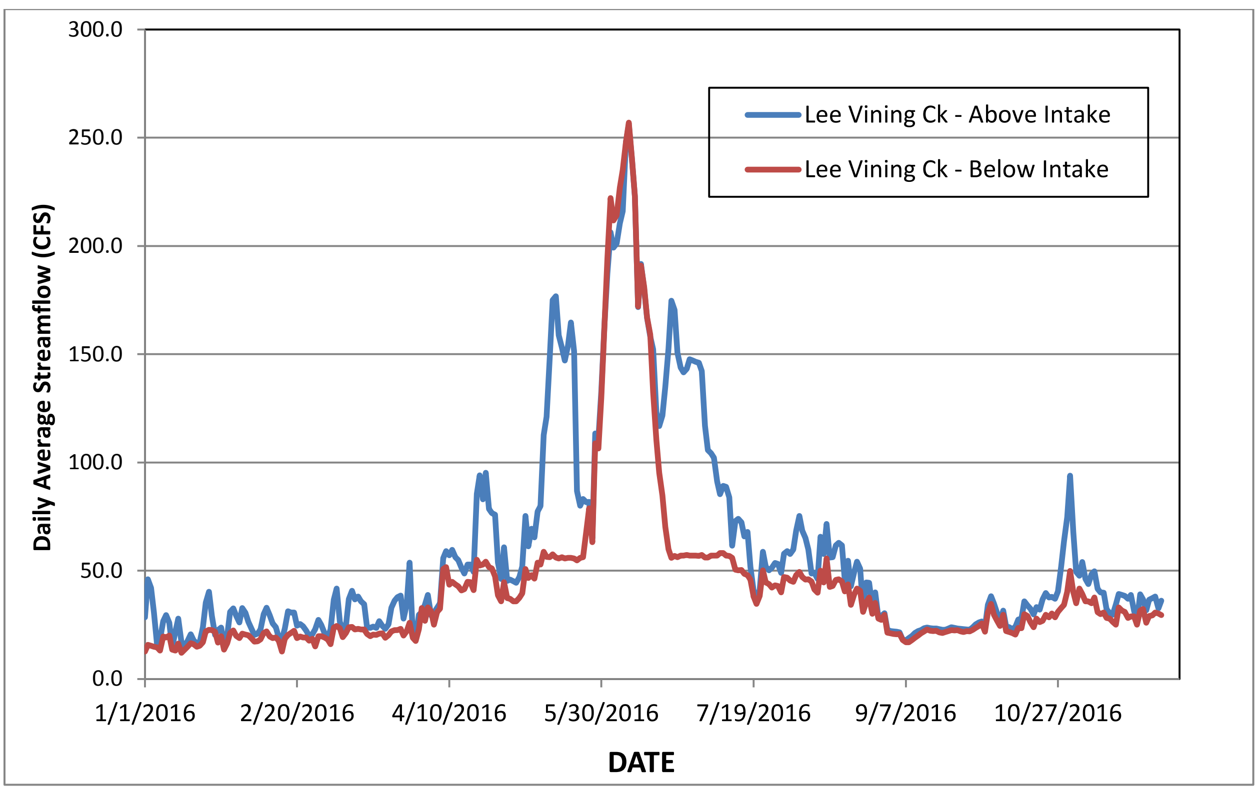


Figure 3. Lee Vining Creek hydrographs between January 1st and November 31st of 2016.

Grant Lake Reservoir

In 2016, storage elevation levels in Grant Lake Reservoir (GLR) fluctuated from a low of 7,088.5 ft to a high of 7,110.7 ft (Figure 4). In 2016, GLR's elevation started at a four-year low due to the prolonged drought, yet storage elevations increased throughout the year until the peak elevation of 7,110.7 ft on August 10th (Figure 4). Then between August 10th and October 30th of 2016, GLR's storage elevation dropped 10.8 feet as LADWP exported their allotted 4,500 AF and as SRF baseflow releases to lower Rush Creek exceeded streamflows into GLR (Figure 4).

After several consecutive years of decreases in GLR's maximum elevations, the 2016 GLR maximum elevation was 7,110.7 ft (19.3 feet below spill level and 12.3 feet higher than 2015's maximum level) (Figure 4).

Between May 23rd and October 25th, GLR's elevation was above the "*low*" GLR level as defined in the Synthesis Report by the Stream Scientists as a level where warm water temperatures should be a concern (<20,000 AF storage or approximately 7,100 ft elevation) (Figure 4). However, the 2016 summer water temperature monitoring documented substantial increases in Rush Creek water temperatures as flow moved downstream through GLR and the MGORD.

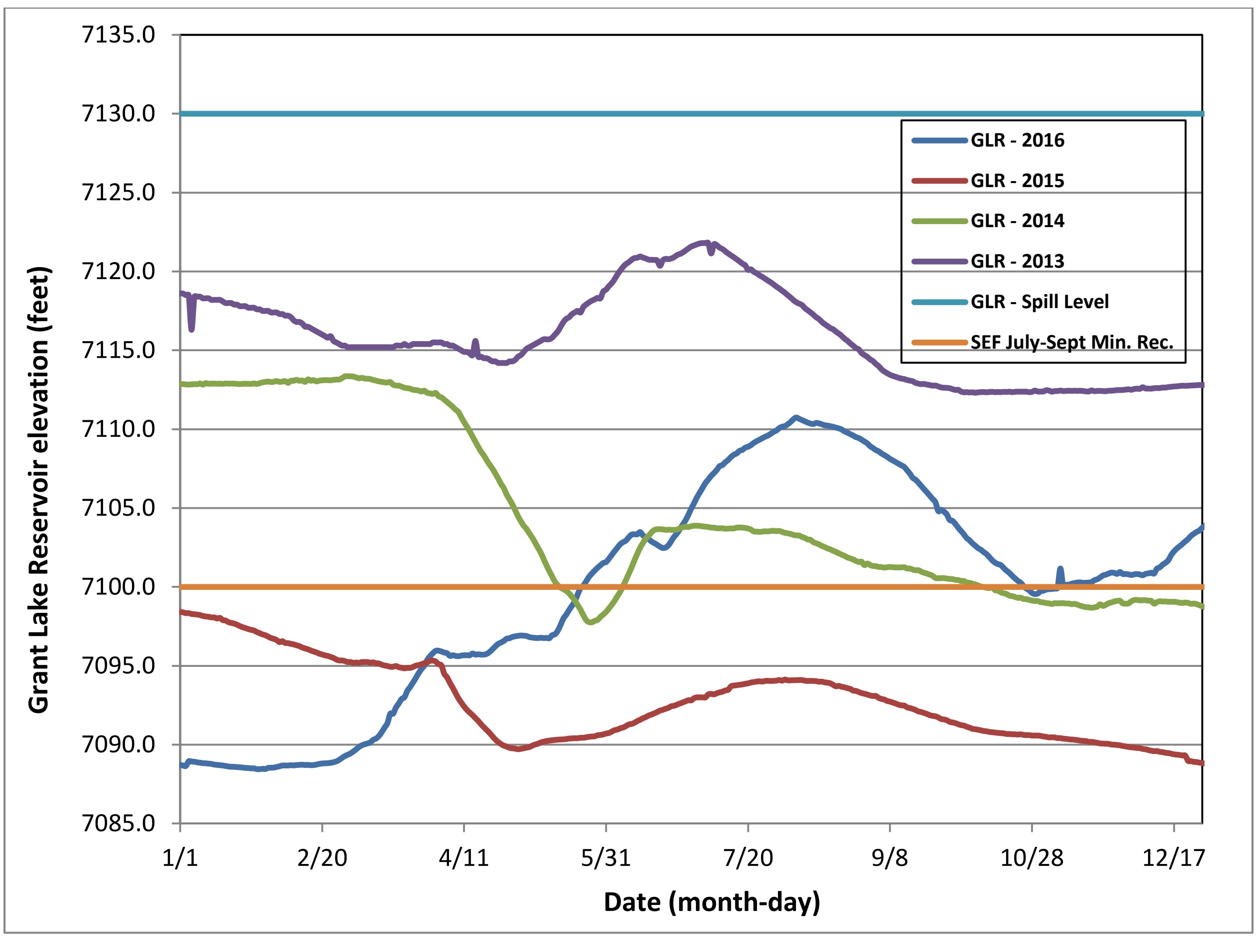


Figure 4. Grant Lake Reservoir's elevation between January 1st and December 31st 2016.

Methods

The annual fisheries monitoring was conducted between September 13th and 23rd of 2016. Closed population mark-recapture and depletion methods were utilized to estimate trout abundance. The mark-recapture method was used on the MGORD, Upper and Bottomlands sections of Rush Creek and the Lee Vining Creek main channel section. The depletion method was used on the Lee Vining Creek side channel and Walker Creek sections.

For the mark-recapture method to meet the assumption of a closed population, semi-permanent block fences were installed at the upper and lower ends of each section (excluding the MGORD). The semi-permanent fences were 48 inches tall, constructed with ½ inch-mesh hardware cloth, t-posts, and rope. Hardware cloth was stretched across the entire width of the creek and t-posts were then driven at roughly five-foot intervals through the cloth on the upstream side approximately one foot from the edge. Rocks were placed on the lower edge to prevent trout from swimming underneath the fence. Rope was secured across the tops of the t-posts and anchored to both banks upstream of the fence. The hardware cloth downstream of the t-posts was raised and secured to the rope with bailing wire. Fences were raised the morning of the mark run and left in place for seven days until the recapture run was finished. To prevent failure, all fences were cleaned of leaves, twigs, and checked for mortalities at least twice daily (morning and evening).

Depletion estimates only required temporary fencing to prevent fish movement in and out of the study area while conducting the survey. Temporary fencing was erected at the upper and lower ends of the study areas with 3/16 inch-mesh nylon seine nets installed across the channel. Rocks were placed on the lead line to prevent trout from swimming underneath the seine net. Sticks were used to keep the top of the seine above the water surface. Both ends of the seine net were then tied to bank vegetation to hold it in place.

Equipment used to conduct mark-recapture electrofishing on Rush Creek included a six foot plastic barge that contained the Smith-Root© 2.5 GPP electro-fishing system, an insulated cooler, and battery powered aerators. The Smith-Root© 2.5 GPP electro-fishing system included a 5.5 horsepower Honda© generator which powered the 2.5 GPP control box. Electricity from the 2.5 GPP control box was introduced into the water via two anodes. The electrical circuit was completed by the metal plate cathode attached to the bottom of the barge. Due to the steep-gradient and relatively narrow width of Lee Vining Creek, two Smith-Root© LR-24 backpack electrofisher units were used for the mark-recapture runs.

Mark-recapture runs on Rush Creek consisted of a single downstream pass starting at the upper block fence and ending at the lower block fence. In 2016, the field crew consisted of a barge operator, two anode operators, and four netters, two for each anode. The barge operator's job consisted of carefully maneuvering the barge down the creek and ensuring overall safety of the entire crew. The anode operator's job was to safely shock and hold trout until they were netted. The netters' job was to net and transport fish to the insulated cooler and monitor trout for signs of stress. Once the cooler was full, electrofishing was temporarily stopped to process the trout. The trout were then transferred from the cooler to live cars and placed back in the creek. The trout were then processed in small batches and then returned to a recovery live car in the creek. Once all the trout were processed at a sub-stop, the crew resumed electrofishing until the cooler was once again full.

Mark-recapture runs on Lee Vining Creek consisted of an upstream pass starting at the lower block fence and ending at the upper block fence, followed shortly by a downstream pass back to the lower block fence. The electrofishing crew consisted of two crew members running the backpack electrofishers, four netters, and one bucket carrier who transported the captured trout to several live cars positioned throughout the sample reach. Once the up-and-down passes were finished, the crew processed the trout.

Due to the depth of the MGORD, all electrofishing and netting was done from inside a drift boat. The drift boat was held perpendicular to the flow by two crew members who walked it down the channel. The electrofishing barge was tied off to the upstream side of the drift boat and a single throw anode was used. A single netter used a long handled dipnet to net the stunned trout, which were then placed in an insulated cooler equipped with aerators. A safety officer sat at the stern of the drift boat whose job was to monitor the trout in the cooler, the electrofishing equipment, the electrofishing crew, and shut off the power should the need arise. Once the cooler was full, the trout were moved to a live car and placed back in the creek for the shore-based crew to process before continuing the electrofishing effort.

For the Walker Creek and Lee Vining Creek side channel (B-1 side channel) depletions, a single pass was considered an upstream pass from the lower seine net to the upper seine net followed by a downstream pass back to the lower seine net. One member of the electrofishing crew operated the LR-24 electrofisher; another member was the primary netter and a third member was the backup netter/bucket carrier. The other crew members processed the trout captured during the first pass while the electrofishing crew was conducting on the second pass. Processed first-pass fish were temporarily held in a live car until the second pass was completed and it was determined that only two passes were required (Walker Creek) to generate a suitable estimate, or additional passes were required (Lee Vining Creek). The temporarily held fish were released once all fish were processed and we determined that no additional electrofishing passes were required to generate estimates.

To process trout during the mark-run, small batches of fish from the live car were transferred to a five gallon bucket equipped with aerators. Trout were then anesthetized, identified as either Brown Trout or Rainbow Trout, measured to the nearest millimeter (total length), and weighed to the nearest gram on an electronic balance. Trout were then “marked” with a small (< 3 mm) fin clip for identification during the recapture run. Trout captured in the Rush Creek Bottom-lands and MGORD sections and in the main channel of Lee Vining Creek received anal fin clips. Trout captured in the Upper section of Rush Creek received a lower caudal clip. Before placing trout into the aerated recovery bucket, each fish was examined for a missing adipose fin. Trout missing their adipose fin were then scanned for their Passive Integrated Transponder (PIT) tag number. Any trout missing their adipose fin that failed to produce a tag number when scanned were recorded as having “shed” the PIT tag; in most instances these fish were retagged. Partially regenerated adipose fins of fish with PIT tags were reclipped for ease of future identification. Once recovered, fish were then moved from the recovery bucket to a live car to be held until the day's sampling effort was completed; this was done to prevent captured fish from potentially moving downstream into the actively sampled section. At the end of the electrofishing effort, fish were released from the live cars back into the sub-sections they had been captured in. Fish were then provided a seven-day period to remix back into the section's population prior to conducting the recapture-run.

Processing trout during the recapture-run was similar to the mark-run. Trout were transferred in small batches to a five gallon bucket. They were then anesthetized, identified, and examined for the "mark" fin clip. Trout that were fin clipped were only measured to the nearest millimeter and placed in the recovery bucket. Trout that were not clipped during the "mark" run (i.e. new fish) were measured to the nearest millimeter "total length," weighed to the nearest gram, and examined for missing adipose fins. New trout missing adipose fins were then scanned for their PIT tag number then placed into recovery. Again, trout that failed to produce a tag number were recorded as having "shed" the PIT tag, and were usually re-tagged.

Between 2009 and 2012, PIT tags were implanted in most age-0 trout in Rush and Lee Vining Creeks and in all ages of trout in the MGORD. No PIT tags were deployed in 2013; however the tagging program was resumed during the 2104 - 2016 field seasons.

All data collected in the field, were written on data sheets and entered into Excel spreadsheets using a field laptop computer. Data sheets were then used to proof the Excel spreadsheets.

Calculations

To calculate the area of each sample section, channel lengths and wetted widths were measured within the sample reaches. Wetted widths were measured at approximately 10-meter intervals to 0.1 meter accuracy within each reach. Average wetted widths were used in area calculations which were then used to calculate each section's estimates of trout biomass and density.

Mark-recapture population estimates were derived from the Chapman modification of the Petersen equation (Ricker 1975 as cited in Taylor and Knudson 2011). Depletion estimates and condition factors were derived from MicroFish 3.0 software program. Estimates were generated for three size groups of trout: <125 mm in length, 125-199 mm in length, and ≥200 mm in length (200 mm is approximately eight inches).

Mortalities

For the purpose of conducting the mark-recapture methodology, accounting for fish killed during the sampling process was important. Depending on when the fish were killed and whether or not they were sampled during the mark-run, how these fish were accounted for varied.

All fish killed during the mark-run were unavailable for sampling during the recapture-run. These fish were considered "morts" in the mark-run for the purposes of mark-recapture estimates, were removed from the mark-run data, and then were added back into the total estimate after computing the mark-recapture estimate.

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During the seven-day period between the mark-run and the recapture-run, when the block fences were cleaned twice daily, fence cleaners also looked for additional morts. When "marked" morts were found on the fences, we went back into the mark-run data and assigned block fence morts on a one-to-one basis as "morts" to individual fish on the mark-run based on species and size. When this occurred, a comment was added to the individual fish, such as "assigned as fence mort". These marked morts were then removed from the mark-run data since they were unavailable for sampling during the recapture-run. Because of fin deterioration on some morts, exact lengths were not always available. Fortunately, it was not critical to match the exact length when assigning these marked fence morts to fish from the mark-run, but it was important that the fence morts were placed within the proper "length group" for which estimates were computed. As with fish killed during the mark-run, these marked fence morts were added back into the total estimate after the mark-recapture estimate was computed.

Unmarked fence morts (fish not caught and clipped during the mark-run) were measured and tallied by the three length groups for which estimates were computed. These fish were then added to the total number of morts (for each length group), which were then added back into the mark-recapture estimates to provide unbiased total estimates for each length group.

Length-Weight Relationships

Length-weight regressions (Cone 1989 as cited in Taylor and Knudson. 2011) were calculated for all Brown Trout greater than 100 mm in all sections of Rush Creek. Regressions using Log10 transformed data were used to compare length-weight relationships by year and by section.

Fulton-type condition factors were computed in MicroFish 3.0 using methods previously reported (Taylor and Knudson 2011) for Brown Trout 150 to 250 mm. A trout condition factor of 1.00 was considered average (Reimers 1963; Blackwell et al. 2000).

Relative Stock Density (RSD) Calculations

Relative stock density (RSD) is a numerical descriptor of length frequency data (Hunter et al. 2007). RSD values are the proportions (percentage x 100) of the total number of Brown Trout ≥150 mm in length that are also ≥225 mm or (RSD-225), ≥300 mm (RSD-300) and ≥375 mm or (RSD-375). These three RSD values are calculated by the following equations:

RSD-225 = [(# of Brown Trout ≥225 mm) ÷ (# of Brown Trout ≥150 mm)] x 100
RSD-300 = [(# of Brown Trout ≥300 mm) ÷ (# of Brown Trout ≥150 mm)] x 100
RSD-375 = [(# of Brown Trout ≥375 mm) ÷ (# of Brown Trout ≥150 mm)] x 100

Termination Criteria Calculations and Analyses

Information regarding the proposed termination criteria, calculations, and analyses were conducted as described in past Annual Fisheries Reports (Taylor and Knudson 2011).

Water Temperature Monitoring

Water temperatures were recorded (in degrees Fahrenheit) at various locations within Rush and Lee Vining creeks as part of the fisheries monitoring program. Data loggers were deployed in January and collected data throughout the year in one-hour time intervals. Data loggers were downloaded at the end of the year and the data were summarized in spreadsheets. Water temperature data loggers were deployed at the following locations in 2016:

1. Rush Creek at Damsite – upstream of GLR.
2. Rush Creek – top of MGORD.
3. Rush Creek – bottom of MGORD.
4. Rush Creek – at old Highway 395 Bridge.
5. Rush Creek – above Parker Creek.
6. Rush Creek – below Narrows.
7. Rush Creek – at County Road crossing.
8. Lee Vining Creek – at County Road crossing.

For the fisheries monitoring program, the year-long data sets were edited to focus on summer water temperature regimes (July – September) in Rush and Lee Vining creeks, with particular focus on Rush Creek. Analysis of summer water temperature included the following metrics:

1. Daily mean temperature.
2. Average daily minimum temperature.
3. Average daily maximum temperature.
4. Number of days with daily maximums exceeding 70°F.
5. Number of hours with temperatures exceeding 66.2°F.
6. Number of good/fair/poor potential growth days, based on daily average temperature.
7. Number of bad thermal days based on daily average temperature.
8. Maximum diurnal fluctuations.
9. Average maximum diurnal fluctuation for consecutive 21-day period.

Results

Channel Lengths and Widths

Differences in wetted widths between years can be due to several factors such as, magnitude of spring peak flows, stream flows at time of measurements, and locations of where the measurements were taken. In 2016, widths in the Upper Rush, Bottomlands, Walker Creek, and Lee Vining sections were slightly wider than in 2015. The length of the Lee Vining side channel increased in 2016 due to the dry-normal 1 RY peak flow after four dry RY's. Lengths, widths, and areas from 2015 are provided for comparisons (Table 1). In 2016, the Upper Rush sample section's length was shortened at the upstream end due to difficulties of maintaining the block fence at the traditional location due to water velocities and algae build-up (Table 1).

Table 1. Total length, average wetted width, and total surface area of sample sections in Rush, Lee Vining, and Walker Creeks sampled between September 13-23, 2016. Values from 2015 are provided for comparisons.

Sample Section	Length (m) 2015	Width (m) 2015	Area (m^2) 2015	Length (m) 2016	Width (m) 2016	Area (m^2) 2016	Area (ha) 2016
Rush – Upper	430	7.3	3,139.0	406	8.2	3,329.0	0.3329
Rush - Bottomlands	437	6.7	2,927.9	437	7.3	3,190.1	0.3190
Rush – MGORD	2,230	8.3	18,509.0	2,230	8.3	18,509.0	1.8509
Lee Vining – Main	255	4.8	1,224.0	255	5.3	1,351.5	0.1352
Lee Vining - Side	70.3	1.0	70.3	137	1.7	232.9	0.02329
Walker Creek	193	1.7	328.1	193	2.3	443.9	0.04439

Trout Population Abundance

Rush Creek

In 2016, a total of 182 Brown Trout ranging in size from 83 mm to 410 mm were captured in Upper Rush section (Figure 5). For comparison, in 2015, a total of 759 Brown Trout were captured in the Upper Rush section. In 2016, age-0 Brown Trout comprised 41% of the total catch this year (compared to 57% in 2015). The Upper Rush section supported an estimated 146 age-0 Brown Trout in 2016 (including morts) compared to 647 age-0 Brown Trout in 2015 (a 77% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of age-0 Brown Trout in Upper Rush has decreased from 2,895 to 146 fish (a 95% decrease). Standard error for the 2016 age-0 Brown Trout estimate was 18% of the estimate (Table 2).

In 2016, Brown Trout 125-199 mm in length comprised 19% of the total catch in the Upper Rush section (compared to 30% in 2015). This section supported an estimated 55 Brown Trout 125-199 mm in length in 2016 (including morts) compared to 297 fish in 2015 (an 81% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of Brown Trout 125-199 mm in Upper Rush decreased from 492 to 55 fish (an 89% decrease). Standard error for this size class was 18% of the estimate (Table 2).

Brown Trout ≥200 mm in length comprised of 40% of the Upper Rush total catch in 2016 (compared to 13% in 2015 and 7% in 2014). In 2016, Upper Rush supported an estimated 110 Brown Trout ≥200 mm in length compared to an estimate of 117 fish in 2015 (a 6% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of Brown Trout ≥200 mm in Upper Rush has decreased from 177 to 110 fish (a 39% decrease). Standard error for this size class was 14% of the 2016 estimate versus 5% in 2015. In 2016, three Brown Trout ≥300 mm in length were captured in the Upper Rush section; these fish were 311, 405 and 410 mm in length (Figure 5).

A total of five Rainbow Trout were captured on the Upper Rush section comprising 2.7% of the section's total catch in 2016. The five Rainbow Trout ranged in size from 110 mm to 285 mm, with three fish >200 mm in length (Figure 6). In 2016, there were too few recaptures of Rainbow Trout to generate estimates for any of the size classes.

Within the Bottomlands section of Rush Creek a total of 148 Brown Trout were captured in 2016 (Table 2) which ranged in size from 77 mm to 470 mm (Figure 7). For comparison, 393 Brown Trout were captured in 2015 which ranged in size from 68 mm to 470 mm. Age-0 Brown Trout comprised 54% of the total catch in 2016 versus 67% of the total catch in 2015. The Bottomlands section supported an estimated 146 age-0 Brown Trout in 2016 versus 465 age-0 fish in 2015 (a 69% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of age-0 Brown Trout in the Bottomlands section decreased from 843 fish to 146 fish (an 83% decrease). Standard error on age-0 Brown Trout was 16% of the estimate in 2016 compared to 9% in 2015 (Table 2).

Brown Trout 125-199 mm in length comprised 23% of the total catch in the Bottomlands section in 2016 versus 19% of the total catch in 2015. This section supported an estimated 40 Brown Trout 125-199 mm in length in 2016 compared to 96 fish in 2015 (a 58% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of 125-199 mm Brown Trout in the Bottomlands section decreased from 460 to 40 fish (a 91% decrease). Standard error for this size class was 10% of the estimate in 2016 versus 7% in 2015 (Table 2).

Brown Trout ≥200 mm in length comprised of 23% of the total catch in 2016 (14% in 2015) with the largest trout 470 mm in length. The Bottomlands section supported an estimated 38 Brown Trout ≥200 mm in 2016 compared to 62 trout in 2015 (a 39% decrease). Between 2012 and 2016 (the five consecutive drier years), the estimate of Brown Trout ≥200 mm has decreased by 62%. Standard error for this size class was 8% of the 2016 estimate versus 6% in 2015 (Table 2). In 2016, three Brown Trout ≥300 mm was captured in the Bottomlands section; these fish were 318, 450, and 470 mm in length (Figure 7).

Table 2. Rush Creek and Lee Vining Creek mark-recapture estimates for 2016 showing total number of trout marked (M), total number captured on the recapture run (C), total number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species, and size class. Mortalities (Morts) were those trout that were captured during the mark run, but died prior to the recapture run. Mortalities were not included in mark-recapture estimates and were added to estimates for accurate total estimates. NP = estimate not possible. BNT = Brown Trout RBT = Rainbow Trout

Stream / Section / Species / Date	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
		Mark - recapture estimate					
Rush Creek							
Upper Rush-BNT							
9/13/2016 & 9/20/2016							
	0 - 124 mm	49	37	12	1	**146**	27
	125 - 199 mm	24	19	8	0	**55**	10
	≥200 mm	47	43	18	0	**110**	15
Bottomlands-BNT							
9/14/2016 & 9/21/2016							
	0 - 124 mm	46	49	15	0	**146**	24
	125 - 199 mm	25	24	15	0	**40**	4
	≥200 mm	26	25	17	0	**38**	3
MGORD-BNT							
9/15/2016 & 9/22/2016							
	0 - 124 mm	4	0	0	0	**NP**	N/A
	125 - 199 mm	6	5	2	0	**13***	4
	≥200 mm	106	101	37	0	**286**	29
Lee Vining Creek							
Main Channel-BNT							
9/16/2016 & 9/23/2016							
	0 - 124 mm	44	36	13	0	**118**	20
	125 - 199 mm	104	68	47	0	**150**	9
	≥200 mm	44	26	23	0	**50**	2
Main Channel-RBT							
9/16/2016 & 9/23/2016							
	0 - 124 mm	0	0	0	0	**0**	0
	125 - 199 mm	0	0	0	0	**0**	0
	≥200 mm	7	5	5	0	**7**	0
***estimate made with the <3 recaps**							

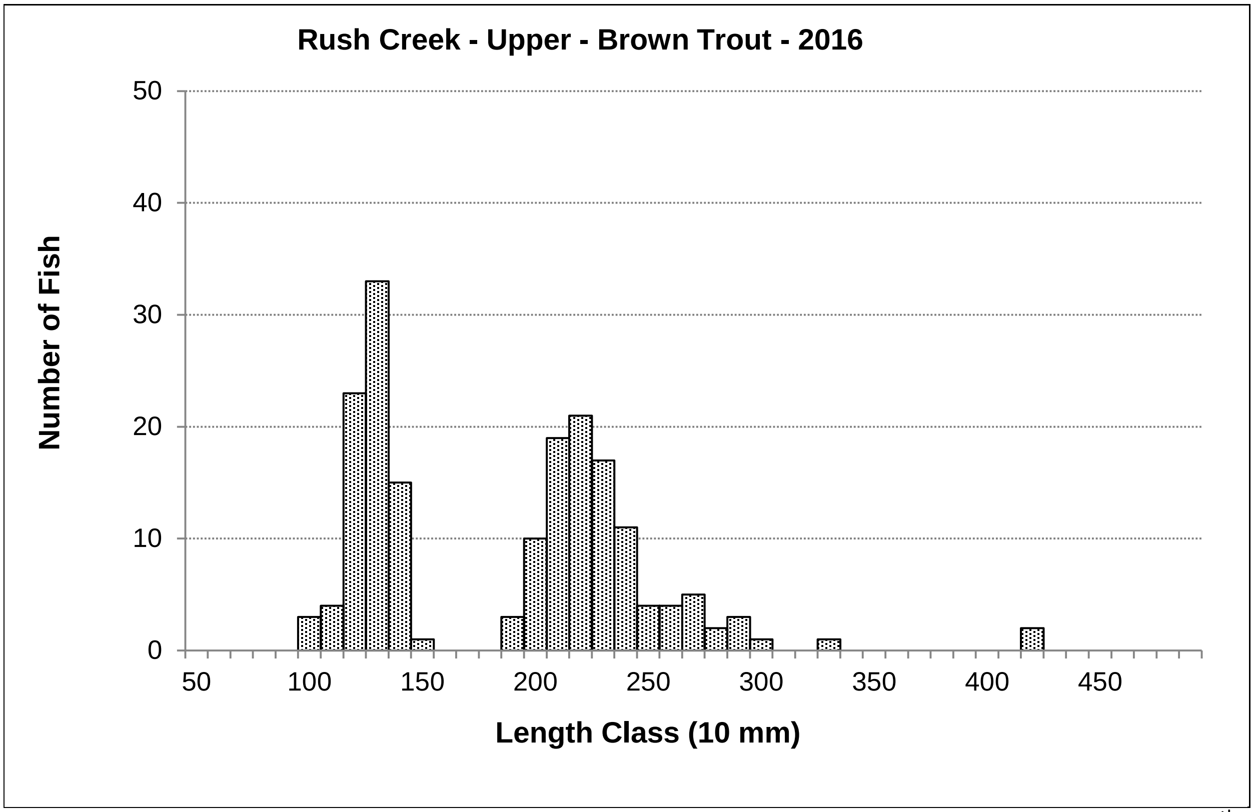

Figure 5. Length-frequency histogram of Brown Trout captured in Upper Rush, September 13th and 20th, 2016.

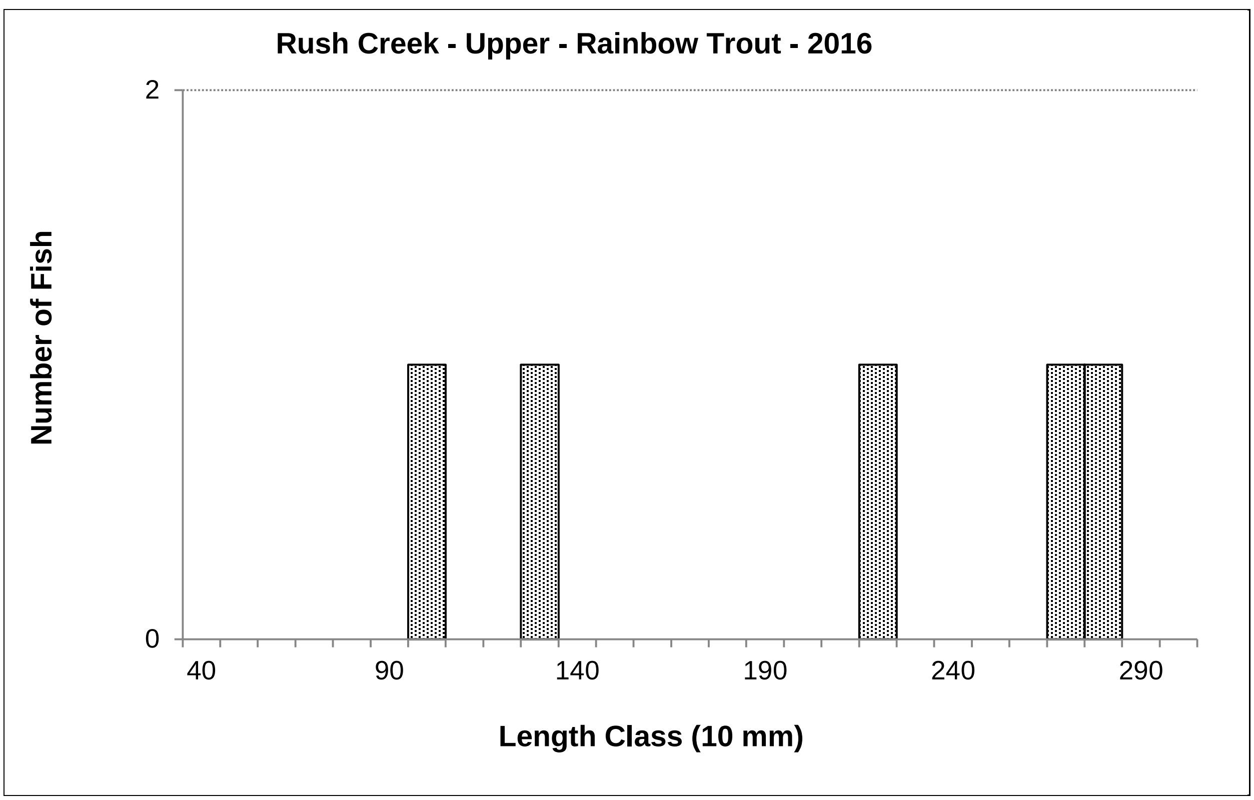

Figure 6. Length-frequency histogram of Rainbow Trout captured in Upper Rush, September 13th and 20th, 2016.

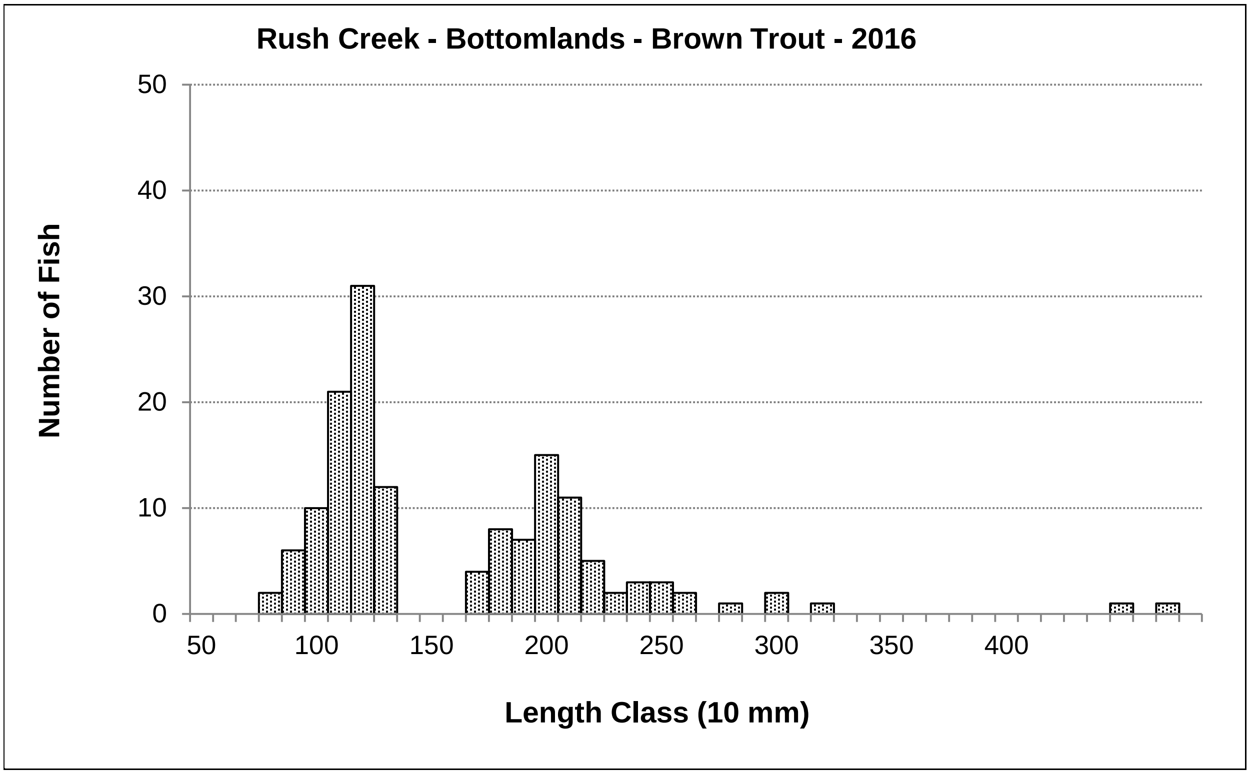

Figure 7. Length-frequency histogram of Brown Trout captured in the Bottomlands section of Rush Creek, September 14th and 21st, 2016.

Within the MGORD section of Rush Creek a total of 183 Brown Trout were captured during the mark and recapture electrofishing passes made in 2016. Only four age-0 Brown Trout were captured in 2016 which comprised 2% of the total catch, compared to 17% of the Brown Trout captured in 2015. No estimate of age-0 Brown Trout was possible due to no age-0 fish caught during the recapture electrofishing effort.

Brown Trout 125-199 mm in length comprised 5% of the total catch in the MGORD section in 2016 versus 23% of the total catch in 2015. This section supported an estimated 13 Brown Trout 125-199 mm in length in 2016, a 95% decrease from the 2014 estimate of 237 fish.

Brown Trout ≥200 mm in length comprised of 93% of the total catch in 2016 (60% in 2015). The MGORD section supported an estimated 286 Brown Trout ≥200 mm in 2016 compared to 555 trout in 2014 (a 48% decrease). In 2016, 38 Brown Trout ≥300 mm were captured in the MGORD (21% of the total catch). Twenty Brown Trout ≥375 mm in length were captured in 2016, 13 of these fish were >400 mm in length and three of these fish were >500 mm in length (Figure 8).

In 2016, eight Rainbow Trout were captured on the MGORD (Figure 9). In the previous four years, two Rainbow Trout were captured in 2015, no Rainbow Trout were captured in 2014, nine Rainbow Trout were captured in 2013 and 40 Rainbow Trout were captured in 2012.

Since 2012, the total numbers of trout caught (browns and rainbows combined) in the MGORD section of Rush Creek has decreased by 82%. For the past 11 sampling years, electrofishing passes through the MGORD have produced the following total catch values:

- 2016 – Mark run = 121 trout. Recapture run = 110 trout. Two-pass average = 115.5 fish.
- 2015 – Single pass = 176 trout.
- 2014 – Mark run = 206 trout. Recapture run = 268 trout. Two-pass average = 237 fish.
- 2013 – Single pass = 451 trout.
- 2012 – Mark run = 606 trout. Recapture run = 543 trout. Two-pass average = 574.5 fish.
- 2011 – Single pass = 244 trout.
- 2010 – Mark run = 458 trout. Recapture run = 440 trout. Two-pass average = 449 fish.
- 2009 – Single pass = 649 trout.
- 2008 – Mark run = 450 trout. Recapture run = 419 trout. Two-pass average = 434.5 fish.
- 2007 – Single pass = 685 trout.
- 2006 – Mark Run = 283 trout. Recapture run = 375 trout. Two-pass average = 329 fish.

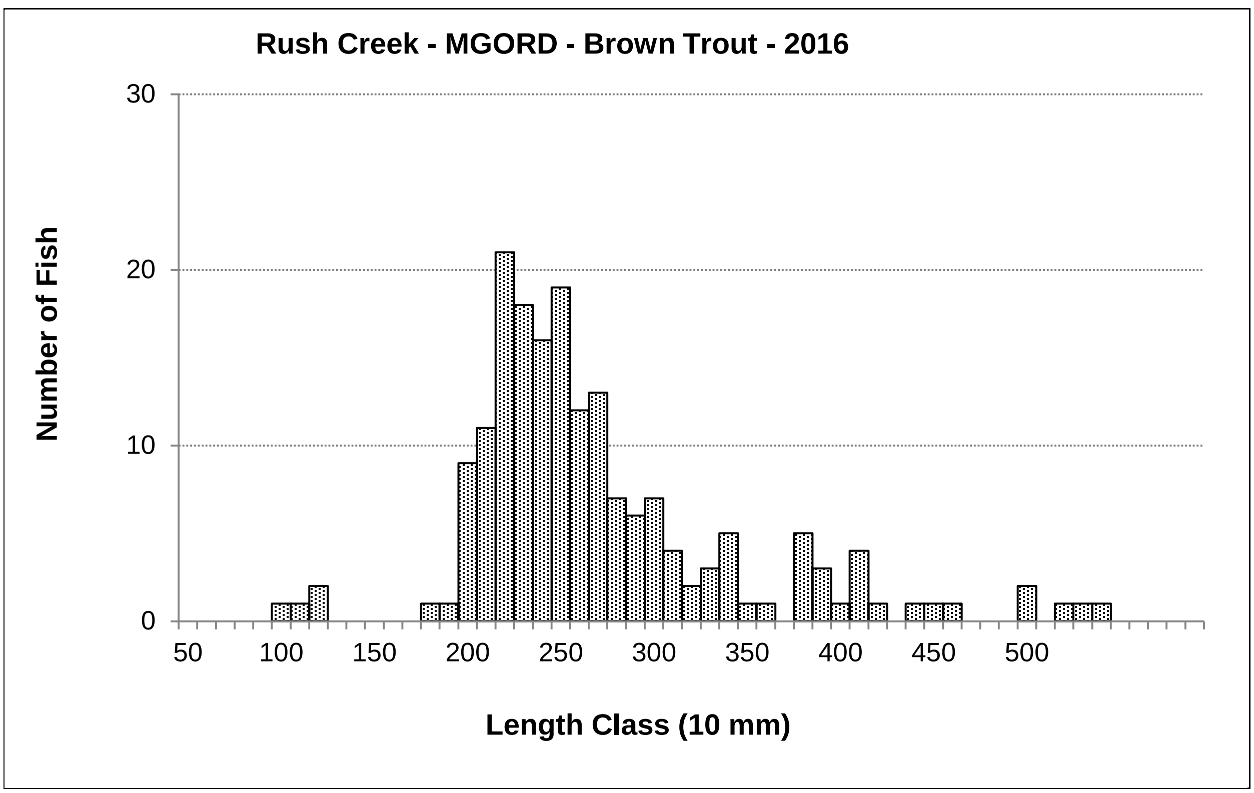

Figure 8. Length-frequency histogram of Brown Trout captured in the MGORD section of Rush Creek, September 15th and 22nd, 2016.

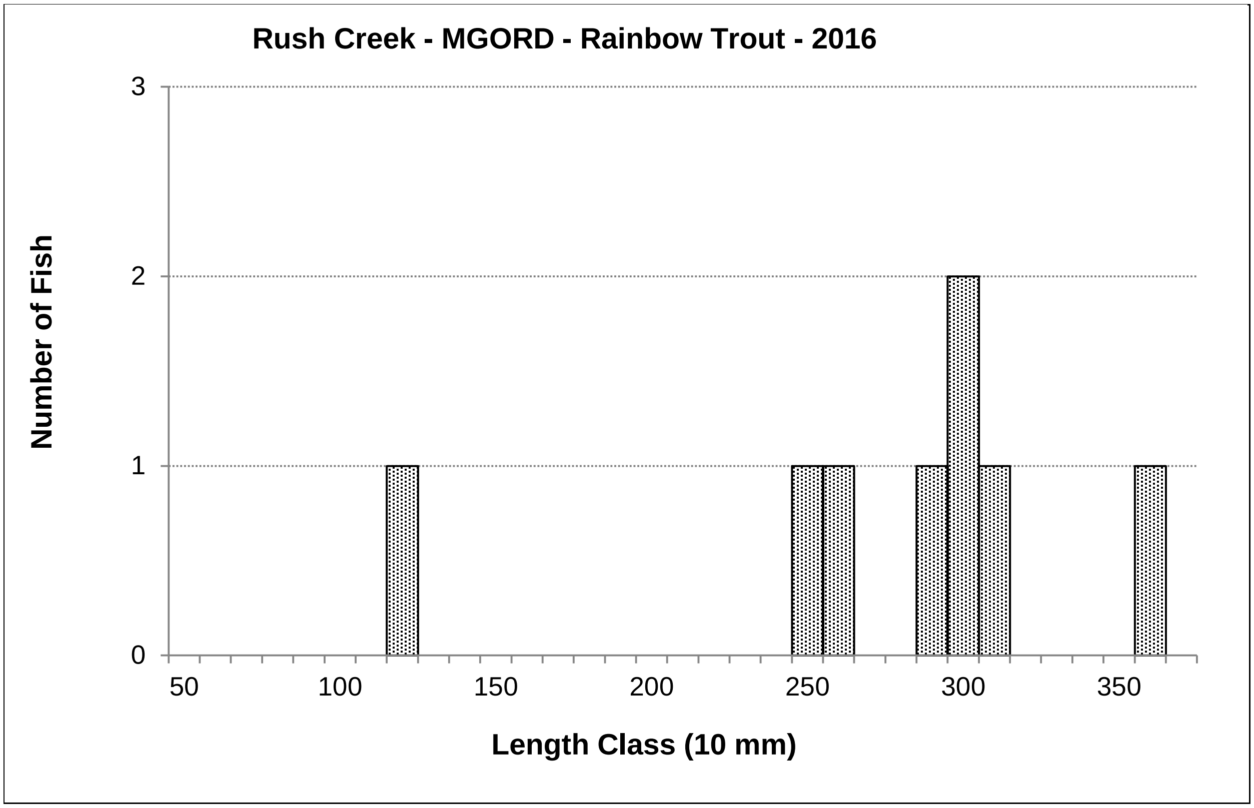

Figure 9. Length-frequency histogram of Rainbow Trout captured in the MGORD section of Rush Creek, September 15th and 22nd, 2016.

Lee Vining Creek

In 2016, a total of 246 trout were captured in the Lee Vining Creek main channel section versus 422 fish in 2015 and 838 fish in 2012 (Table 2). Of the 246 trout captured in 2015, 239 were Brown Trout making up 97% of the total trout captured. In 2016, Brown Trout ranged in size from 68 mm to 267 mm (Figure 10). Age-0 fish comprised 28% of the total Brown Trout catch in 2016, compared to 49% in 2015. Lee Vining Creek's main channel section supported an estimated 118 age-0 Brown Trout in 2016, compared to an estimated 251 age-0 Brown Trout in 2015, a 53% decrease (Table 2). Between 2012 and 2016 (the five consecutive dry years) the age-0 Brown Trout estimates dropped from 677 fish to 118 fish (an 83% decrease). Standard error for age-0 Brown Trout was 17% of the 2016 estimate vs. 2015's 6% (Table 2).

In 2016, 125 Brown Trout 125-199 mm in length were captured and comprised 52% of the total Brown Trout catch in Lee Vining Creek's main channel section (versus 38% in 2015). This section supported an estimated 150 Brown Trout 125-199 mm in length in 2016 (Table 2) compared to 192 fish in 2015 (a 22% decrease). Standard error for this size class in 2016 was 6% of the estimate compared to 5% in 2015.

Brown Trout ≥200 mm in length comprised of 20% of the total Brown Trout catch in 2016 (versus 13% in 2015). Lee Vining Creek's main channel supported an estimated 50 brown ≥200 mm (versus 55 fish in 2015) (Table 2). Standard error for this size class was 4% of the 2016 estimate vs. 5% in 2015.

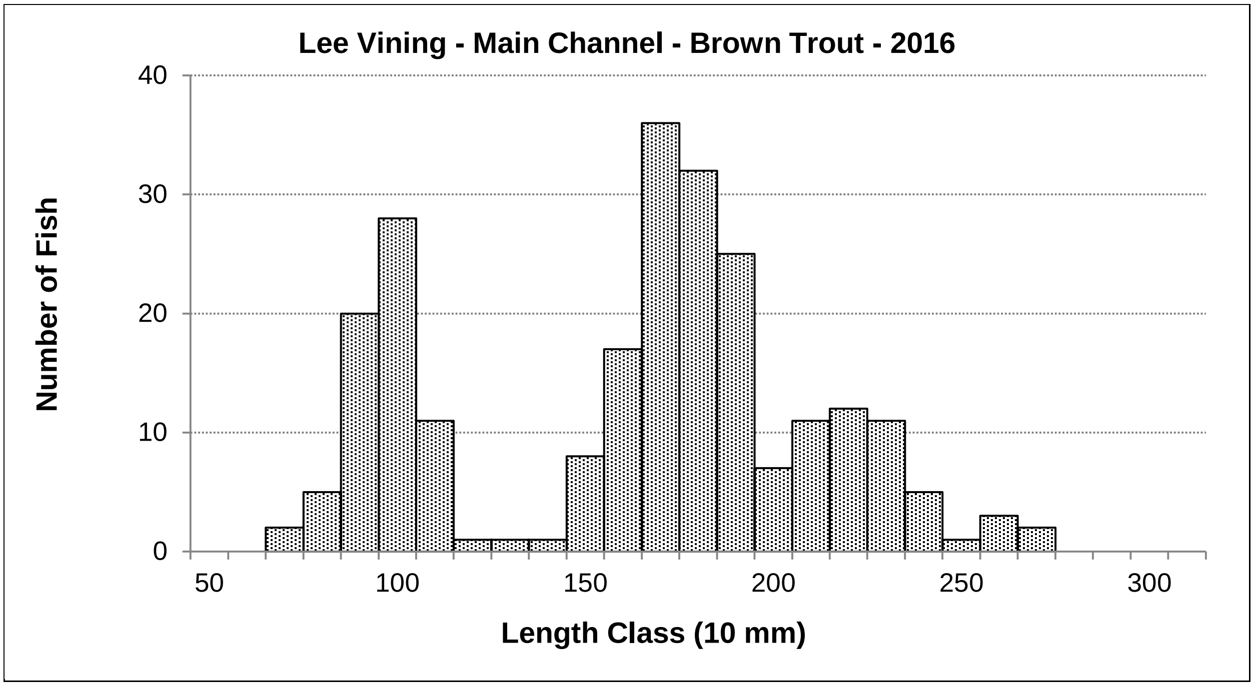

Figure 10. Length-frequency histogram of Brown Trout captured in the main channel section of Lee Vining Creek, September 16th and 23rd, 2016.

A total of seven Rainbow Trout were captured in Lee Vining's main channel making up approximately 3% of the total catch in 2016 (versus 5% of the 2015 total catch, 14% of the 2014 total catch and 19% of the 2013 total catch) (Table 2). These seven Rainbow Trout ranged in size from 220 mm to 255 mm (Figure 11). The 2016 estimate for Rainbow Trout in the ≥200 mm size class was seven fish (Table 2). The 2016 season was the second consecutive year in which no Rainbow Trout in the <125 mm (or age-0) size class were captured. It also appears that no age-1 Rainbow Trout were represented in the 2016 catch.

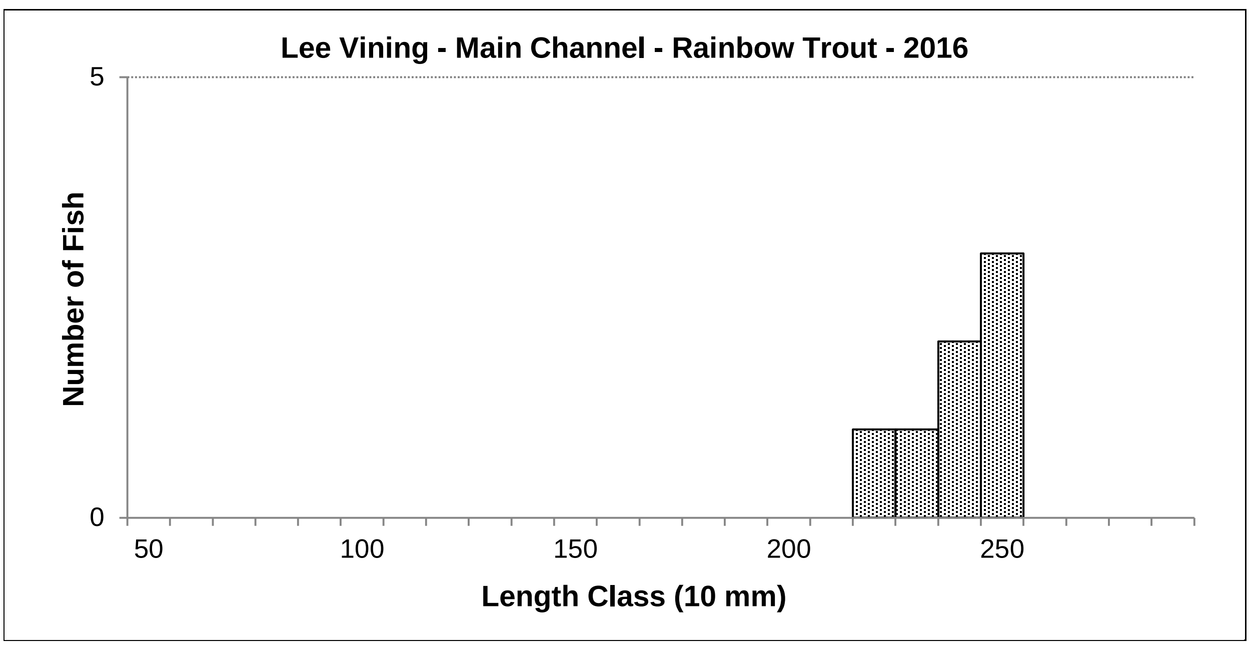

Figure 11. Length-frequency histogram of Rainbow Trout captured in the main channel section of Lee Vining Creek, September 16th and 23rd, 2016.

In the Lee Vining Creek side channel, 12 Brown Trout were captured in four electrofishing passes made during the 2016 sampling (Table 3). Two age-0 fish were captured, seven fish were in the 125-199 mm size class, and three fish were in the ≥200 mm size class (Figure 12). The estimates for the three size classes were equal to the catch numbers (Table 3). No Rainbow Trout were captured in the side channel in 2016. This was the eighth consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the sixth consecutive year that no age-1+ Rainbow Trout were captured.

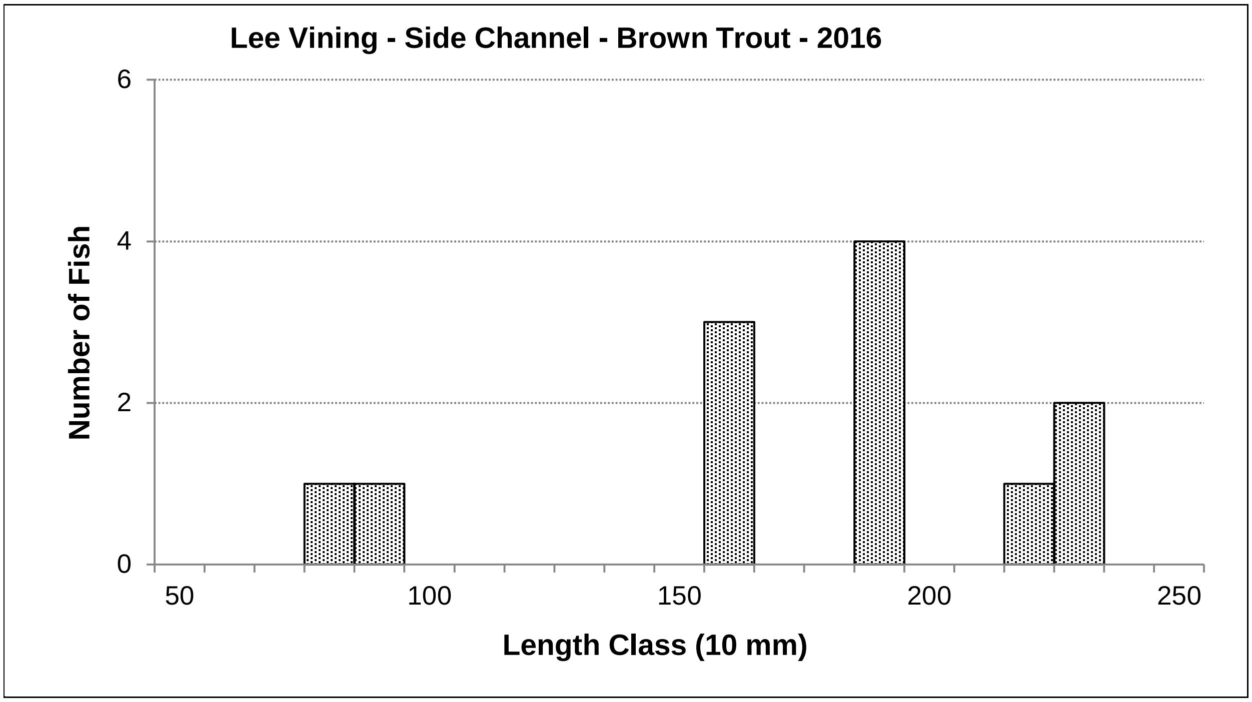

Figure 12. Length-frequency histogram of Brown Trout captured in the side channel section of Lee Vining Creek, September 17th, 2016.

Walker Creek

In 2016, 312 Brown Trout were captured in two electrofishing passes in the Walker Creek section (190 were captured in 2015, 185 were captured in 2014 and 345 were captured in 2013) (Table 3). Of these, 228 Brown Trout or 73% were age-0 fish ranging in size from 79 mm to 117 mm in length (Figure 13). The 2016 age-0 Brown Trout estimate for Walker Creek was 292, a 161% increase from the 2015 estimate of 112 fish. For trout <125 mm in length, the 2016 probability of capture was 53% (Table 3). The 95% confidence level was ±50 fish.

Brown Trout in the 125-199 mm size class (67 fish) accounted for 22% of the total catch in 2016 (compared to 31% in 2015). The 2016 population estimate for Brown Trout in the 125-199 mm size class was 70 trout with a probability of capture of 78% (Table 3). The 95% confidence level was ±6 fish.

Brown Trout ≥200 mm in length (17 fish) accounted for 5% of the total catch in 2016 (was 10% in 2015). The 2016 population estimate for this size class was 17 Brown Trout with a probability of capture of 81% (Table 3). The largest Brown Trout captured in Walker Creek in 2016 was 271 mm in length (Figure 13). The 95% confidence level was ±2 fish.

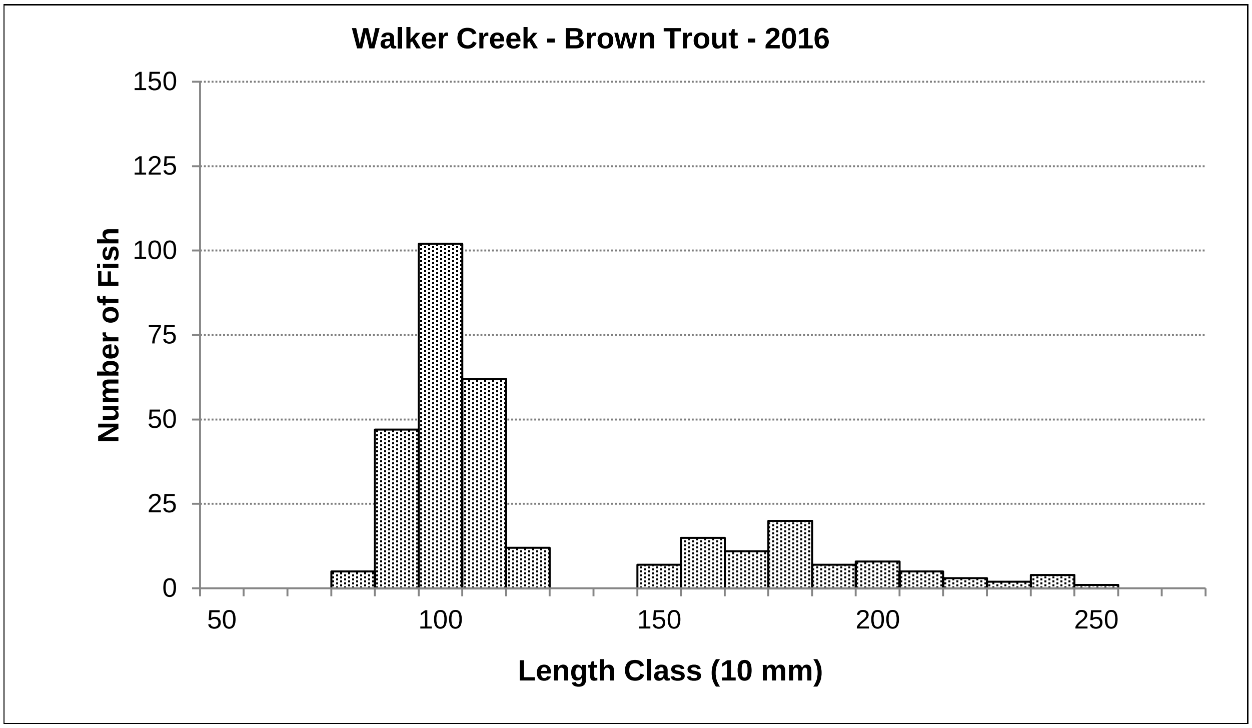

Figure 13. Length-frequency histogram of Brown Trout captured in Walker Creek, September 17th, 2016.

Table 3. Depletion estimates made in the side channel section of Lee Vining Creek and Walker Creek during September 2016 showing number of trout captured in each pass, estimated number, probability of capture (P.C.) by species and size class.

Stream - Section Date **Species**	Size Class (mm)	Removals	Removal Pattern	**Estimate**	P.C.
Lee Vining Creek- Side Channel - 9/17/2016					
Brown Trout					
	0 - 124 mm	2	1 0 1 0	**2**	0.50
	125 - 199 mm	2	4 2 1 0	**7**	0.64
	200 + mm	2	3 0 0 0	**3**	1.00
Walker Creek - above old Hwy 395 - 9/17/2016					
Brown Trout					
	0 - 124 mm	2	154 74	**292**	0.53
	125 - 199 mm	2	54 13	**70**	0.78
	200 + mm	2	13 4	**17**	0.8

Catch of Rainbow Trout in Rush and Lee Vining Creeks

Beginning with the 2008 annual report, Rainbow Trout catch numbers have simply been reported for Rush Creek (no statistical analysis). This decision was made because Rainbow Trout usually accounted for <5% of Rush Creek's total catch. In 2011 when GLR spilled, hatchery-origin Rainbow Trout also spilled out of the reservoir, resulting in Rainbow Trout accounting for 8% of the total catch in 2011, the highest ever in Rush Creek. For the sampling years since 2011; Rainbow Trout accounted for 5% of the total Rush Creek catch in 2012, 2% of the total catch in 2013, 0.75% of the total catch in 2014, and 1.9% of the total catch in 2015. For the 2016 sampling, Rainbow Trout comprised 2.5% of the total catch in Rush Creek (13 rainbows/526 total trout). Given the California Department of Fish and Wildlife (CDFW) current policy of stocking sterile catchable Rainbow Trout, it is unlikely that future Rainbow Trout numbers will approach 5% of the total fish catch in Rush Creek unless another major spill occurs from GLR during a wet RY.

Between 1999 and 2012 Rainbow Trout numbers in Lee Vining Creek were variable, generally higher during drier RY types and lower during wetter years. However, since 2012 the annual catch of Rainbow Trout in Lee Vining Creek has dropped steadily and dramatically. In 2012, a total of 235 Rainbow Trout were captured, including 226 age-0 fish. In 2013, 127 Rainbow Trout were captured (26 were age-0 fish), followed by 57 rainbows in 2014 (six were age-0 fish), 20 rainbows in 2015 (no age-0 fish) and seven rainbows in 2016 (no age-0 fish). This dramatic drop in Rainbow Trout numbers has occurred during the five consecutive drier water years, which is worrisome since Rainbow Trout (as spring spawners) have typically flourished in drier years when peak flows were too small to mobilize the channel bed and disrupt incubating eggs or newly hatched alevins. This large drop in Rainbow Trout numbers has also occurred during the time period when CDFW has been stocking sterile catchable Rainbow Trout, which suggests that in past years successful spawning by hold-over Rainbow Trout probably, to a large degree, supported the Lee Vining Creek population.

Sufficient numbers of age-0 Rainbow Trout were captured in the main channel to generate population estimates for only four of the 16 years sampled (Table 4). Adequate numbers of age-1 and older Rainbow Trout were captured in the main channel to generate population estimates for eight of the 16 years sampled (Table 5). The side channel produced enough numbers of age-0 and age-1 and older Rainbow Trout to generate population estimates for six of the 17 years sampled (Tables 6 and 7). However, no age-0 Rainbow Trout have been caught in the side channel in the past eight years and no age-1 and older rainbows have been caught in the past six years (Tables 6 and 7).

Due to Rainbow Trout historically encompassing a large portion (10-40%) of the Lee Vining Creek fishery, an effort has been made to generate density and biomass values using all data available. In years when adequate numbers of rainbows have been captured, statistically valid density and biomass estimates have been generated. In years when less than adequate numbers of Rainbow Trout have been captured, catch numbers have been used to generate density and biomass estimates. While catch numbers are not statistically valid they are consistently lower than statistically valid estimates and allow for comparison between all sampling years (Tables 4-7).

Table 4. Numbers of age-0 Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2016.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2016	**0.1352**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2015	0.1224	0	0	0	0	0	0	0
2014	0.1403	4	4	2	NP	NP	6	43
2013	0.1454	19	12	5	40	275	26	179
2012	0.1279	155	138	67	318	2,494	226	1,773
2011	0.1428	1	0	0	NP	NP	1	7
2010	0.1505	0	0	0	0	0	0	0
2009	0.1505	4	4	0	NP	NP	8	53
2008	0.1377	17	31	9	57	414	39	283
2007	0.0884	42	56	22	106	1,199	76	860
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	0	0	0	0	0	0	0
2004	0.0744	1	0	0	NP	NP	1	13
2003	0.0744	0	0	0	0	0	0	0
2002	0.0744	0	1	0	NP	NP	1	13
2001	0.0898	3	5	1	NP	NP	7	78
2000	0.0898	0	1	0	NP	NP	1	22

*NS stands for not sampled due to high flows

Table 5. Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2016.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2016	**0.1352**	**7**	**5**	**5**	**7**	**52**	**7**	**52**
2015	0.1224	18	14	12	21	172	20	163
2014	0.1403	36	36	21	63	449	51	364
2013	0.1454	61	45	29	120	826	77	530
2012	0.1279	7	7	5	NP	NP	9	71
2011	0.1428	5	8	5	NP	NP	8	56
2010	0.1505	12	9	7	15	100	14	93
2009	0.1505	39	32	12	98	651	59	392
2008	0.1377	71	64	37	129	936	98	712
2007	0.0884	3	5	1	NP	NP	7	79
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	3	3	0	NP	NP	6	81

Table 5 (continued). Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2016.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2004	0.0744	2	2	2	NP	NP	2	27
2003	0.0744	5	6	5	NP	NP	6	81
2002	0.0744	10	10	7	14	188	13	175
2001	0.0898	9	8	4	NP	NP	13	145
2000	0.0898	1	3	0	NP	NP	4	45

Table 6. Numbers of age-0 Rainbow Trout caught in Lee Vining Creek side channel section, 2000-2016.

Sample Year	Area of Sample Section (Ha)	Number of Trout Caught on Pass #1	Number of Trout Caught on Pass #2	Number of Trout Caught on Pass #3	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2016	**0.0233**	**0**	**0**	**--**	**0**	**0**	**0**	**0**
2015	0.0328	0	0	--	0	0	0	0
2014	0.0191	0	0	--	0	0	0	0
2013	0.0195	0	0	--	0	0	0	0
2012	0.0365	0	0	--	0	0	0	0
2011	0.0507	0	0	--	0	0	0	0
2010	0.0507	0	0	--	0	0	0	0
2009	0.0488	0	0	--	0	0	0	0
2008	0.0488	5	2	--	7	143	7	143
2007	0.0488	4	0	--	NP	NP	4	82
2006	0.0761	46	26	--	100	1,314	72	946
2005	0.0936	0	0	--	0	0	0	0
2004	0.0936	82	30	--	127	1,357	112	1,197
2003	0.0936	0	0	--	0	0	0	0
2002	0.0936	28	17	--	64	684	45	481
2001	0.1310	69	23	--	102	779	92	702
2000	0.0945	32	15	--	57	603	47	497

Table 7. Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek side channel section, 2000-2016.

Sample Year	Area of Sample Section (Ha)	Number of Trout Caught on Pass #1	Number of Trout Caught on Pass #2	Number of Trout Caught on Pass #3	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2016	**0.0233**	**0**	**0**	**--**	**0**	**0**	**0**	**0**
2015	0.0328	0	0	--	0	0	0	0
2014	0.0191	0	0	--	0	0	0	0
2013	0.0195	0	0	--	0	0	0	0
2012	0.0365	0	0	--	0	0	0	0
2011	0.0507	0	0	--	0	0	0	0
2010	0.0507	1	0	--	1	20	1	20
2009	0.0488	15	0	--	15	307	15	307
2008	0.0488	3	1	--	4	82	4	82
2007	0.0488	6	0	--	NP	NP	6	123
2006	0.0761	5	0	--	NP	NP	5	66
2005	0.0936	7	2	--	9	96	9	96
2004	0.0936	5	0	--	NP	NP	5	53
2003	0.0936	13	0	--	NP	NP	13	139
2002	0.0936	29	4	--	33	353	33	353
2001	0.1310	38	3	--	41	313	41	313
2000	0.0945	9	0	--	NP	NP	9	95

Relative Condition of Brown Trout

After Log_{10} transformations were performed on the lengths and weights of captured Brown Trout ≥ 100 mm, and a simple linear regression analysis was then performed. All sections had r^2 values 0.98 or greater, indicating that length was strongly correlated with weight (Table 8).

Table 8. 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. The 2016 regression equations are in ***bold*** type.

Section	Year	N	Equation	r^2	P
Bottomlands	***2016***	***132***	***$Log_{10}(WT) = 3.0831*Log_{10}(L) – 5.2137$***	***0.99***	***<0.01***
	2015	301	$Log_{10}(WT) = 3.0748*Log_{10}(L) – 5.1916$	0.99	<0.01
	2014	238	$Log_{10}(WT) = 3.0072*Log_{10}(L) – 5.0334$	0.98	<0.01
	2013	247	$Log_{10}(WT) = 2.7997*Log_{10}(L) – 4.591$	0.98	<0.01
	2012	495	$Log_{10}(WT) = 2.8149*Log_{10}(L) – 4.6206$	0.98	<0.01
	2011	361	$Log_{10}(WT) = 2.926*Log_{10}(L) – 4.858$	0.99	<0.01
	2010	425	$Log_{10}(WT) = 2.999*Log_{10}(L) – 5.005$	0.99	<0.01
	2009	511	$Log_{10}(WT) = 2.920*Log_{10}(L) – 4.821$	0.99	<0.01
	2008	611	$Log_{10}(WT) = 2.773*Log_{10}(L) – 4.524$	0.99	<0.01

Table 8 (continued).

Section	Year	N	Equation	R^2	P
Upper Rush	***2016***	***176***	***$Log_{10}(WT) = 3.0702*Log_{10}(L) – 5.1608$***	***0.99***	***<0.01***
	2015	643	$Log_{10}(WT) = 2.9444*Log_{10}(L) – 4.8844$	0.99	<0.01
	2014	613	$Log_{10}(WT) = 2.9399*Log_{10}(L) – 4.8705$	0.99	<0.01
	2013	522	$Log_{10}(WT) = 2.9114*Log_{10}(L) – 4.816$	0.99	<0.01
	2012	554	$Log_{10}(WT) = 2.8693*Log_{10}(L) – 4.721$	0.99	<0.01
	2011	547	$Log_{10}(WT) = 3.006*Log_{10}(L) – 5.014$	0.99	<0.01
	2010	420	$Log_{10}(WT) = 2.995*Log_{10}(L) – 4.994$	0.99	<0.01
	2009	612	$Log_{10}(WT) = 2.941*Log_{10}(L) – 4.855$	0.99	<0.01
	2008	594	$Log_{10}(WT) = 2.967*Log_{10}(L) – 4.937$	0.99	<0.01
	2007	436	$Log_{10}(WT) = 2.867*Log_{10}(L) – 4.715$	0.99	<0.01
	2006	485	$Log_{10}(WT) = 2.99*Log_{10}(L) – 4.98$	0.99	<0.01
	2005	261	$Log_{10}(WT) = 3.02*Log_{10}(L) – 5.02$	0.99	<0.01
	2004	400	$Log_{10}(WT) = 2.97*Log_{10}(L) – 4.94$	0.99	<0.01
	2003	569	$Log_{10}(WT) = 2.96*Log_{10}(L) – 4.89$	0.99	<0.01
	2002	373	$Log_{10}(WT) = 2.94*Log_{10}(L) – 4.86$	0.99	< 0.01
	2001	335	$Log_{10}(WT) = 2.99*Log_{10}(L) – 4.96$	0.99	< 0.01
	2000	309	$Log_{10}(WT) = 3.00*Log_{10}(L) – 4.96$	0.98	< 0.01
	1999	317	$Log_{10}(WT) = 2.93*Log_{10}(L) – 4.84$	0.98	< 0.01
MGORD	***2016***	***183***	**$Log_{10}(WT) = 3.0031*Log_{10}(L) – 5.3093$**	**0.99**	**<0.01**
	2015	172	$Log_{10}(WT) = 3.131*Log_{10}(L) – 5.0115$	0.99	<0.01
	2014	399	$Log_{10}(WT) = 2.9805*Log_{10}(L) – 4.9827$	0.98	<0.01
	2013	431	$Log_{10}(WT) = 2.8567*Log_{10}(L) – 4.692$	0.98	<0.01
	2012	795	$Log_{10}(WT) = 2.9048*Log_{10}(L) – 4.808$	0.99	<0.01
	2011	218	$Log_{10}(WT) = 2.917*Log_{10}(L) – 4.823$	0.98	<0.01
	2010	694	$Log_{10}(WT) = 2.892*Log_{10}(L) – 4.756$	0.98	<0.01
	2009	689	$Log_{10}(WT) = 2.974*Log_{10}(L) – 4.933$	0.99	<0.01
	2008	862	$Log_{10}(WT) = 2.827*Log_{10}(L) – 4.602$	0.98	<0.01
	2007	643	$Log_{10}(WT) = 2.914*Log_{10}(L) – 4.825$	0.98	<0.01
	2006	593	$Log_{10}(WT) = 2.956*Log_{10}(L) – 4.872$	0.98	<0.01
	2004	449	$Log_{10}(WT) = 2.984*Log_{10}(L) – 4.973$	0.99	<0.01
	2001	769	$Log_{10}(WT) = 2.873*Log_{10}(L) – 4.719$	0.99	<0.01
	2000	82	$Log_{10}(WT) = 2.909*Log_{10}(L) – 4.733$	0.98	<0.01

Condition factors of Brown Trout 150 to 250 mm in length in 2016 decreased in two sections (Bottomlands and Walker) from 2015's values and increased in four sections from 2015's values (MGORD, Upper Rush, Lee Vining side channel, and Lee Vining main channel) (Figure 14). In 2016, three sections (MGORD, Upper Rush, and Lee Vining Side Channel) had Brown Trout condition factors ≥1.00 (Figure 14).

The Upper Rush section had a condition factor of 1.00 in 2016, an increase from 0.97 in 2015 (Figure 14). The last time Upper Rush Brown Trout had a condition factor ≥1.00 was in 2011, prior to the extended dry period (Figure 14).

The Bottomlands section had a condition factor of 0.95 in 2016, a slight decrease from the value of 0.96 in 2015 and 2014 (Figure 14). In nine years of sampling, the Bottomlands section has failed to generate a Brown Trout condition factor ≥1.00 (Figure 14).

The MGORD's 2016 condition factor was 1.00, an increase from the 2015 value of 0.97 and from the 2014 value of 0.94. For six previous consecutive years, the condition factor of Brown Trout 150 to 250 mm in length had been less than average (Figure 14). In 2016, condition factors for larger Brown Trout in the MGORD were also computed: fish ≥300 mm had a condition factor of 1.03 and fish ≥375 mm had a condition factor of 1.09.

For the fourth consecutive year, Brown Trout in Lee Vining Creek's main channel had a condition factor below 1.00 (Figure 14). The 2016 value was 0.99, an improvement from 2015's value of 0.94 and 2014's value of 0.93 (Figure 14). The seven Rainbow Trout 150 to 250 mm in length from the main channel in 2016 had a condition factor of 1.10 (Figure 15). Rainbow Trout in 2016 once again had a better condition factor than the Brown Trout (1.10 versus 0.99) in the main channel section of Lee Vining Creek (Figure 15).

In 2016, Brown Trout in Lee Vining Creek's side channel had a condition factor 1.02, a relatively large increase from 2015's value of 0.90 (Figure 14). For the sixth year in a row, no Rainbow Trout were captured in the Lee Vining Creek side channel.

In Walker Creek, Brown Trout had a condition factor of 0.95 in 2016, a decrease from 0.98 in 2015 and 1.00 in 2014 (Figure 14). Brown Trout condition factors in Walker Creek have been ≥1.00 in 11 of the 18 sampling years (Figure 14).

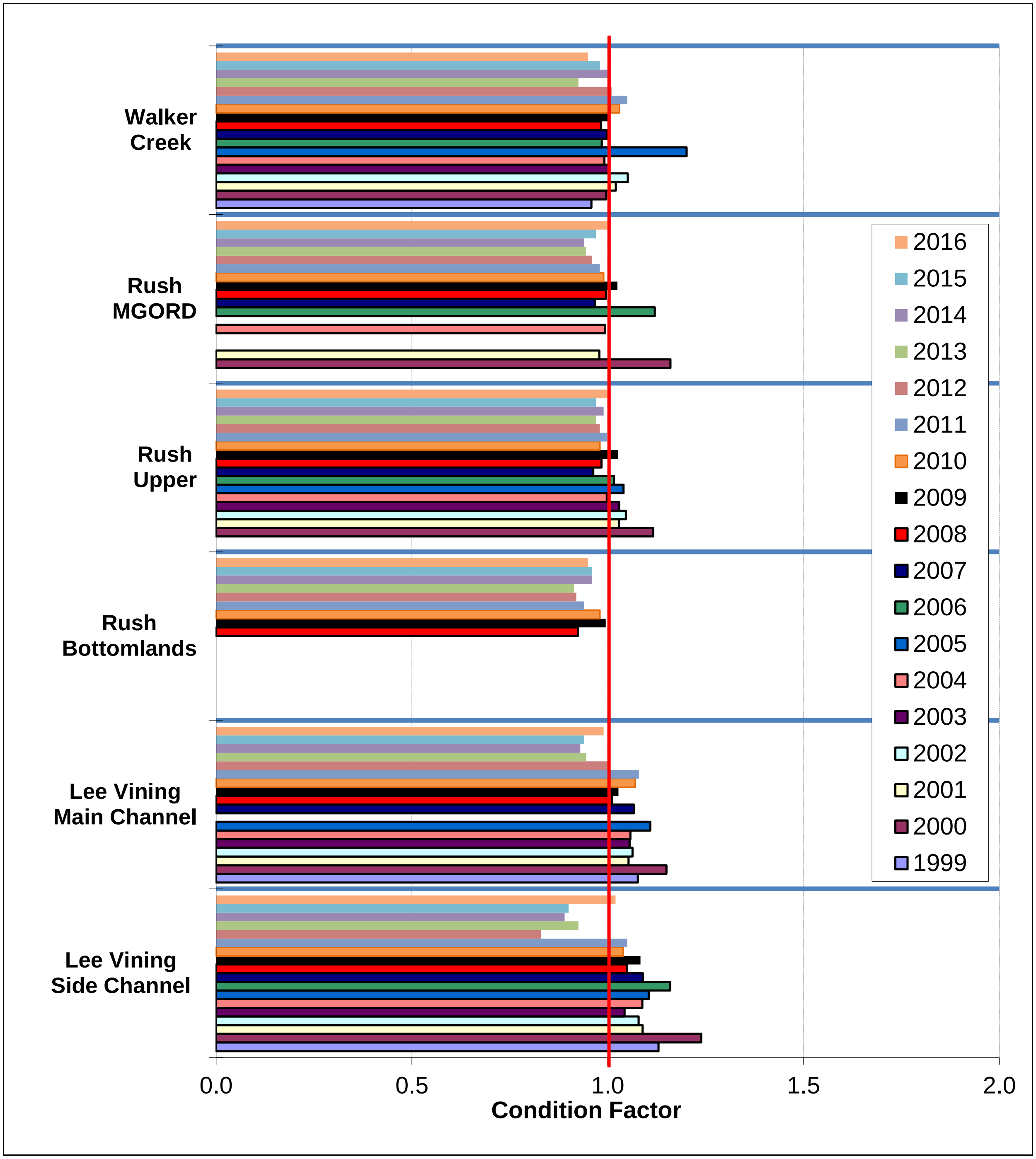

Figure 14. Condition factors for Brown Trout 150 to 250 mm in length from sample sections of Rush, Lee Vining, and Walker Creeks from 1999 to 2016.

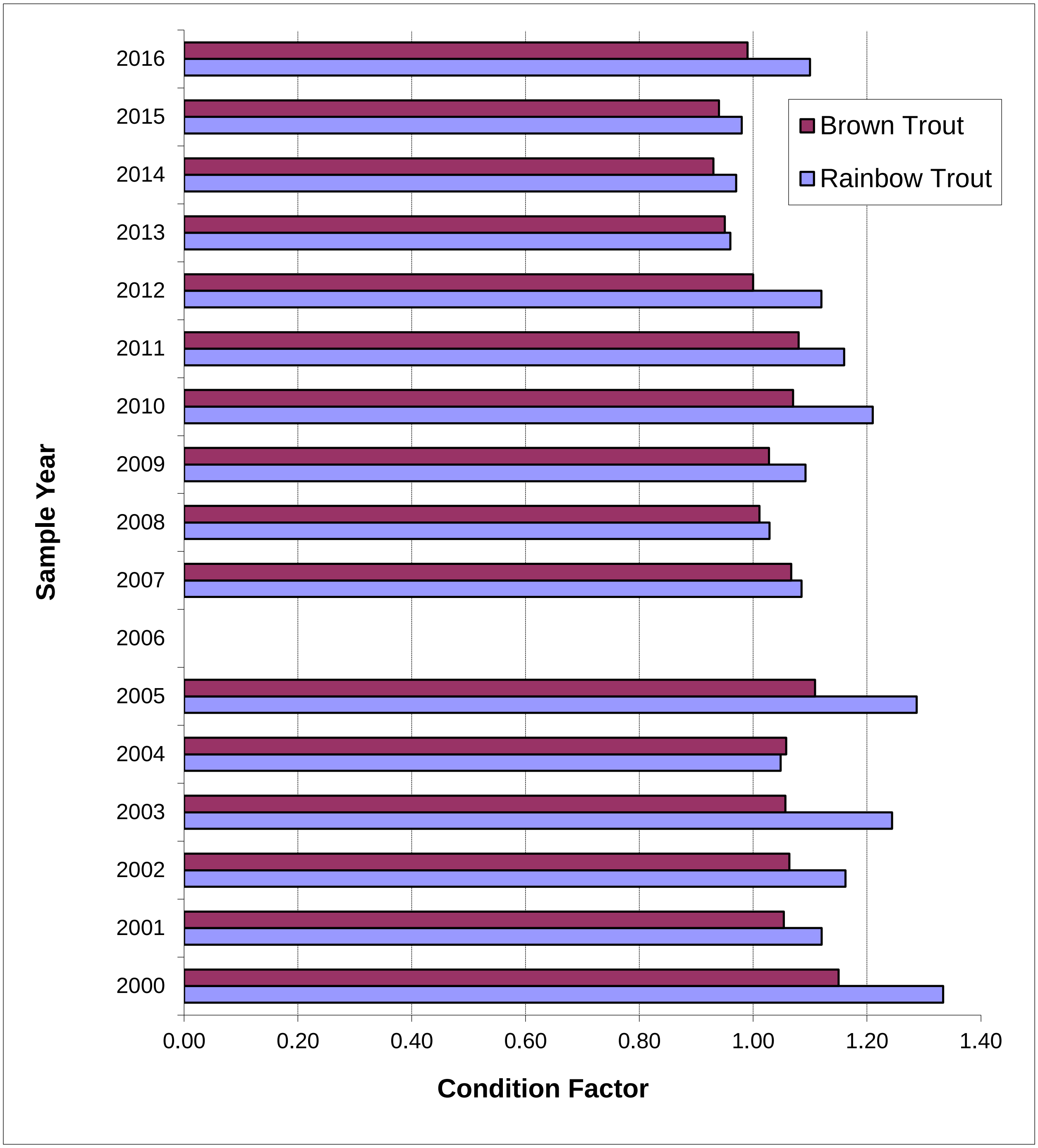

Figure 15. Comparison of condition factors for Rainbow Trout and Brown Trout 150 to 250 mm in length from the main channel section of Lee Vining Creek from 2000 to 2016. Main channel was not sampled in 2006 due to high flows.

Estimated Trout Densities

Age-0 Brown Trout

The Upper Rush section had an estimated density of 439 age-0 Brown Trout/ha in 2016, a decrease of 79% from 2015's estimate of 2,061 age-0 trout/ha (Figure 16). Between 2012 and 2016 (the five consecutive dry/below average years) the age-0 Brown Trout density estimates dropped from 8,624 fish to 439 fish (a 95% decrease). The 2016 density value in the Upper Rush section was 93% lower than the 17-year average of 5,945 age-0 Brown Trout/ha.

The Bottomlands section of Rush Creek had a density estimate of 458 age-0 Brown Trout/ha in 2016. This estimate was a 71% decrease in the number of age-0 trout/ha when compared to the 2015 estimate of 1,581 age-0 trout/ha (Figure 16). Between 2012 and 2016 (the five consecutive dry/below average years) the age-0 Brown Trout density estimates dropped from 2,616 fish to 458 fish (an 82% decrease). When compared to the nine-year average of 1,902 age-0 Brown Trout/ha, the 2016 estimate was 76% lower.

In Walker Creek, the 2016 density estimate of 6,578 age-0 Brown Trout/ha was a 93% increase from the 2015 estimate of 3,414 age-0 trout/ha (Figure 16). The 2016 density estimate was 72% greater than the 18-year average of 3,711 age-0 trout/ha (Figure 16).

In 2016, the age-0 Brown Trout density estimate in the main channel section of Lee Vining Creek was 873 age-0 trout/ha, which was a 57% decrease from the 2015 density estimate of 2,051 age-0 trout/ha (Figure 17). Between 2012 and 2016 (the five consecutive dry/below average years) the age-0 Brown Trout density estimates dropped from 5,293 fish to 873 fish (an 84% decrease). The 2016 estimate was 49% lower than the 18-year average of 1,707 age-0 Brown Trout/ha.

The estimate (and catch) of two age-0 Brown Trout in the Lee Vining Creek side channel during the 2016 sampling generated a density estimate of 86 age-0 Brown Trout/ha (Figure 17). The 2016 estimate was 75% lower than the 18-year average of 347 age-0 Brown Trout/ha.

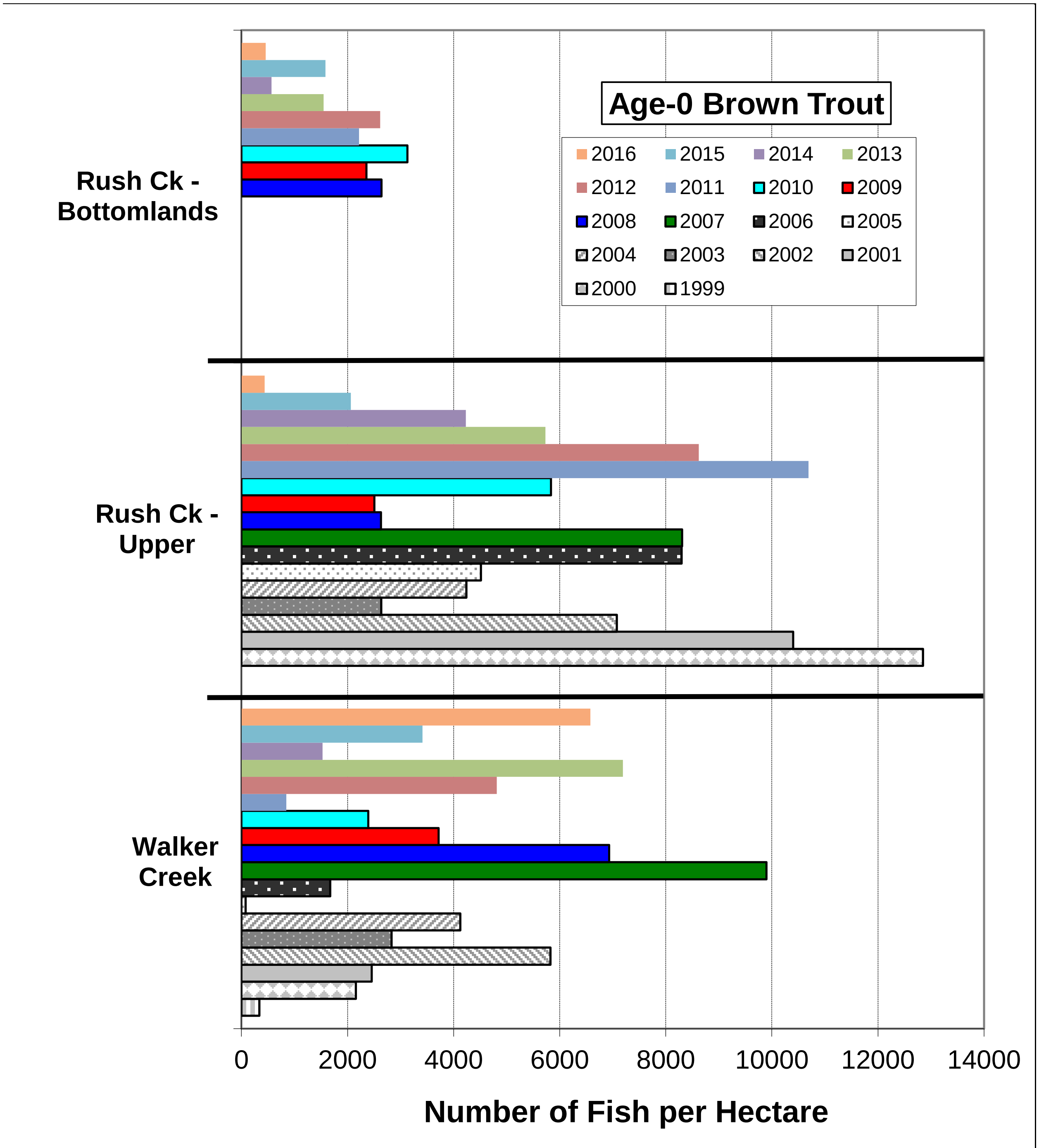

Figure 16. Estimated number of age-0 Brown Trout per hectare in Rush Creek and Walker Creek from 1999 to 2016.

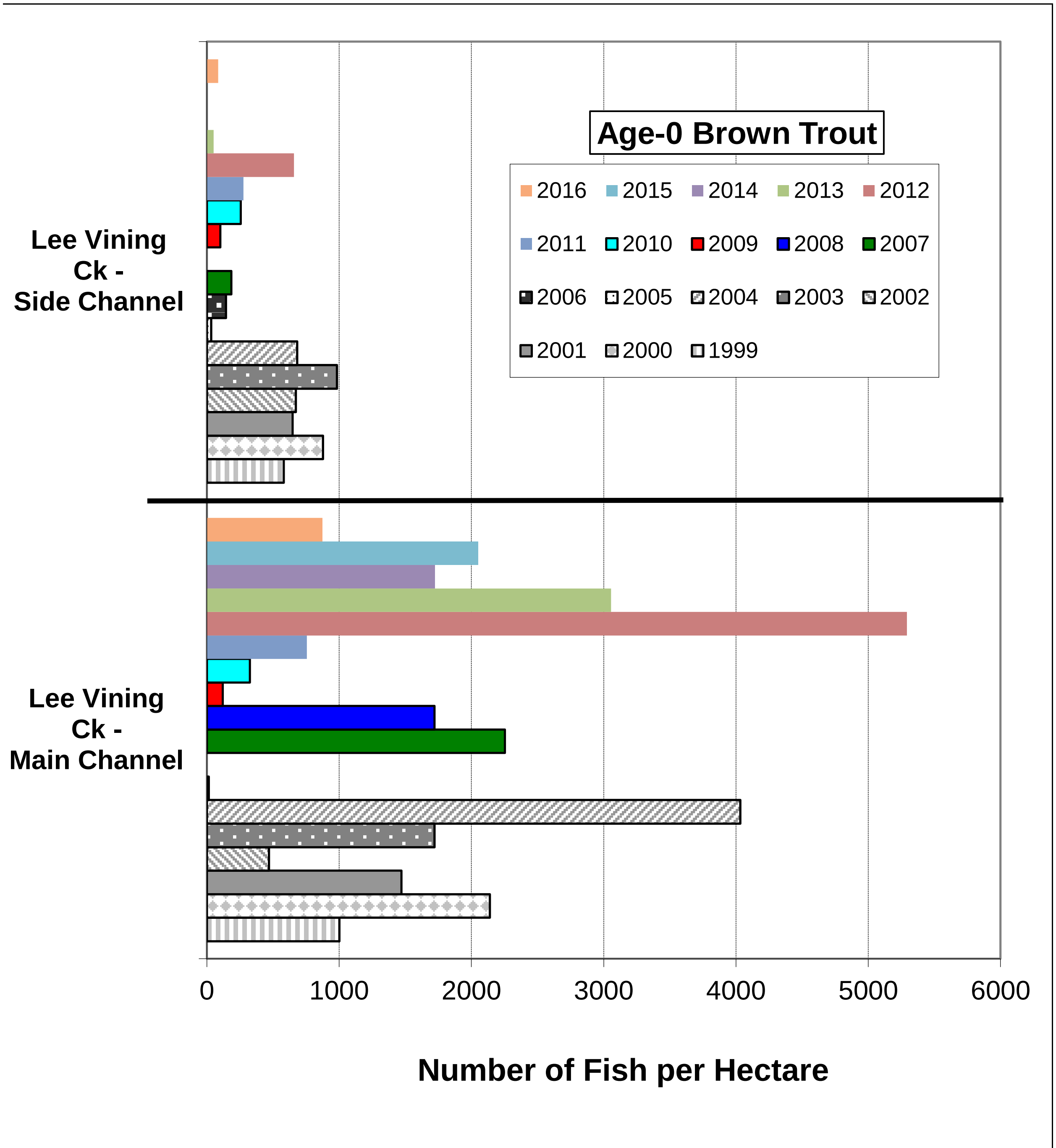

Figure 17. Estimated number of age-0 Brown Trout per hectare in Lee Vining Creek from 1999 to 2016.

Age-1 and older (aka Age-1+) Brown Trout

The Upper Rush section had an estimated density (number per hectare) of 496 age-1+ Brown Trout/ha in 2016, a decrease of 62% from the 2015 estimate of 1,319 trout/ha (Figure 18). Between 2012 and 2016 (the five consecutive dry/below average years), the age-1+ Brown Trout density estimates dropped from 1,993 fish to 496 fish (a 75% decrease). The 2016 estimate was the lowest recorded for this section and was 65% lower than the 18-year average of 1,410 age-1+ Brown Trout/ha.

The Bottomlands section of Rush Creek produced a density estimate of 245 age-1+ Brown Trout/ha in 2016, a 55% decrease from the 2015 estimate of 540 age-1+trout/ha (Figure 18). The 2016 density estimate of age-1+ Brown Trout/ha was the lowest since the start of sampling the Bottomlands section in 2008 and was also the fourth consecutive decrease since 2012's estimate of 1,735 age-1+ trout/ha (Figure 18). The density estimate of age-1+ Brown Trout has dropped by 86% since 2012 (Figure 18).

The 2016 density estimate for age-1+ Brown Trout for the Walker Creek section was 1,960 age-1+trout/ha which was a 18% decrease from the 2015 estimate of 2,377 age-1+ trout/ha (Figure 18). The 2016 density estimate of age-1+ Brown Trout was sixth highest estimate for the 18 years that Walker Creek has been sampled (Figure 18).

The 2016 density estimate for age-1+ Brown Trout in the Lee Vining main channel section was 1,479 trout/ha, a 26% decrease from the 2,002 age-1+ trout/ha in 2015 (Figure 19). The 2016 estimate was the third consecutive decrease in the density estimate of age-1+ Brown Trout for this section since 2013's estimate of 2,449 age-1+ Brown Trout/ha (Figure 19).

In 2016, the side channel of Lee Vining Creek produced an estimated density of 430 age-1+ Brown Trout/ha (Figure 19). As discussed in last year's annual report, the side channel's large variations in wetted area has been the driving influence in density and standing crop estimates for this section, such that the lowest catch number (seven fish in 2015) resulted in the largest density estimate (Table 9). In September of 2016, more flow was entering the top of the side channel, which increased the wetted area within the sampling section by 230% (Table 9).

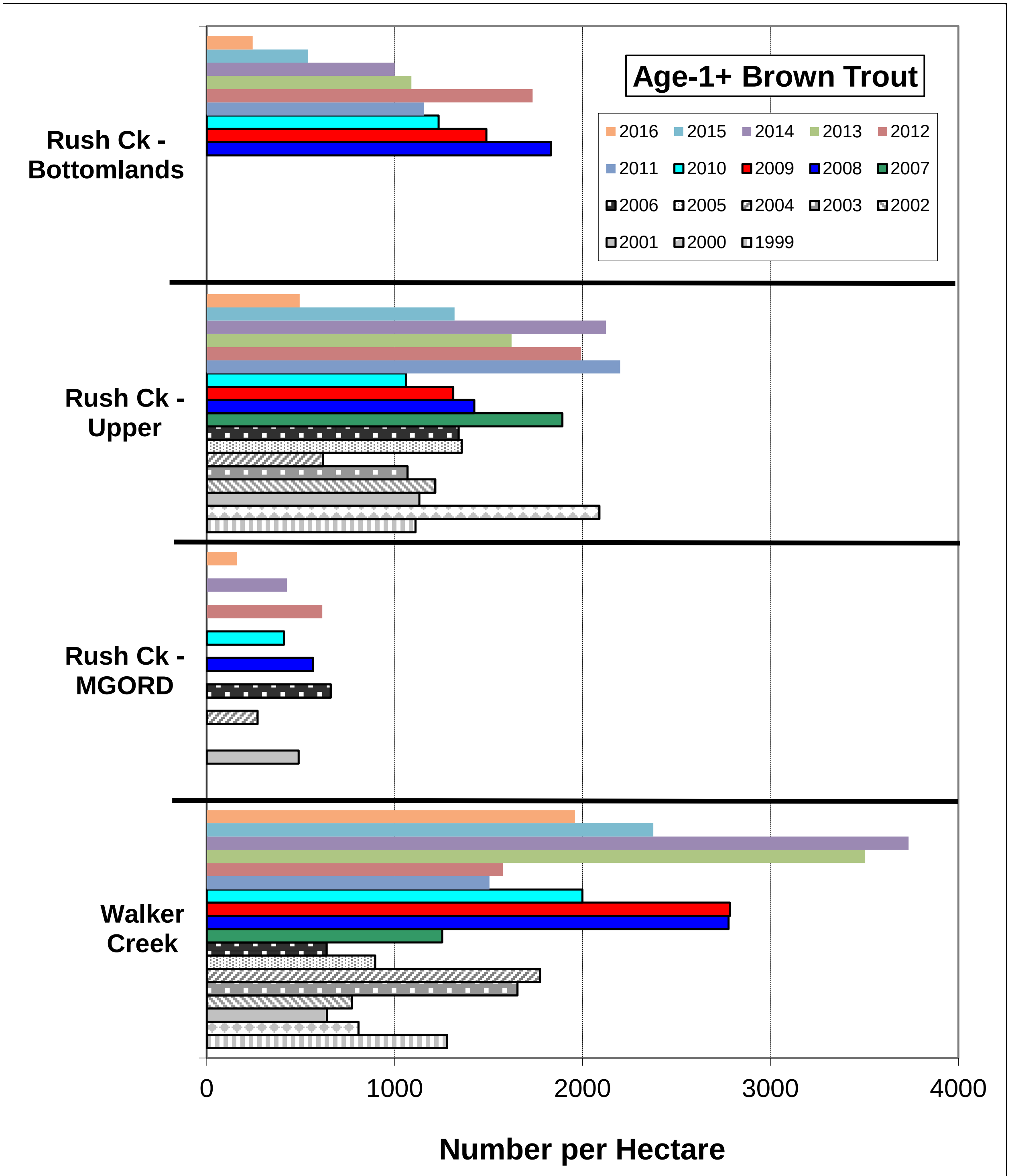

Figure 18. Estimated number of age-1 and older Brown Trout per hectare in sections of Rush and Walker Creeks from 1999 to 2016.

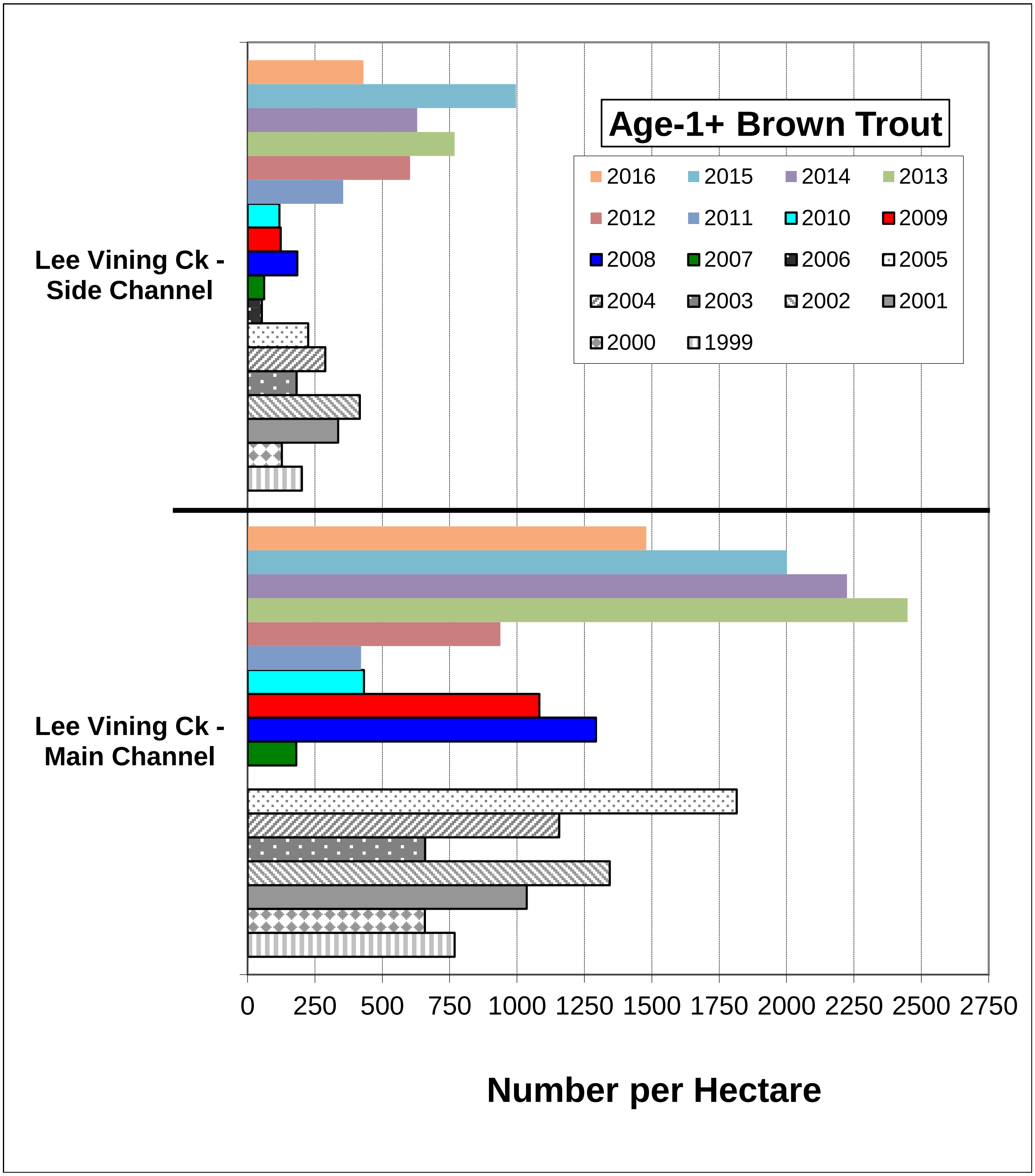

Figure 19. Estimated number of age-1 and older Brown Trout per hectare in sections of Lee Vining Creek from 1999 to 2016.

Table 9. Wetted surface area and total numbers of trout captured in the Lee Vining Creek side channel, from 2007 to 2016.

Sample Year	Wetted Channel Area (m^2)	Total Number of Trout Captured
2007	487.5	22
2008	487.5	20
2009	487.5	26
2010	507.0	20
2011	507.0	30
2012	365.0	45
2013	328.0	16
2014	190.5	12
2015	70.3	7
2016	232.9	12

Age-0 Rainbow Trout

In 2016, for the eighth consecutive year no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel.

In the Lee Vining Creek main channel, for a second consecutive year, no age-0 Rainbow Trout were captured during the 2016 sampling.

Age-1 and older (aka Age-1+) Rainbow Trout

In 2016, for the sixth consecutive year no age-1 and older Rainbow Trout were captured in the Lee Vining Creek side channel.

For the Lee Vining Creek main channel, the estimated densities of age-1 and older Rainbow Trout decreased by 70% from 172 trout/ha in 2015 to 52 trout/ha in 2016 (Figure 21). Between 2013 and 2016, the density estimate of age-1+ Rainbow Trout has decreased by 94%, from 826 fish/ha to 52 fish/ha (Figure 21). Sampling years (1999-2001, 2003-2005, 2007 and 2011) produced insufficient numbers of age-1 and older Rainbow Trout to generate population estimates, thus these density estimates were derived from catch data.

As previously mentioned (page 27), the numbers of Rainbow Trout captured in Lee Vining Creek have dropped dramatically since 2012, from 235 fish to seven fish, a 97% decline during the five consecutive dry/below average water-years and during the first four years of CDFW stocking sterile Rainbow Trout into Mono Basin streams.

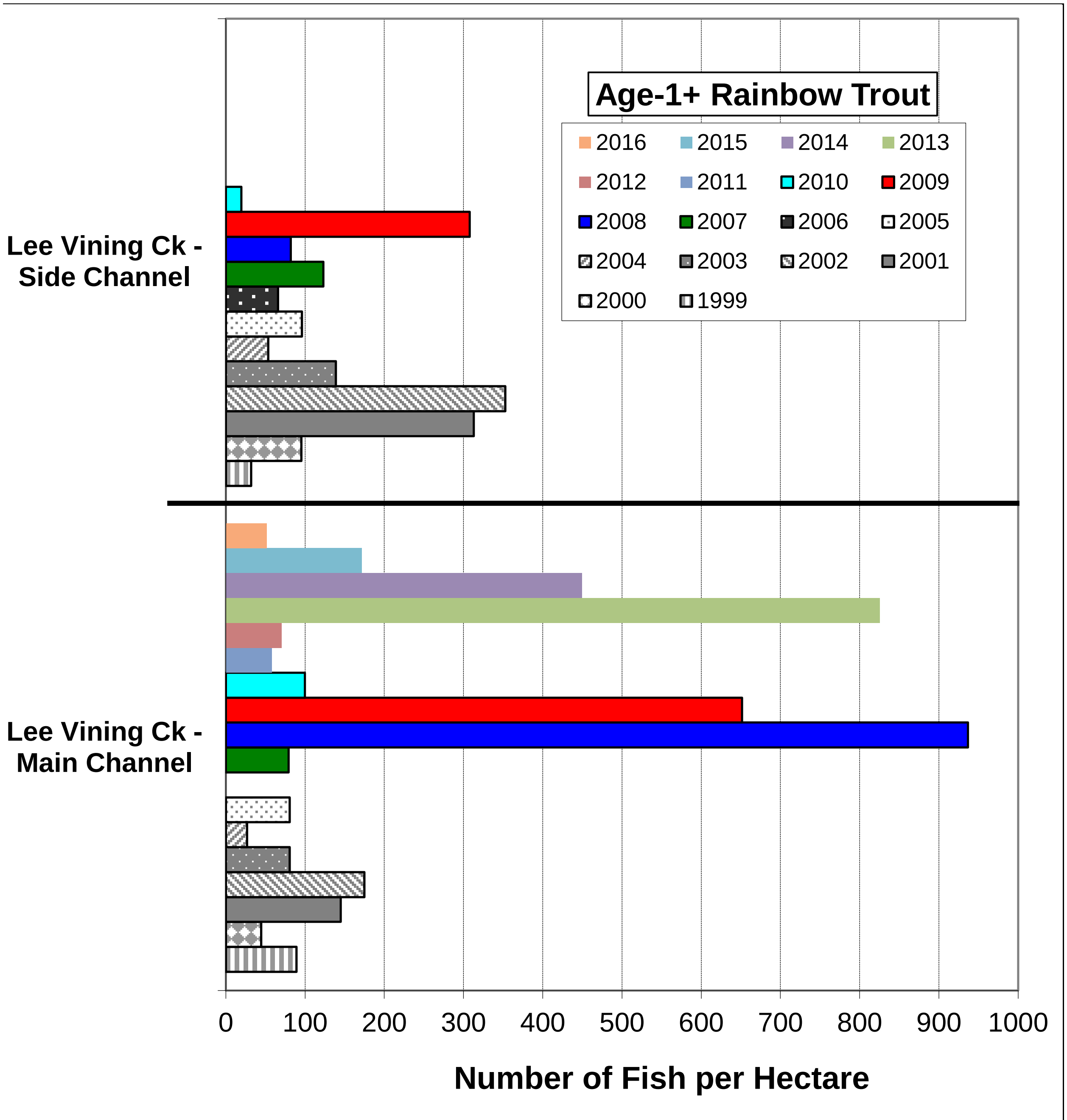

Figure 21. Estimated number of age-1 and older Rainbow Trout per hectare in sections of Lee Vining Creek from 1999 to 2016.

Estimated Trout Densities Expressed in Numbers per Unit Length

The Upper Rush section produced a total density estimate of 766 Brown Trout per kilometer in 2016 which was a 69% decrease from the 2015 estimate of 2,468 Brown Trout per kilometer (Table 10). The estimated numbers of Brown Trout per kilometer have fallen for five straight years in the Upper Rush section (Table 10). In 2011, the year prior to the five consecutive dry/below normal years, the total density estimate was 10,821 Brown Trout per kilometer, thus the decrease over this five-year span was 93%. The estimated density of age-1+ Brown Trout in 2016 was 406 fish/km which was a 58% decrease from the 2015 estimate of 963 fish/km (Table 10).

The Bottomlands section in 2016 produced a total density estimate of 523 Brown Trout/km which was a 63% decrease from the 2015 estimate of 1,422 fish/km (Table 10). Between 2012 and 2016, the five consecutive dry/below normal water years, the estimated numbers of Brown Trout per kilometer have fallen from 3,208 to 523 fish/km; an 84% decrease. In 2016, the estimate of 176 age-1+ Brown Trout/km was the lowest estimate for the nine-year sampling period in the Bottomlands section (Table 10).

The Lee Vining Creek main channel produced a total density estimate of 1,973 Rainbow Trout and Brown Trout/km in 2016 (Table 11). The 2016 estimate was 3% less than the 2015 estimate of 2,027 Rainbow Trout and Brown Trout/km (Table 11). After the peak estimate of 4,361 fish/km in 2012 (the first of five consecutive dry/below normal years), the estimate has decreased each subsequent year, and 2016's estimate was 55% less than 2012's estimate. For age-1+ Rainbow Trout and Brown Trout combined, the estimated density was 989 fish/km in 2016, which was a 5% decrease from the 2015 estimate of 1,043 age-1+ fish/km (Table 11).

The Lee Vining side channel produced a total density estimate of 97 Brown Trout/km in 2016, a 3% decrease from the 2015 estimate of 100 fish/km (Table 11). For age-1+ Brown Trout, the 2016 density estimate was also 97 Brown Trout/km which was a 3% decrease from the 2015 density estimate 100 fish/km (Table 11).

The Lee Vining Creek main channel and the side channel densities were added in order to compare to the proposed termination criteria as discussed in the 2011 Annual Fisheries Report (Taylor and Knudson 2011). When combined, the two channels produced a total density estimate of 860 Rainbow Trout and Brown Trout/km in 2016, a decrease of 46% from the 2015 estimate of 1,591 Rainbow Trout and Brown Trout/km (Table 11). Age-1+ trout in these two channels produced an estimate of 554 Rainbow Trout and Brown Trout/km in 2016, a 32% decrease from 819 fish/km in 2015 (Table 11).

Table 10. Total number of Brown Trout per kilometer of stream channel for Rush Creek sample sections from 2005 to 2016. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rush Creek, Upper Rush	5,032 (1,167)	7,905 (1,100)	8,698 (1,621)	3,607 (1,267)	3,444 (1,186)	5,726 (881)	10,821 (1,833)	8,288 (1,556)	6,105 (1,347)	4,574 (1,530)	2,468 (963)	**766 (406)**
Rush Creek, Bottom-lands	N/A	N/A	N/A	3,579 (1,467)	2,961 (1,146)	3,405 (963)	2,725 (929)	3,208 (1,279)	1,980 (817)	1,098 (700)	1,422 (362)	**523 (179)**

Table 11. Total number of brown and Rainbow Trout per kilometer of stream channel for Lee Vining Creek sample sections from 2005 to 2016. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Lee Vining, Main Channel	917 (910)	No Sample high flow	2,103 (148)	2,357 (1,204)	1,192 (1,023)	518 (326)	727 (258)	4,361 (506)	3,765 (1,867)	2,444 (1,471)	2,027 (1,043)	**1,973 (989)**
Lee Vining, Side Channel	169 (154)	618 (48)	129 (62)	103 (67)	133 (108)	103 (36)	159 (87)	257 (123)	131 (123)	95 (95)	100 (100)	**97 (97)**
LV Main + LV Side Additive Approach	543 (532)	N/A	1,116 (105)	1,230 (636)	663 (566)	311 (181)	443 (173)	2,668 (348)	2,588 (1,302)	1,662 (1,013)	1,591 (819)	**860 (554)**

Estimated Trout Standing Crop Comparisons

The estimated standing crop for Brown Trout in the Upper Rush section was 62 kg/ha in 2016, a 50% decrease from the 2015 estimate of 123 kg/ha, and was also the lowest estimate for the 18 sampling years (Table 12 and Figure 22). Since the record high estimate of 224 kg/ha in 2011, the standing crop of Brown Trout in the Upper Rush section has declined by 72% over the subsequent five consecutive dry/below average water years (Figure 22). When compared to the 18-year average of 145 kg/ha, the 2016 standing crop estimate was approximately 57% lower (Figure 22).

The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 34 kg/ha in 2016, a 42% decrease from 59 kg/ha in 2015, and the lowest estimate for the nine sampling years (Table 12 and Figure 22). When compared to the nine-year average of 82 kg/ha, the 2016 standing crop estimate was approximately 59% lower (Figure 22).

Although there is not a standing crop termination criterion for Walker Creek, an estimate was still generated for this annually-sampled section. The estimated standing crop for Brown Trout in Walker Creek was 172 kg/ha in 2016, a 6% decrease from the 2015 estimate of 183 kg/ha (Table 12 and Figure 22). The 2016 standing crop estimate was the fifth highest value recorded in Walker Creek over the 18-year sample period and the long-term average for this period is 134 kg/ha.

The Lee Vining Creek main channel in 2016 produced a total standing crop of 113 kg/ha for both Rainbow Trout and Brown Trout (Table 13 and Figure 23). The 2016 total estimate was a 23% decrease from the 2015 estimate of 150 kg/ha (Table 13). The 2016 Brown Trout standing crop estimate was 105 kg/ha and the Rainbow Trout standing crop estimate was 8 kg/ha. In 2016, the Brown Trout estimated standing crop decreased from the 2015 estimate by 24% and the 2016 Rainbow Trout estimated standing crop decreased by 34% from the 2015 estimate. Between 2013 and 2016, the Rainbow Trout estimated standing crop has decreased by 84%. The 2016 total standing crop of 113 kg/ha was 14% lower than the 17-year average of 131 kg/ha.

The Lee Vining Creek side channel produced a Brown Trout standing crop estimate of 31 kg/ha in 2016 which was a 31% decrease from 2015’s estimate of 45 kg/ha (Table 13 and Figure 23). No Rainbow Trout were captured in the Lee Vining Creek side channel in 2016 and none have been sampled in the side channel section for six consecutive years (2011-2016).

When an additive standing crop estimate was generated for the Lee Vining Creek main channel and the side channel, the total standing crop estimate equaled 101 kg/ha for 2016, a 30% decrease from the 2015 estimate of 145kg/ha (Table 13).

Table 12. Comparison of Brown Trout standing crop (kg/ha) estimates between 2012 and 2016 for Rush Creek sections.

Collection Location	2012 Total Standing Crop (kg/ha)	2013 Total Standing Crop (kg/ha)	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	Percent Change Between 2015 and 2016
Rush Creek – Upper	178	140	167	123	62	-50%
Rush Creek - Bottomlands	103	55	52	59	34	- 42%
Walker Creek	156	194	189	183	172	- 6%

Table 13. Comparison of total (brown and Rainbow Trout) standing crop (kg/ha) estimates between 2012 and 2016 for the Lee Vining Creek sections.

Collection Location	2012 Total Standing Crop (kg/ha)	2013 Total Standing Crop (kg/ha)	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	Percent Change Between 2015 and 2016
Lee Vining Creek - Main Channel	173	184	140	150	113	-23%
Lee Vining Creek – Side Channel	39	26	30	45	31	-31%
Lee Vining Main/Side Channels Combined	143	165	126	145	101	-30%

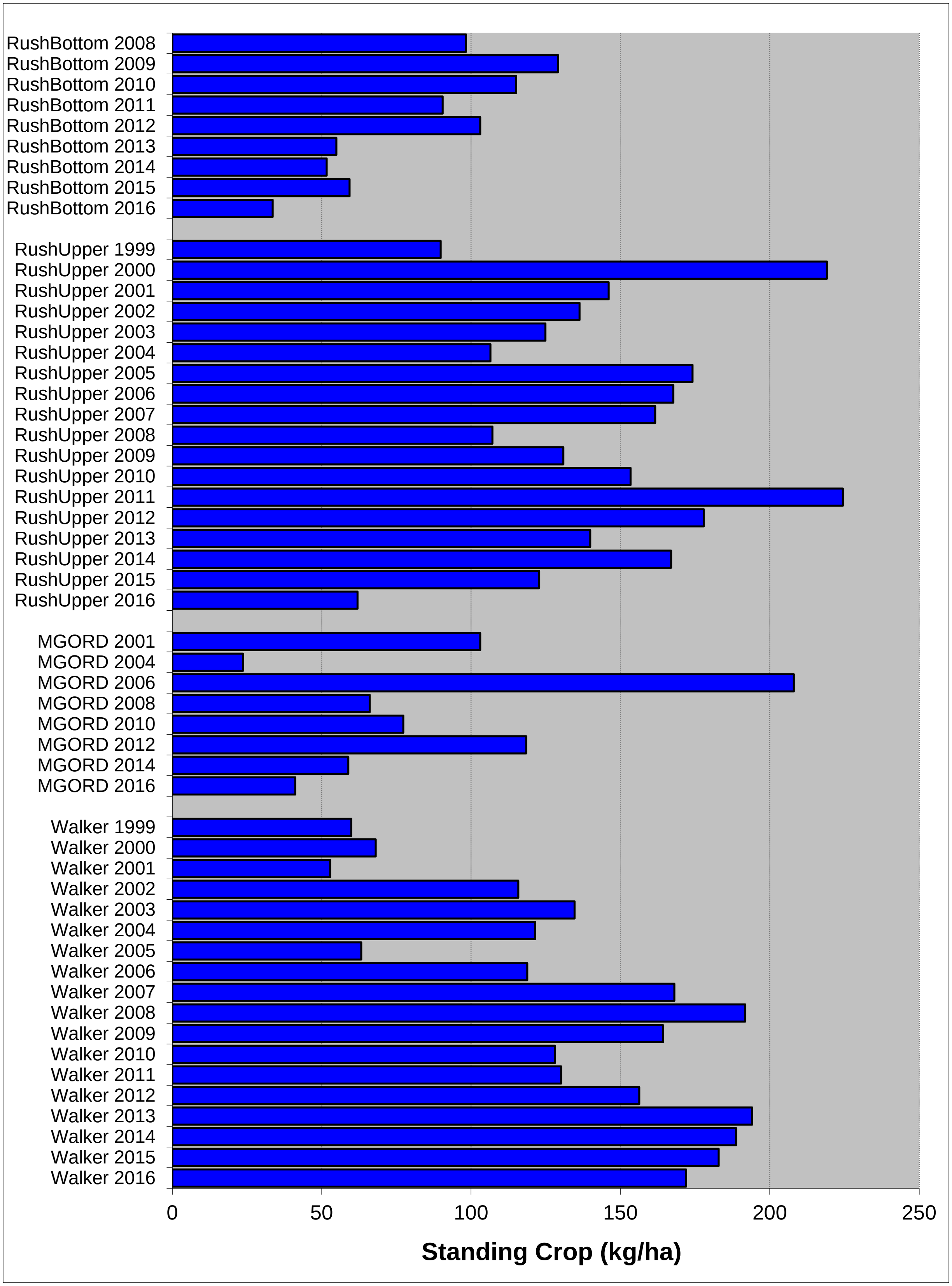

Figure 22. Estimated total standing crop (kilograms per hectare) of Brown Trout in Rush Creek sample sections from 1999 to 2016. NOTE: After 2001, MGORD estimates only made during even years.

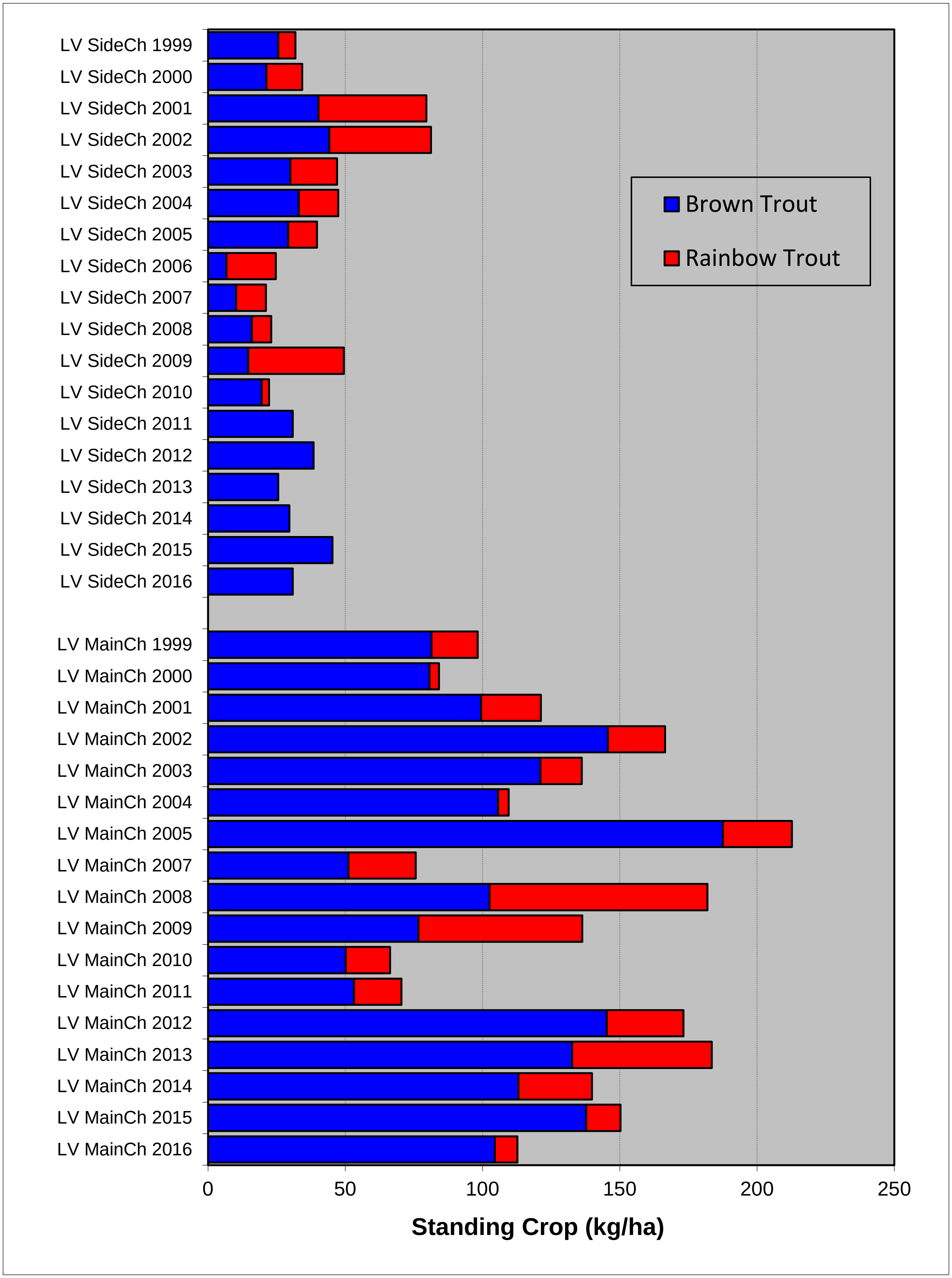

Figure 23. Estimated total standing crop (kilograms per hectare) of Brown Trout and Rainbow Trout (red) in Lee Vining Creek sample sections from 1999 to 2016.

Relative Stock Density (RSD) Results for Rush and Lee Vining Creeks

In the Upper Rush section, the 2016 RSD-225 of 28 was the highest value for this section since 2010's value of 34 (Table 14). This increase in the RSD-225 value was most likely influenced by the overall low numbers of fish along with poor age-0 recruitment during the previous years, leading to low numbers of age-1 and older fish in the 150-224 mm size class. The RSD-300 value was 3 in 2016, back up to the same value as 2010's (Table 14). Over the 17 sampling years, a total of 92 Brown Trout ≥300 mm were captured in the Upper Rush Creek section, an average of 5.4 fish ≥300 mm per year (Table 14).

In the Bottomlands section of Rush Creek, the RSD-225 for 2016 was 21, a slight drop from 2015's value of 23 (Table 14). As in the Upper Rush section, low numbers of age-1 and older trout affected the Bottomlands RSD-225 value. In 2016, only 14 Brown Trout ≥225 mm in length were captured (Table 14). The average number of Brown Trout ≥225 mm captured over the nine-year sampling history was 32 trout per year, a 35% decrease compared to the average of 49 trout/year ≥225 mm for the five years prior to the drought (Table 14). The RSD-300 value was 5 in 2016, based on the capture of three Brown Trout ≥300 mm, of which two were >400 mm (Table 14). Over the nine sampling years, a total of 12 Brown Trout ≥300 mm were captured in the Bottomlands section, an average of 1.3 fish ≥300 mm per year (Table 14).

In the MGORD, the RSD-225 value increased from 72 in 2015 to 74 in 2016; this was the third consecutive increase since the low value of 42 in 2013 (Table 14). The increasing RSD-225 values were most likely indicative of the continued poor recruitment of age-0 fish in the previous drought years and very few fish available for capture in the 150-224 mm size class. In 2016, the RSD-300 value was 21, a slight decrease from a value of 25 in 2015 (Table 14). The RSD-375 value in 2016 was 11, the highest this has been since the 2001 season (Table 14). Although the total catch of Brown Trout in the MGORD during the 2016 season was lowest ever (116 fish average for two electrofishing passes), 38 trout ≥300 mm in length were caught, including 20 fish ≥375 mm in length (Table 14). For sampling conducted between 2001 and 2012, the annual average catch of trout ≥300 mm equaled 180 fish/year; then for the past four sampling years the annual average catch of trout ≥300 mm equaled 38 fish/year (Table 14). This 79% decline in larger Brown Trout coincided with the five years of drier water-years and poor summer thermal regimes within the MGORD.

RSD values in Lee Vining Creek were generated for the main channel combined with the side channel and for the main channel only (Table 15). The RSD-225 values for the main/side combined and main-only equaled 14 for 2016, an increase compared to the 2015 value (Table 15). For a third straight year, no trout greater than 300 mm in length were captured in Lee Vining Creek (Table 15).

Table 14. RSD values for Brown Trout in Rush Creek sections from 2000 to 2016.

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300	RSD-375
Upper Rush	**2016**	**103**	**74**	**26**	**1**	**2**	**28**	**3**	**2**
Upper Rush	2015	289	246	41	0	2	15	1	1
Upper Rush	2014	366	331	31	4	0	10	1	
Upper Rush	2013	336	288	45	3	0	14	1	
Upper Rush	2012	354	284	66	3	1	20	1	
Upper Rush	2011	498	381	110	6	1	23	1	
Upper Rush	2010	308	202	97	7	2	34	3	1
Upper Rush	2009	372	322	43	5	2	13	2	1
Upper Rush	2008	227	189	31	6	1	17	3	
Upper Rush	2007	282	210	61	9	2	26	4	1
Upper Rush	2006	233	154	69	10	0	34	4	
Upper Rush	2005	202	139	56	5	2	31	3	
Upper Rush	2004	179	112	64	2	1	37	2	
Upper Rush	2003	264	216	45	2	1	18	1	
Upper Rush	2002	220	181	35	1	2	18	2	1
Upper Rush	2001	223	190	27	6	0	15	3	
Upper Rush	2000	182	158	22	2	0	13	1	
Bottomlands	**2016**	**66**	**52**	**11**	**1**	**2**	**21**	**5**	**3**
Bottomlands	2015	115	88	26	0	1	23	1	1
Bottomlands	2014	154	152	1	0	1	1	1	1
Bottomlands	2013	128	123	5	0	0	4	0	
Bottomlands	2012	325	290	34	1	0	11	0	
Bottomlands	2011	267	218	46	3	0	18	1	
Bottomlands	2010	307	225	81	1	0	27	0	
Bottomlands	2009	379	321	56	1	1	15	1	
Bottomlands	2008	160	141	19	0	0	12	0	
MGORD	**2016**	**179**	**46**	**95**	**18**	**20**	**74**	**21**	**11**
MGORD	2015	116	33	54	20	9	72	25	8
MGORD	2014	388	184	175	19	10	53	7	3
MGORD	2013	411	237	118	41	15	42	14	4
MGORD	2012	694	176	319	173	26	75	29	4
MGORD	2011	216	36	117	55	8	83	29	4
MGORD	2010	694	252	292	115	35	64	22	5
MGORD	2009	643	156	338	123	26	76	23	4
MGORD	2008	856	415	301	118	22	52	16	3
MGORD	2007	621	144	191	259	27	77	46	4
MGORD	2006	567	60	200	280	27	89	54	5
MGORD	2004	424	130	197	64	33	69	23	8
MGORD	2001	774	330	217	119	108	57	29	14

Table 15. RSD values for brown and Rainbow Trout in the Lee Vining Creek main channel and side channel sections from 2008 to 2016. RSD values for brown and Rainbow Trout in the Lee Vining Creek main channel section from 2000 to 2016.

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300
Main & Side	**2016**	**179**	**154**	**24**	**0**	**0**	**14**	**0**
Main & Side	2015	227	206	21	0	0	9	0
Main & Side	2014	212	184	28	0	0	13	0
Main & Side	2013	327	309	17	1	0	6	0
Main & Side	2012	128	87	39	2	0	32	2
Main & Side	2011	78	46	26	5	1	41	1
Main & Side	2010	68	31	35	2	0	54	3
Main & Side	2009	192	159	32	1	0	17	1
Main & Side	2008	252	242	19	0	0	8	0
Main Channel	**2016**	**169**	**145**	**24**	**0**	**0**	**14**	**0**
Main Channel	2015	210	192	18	0	0	9	0
Main Channel	2014	200	173	27	0	0	14	0
Main Channel	2013	325	308	16	1	0	5	0
Main Channel	2012	111	72	37	2	0	35	2
Main Channel	2011	60	31	23	5	1	48	10
Main Channel	2010	62	28	32	2	0	55	3
Main Channel	2009	137	106	30	1	0	23	1
Main Channel	2008	149	138	11	0	0	7	0
Main Channel	2007	29	24	5	0	0	17	0
Main Channel	2006*	NS	NS	NS	NS	NS	-	-
Main Channel	2005	60	37	20	2	1	38	5
Main Channel	2004	70	60	8	2	0	14	3
Main Channel	2003	52	27	23	2	0	48	4
Main Channel	2002	100	74	23	3	0	26	3
Main Channel	2001	90	71	16	3	0	21	3
Main Channel	2000	51	32	18	1	0	37	2

*not sampled due to high flows.

Termination Criteria Results based on 2012 – 2016 Data Sets

The Rush Creek sampling sections for years 2012 through 2016, failed to meet four of the five termination criteria for any of the three, three-year running averages.

For the 2014-2016 three-year average, the Upper Rush section failed to meet any of the termination criteria (Table 16).

Table 16. Termination criteria analyses for the Upper Rush section of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2014 – 2016 Average	2013 – 2015 Average	2012 – 2014 Average
Biomass (≥175 kg/ha)	117	143	162
Density (≥3,000 trout/km)	2,603	**4,382**	**6,322**
Condition Factor (≥1.00)	0.99	0.98	0.98
RSD-225 (≥35)	18	13	15
RSD-300 (≥5)	2	1	1
Conclusion	**Met none of five TC**	**Met one of five TC**	**Met one of five TC**

For the 2014-2016 three-year average, the Bottomlands section failed to meet any of the termination criteria (Table 17).

Table 17. Termination criteria analyses for the Bottomlands of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2014 – 2016 Average	2013 – 2015 Average	2012 – 2014 Average
Biomass (≥175 kg/ha)	48	55	70
Density (≥3,000 trout/km)	1,014	1,500	2,095
Condition Factor (≥1.00)	0.96	0.94	0.93
RSD-225 (≥35)	15	9	5
RSD-300 (≥5)	2	1	0
Conclusion	**Met none of five TC**	**Met none of five TC**	**Met none of five TC**

For the 2014-2016 three-year average, the MGORD met both the RSD-225 and RSD-375 termination criterion (Table 18).

Table 18. Termination criteria analyses for the MGORD section of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	**2014 – 2016 Average**	**2013 – 2015 Average**	**2012 – 2014 Average**
RSD-225 (≥60)	**66**	55	57
RSD-300 (≥30)	18	15	17
RSD-375 (≥5)	**7**	**5**	3
Conclusion	**Met TC two of three RSD values**	**Met TC one of three RSD values**	**Met TC none of three RSD values**

For the 2014-2016 three-year average, the main and side channel sections of Lee Vining Creek together failed to meet any of the termination criteria (Table 19).

Table 19. Termination criteria analyses for the Lee Vining Creek sample sections. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	**2014 - 2016 Average**	**2013 - 2015 Average**	**2012 - 2014 Average**
Biomass (≥150 kg/ha)	101	145	145
Density (≥1,400 trout/km)	1,371	**1,947**	**2,306**
Condition Factor (≥1.00)	0.97	0.94	0.95
RSD-225 (≥30)	12	9	17
Conclusion	**Met none of four TC**	**Met one of four TC**	**Met one of four TC**

PIT Tag Recaptures

PIT Tags Implanted between 2009 and 2016

In 2009, a total of 1,596 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 20). Of the 1,596 trout tagged, 711 were age-0 and 861 were age-1+ Brown Trout, 19 were age-0 Rainbow Trout, and five were age-1 and older Rainbow Trout. In 2008, age-0 trout received adipose fin clips to help track growth rates of that cohort of trout into the future. Knowing that this cohort of trout was age-1 in 2009, 224 trout with adipose fin clips were PIT tagged in 2009. All trout in the MGORD were tagged; a total of 54 age-0 Brown Trout and 642 age-1 and older Brown Trout. No Rainbow Trout were captured in the MGORD. Most of these trout in the MGORD were older than age-1.

In 2010, a total of 1,274 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 21). Of the 1,274 trout, 855 were age-0 and 43 were age-1 and older Brown Trout. Four age-0 and one age-1 and older Rainbow Trout received PIT tags and adipose fin clips. Again all trout in the MGORD (371 trout) were tagged and given an adipose fin clip. Of the 371 trout, 359 were age-1 and older Brown Trout and 12 were age-1 and older Rainbow Trout. Like 2009, most of the trout tagged in the MGORD were older than age-1.

In 2011, a total of 1,065 trout received adipose fin clips and PIT tags in Rush, Lee Vining, and Walker Creeks (Table 22). Of these 1,065 trout, 851 were age-0 Brown Trout and 19 were age-1 and older Brown Trout. Fifty age-0 Rainbow Trout received PIT tags and adipose fin clips. All age-1 and older trout in the MGORD (145 trout) were tagged and given adipose fin clips. Of the 145 trout 142 were age-1 and older (mostly older) Brown Trout and three were age-1 and older Rainbow Trout.

In 2012, a total of 496 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 23). Of the 496 trout tagged, 412 were age-0 and 4 were age-1 and older Brown Trout. For Rainbow Trout, only age-0 fish were tagged in 2012 which totaled 80 trout. No new tags were implanted in trout in the County Road section, but trout with missing adipose fins and did not produce a tag number when scanned were retagged. No trout in the MGORD in 2012 were tagged or retagged due to a limited number of PIT tags available for deployment.

In 2013, no PIT tags were implanted in any fish. Only length and weight data from recaptures of previously tagged fish were collected during the September 2013 sampling.

In 2014, a total of 964 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 24). Of the 964 trout tagged, 459 were age-0 and 477 were age-1 and older Brown Trout. For Rainbow Trout, six age-0 fish were tagged and 22 age-1 and older fish were tagged. Because no PIT tags were deployed in 2013, suspected age-1 trout were tagged in 2014 and these fish were between 125 mm and 170 mm in length.

In 2015, a total of 863 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 25). In addition, eight recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 871 PIT tags were deployed during the 2015 fisheries sampling (Table 25). Of the 871 trout tagged, 738 were age-0 Brown Trout and 126 were age-1 and older Brown Trout (Table 25). For Rainbow Trout, seven age-0 fish were tagged in the Upper Rush section (Table 25).

Table 20. Total numbers of trout implanted with PIT tags during the 2009 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout	Number of Age-1 Brown Trout	Number of Age-0 Rainbow Trout	Number of Age-1 Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	256	26	15	1	**298 Trout**
	Bottomlands	164	68	0	0	**232 Trout**
	County Road	108	29	0	0	**137 Trout**
	MGORD	54	642*	0	0	**696 Trout**
Lee Vining Creek	Main Channel	10	45	4	3	**62 Trout**
	Side Channel	5	0	0	1	**6 Trout**
Walker Creek	Above old 395	114	51	0	0	**165 Trout**
Totals:		**711**	**861**	**19**	**5**	**Total Trout: 1,596**

*Many of these MGORD trout were >age-1.

Table 21. Total numbers of trout implanted with PIT tags during the 2010 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	242	11	4	0	**257 Trout**
	Bottomlands	284	3	0	0	**287 Trout**
	County Road	210	7	0	0	**217 Trout**
	MGORD	1	359*	0	12	**372 Trout**
Lee Vining Creek	Main Channel	24	8	0	1	**33 Trout**
	Side Channel	13	0	0	0	**13 Trout**
Walker Creek	Above old 395	81	14	0	0	**95 Trout**
Totals:		**855**	**402**	**4**	**13**	**Total Trout: 1,274**

*Many of these MGORD trout were >age-1.

Table 22. Total numbers of trout implanted with PIT tags during the 2011 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	393	3	30	0	**426 Trout**
	Bottomlands	178	1	11	0	**190 Trout**
	County Road	196	1	6	0	**203 Trout**
	MGORD	8	142*	3	3	**156 Trout**
Lee Vining Creek	Main Channel	24	0	0	0	**24 Trout**
	Side Channel	11	14	0	0	**25 Trout**
Walker Creek	Above old 395	41	0	0	0	**41 Trout**
Totals:		**851**	**161**	**50**	**3**	**Total Trout: 1,065**

*Many of these MGORD trout were >age-1.

Table 23. Total numbers of trout implanted with PIT tags during the 2012 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	117	1	2	0	**120 Trout**
	Bottomlands	110	1	6	0	**117 Trout**
	County Road	0	2	0	0	**2 Trout**
	MGORD	0	0	0	0	**0 Trout**
Lee Vining Creek	Main Channel	125	0	72	0	**197 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	60	0	0	0	**60 Trout**
Age Class Sub-totals:		**412**	**4**	**80**	**0**	**Total Trout: 496**

Table 24. Total numbers of trout implanted with PIT tags during the 2014 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 Brown Trout (125-170 mm)	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 Rainbow Trout (125-170 mm)	Section Totals
Rush Creek	Upper Rush	243	86	1	0	**330 Trout**
	Bottomlands	34	43	0	0	**77 Trout**
	MGORD	13	125-199 mm = 60 Brown Trout ≥200 mm = 185 Brown Trout			**258 Trout**
Lee Vining Creek	Main Channel	127	103	5	22	**257 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	42	0	0	0	**42 Trout**
Age Class Sub-totals:		**459**	**232***	**6**	**22**	**Total Trout: 964**

*this sub-total excludes age-1 and older MGORD fish

Table 25. Total numbers of trout implanted with PIT tags during the 2015 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Section Totals
Rush Creek	Upper Rush	234	2*	7	0	**243 Trout**
	Bottomlands	167	3*	0	0	**170 Trout**
	MGORD	29	125-199 mm = 37 Brown Trout ≥200 mm = 83 Brown Trout (2 shed/new)			**149 Trout**
Lee Vining Creek	Main Channel	195	1*	0	0	**196 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	113	0	0	0	**113 Trout**
Age Class Sub-totals:		**738**	**6****	**7**	**0**	**Total Trout: 871**

*shed tag/new tag implanted **this sub-total excludes age-1 and older MGORD fish

In 2016, a total of 564 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 26). In addition, five recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 569 PIT tags were implanted during the 2016 fisheries sampling (Table 26). Of the 569 trout tagged, 394 were age-0 Brown Trout and 166 were age-1 and older Brown Trout (Table 26). For Rainbow Trout, two age-0 fish were tagged (one in the Upper Rush and one in the MGORD) and seven age-1 and older Rainbow Trout were tagged in the MGORD (Table 26).

Table 26. Total numbers of trout implanted with PIT tags during the 2016 sampling season, by stream, sample section, age-class and species.

<table>
<tr><th>Stream</th><th>Sample Section</th><th>Number of Age-0 Brown Trout (<125 mm)</th><th>Number of Age-1 and older Brown Trout</th><th>Number of Age-0 Rainbow Trout (<125 mm)</th><th>Number of Age-1 and older Rainbow Trout</th><th>Section Totals</th></tr>
<tr><td rowspan="3">Rush Creek</td><td>Upper Rush</td><td>36</td><td>0</td><td>1</td><td>0</td><td>37 Trout</td></tr>
<tr><td>Bottomlands</td><td>79</td><td>1*</td><td>0</td><td>0</td><td>80 Trout</td></tr>
<tr><td>MGORD</td><td>4 BNT
1 RBT</td><td colspan="3">125-199 mm = 9 BNT
≥200 mm = 154** BNT and 7 RBT</td><td>175 Trout</td></tr>
<tr><td rowspan="2">Lee Vining Creek</td><td>Main Channel</td><td>46</td><td>1*</td><td>0</td><td>0</td><td>47 Trout</td></tr>
<tr><td>Side Channel</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1 Trout</td></tr>
<tr><td>Walker Creek</td><td>Above old 395</td><td>228</td><td>1*</td><td>0</td><td>0</td><td>229 Trout</td></tr>
<tr><td colspan="2">Age Class Sub-totals:</td><td>394</td><td>166</td><td>2</td><td>7</td><td>Total Trout: 569</td></tr>
</table>

*shed tag/new tag implanted **two of these BNT = shed tag/new tag implanted

In September of 2016, a total of 77 previously tagged trout (that retained their tags) were recaptured in Rush Creek (Appendix B: Table 1). Most of the recaptures occurred in Walker Creek (41 fish), followed by 17 recaptures in the Upper Rush section, 13 recaptures in the MGORD, and six recaptures in the Bottomlands section (Appendix B: Table 1). Most fish were recaptured in the sections where they were initially captured and PIT-tagged, except for three Brown Trout initially tagged in Upper Rush Creek that were recaptured in the MGORD and one fish that was initially tagged in the County Road section was recaptured in the Bottomlands section (Appendix B: Table 1).

In September of 2016, a total of 75 previously tagged trout (that retained their tags) were recaptured in Lee Vining Creek; 73 Brown Trout and two Rainbow Trout (Appendix B: Table 2).

In the following text, growth between 2015 and 2016 will be referred as 2016 growth rates. A 2016 trout refers to a fish recaptured in September of 2016. An age of a PIT tagged trout reflects the age during the sampling year. For instance, an age-1 trout in 2016 indicates that a trout had been tagged in 2015 as age-0 and its length and weight were measured in 2016 when it was recaptured.

Growth of Age-1 Brown Trout between 2015 and 2016

In 2016, a total of 117 known age-1 Brown Trout were recaptured that were tagged as age-0 fish in 2015, for an overall recapture rate of 15.9% (117/738 age-0 fish tagged in 2015). Of the 117 age-1 recaptures; 22 of these fish were from Rush Creek sections, 33 fish were from Walker Creek and 62 fish were from the Lee Vining Creek main channel section. Thus, by creek, the age-1 recapture rates were 32% in Lee Vining Creek, 29% in Walker Creek, and 5% in Rush

Creek. These recapture rates suggest relatively high survival between age-0 and age-1 in Lee Vining Creek and Walker Creek, but poor survival between age-0 and age-1 in Rush Creek.

In the Bottomlands section of Rush Creek, five age-1 Brown Trout were recaptured in 2016 and the average growth rates of these trout were 94 mm and 62 g (Table 27). Compared to 2015 rates, the growth rates of the five age-1 Brown Trout were greater by 10 mm and 21 g (Table 27). Growth rates of age-1 Brown Trout in the Bottomlands section had generally declined annually from 2010 to 2014, but the 2015 and 2016 growth rates were the greatest since 2009 (Table 27).

In the Upper section of Rush Creek, 17 age-1 Brown Trout were recaptured in 2016 and the average growth rates of these trout were 105 mm and 77 g (Table 27). Compared to 2015 rates, the average growth rates of the 17 age-1 Brown Trout were greater by 15 mm and 22 g (Table 27). Growth rates of age-1 Brown Trout in the Upper Rush section had generally declined annually from 2010 to 2014, but the 2015 and 2016 growth rates were the greatest since 2009 (Table 27).

In Walker Creek, 33 age-1 Brown Trout were recaptured in 2016 and the average growth rates of these trout were 72 mm and 36 g (Table 27). Compared to 2015 rates, the average growth rates of the 33 age-1 Brown Trout in 2016 were greater by 14 mm and 12 g (Table 27).

In Lee Vining Creek, 62 age-1 Brown Trout were recaptured in 2016 and the average growth rates of these trout were 74 mm and 40 g (Table 27). Compared to 2015 rates, the average growth rates of the 62 age-1 Brown Trout were greater by 1 mm and 7 g (Table 27). Growth rates of age-1 Brown Trout in Lee Vining Creek for the six years of available data have averaged 77 mm in length and 39 g in weight (Table 27).

Growth of Age-2 Brown Trout between 2015 and 2016

In 2016, a total of 14 known age-2 Brown Trout were recaptured that were tagged as age-0 fish in 2014, for a recapture rate of 3.1% (14/459 age-0 fish tagged in 2014). Of these 14 fish, nine were recaptured in Rush Creek sections and five were recaptured in Lee Vining Creek.

In the Bottomlands section of Rush Creek, no age-2 fish were recaptured in 2016 that had been tagged as age-0 fish in 2014.

Within the Upper section of Rush Creek, no age-2 fish were recaptured in 2016 that had been tagged as age-0 fish in 2014 (Table 27). However, an age-2 Brown Trout was captured in the MGORD that had been tagged at age-0 in the Upper Rush section in 2014, and this fish grew 99 mm and 176 g between age-1 and age-2 (Table 27). This fish was also recaptured in the Upper section as an age-1 fish in 2015 and had grown by 93 mm and 60 g between age-0 and age-1. In 2016, another age-2 Brown Trout was captured in the MGORD that had been tagged in the Upper Rush section at age-0 in 2014; but this fish was not recaptured in 2015 at age-1. This trout had grown 187 mm and 216 g between age-0 and age-2.

The Lee Vining Creek main channel had five age-2 PIT tagged Brown Trout recaptured in 2016. The average growth rates of these five Brown Trout were 47 mm and 49 g (Table 27). When compared to the 2015 growth rates of age-2 fish, the 2016 growth rates for length were the same and increased by 9 g for weight (Table 27). Growth rates of age-2 Brown Trout in the Lee Vining Creek main channel section have averaged 52 mm in length and 60 g in weight for the six years of available data (Table 27). Prior to the five consecutive dry/below normal water years, growth rates of age-2 fish in Lee Vining Creek averaged 72 mm and 103 g (Table 27).

In Walker Creek eight age-2 PIT tagged Brown Trout recaptured in 2016 that had been tagged as age-0 fish in 2014 and the average growth rates of these trout were 47 mm and 44 g (Table 27). The 2016 growth rates of age-2 fish in Walker Creek were the highest since the 2011 sampling season (Table 27).

Table 27. Average growth (length and weight) of all Brown Trout recaptured from 2009 through 2016 by age. Note: *denotes only one PIT tagged fish recaptured.

Stream and Reach	Cohort	Average Annual Growth in Length and Weight (mm/g)							
		2008 - 2009	2009 - 2010	2010 - 2011	2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016
Upper Rush Creek	Age 1	89/51	81/50	83/48	72/33	67/35		90/55	105/77
	Age 2		58/70	54/73	43/42	41/42		64/69	99/176*
	Age 3				14/29		24/41		
	Age 4					12/-22			
	Age-5								
Rush Creek Bottom-lands	Age 1	84/43	77/40	71/35	58/25	56/24		84/41	94/62
	Age 2		50/54	35/32	30/28	27/22	32/29*	62/62	
	Age 3			13/14	17/16	11/9	35/31		
	Age 4				4/-11		18/20		
	Age-5								
LV Main Channel Brown Trout	Age 1		80/42*	72/37	99/52	61/27		73/33	74/40
	Age 2		66/95		77/110	33/34	35/29	47/40	47/49
	Age 3			34/92		23/48*	16/20*	27/32	42/75
	Age 4				21/41*				25/47*
	Age-5								
LV Main Channel Rainbow Trout	Age 1					78/47		80/35	
	Age 2						40/48*	52/50	62/74*
	Age 3								38/82*
	Age 4								
	Age-5								
Walker Creek Above Old 395	Age 1	68/27	51/20	71/34	68/36	59/23		58/24	72/36
	Age 2		31/26	60/56	40/33	27/21	39/35		47/44
	Age 3			28/44	18/12	9/2	20/36	27/29	
	Age 4				7/2	2/-16*		28/45*	
	Age-5						0/-10*		

Growth of Age-3 Brown Trout between 2015 and 2016

As previously mentioned, no PIT tags were implanted during the 2013 sampling, but 232 suspected age-1 fish were tagged during the 2014 season to avoid completely missing the 2013 cohort. In 2016, a total of four known age-3 Brown Trout were recaptured that were tagged as age-1 fish in 2014, for a recapture rate of 1.7% (4/232 age-1 fish tagged in 2014).

In the Upper and Bottomlands sections of Rush Creek and in Walker Creek, no PIT tagged age-3 Brown Trout were recaptured during the 2016 sampling that had also been recaptured as age-2 fish in 2015 (Table 27).

In the Lee Vining Creek main channel, four PIT tagged age-3 Brown Trout were recaptured in 2016 that had also been recaptured at age-2 during the 2015 sampling. These four trout had average growth rates of 42 mm and 75 g (Table 27). Known age-3 Brown Trout have now been recaptured in Lee Vining Creek for four consecutive years and the 2016 growth rates were the highest (Table 27).

Growth of Age-4 and Age-5 Brown Trout between 2015 and 2016

The only age-4, PIT-tagged, Brown Trout recaptured during the 2016 sampling was caught in the Lee Vining Creek main channel and this fish had a growth rate of 25 mm and 47 g between age-3 and age-4 (Table 27). At age-4 this fish had a total length of 237 mm (or 9.3 inches).

An age-5 Brown Trout was recaptured in the Bottomlands section of Rush Creek that was tagged in the County Road section as an age-0 in 2011. At age-5 this fish had a total length of 318 mm (or 12.5 inches).

Growth of Age-1 Rainbow Trout in Lee Vining Creek between 2015 and 2016

No age-1 Rainbow Trout were available for recapture during the 2016 because no age-0 fish were captured and PIT tagged during the 2015 sampling.

Growth of Age-2 Rainbow Trout in Lee Vining Creek between 2015 and 2016

In 2016, one age-2 Rainbow Trout was recaptured in Lee Vining Creek that was also recaptured as age-1 fish in 2015. This fish's growth rates were 62 mm and 74 g (Table 27).

Growth of Age-3 Rainbow Trout in Lee Vining Creek between 2015 and 2016

In 2016, one age-3 Rainbow Trout was recaptured in Lee Vining Creek that was also recaptured as age-2 fish in 2015. This fish's growth rates were 38 mm and 82 g (Table 26). This was the first PIT tagged age-3 Rainbow Trout to be recaptured in Lee Vining Creek (Table 27). This age-3 Rainbow Trout was 242 mm in length (compared to the age-4 Brown Trout at 237 mm in length).

Growth of MGORD Brown Trout by size class between 2015 and 2016

Because the actual age at-time-of-tagging was unknown for most trout PIT tagged in the MGORD, determination of actual ages of recaptured trout was not possible. Thus, growth rate comparisons within the MGORD were based on size classes (Table 28). Due to the majority of the Brown Trout in the MGORD being larger sized, size classes were based on the RSD values for the MGORD. When evaluating growth rates by size classes, the size classes in Table 28 designate each fish's size class in 2015, not its size class at the time of recapture in 2016.

In 2016, a total of 10 PIT tagged Brown Trout were recaptured in the MGORD that were originally PIT tagged in the MGORD. Of these 10 recaptures, six fish had also been captured in 2015, thus one-year growth rates between 2015 and 2016 were calculated for these six fish (Table 28).

No Brown Trout PIT tagged in the MGORD during the 2015 sampling within the <125 mm and the 125-225 mm size classes were recaptured in 2016.

There were three Brown Trout PIT tagged in the MGORD during the 2015 sampling within the 226-300 mm size class that were recaptured in 2016. These three trout had average growth rates of 80 mm and 184 g between 2015 and 2016 (Table 28). The weight gains of these three fish were 40, 214, and 297 g.

There was one PIT tagged Brown Trout captured in the MGORD during the 2015 sampling within the 301-375 mm size class (346 mm) that was recaptured in 2016. This trout grew 74 mm in length and gained 365 g in weight (Table 28).

There were two PIT tagged Brown Trout captured in the MGORD during the 2015 sampling within the >375 mm size class (423 and 485 mm) that were recaptured in 2016. These two trout had average growth rates of 34 mm and 208 g between 2015 and 2016 (Table 28). The trout that was 423 mm in 2015 grew 17 mm in length and gained 154 g in weight and the trout (tag #5121023369646) that was 485 mm in 2015 grew 50 mm in length and gained 261 g. This particular trout was tagged in 2011 and has been recaptured in 2011, 2014, 2015, and 2016; and experienced positive growth with weight gains of 108, 144, 743, and 261 g at those respective recaptures.

Table 28. Average growth rates, length (mm) and weight (g), of all PIT tagged MGORD Brown Trout recaptured from 2009 through 2016 by size class. Note: *denotes only one fish recaptured.

Size Class (mm)	Average Annual Growth Length (mm)						
	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
0-124	121						
125-225	55	59	63			70*	
226-300	32	39	22	7		61	80
301-375	20	17	9	12	30*	84*	74*
>375	13	18	**-1**	10	17	69	34
Size Class (mm)	**Average Annual Growth Weight (g)**						
	2009-2010	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**
0-124	91						
125-225	85	90	78			155*	
226-300	53	81	34	2		203	184
301-375	23	54	**-5**	49	178*	421*	365*
>375	**-10**	134	**-47**	**-2**	283	718	208

Growth of MGORD Brown Trout from non-consecutive years

Four of the 10 PIT tagged Brown Trout captured in the MGORD during the September 2016 sampling were last recaptured, measured and weighed in years prior to 2015; thus annual growth calculations were not possible. Three of the four Brown Trout were tagged in 2014 and recaptured in 2016 and during this two-year period had an average weight gain of 150 g (Table 29).

The other non-consecutive recapture was a Brown Trout initially tagged in 2009 (#725328) that was recaptured for the first time in 2016. During this seven year period between captures, this fish grew 92 mm in length and gained 876 g (Table 29). When recaptured in 2016, this fish had carried its PIT tag for seven years and was at least a 10-year old fish, possibly older.

Table 29. PIT tagged Brown Trout caught in the MGORD section, for recaptures in non-consecutive years.

Last 7 Digits of PIT Tag #	Year of Capture	Total Length (mm)	Weight (g)	Difference in Length (mm)	Difference in Weight (g)
#7025328	2009	403	836		
	2016	495	1,712	+92	+876
#1354666	2014	207	81		
	2016	401	631	+194	+550
#1356456	2014	286	200		
	2016	453	1,045	+167	+845
#1360038	2014	296	222		
	2016	384	571	+88	+349

Movement of PIT Tagged Trout between Sections

From 2009 to 2016 a total of 6,584 PIT tags were surgically implanted in Brown Trout and Rainbow Trout in the following stream reaches: Upper Rush, County Road, Bottomlands, MGORD, and Walker Creek. Between 2010 and 2016, 35 Brown Trout were recaptured in stream reaches other than where they were initially tagged. The majority of movement between sections has occurred from the Upper Rush section upstream into the MGORD, and from the MGORD downstream into the Upper Rush section. We have also documented some limited movement between the Bottomlands and County Road sections. Up to 2013, no movement between other sections had been recorded. However in 2014, a large Brown Trout initially tagged in the MGORD was recaptured in the Bottomlands section.

The 2012 Annual Fisheries Report presented the summarized data for 23 Brown Trout that had moved from one section to another. In all cases, fish which moved experienced higher growth rates than other members of their cohorts which stayed in the section where they had been tagged (LADWP 2013). These growth differences were most markedly different for Brown Trout PIT tagged as age-0 fish in the Upper Rush section that were eventually recaptured in the MGORD as age-1 or age-2 fish. Since the 2012 report, this phenomenon of superior growth rates by fish that moved relatively large distances has continued. For example, three Brown Trout tagged as age-0 fish in Upper Rush in 2014 where recaptured in 2015 in different sampling sections; two were recaptured in the MGORD and one was recaptured in the Bottomlands. These three fish experienced average growth rates of 100 mm in length and 79 g in weight; compared to average growth rates of 88 mm and 53 g for the age-1 fish that remained in the Upper Rush section.

In 2016, three Brown Trout originally tagged in the Upper Rush section were recaptured in the MGORD. One trout (#1951970) was tagged at age-0 in 2014, was recaptured at age-1 in 2015 in Upper Rush, and was recaptured at age-2 in the MGORD in 2016. This fish gained 176 g during the year it moved into the MGORD. A second trout (#4581050) was tagged in at age-0 in 2015 and was recaptured at age-1 in the MGORD in 2016; this fish gained 103g (26 g more than the average weight gain of age-1 fish that stayed in the Upper Rush section). The third trout (#1952061) was tagged at age-0 in 2014 (at 91 mm in length) and was recaptured in the MGORD in 2016 at age-2 (at 278 mm in length). Because this fish eluded capture in 2015, the timing of its movement upstream was unknown, but its two-year growth rates were 187 mm in length and 216 g in weight.

PIT Tag Shed Rate of Trout Recaptured in 2016

In 2016, a total of 157 trout with adipose fin clips were recaptured and five of these fish failed to produce a PIT tag number when scanned with the tag reader. Assuming that all these fish were previously PIT tagged, the 2016 calculated shed rate was 3.2% (5 shed tags/157 clipped fish recaptured). This rate was similar to rates reported by other PIT tagging studies for juvenile trout: 3% for juvenile Brown Trout (Ombredane et al. 1998) and 3% for juvenile steelhead (Bateman and Gresswell 2006). Our relatively low shed rate may also be attributed to only tagging age-0 fish ≥70 mm in length because some research has documented increasing shed rates for smaller sized Brown Trout. For example, one study calculated 10.6% and 30.6% shed rates for Brown Trout 50-55 mm in length (injection versus surgical implantation) and 13.4% shed rate for Brown Trout 56-60 mm in length (Richard et al. 2013).

Comparison of Length-at Age amongst Sample Sections

During 2016, four age-classes of PIT tagged Brown Trout were recaptured within four fisheries monitoring sections in Rush, Walker and Lee Vining creeks (Table 30). In Lee Vining Creek, three age-classes of PIT tagged Rainbow Trout were recaptured in 2016 (Table 30). Along with providing age-specific length information for each section, these data also allowed comparisons of length-at-age between sample sections and also between the years 2013-2016 (Table 30). Unfortunately, the low number of tags implanted in 2012 and the absence of a tagging program in 2013 limited opportunities to generate comparisons of age-3 and age-4 growth.

In Upper Rush, the average length-at-age-1 in 2016 was 21 mm greater than the average length-at-age-1 in 2015 (Table 30). Similar to 2015, in 2016, age-1 Brown Trout in Upper Rush were larger than age-1 fish in the Bottomlands section (Table 30).

In Upper Rush, no PIT tagged age-2 Brown Trout were caught in 2016. However, the length-at-age-2 of a Brown Trout that moved from the Upper section to the MGORD between age-1 and age-2 was 289 mm, 72 mm greater than the average length-at-age-2 in 2015 (Table 30). In the Bottomlands section, no age-2 Brown Trout were recaptured in 2016 (Table 30).

In 2015 and 2016, no PIT tagged age-3 or age-4 Brown Trout were captured in the Bottomlands or Upper Rush sampling sections (Table 30). A single age-5 Brown Trout was caught in the Bottomlands section that had been tagged in the County Road section in 2011 – this trout was 318 mm in length (Table 30).

In the Lee Vining Creek main channel length-at-age-1 Brown Trout were of similar sizes in 2015 and 2016 (Table 30). The age-2 Brown Trout in 2016 were on average, 13 mm larger than in 2015 and 22 mm larger than in 2014 (Table 30). In 2016, the age-3 Brown Trout in Lee Vining Creek were on average, 25 mm longer than age-3 fish in 2015 (Table 30). In 2016, the first age-4 Brown Trout was recaptured in Lee Vining Creek and its length was 237 mm (Table 30).

For Walker Creek in 2016, the average length-at-age-1 was 13 mm greater than in 2015 (Table 30). In 2016, age-2 Brown Trout in Walker Creek were, on average, 15 mm longer than age-2 fish in 2015 (Table 30). No PIT tagged age-3 or age-4 Brown Trout were recaptured in 2016 (Table 30).

These findings of average lengths by age-class appear to support the previous conclusions by the Stream Scientist that very few Brown Trout reach age-4 or older on Rush Creek or Lee Vining Creek. Also, the growth rates that Brown Trout exhibited in Rush Creek, outside of the

MGORD, make it highly unlikely that many fish survive long enough to attain lengths ≥300 mm, the size class approaching the metrics of the pre-1941 fishery. In the past four years only two age-5 Brown Trout (based on PIT tag data) were recaptured in Rush Creek, in the Upper section in 2014 and in the Bottomlands section in 2016 (Table 30).

Table 30. Size range of PIT tagged fish recaptured in 2013-2016 by age class for Brown Trout at three electrofishing sections on Rush and Walker Creeks and for Brown Trout and Rainbow Trout on Lee Vining Creek. NOTE: years omitted if no fish were caught.

Section	Cohort	Size Range (mm)	Average Length (mm)
Upper Rush	Age-1	**2016** = 192-237 **2015** = 169-203	**2016** = 208 **2015** = 187
	Age-2	**2016** = 289* **2015** = 205-242	**2016** = 289* **2015** = 217
	Age-3	**2014** = 226-236 **2013** = 227-263	**2014** = 231 **2013** = 245
	Age-4	**2014** = 288 **2013** = 252-255	**2014** = 288 **2013** = 254
	Age-5	**2014** = 298	**2014** = 298
Bottomlands	Age-1	**2016** = 172-217 **2015** = 150-181	**2016** = 197 **2015** = 169
	Age-2	**2015** = 197-239 **2014** = 192 **2013** = 156-196	**2015** = 219 **2014** = 192 **2013** = 178
	Age-3	**2014** = 194 **2013** = 194-227	**2014** = 194 **2013** = 204
	Age-4	**2014** = 215-219	**2014** = 216
	Age-5	**2016** = 318	**2016** = 318
Walker Creek	Age-1	**2016** = 145-187 **2015** = 133-177	**2016** = 167 **2015** = 154
	Age-2	**2016** = 180-226 **2014** = 168-200 **2013** = 181-208	**2016** = 201 **2014** = 186 **2013** = 197
	Age-3	**2015** = 211-231 **2014** = 207-222 **2013** = 219-221	**2015** = 219 **2014** = 217 **2013** = 220
	Age-4	**2015** = 249 **2014** = 211 **2013** = 219	**2015** = 249 **2014** = 211 **2013** = 219
	Age-5	**2014** = 220	**2014**=220
Brown Trout in Lee Vining Main Channel	Age-1	**2016** = 147-186 **2015** = 149-190	**2016** = 171 **2015** = 166
	Age-2	**2016** = 205-217 **2015** = 176-214 **2014** = 174-195 **2013** = 206-225	**2016** = 211 **2015** = 197 **2014** = 188 **2013** = 215
	Age-3	**2016** = 210-256 **2015** = 188-228 **2014** = 234-241 **2013** = 238-271	**2016** = 240 **2015** = 215 **2014** = 238 **2013** = 253
	Age-4	**2016** = 237	**2016** = 237
	Age-5	None captured in past four years	
Rainbow Trout in Lee Vining Main Channel	Age-1	**2016** = N/A **2015** = 140-177	**2015** = 157
	Age-2	**2016** = 232 **2015** = 195-216 **2014** = 201-229	**2016** = 232 **2015** = 204 **2014** = 215
	Age-3	**2016** = 242	**2016** = 242
	Age-4	None captured in past four years	
	Age-5	None captured in past four years	

*Fish was tagged in Upper Rush, but moved to MGORD between age-1 and age-2.

Summer Water Temperature

During 2016, the Mono Lake Committee (MLC) also deployed water temperature data loggers, which assisted in collecting data from sites not monitored by LADWP. The MLC deployed Onset HOBO Pro v2 data loggers set to record water temperature in hourly intervals in degrees Fahrenheit so their data were compatible with LADWP's data. The MLC data utilized in this report were collected at three Rush Creek locations: At Damsite, Old 395 Bridge and Above Parker Creek. Water temperature data from the remaining locations were collected by LADWP. Although water temperatures were recorded year-round during 2016, summer water temperatures in July-September were more closely examined due to influences of warmer temperatures on trout growth and condition factor (Table 31).

Compared to 2014 and 2015, the 2016 summer water temperatures with the MGORD section of Rush Creek were not as severe. In both 2014 and 2015, there were 20 days of daily maximum water temperatures above 70°F at the "Bottom of MGORD" monitoring location, compared to just one day in 2016 (Table 31). Daily mean temperatures and maximum diurnal fluctuations within the MGORD were also less severe in 2016, compared to 2014 and 2015. However, farther downstream at "Below Narrows" and "County Road" the total number of days with peak temperatures above 70°F were zero and two days in 2015, compared to 34 and 32 days in 2016 (Table 31). No data were available at "Old 395 Bridge" and "Above Parker Ck" for 2015; but these locations experienced, respectively, 47 and 55 days with peaks above 70°F in 2016 (Table 31). Maximum diurnal fluctuations in Rush Creek downstream of the MGORD were higher in 2016 compared to 2015, and were similar to the diurnal fluctuations during the summers of 2013 and 2014(Table 31). In 2016, the summer water temperature metrics in Lee Vining Creek were similar to the two previous years and well within acceptable levels for Brown Trout and Rainbow Trout (Table 31).

Similar to the 2013 - 2015 annual reports, a closer examination of the 2016 Rush Creek summer water temperature data was done by classifying daily average temperatures as either: 1) good potential growth days, 2) fair potential growth days, 3) poor potential growth days (daily averages within one degree or less of a "bad thermal day"), or 4) bad thermal days (Table 31). Development of the daily average temperature ranges from results of the Rush Creek temperature modeling which defined these "thermal days" was fully described in previous annual reports (Taylor 2013 and 2014). Using these daily average metrics, good potential growth days in 2016 varied from nine to 24 days in Rush Creek out of the 92-day period from July 1 to September 30. Nearly all of these "good" days occurred in mid to late September. The "At Damsite" location (upstream of GLR) had 69 days of good potential growth, 23 days of fair potential growth, and no poor-growth or bad thermal days in 2016 (Table 32).

Within the MGORD, the numbers of "good" and "fair"days in 2016 were higher than in 2014 and 2015, and may be related to LADWP maintaining a higher GLR storage elevation in 2016 (Table 31 and Figure 4). The days designated as "fair" occurred primarily in July and September. The "poor" days and "bad" thermal days were mostly clustered in late-July through August. At both MGORD locations, the numbers of "poor" and "bad" thermal days were consistently higher than temperature monitoring locations farther downstream and this metric is most likely affected by the relatively warm water releases from GLR that also experienced minimal night-time cooling (diurnal fluctuation). Thus, MGORD daily average temperatures remained relatively high compared to downstream locations that experienced more days with peaks >70°F, yet had lower daily averages due to night-time cooling (Table 32).

The addition of the "Above Parker Ck" water temperature monitoring location was valuable in depicting the worsening of Rush Creek's thermal conditions as flow moved downstream, as well as documenting the effects of cooler water accretions from Parker and Walker creeks when compared to data collected at the "Below Narrows" location (Tables 31 and 32). Cool water accretions from Parker and Walker creeks dropped the number of days with peak temperatures >70°F by 38% and the number of "bad" thermal days decreased from 25 days to two days between the "Above Parker" and "Below Narrows" locations in 2016 (Tables 31 and 32).

Table 31. Summary of water temperature data during the summer of RY 2016 (July to September). Averages were calculated for daily mean, daily minimum, and daily maximum temperatures between July 1st and September 30th. All temperature data are presented in °F. When available, values for 2013-2015 are provided for comparison.

Temperature Monitoring Location	Daily Mean (°F)	Ave Daily Minimum (°F)	Ave Daily Maximum (°F)	No. Days > 70°F	Max Diurnal Fluctuation (°F)	Date of Max. Fluct.
Rush Ck. – At Damsite	**2016 = 58.9**	**2016 = 58.3**	**2016 = 59.5**	**2016 = 0**	**2016 = 3.2**	**8/11/16**
Rush Ck. – Top of MGORD	2013 = 63.1 2014 = 64.8 2015 = 64.4 **2016 = 63.8**	2013 = 62.7 2014 = 64.6 2015 = 64.1 **2016 = 63.0**	2013 = 63.7 2014 = 65.0 2015 = 64.8 **2016 = 64.7**	2013 = 0 2014 = 0 2015 = 0 **2016 = 0**	2013 = 3.4 2014 = 3.9 2015 = 2.1 **2016 = 6.5**	7/09/13 8/13/14 7/03/15 **7/07/16**
Rush Ck. – Bottom MGORD	2013 = 63.2 2014 = 64.8 2015 = 64.4 **2016 = 63.8**	2013 = 60.9 2014 = 62.9 2015 = 62.3 **2016 = 61.8**	2013 = 67.1 2014 = 68.5 2015 = 68.0 **2016 = 66.9**	2013 = 1 2014 = 20 2015 = 20 **2016 = 1**	2013 = 9.0 2014 = 8.3 2015 = 8.4 **2016 = 8.0**	7/09/13 7/13/14 7/06/15 **7/04/16**
Rush Ck. – Old Highway 395 Bridge	2013 = 62.6 2014 = 64.0 2015 = N/A **2016 = 63.5**	2013 = 58.8 2014 = 60.5 2015 = N/A **2016 = 60.1**	2013 = 68.7 2014 = 69.8 2015 = N/A **2016 = 68.8**	2013 = 40 2014 = 51 2015 = N/A **2016 = 47**	2013 = 13.5 2014 = 13.3 2015 = N/A **2016 = 12.5**	7/09/13 7/13/14 N/A **7/11/16**
Rush Ck. – Above Parker	**2016 = 63.2**	**2016 = 58.8**	**2016 = 69.4**	**2016 = 55**	**2016 = 13.7**	**7/11/16**
Rush Ck. – below Narrows	2013 = 61.2 2014 = 63.2 2015 = 62.3 **2016 = 61.7**	2013 = 56.2 2014 = 57.1 2015 = 58.8 **2016 = 56.9**	2013 = 67.6 2014 = 69.4 2015 = 66.1 **2016 = 68.3**	2013 = 24 2014 = 46 2015 = 0 **2016 = 34**	2013 = 16.3 2014 = 17.3 2015 = 11.5 **2016 = 14.3**	7/19/13 7/26/14 9/23/15 **7/13/16**
Rush Ck. – County Road	2013 = 61.4 2014 = 62.0 2015 = 62.1 **2016 = 61.6**	2013 = 56.5 2014 = 56.7 2015 = 59.1 **2016 = 56.0**	2013 = 66.6 2014 = 67.8 2015 = 65.5 **2016 = 68.3**	2013 = 7 2014 = 24 2015 = 2 **2016 = 32**	2013 = 14.7 2014 = 17.6 2015 = 9.2 **2016 = 16.1**	8/02/13 7/26/14 7/28/15 **7/11/16**
Lee Vining – at County Road	2014 = 54.9 2015 = 55.5 **2016 = 54.6**	2014 = 50.5 2015 = 51.4 **2016 = 50.7**	2014 = 59.4 2015 = 59.7 **2016 = 58.6**	2014 = 0 2015 = 0 **2016 = 0**	2014 = 11.6 2015 = 11.2 **2016 = 10.9**	7/01/14 7/29/15 **7/20/16**

Table 32. Classification of 2013-2016 summer water temperature data into good growth days, fair growth days, poor growth days and bad thermal days based on daily average temperatures (92-day period from July 1 to September 30). The percent (%) designates each thermal day-type's occurrence for the 92-day summer period.

Temperature Monitoring Location	No. of Days for Good Growth Potential – Daily Ave. 55.5° - 60.5°F	No. of Days for Fair Growth Potential – Daily Ave. 60.6° – 63.9°F	No. of Days of Poor Growth Potential – Daily Ave. 64.0° - 64.9°F	No. of Bad Thermal Days - Daily Ave. ≥65°F
Rush Ck. – At Damsite	**2016 = 69 (75%)**	**2016 = 23 (25%)**	**2016 = 0**	**2016 = 0**
Rush Ck. – Top of MGORD	2013 = 14 (15%) 2014 = 5 (6%) 2015 = 7 (8%) **2016 = 10 (11%)**	2013 = 43 (47%) 2014 = 14 (15%) 2015 = 20 (22%) **2016 = 32 (35%)**	2013 = 17 (18%) 2014 = 25 (27%) 2015 = 5 (5%) **2016 = 17 (18%)**	2013 = 18 (20%) 2014 = 48 (52%) 2015 = 60 (65%) **2016 = 33 (36%)**
Rush Ck. – Bottom MGORD	2013 = 11 (12%) 2014 = 6 (6%) 2015 = 8 (9%) **2016 = 9 (10%)**	2013 = 38 (41%) 2014 = 11 (12%) 2015 = 20 (22%) **2016 = 31 (34%)**	2013 = 20 (22%) 2014 = 21 (23%) 2015 = 5 (6%) **2016 = 16 (17%)**	2013 = 23 (25%) 2014 = 54 (59%) 2015 = 59 (64%) **2016 = 36 (39%)**
Rush Ck. – Old Highway 395 Bridge	2013 = 14 (15%) 2014 = 7 (8%) 2015 = N/A **2016 = 16 (17%)**	2013 = 41 (45%) 2014 = 25 (27%) 2015 = N/A **2016 = 24 (26%)**	2013 = 33 (36%) 2014 = 27 (29%) 2015 = N/A **2016 = 19 (21%)**	2013 = 4 (4%) 2014 = 33 (36%) 2015 = N/A **2016 = 33 (36%)**
Rush Ck. – Above Parker Ck.	**2016 = 17 (18%)**	**2016 = 26 (28%)**	**2016 = 24 (26%)**	**2016 = 25 (27%)**
Rush Ck. – Below Narrows	2013 = 17 (18%) 2014 = 13 (14%) 2015 = 24 (26%) **2016 = 22 (24%)**	2013 = 69 (75%) 2014 = 58 (63%) 2015 = 44 (48%) **2016 = 52 (57%)**	2013 = 6 (7%) 2014 = 18 (20%) 2015 = 22 (24%) **2016 = 16 (17%)**	2013 = 0 2014 = 3 (3%) 2015 =2 (2%) **2016 = 2 (2%)**
Rush Ck. – County Road	2013 = 17 (18%) 2014 = 17 (18%) 2015 = 25 (27%) **2016 = 24 (26%)**	2013 = 64 (70%) 2014 = 59 (65%) 2015 = 39 (42%) **2016 = 50 (54%)**	2013 = 8 (9%) 2014 = 14 (15%) 2015 =23 (25%) **2016 = 13 (14%)**	2013 = 3 (3%) 2014 = 2 (2%) 2015 = 5 (6%) **2016 = 5 (6%)**

As was done with the 2013 - 2015 data, the diurnal temperature fluctuations for July–September 2016 were characterized by the one-day maximum fluctuation that occurred each month and by monthly averages (Table 33). Also, for each temperature monitoring location, the highest average diurnal fluctuation over a consecutive 21-day duration was determined (Table 33). Diurnal fluctuations consistently increased in a downstream direction for all months at all temperature monitoring locations (Table 33). For all months, the one-day maximum and monthly average fluctuations at the Below Narrows and County Road locations were consistently higher in 2016, compared to 2015 (Table 33). In 2016, the 21-day duration value for the County Road location exceeded the 12.6°F tolerance limit defined by Werley et al. (2007); however in 2015 this tolerance level was never approached (Table 33). At both MGORD locations, the 2016 diurnal fluctuations were close to the 2015 values, with slightly higher variations at the Top of MGORD location (Table 33). Inflow from GLR entered the top of the MGORD warm and varied little throughout the summer (Tables 31 and 33).

Table 33. Diurnal temperature fluctuations in Rush Creek for 2016: maximum daily for month, daily average for month, and highest average for consecutive 21-day duration (92-day period from July 1 to September 30). NOTE: 2015 values in ( ) for comparison.

Temperature Monitoring Location	Maximum and Average Daily Diurnal Fluctuation for July	Maximum and Average Daily Diurnal Fluctuation for August	Maximum and Average Daily Diurnal Fluctuation for September	Highest Average Diurnal Fluctuation for a Consecutive 21-Day Duration
Rush Ck. – At Damsite	Max = 2.1°F Ave = 1.3°F	Max = 3.2°F Ave = 1.6°F	Max = 1.3°F Ave = 0.9°F	2.4 °F August 11-17
Rush Ck. – Top of MGORD	Max = 6.5°F (2.1) Ave = 3.1°F (0.9)	Max = 4.8°F (1.4) Ave = 1.3°F (0.7)	Max = 1.4°F (1.2) Ave = 0.7°F (0.5)	3.4°F (0.9) July 1-7
Rush Ck. – Bottom MGORD	Max = 8.0°F (8.4) Ave = 5.4°F (5.8)	Max = 7.0°F (7.3) Ave = 4.8°F (5.8)	Max = 6.4°F (6.4) Ave = 5.1°F (5.2)	5.7°F (6.1) July 1-21
Rush Ck. – Old Highway 395 Bridge	Max = 12.5°F (13.4) Ave = 9.9°F (10.1)	Max = 10.1°F (12.0) Ave = 8.4°F (9.4)	Max = 9.4°F (11.5) Ave = 7.9°F (8.7)	10.4°F (10.4) July 1-21
Rush Ck. – Above Parker Ck.	Max = 13.7°F Ave = 11.3°F	Max = 12.4°F Ave = 10.6°F	Max = 12.2°F Ave = 9.9°F	11.8°F July 3-24
Rush Ck. – below Narrows	Max = 14.3°F (10.0) Ave = 11.9°F (6.0)	Max = 13.2°F (10.1) Ave = 11.4°F (8.0)	Max = 13.9°F (11.5) Ave = 11.1°F (7.8)	12.3°F (8.5) July 3 – 23
Rush Ck. – County Road	Max = 16.1°F (9.2) Ave = 13.3°F (6.5)	Max = 14.0°F (8.4) Ave = 12.0°F (6.5)	Max = 14.6°F (7.5) Ave = 11.7°F (6.1)	14.0°F (7.5) July 6 - 26

The thermal window bounded by 66.2-71.6°F where Brown Trout may be physiologically stressed and living at the edge of their survival tolerance as defined by Bell (2006) was quantified for each Rush Creek temperature monitoring location in 2016. The hourly temperature data for the 92-day (or 2,208-hour) summer period were sorted from low to high and the number of hours where temperatures exceeded 66.2°F were summed by month and entire summer period (Table 34). The values from 2013 - 2015 were also included in Table 34 to better illustrate the variability that occurred at all the temperature monitoring locations. The 2016 data show that all the temperature monitoring locations downstream of GLR were within the 66.2-71.6°F thermal window for 8% to 26% of the 92-day summer period. Between 2015 and 2016, the two MGORD locations experienced decreases in the number of hourly temperatures ≥66.2 °F for the entire 92-day summer period (Table 34). The three lowermost temperature monitoring locations had 20-26% of their hourly temperatures ≥66.2 °F for the entire 92-day period (Table 34). Consistent with the 2013 -2016 data, the 2016 data also confirmed a sizeable warming trend as streamflow travelled down the MGORD (Table 34).

Table 34. Number of hours that temperature exceeded 66.2°F in Rush Creek: by month and for 92-day period from July 1 to September 30, 2013 - 2016. Percent (%) designates amount of month or summer where hourly temperatures exceeded 66.2°F.

Temperature Monitoring Location	Number of Hours Temperature exceeded 66.2°F in July (744 hours)	Number of Hours Temperature exceeded 66.2°F in August (744 hours)	Number of Hours Temperature exceeded 66.2°F in Sept. (720 hours)	Number of Hours Temperature exceeded 66.2°F in 92-day period
Rush Ck. – At Damsite	**2016 = 0 hrs**	**2016 = 0 hrs**	**2016 = 0 hrs**	**2016 = 0 hrs**
Rush Ck. – Top of MGORD	2013 = 4 hrs (0.5%) 2014 = 315 hrs (42%) 2015 = 140 hrs (19%) **2016 = 42 hrs (6%)**	2013 = 4 hrs (0.5%) 2014 = 96 hrs (13%) 2015 = 205 hrs (28%) **2016 = 127 hrs (17%)**	2013 = 0 hrs 2014 = 0 hrs 2015 = 0 hrs **2016 = 0 hrs**	2013 = 8 hrs (0.4%) 2014 = 411 hrs (19%) 2015 = 345 hrs (16%) **2016 = 169 hrs (8%)**
Rush Ck. – Bottom MGORD	2013 = 121 hrs (16%) 2014 = 282 hrs (38%) 2015 = 305 hrs (41%) **2016 = 142 hrs (19%)**	2013 = 229 hrs (31%) 2014 = 248 hrs (33%) 2015 =282 hrs (38%) **2016 = 268 hrs (36%)**	2013 = 61 hrs (9%) 2014 = 115 hrs (16%) 2015 = 17 hrs (2%) **2016 = 38 hrs (5%)**	2013 = 411 hrs (19%) 2014 = 645 hrs (29%) 2015 = 604 hrs (27%) **2016 = 448 hrs (20%)**
Rush Ck. – Old 395 Bridge	2013 = 181 hrs (24%) 2014 = 287 hrs (39%) **2016 = 216 hrs (29%)**	2013 = 228 hrs (31%) 2014 = 248 hrs (33%) **2016 = 263 hrs (35%)**	2013 = 73 hrs (10%) 2014 = 117 hrs (16%) **2016 = 53 hrs (7%)**	2013 = 482 hrs (22%) 2014 = 639 hrs (29%) **2016 = 532 hrs (24%)**
Rush Ck. – Above Parker Creek	**2016 = 240 hrs (32%)**	**2016 = 269 hrs (36%)**	**2016 = 65 hrs (9%)**	**2016 = 574 hrs (26%)**
Rush Ck. – below Narrows	2013 = 158 hrs (21%) 2014 = 244 hrs (33%) 2015 = 129 hrs (17%) **2016 = 167 hrs (22%)**	2013 = 192 hrs (26%) 2014 = 193 hrs (26%) 2015 = 189 hrs (25%) **2016 = 222 hrs (30%)**	2013 = 55 hrs (7%) 2014 = 105 hrs (15%) 2015 = 0 hrs (0%) **2016 = 49 hrs (7%)**	2013 = 405 hrs (18%) 2014 = 542 hrs (25%) 2015 = 318 hrs (14%) **2016 = 438 hrs (20%)**
Rush Ck. – County Road	2013 = 197 hrs (27%) 2014 = 222 hrs (30%) 2015 = 174 hrs (23%) **2016 = 212 hrs (28%)**	2013 = 172 hrs (23%) 2014 = 195 hrs (26%) 2015 = 119 hrs (16%) **2016 = 233 hrs (31%)**	2013 = 42 hrs (6%) 2014 = 79 hrs (11%) 2015 = 0 hrs (0%) **2016 = 42 hrs (6%)**	2013 = 411 hrs (19%) 2014 = 496 hrs (23%) 2015 = 293 hrs (13%) **2016 = 487 hrs (22%)**

In 2016, the “At Damsite” water temperature monitoring location (in Rush Creek upstream of GLR) allowed for an examination of how Rush Creek’s summer flow was thermally loaded as it passed through LADWP’s infrastructure, consisting of GLR and the MGORD (Figure 24). This thermal loading was evident by contrasting the “At Damsite” location’s relatively cool temperatures and minimal diurnal fluctuations with the “Bottom of MGORD” where temperatures were frequently between 65-70°F (Figure 24). Figures 24 -26 also depicted changes in the characteristics of Rush Creek’s water temperature regime as flow moved downstream. The frequency of daily peaks >70°F were obvious, as well as the increases in diurnal fluctuations as flow moved downstream (Figures 24-26).

Figure 24. Water temperatures in Rush Creek collected at "At Damsite" and "Bottom of MGORD" stations between July 1 and September 30, 2016.

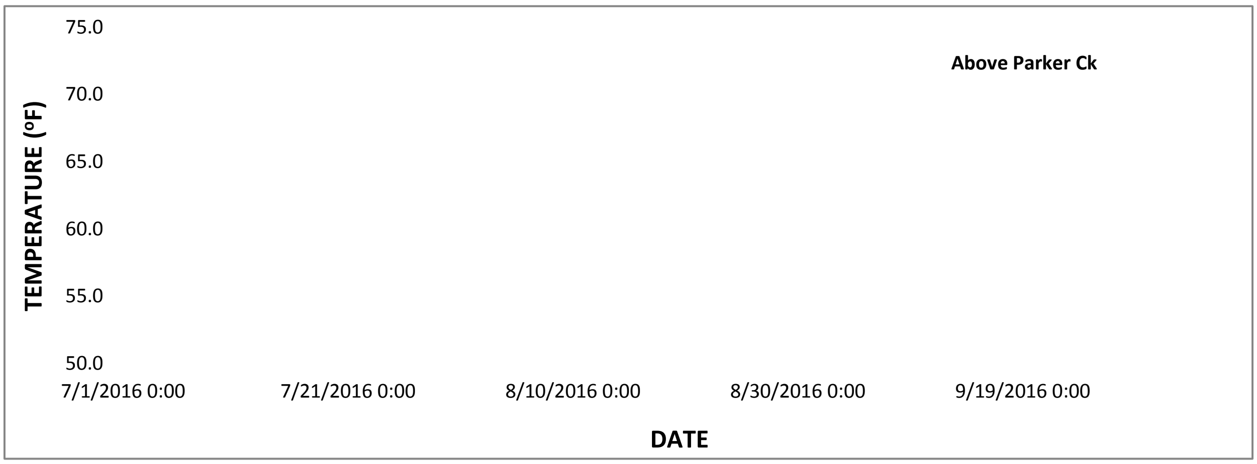

Figure 25. Water temperatures in Rush Creek collected at "Above Parker Ck" station between July 1 and September 30, 2016.

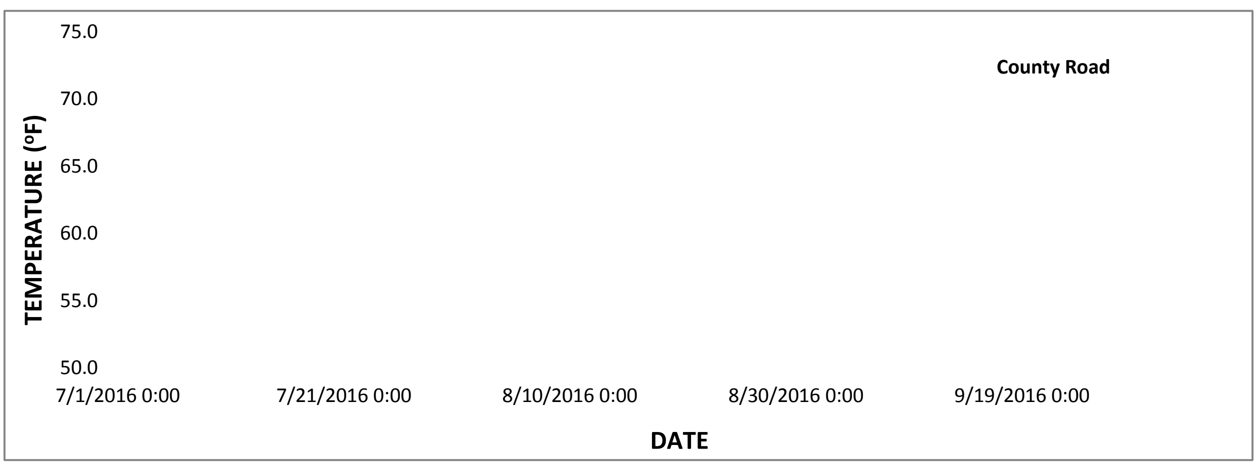

Figure 26. Water temperatures in Rush Creek collected at "County Road" station between July 1 and September 30, 2016.

Discussion

The 2016 sampling year was highlighted by the extended drought conditions that persisted throughout most of California. Within the Mono Basin the 2016 runoff year was 74% of normal and classified as a Dry-Normal 1 RY and was a slight reprieve from the four driest consecutive years on record for the Mono Basin. RY 2016 was the fifth consecutive below normal year type (RY 2015 was 25%, RY 2014 was 48% of normal, RY 2013 was 66% of normal and RY 2012 was 55% of normal). Calendar year 2016 was also marked by LADWP, the Mono Lake Committee, California Trout, and the California Department of Fish and Wildlife continuing to translate the settlement terms (signed in September 2013) into enforceable license language prior to issuance of amended licenses by the State Water Resources Control Board.

The past three Annual Fisheries Report's Discussion sections were focused on the 2013-2015 summer thermal regimes in Rush Creek and the potential effects of summer water temperature on trout growth, condition factor and survival. Because 2016 was marked by a fifth below normal RY, this report's Discussion will focus on similar analyses. Before discussing the 2016 water temperature data, fish growth and condition factor results; a summary of trout population metrics is provided.

Sampling Section Summaries for Five Below-normal RYs

By sample section, the following bulleted list summarizes notable trout population metrics that have occurred during the drought conditions that have persisted for the past five years in the Mono Lake watershed. On Rush Creek, the three sections are listed in a downstream direction.

Rush Creek – MGORD

- Poor thermal conditions have persisted for the past four summers. The number of "bad" thermal days increased each year between 2013 and 2015, with 65% bad thermal days during the summer of 2015. In 2016, the number of bad thermal days decreased to 36%.
- Low numbers of total fish captured. Between 2012 and 2016, the catch dropped from 575 fish (average of two passes) to 116 fish (average of two passes), an 80% decline.
- Low numbers of larger Brown Trout. Between 2012 and 2016, the catch of trout ≥300 mm dropped from 199 fish to 38 fish, an 81% decline. These were both two-pass sampling years.
- In 2016, PIT tagged fish that were recaptured all experienced positive growth between 2015 and 2016.
- Condition factor below average (<1.00) for all four dry RYs and average (1.00) for 2016.

Rush Creek – Upper

- Low numbers of total fish captured. Between 2012 and 2016, the total population estimate dropped from 3,564 fish to 311 fish, a 91% decline.
- Low numbers of age-0 Brown Trout. Between 2012 and 2016, the population estimate of Brown Trout <125 mm has decreased by 95%.

- In 2016, PIT tagged age-1 and age-2 fish that were recaptured experienced good growth between 2015 and 2016.
- Condition factor below average for all four dry RYs and average (1.00) for the 2016 dry-normal 1 RY.

Rush Creek – Bottomlands

- Low numbers of total fish captured. Between 2012 and 2016, the total population estimate dropped from 1,402 fish to 224 fish, an 84% decline.
- Low numbers of age-0 Brown Trout. Between 2012 and 2016, the population estimate of Brown Trout <125 mm has decreased by 83%.
- In 2016, PIT tagged age-1 and age-2 fish that were recaptured experienced good growth between 2015 and 2016.
- Condition factor below average for all four dry RYs and for 2016, the dry-normal 1 RY.

Walker Creek

- Compared to the Rush Creek sections, relatively consistent population estimates between 2012 and 2016 in Walker Creek.
- In 2016, recaptured PIT tagged age-1 and age-2 fish experienced better growth than the same age fish recaptured in the previous three years.
- Condition factor below average for two of the four dry RYs. Average for the other two RYs (1.00 and 1.01). Condition factor in 2016 was below average.

Lee Vining Creek – Main Channel

- Lower numbers of total fish captured. Between 2012 and 2016, the total Brown Trout population estimate dropped from 797 fish to 318 fish, a 60% decline.
- Lower numbers of age-0 Brown Trout. From 2012 to 2016, the estimate went from 677 to 118 age-0 fish, an 83% decline.
- PIT tagged age-1 and age-2 fish that were recaptured experienced average growth between 2015 and 2016.
- Condition factor of Brown Trout and Rainbow Trout below average for four of the past five years. In the 12 sampling years prior to 2012, condition factors were always >1.00.
- Rainbow Trout numbers in severe decline between 2012 and 2016. In 2012, a total of 235 Rainbow Trout were captured (226 age -0 fish) and in 2016 only seven Rainbow Trout were caught (no age-0 fish), for a 97% decline. This decline has coincided with CDFW stocking of sterile Rainbow Trout in Lee Vining Creek upstream of LADWP's point of diversion.

Lee Vining Creek – Side Channel

- Reduced streamflow to the side channel has resulted in smaller wetted area for fish sampling. Between 2012 and 2015, the wetted channel area decreased from 365 m^2 to 70.3 m^2, an 81% decrease. However in 2016, with a higher peak flow, the wetted increased to 233 m^2.
- Lower numbers of total fish captured. Between 2012 and 2016, the total trout catch has dropped from 45 fish to 12 fish, a 73% decline.

- Low numbers of age-0 Brown Trout. No age-0 Brown Trout captured in 2014 and 2015. Only one age-0 Brown Trout captured in 2012, 2013 and 2016.
- No age-0 Rainbow Trout captured in side channel in past eight years and no age-1 and older Rainbow Trout captured in the past six years.

2016 Summer Water Temperature Data

As presented in the Results section, the poor to marginal water temperatures recorded in Rush Creek during the summers of 2013 -2015 also occurred during the summer of 2016. Although storage levels in GLR during the summer of 2016 were higher than the previous three summers and were above the SEF recommended minimum summer elevation level of 7,100 feet; water passing through GLR still resulted in warm water (with little diurnal fluctuation) that was released into the top of the MGORD. In terms of Brown Trout growth and condition, water temperature metrics within the MGORD were poor and worsened in a downstream direction within the 1.2 mile length of the MGORD. Rush Creek's daily mean water temperature for July-September 2016 increased by 4.9°F between At Damsite and the top of the MGORD; daily mean maximum temperatures increased by 5.2°F between At Damsite and the Top of MGORD and increased by 7.4°F between At Damsite and the Bottom of MGORD (Table 31).

Brown Trout numbers in the MGORD appear to reflect these poor thermal conditions with an 80% decline in total catch numbers between 2012 and 2016. Also, over this five-year stretch the numbers of large trout (>300 mm) sampled has dropped by 81%. To put this recent drop in numbers of Brown Trout >300 mm into a long-term perspective, between 2001 and 2012, an average of 180 trout >300 mm were captured versus an average of 38 trout >300 mm between 2013 and 2016 (a 79% decline). Visually, the elodea beds within the MGORD have appeared impacted by the extended drought. Prior to the drought, the elodea beds during the summer months were lush with vibrant green (and flowering) floating mats that provided cover for trout, as well as surface area for abundant populations of scuds and caddisflies. The past four summers, the elodea beds have appeared stunted, covered in fine sediment, and lacked the growth of floating, trailing surface mats. A qualitative snorkel survey conducted in September of 2015 also suggested that numbers of scuds and caddisflies (important trout food items) were low, relative to pre-drought snorkel observations.

The addition of the Above Parker Ck water temperature monitoring location in 2016 allowed for further documentation of worsening thermal conditions as flow travelled down Rush Creek. For example, during July-September, the number of days with peaks >70°F was greatest at this location (55 out of 92 days) and the number of hours with temperatures >66.2°F (574 hours) was greatest at this location. Also, the Above Parker Ck data when contrasted with data from the next temperature monitoring location downstream (Below Narrows) confirmed the importance of accretions from Parker and Walker creeks in cooling Rush Creek. In 2016, between these two locations, the number of days with peaks >70°F decreased by 38%, the number of hours with temperatures >66.2°F decreased by 27%, and the number of days defined as "poor growth" and "bad thermal" dropped from 49 to 18 days (-63%).

Trout Growth Rates and Survival

Although the analyses of Rush Creek's summer water temperature indicate that certain temperature metrics have been marginal to poor during the extended drought period, growth rates of Brown Trout have actually improved during the past two years. These improved growth rates have occurred as population estimates plummeted by 80% to more than 90%, suggesting that even though survival was poor, fish that survived were growing faster.

The growth rates of age-1 fish in 2015 were comparable to pre-drought growth rates (2008-2011); with average weight gains of 55 g in Upper Rush and 41 g in the Bottomlands (Table 35). Then in 2016 (with 81% and 58% decreases in age-1 fish population estimates), the growth rates of age-1 Brown Trout were the highest ever recorded for Upper Rush (77 g) and the Bottomlands (62 g). Unfortunately, the interruption of the PIT tagging program in 2013 and the relatively low numbers of age-0 fish tagged in 2014 resulted in limited information about the specific growth of age-2 and age-3 trout in 2016 (based on PIT tag recaptures).

However, examination of average weights of three size classes of Brown Trout captured during the past four sampling years confirmed better growth in 2016 and 2015 versus 2014 and 2013 (Table 36). In the Upper Rush section, all three size classes of Brown Trout were larger in 2016 than in the previous three years (Table 36). In the Bottomlands section, Brown Trout in the <125 mm size class had similar average weights in 2013 and 2014, but approximately a 50-55% gain in 2015 and an additional 14% increase between 2015 and 2016 (Table 36). For the ≥200 mm size class, 2016 average weights in both the Upper Rush and Bottomlands were the highest for the previous four below-normal RYs (Table 36).

Density-dependent growth in stream-dwelling salmonids is well researched and there's broad support for the hypothesis that density-dependent growth occurs at low population densities, probably due to exploitive completion (Grant and Imre 2005). One study used controlled reaches of a small stream and determined that population density affected growth in trout parr (yearlings and older) and that competition and population regulation was not just limited to early life-stages, as suggested by other researchers (Bohlin et al. 2002). Another analysis used data collected from 19 trout populations (six species and 16 different studies) and determined that 15 of the 19 populations showed evidence of decreased growth rates with increasing densities (Grant and Imre 2005). This analysis was focused primarily on age-0 trout (Grant and Imre 2005). For Upper Rush, 11 years (2006-2016) of age-0 Brown Trout and total Brown Trout population estimates were plotted versus the average weights of age-0 Brown Trout from those sample years (Figure 25). Trend lines through each of the population estimates strongly suggest density-dependent growth of age-0 fish has occurred in the Upper Rush section (Figure 25).

Interestingly, these improved growth rates failed to translate into better survival (as documented by declining population estimates) or into age-1 and older fish "in good condition" (as determined by condition factor computations). For example, although the average weight of age-1 fish in the Bottomlands section (125-199 mm size class) increased by 50% between 2013 and 2016 and the average weight of age-2+ fish (≥200mm) increased by 43% between 2013 and 2016; the condition factor of Bottomlands Brown Trout in 2013 was 0.91 versus 0.95 in 2016.

Yes, slight increases in condition factor occurred, yet these values remained poor (<1.00), even with 40-50% heavier average weights.

Table 35. Annual growth rate (g) for PIT tagged or fin-clipped age-0 to age-1, age-1 to age-2, and age-2 to age-3 brown trout in two sections of Rush Creek by year. N/A = not available

Age Class	Growth Years	Upper Rush Growth (g)	Bottomlands Growth (g)	Fin clip or PIT Tag
Age-0 to Age-1	2006-2007	32	N/A	Ad Clip
	2008-2009	51	43	Ad Clip
	2009-2010	48	40	PIT Tag
	2010-2011	48	36	PIT Tag
	2011-2012	33	25	PIT Tag
	2012-2013	35	25	PIT Tag
	2013-2014	N/A	N/A	N/A
	2014-2015	55	41	PIT Tag
	2015-2016	**77**	**62**	PIT Tag
Age-1 to Age-2	2008-2009	N/A	N/A	Ad Clip
	2009-2010	70	54	PIT Tag
	2010-2011	73	32	PIT Tag
	2011-2012	42	28	PIT Tag
	2012-2013	42	22	PIT Tag
	2013-2014	N/A	29*	PIT Tag
	2014-2015	69	62	PIT Tag
	2015-2016	176***	N/A	PIT Tag
Age-2 to Age-3	2010-2011	N/A	14	PIT Tag
	2011-2012	29	16	PIT Tag
	2012-2013	N/A	9	PIT Tag
	2013-2014	41**	31**	PIT Tag
	2014-2015	N/A	N/A	PIT Tag
	2015-2016	N/A	N/A	PIT Tag

*one fish **two fish ***fish moved from Upper Rush to MGORD between age-1 and age-2.

Table 36. Average weight comparisons of Rush Creek Brown Trout, in three size classes captured in September of 2013-2016.

	Upper Rush Section				Bottomlands Section			
Size Class (mm)	**2013 Ave Weight (g)**	**2014 Ave Weight (g)**	**2015 Ave Weight (g)**	**2016 Ave Weight (g)**	**2013 Ave Weight (g)**	**2014 Ave Weight (g)**	**2015 Ave Weight (g)**	**2016 Ave Weight (g)**
<125	7.2	9.0	12.6	13.7	7.0	6.7	10.4	11.9
125-199	43.1	47.2	52.3	63.5	37.0	39.8	45.5	57.1
≥200	119.0	131.6	126.8	137.7	84.2	88.5	114.4	120.2

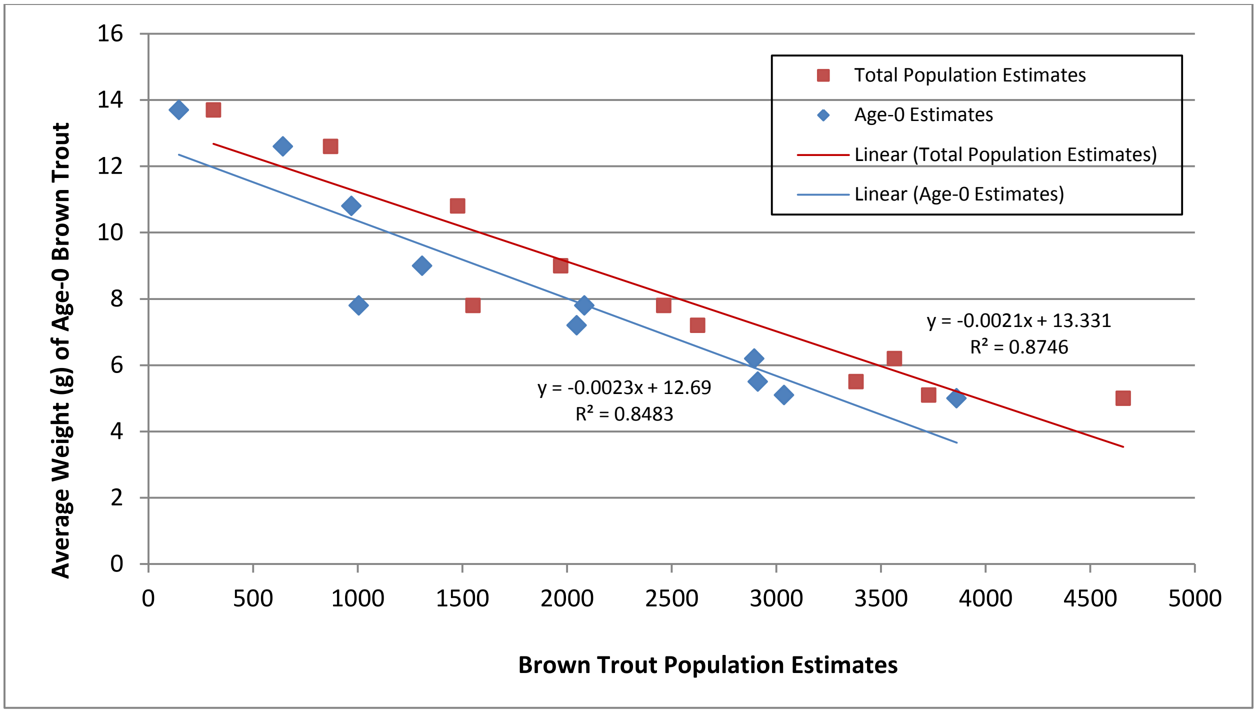

Figure 27. Relationship between average weights of age-0 Brown Trout and population estimates (age-0 and all trout) in the Upper Rush sampling section, 2006-2016.

Relatively low survival rates of Brown Trout in Rush Creek sample sections were also evident in the PIT tag data collected in 2016. Apparent survival rates of age-1 Brown Trout were calculated with the following equation: [# age-1 recaps in 2016/capture probability of age-1 fish] ÷ [# age-0 tagged in 2015 - # shed tags]. For mark-recapture sections, capture probabilities were derived from the recapture run data: # of recaptures/# of captures. Apparent survival rates were lower in Rush Creek; 22.7% in the Upper section and 9.7% in the Bottomlands section (Table 37). In contrast, Lee Vining Creek's age-1 Brown Trout had an apparent survival rate of 46.3% and Walker Creek's equaled 37.8% (Table 37). Both of these creeks consistently exhibit cooler summer water temperatures than Rush Creek.

Table 37. Apparent survival rates of age-1 Brown Trout in Rush, Walker and Lee Vining creeks.

Creek and Section	Capture Probability	No. Age-1 Recaps in 2016	No. Age-0 Tagged in 2015	No. Shed Tags	Apparent Survival Rate
Rush – Upper	.32	17	234	0	22.7%
Rush - Bottomlands	.31	5	167	1	9.7%
Walker Creek	.78	33	113	1	37.8%
Lee Vining Creek	.69	62	195	1	46.3%

In 2016, all previously PIT tagged Brown Trout recaptured in the MGORD experienced positive weight gains (Table 28). In years prior to 2014, many larger fish (>300 mm in length) lost weight or exhibited below average condition factors. It appears that low extremely low fish numbers in the MGORD in 2015 and 2016 has resulted in better growth rates, and unlike the downstream sampling sections, improved condition factors too. MGORD Brown Trout >300 mm in length had condition factors >1.00 in 2016 and condition factors increased with size classes:

- Brown Trout >300 mm = 1.03
- Brown Trout >375 mm = 1.09
- Brown Trout >400 mm = 1.14
- Individual fish 495 mm = 1.41

However, these improved growth rates and condition factors of larger Brown Trout coincided with the lowest number of fish captured in the MGORD over the 13 seasons this section has been sampled (for both single-pass and two-pass sampling efforts). In 2016, the two electrofishing passes caught 121 and 110 total trout.

Age-0 Recruitment in Rush Creek

The availability and location of spawning habitat in Rush Creek was a concern during the development of Decision 1631 and subsequent SWRCB Orders #98-05 and #98-07. The Mono Basin EIR noted that 55 redds were found between 1985 and 1989, primarily in the uppermost 0.85 miles of Rush Creek below GLR dam (page 3D-19). Section 5.4.2 of Decision 1631 (titled Flows for Providing Fishery Habitat) stated, “There is general agreement that adult habitat and spawning habitat in Rush Creek are limited.” Much of the early instream flow recommendations centered on the stability of introduced spawning substrate. In contrast, our experience since 1999 after the fisheries sampling methods were established, was that annual recruitment of age-0 Brown Trout in the Rush Creek sections was variable, yet sufficient enough to translate into ample numbers of age-1 and older fish in subsequent years. Previous annual fisheries monitoring reports have shown that wide ranges in the numbers of age-0 Brown Trout produced in 2000-2004 eventually translated into similar numbers of age -1 and older fish (Hunter et al. 2004 - 2007). We also stated in the Synthesis Report that “In Rush Creek, ample recruitment of age-0 Brown Trout has occurred the past ten years” (McB&T and RTA 2010).

During the past five below-normal RY types, the numbers of age-0 Brown Trout have declined in both annually sampled sections of Rush Creek. In the Upper Rush section, the population estimate of age-0 Brown Trout declined by 95% between 2012 and 2016. Age-0 Brown Trout in the Bottomlands section experienced an 83% decline in population estimates between 2012 and 2016. Between 2012 and 2015, the decreased fish numbers in Rush Creek were fairly steady and progressive. However, the paucity of Brown Trout in 2016 was immediately noticed during the first electrofishing pass on Upper Rush and was sobering. In pre-drought years, we often handled 700 to 1,200 fish in a single electrofishing of the Upper section, thus catching 120 Brown Trout and only 49 age-0 fish was unsettling. Qualitatively, it appeared that trout population had crashed after five years of drought.

The 2016 data in concert with our previous data provides strong evidence that the five years of persistent drought conditions have negatively affected the trout in Rush and Lee Vining creeks, in terms of population numbers and condition factors. These negative responses include:

- Poor age-0 recruitment due to poor condition and low numbers of mature fish.
- Poor egg viability and survival to emergence. Past annual reports have cited papers regarding thermal stress and lowered egg viability (Campbell et al 1992).
- Possible increased cannibalism of age-0 fish by older fish due to reduced flows (Vik et al. 2001).
- A population size structure that started “stacking” fish in larger size categories, but now those larger fish were dying between ages-4 and age-5 as the drought hit its fifth year. Low numbers of spawning age fish then translated into a crash of age-0 recruitment in 2016.
- Growth actually increasing, in a few areas, probably in response to populations crashing allowing for lower densities and increased growth. The population appears to be “self-thinning” in that as numbers decline there are higher proportions of larger fish (as depicted by higher RSD values), but these fish may not be in as good condition (Dunham and Vineyard 1997).

Drought effects on Brown Trout populations are well documented; however the effects and suspected causes are variable. James et al. (2010) documented 66% to 80% declines in Brown Trout biomass in three Black Hills streams in South Dakota between early-drought and late-drought periods. These declines were attributed to flow reductions and loss of pool volume since thermal conditions remained similar. A 30-year study (1966-1996) determined that drought periods lead to increased mortality and decreased growth of Brown Trout (Elliot et al. 1997). This study found that summer droughts which extended into the autumn spawning period resulted in lower densities of spawning females and viable eggs. Finally, another study examined resident Brown Trout confined to isolated pools during two years of drought (Elliot 2000). When compared to pre-drought data, the densities of age-0 and age-1 trout were reduced. The remaining fish utilized the deeper sections of the isolated pools as refugia; to the extent that a preference was detected for cooler water with lower levels of dissolved oxygen at the bottom of the pools versus the top layer of the same pools with higher temperatures, yet more dissolved oxygen (Elliot 2000).

Limited information was found concerning post-drought responses by stream dwelling trout populations. However, an assessment of naturally reproducing Rainbow Trout populations in Colorado on National Forest lands concluded that shortly after an extended period of drought (2000-2004), Rainbow Trout numbers were at stable, or increased, levels due to the fish’s wide distribution across multiple watersheds (Adams et al. 2008).

As of early February 2016, the Mono Basin has experienced an above normal winter and the snow water content is at 200%, which translates into 120% of normal if no more precipitation occurred between February and April 1st. Thus, a fuller GLR extending later into the summer of 2017, with a required peak flow of at least 350 to 400 cfs should start a "re-set" to more favorable physical and thermal conditions for Brown Trout in Rush Creek. However, because of the extremely low numbers of available mature fish for spawning in the fall of 2016, we suspect that overall population numbers and recruitment of age-0 Brown Trout in 2017 will be extremely low, possibly lower than the 2016 population estimates.

Methods Evaluation

In 2016, mark-recapture and depletion estimates were again used to produce population estimates on Rush Lee Vining and Walker Creeks. As in past years, we started off cleaning the block fences twice a day, but several periods of windy conditions and falling leaves resulted in block fence failures. For the first time, large mats of algae were present in Rush Creek, especially upstream of Highway 395, and mats of algae constantly clogged the Upper section fences. After the upstream fences at Upper Rush and the Lee Vining Creek main channel failed several times each we implemented a more rigorous fence cleaning schedule. The relatively similar numbers of fish captured during both the mark and recapture runs suggest little, if any, movement of fish in or out of the sections during these brief fence failures.

As in previous years, small variations in wetted channel widths were measured, which resulted in changes to sample section areas. Also, we moved the location of the Upper Rush section's upper block fence due to the algae load. Thus, it is recommended that channel lengths and widths are re-measured annually.

The PIT tagging program was continued during the September 2016 sampling and tags were implanted primarily in age-0 fish. Because less than 500 tags were implanted in 2012; the recapture of previously tagged age-4 fish was low in 2016. As previously mentioned, no tags were deployed in 2013, which also impacted recaptures of age-3 fish in 2016. These low recapture rates limited inferences about trout growth and survival during the fifth year of drought in the Mono Basin. Resumption (and continuation) of the PIT tagging program is important as the fisheries monitoring program moves towards its post-settlement phase.

Trout size classes (0-124, 125-199, and ≥200 mm) developed and discussed during the 2008 annual report should continue to be used in the future (Hunter et al. 2008). Using these size classes provides for long-term consistency as well as year to year consistency with the annual fisheries data sets.

To ensure that electrofishing sampling can be conducted safely and efficiently, flows in Rush and Lee Vining creeks should not exceed 40 cfs. (± 5 cfs.) during the annual sampling period. Allowances for flow variances to allow for safe wading conditions and effective sampling were included in the new Terms of Settlement. Because of the large snow-melt runoff expected during the summer of 2017, careful management of flows and possibly delaying the timing of the fisheries sampling until early October, will be necessary to allow for safe and effective wading conditions.

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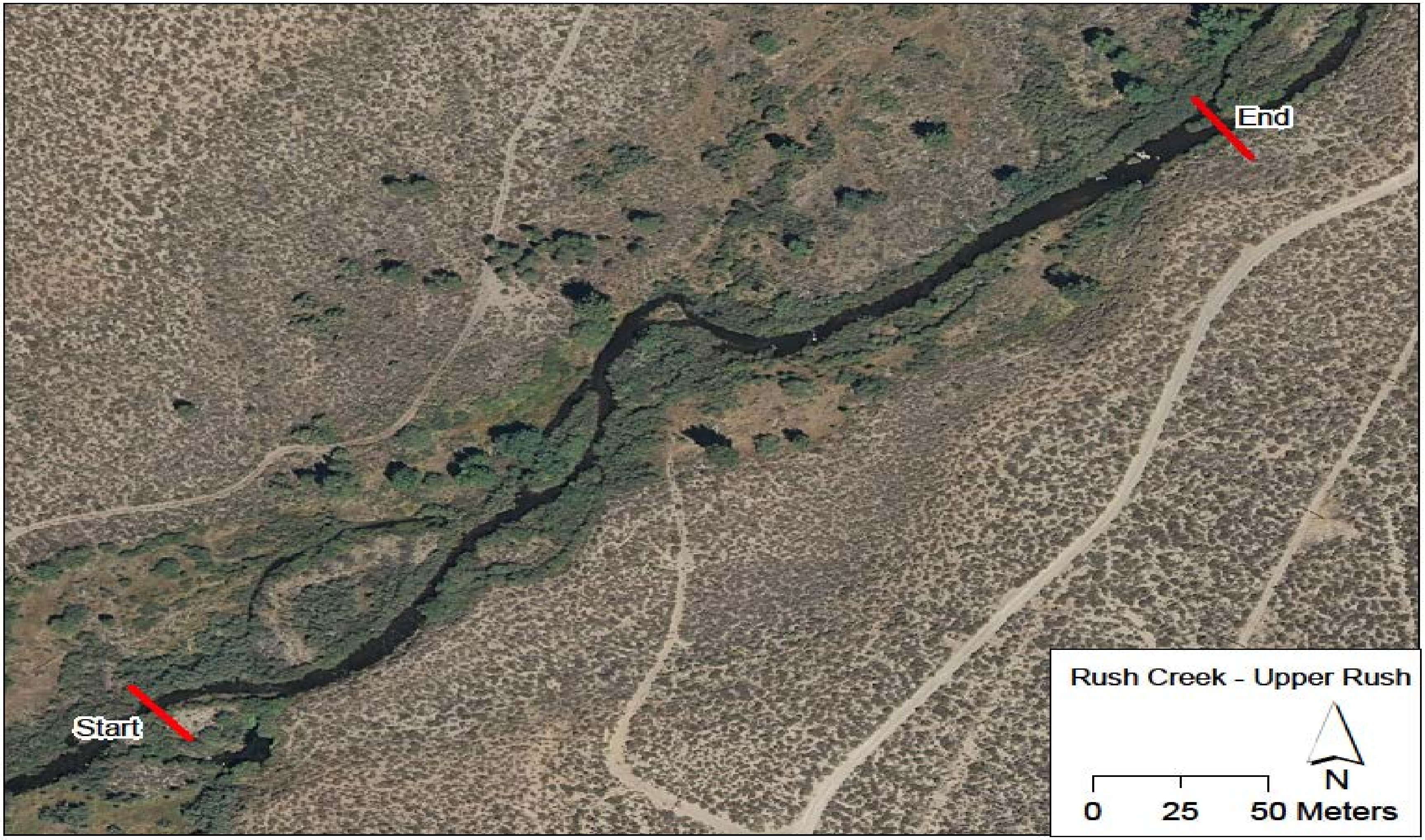
Appendices for the 2016 Mono Basin Annual Fisheries Report

Appendix A: Aerial Photographs of Long-term Monitoring Sections.




End
Start
Rush Creek - Bottomlands
N
0
25
50 Meters


End
Start
Rush Creek - MGORD
N
0
100
200 Meters


End
End
B-1 Side Channel
Main Channel
Start
Start
Lee Vining Creek- Main and B-1 Side Channels
0
20
40 Meters
N


End
Start
Walker Creek
N
0
12.5
25 Meters

Appendix B: Tables of PIT-tagged Fish Recaptured during the September 2016 Sampling

Appendix B: Table 1. PIT tagged trout recaptured in Rush Creek sections, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/14/2016	BNT	318	307	985121028092487	Bottomlands	**County Road**
9/14/2016	BNT	172	50	989001004580994	Bottomlands	Bottomlands
9/14/2016	BNT	217	90	989001004581099	Bottomlands	Bottomlands
9/14/2016	BNT	194	72	989001004581159	Bottomlands	Bottomlands
9/21/2016	BNT	196	74	989001004580953	Bottomlands	Bottomlands
9/21/2016	BNT	205	80	989001004581175	Bottomlands	Bottomlands
9/15/2016	BNT	495	1712	985121017025328	MGORD	MGORD
9/15/2016	BNT	440	948	985121017031639	MGORD	MGORD
9/15/2016	BNT	453	1045	989001001356456	MGORD	MGORD
9/15/2016	BNT	384	571	989001001360038	MGORD	MGORD
9/15/2016	BNT	289	247	989001001951970	MGORD	**Upper Rush**
9/15/2016	BNT	356	470	989001004580752	MGORD	MGORD
9/15/2016	BNT	372	466	989001004580776	MGORD	MGORD
9/15/2016	BNT	325	247	989001004580802	MGORD	MGORD
9/22/2016	BNT	535	1585	985121023369646	MGORD	MGORD
9/22/2016	BNT	420	780	989001001237208	MGORD	MGORD
9/22/2016	BNT	401	631	989001001354666	MGORD	MGORD
9/22/2016	BNT	278	224	989001001952061	MGORD	**Upper Rush**
9/22/2016	BNT	240	124	989001004581050	MGORD	**Upper Rush**
9/13/2016	BNT	237	137	989001004580984	Upper Rush	Upper Rush
9/13/2016	BNT	214	96	989001004581010	Upper Rush	Upper Rush
9/13/2016	BNT	208	88	989001004581035	Upper Rush	Upper Rush
9/13/2016	BNT	201	76	989001004581051	Upper Rush	Upper Rush
9/13/2016	BNT	211	90	989001004581059	Upper Rush	Upper Rush
9/13/2016	BNT	225	119	989001004581074	Upper Rush	Upper Rush
9/13/2016	BNT	192	73	989001004581076	Upper Rush	Upper Rush
9/13/2016	BNT	206	87	989001004581078	Upper Rush	Upper Rush
9/13/2016	BNT	202	82	989001004581082	Upper Rush	Upper Rush
9/13/2016	BNT	216	90	989001004581083	Upper Rush	Upper Rush
9/20/2016	BNT	225	138	989001001953544	Upper Rush	Upper Rush
9/20/2016	BNT	200	74	989001004580726	Upper Rush	Upper Rush
9/20/2016	BNT	204	83	989001004580732	Upper Rush	Upper Rush
9/20/2016	BNT	199	76	989001004580855	Upper Rush	Upper Rush
9/20/2016	BNT	193	66	989001004580961	Upper Rush	Upper Rush
9/20/2016	BNT	203	75	989001004581042	Upper Rush	Upper Rush
9/20/2016	BNT	209	86	989001004581098	Upper Rush	Upper Rush
9/17/2016	BNT	214	94	989001001239275	Walker Creek	Walker Creek
9/17/2016	BNT	194	60	989001001354134	Walker Creek	Walker Creek

Appendix B: Table 1. PIT tagged trout recaptured in Rush Creek sections, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/17/2016	BNT	196	74	989001001953504	Walker Creek	Walker Creek
9/17/2016	BNT	211	91	989001001954348	Walker Creek	Walker Creek
9/17/2016	BNT	195	67	989001001955581	Walker Creek	Walker Creek
9/17/2016	BNT	204	83	989001001955651	Walker Creek	Walker Creek
9/17/2016	BNT	226	111	989001001955655	Walker Creek	Walker Creek
9/17/2016	BNT	180	64	989001001955684	Walker Creek	Walker Creek
9/17/2016	BNT	161	38	989001004580657	Walker Creek	Walker Creek
9/17/2016	BNT	159	33	989001004580697	Walker Creek	Walker Creek
9/17/2016	BNT	174	44	989001004580725	Walker Creek	Walker Creek
9/17/2016	BNT	157	32	989001004580727	Walker Creek	Walker Creek
9/17/2016	BNT	169	49	989001004580856	Walker Creek	Walker Creek
9/17/2016	BNT	187	60	989001004580857	Walker Creek	Walker Creek
9/17/2016	BNT	157	30	989001004580859	Walker Creek	Walker Creek
9/17/2016	BNT	175	49	989001004580862	Walker Creek	Walker Creek
9/17/2016	BNT	172	47	989001004580864	Walker Creek	Walker Creek
9/17/2016	BNT	174	50	989001004580865	Walker Creek	Walker Creek
9/17/2016	BNT	151	34	989001004580876	Walker Creek	Walker Creek
9/17/2016	BNT	173	51	989001004580878	Walker Creek	Walker Creek
9/17/2016	BNT	187	62	989001004580884	Walker Creek	Walker Creek
9/17/2016	BNT	162	40	989001004580887	Walker Creek	Walker Creek
9/17/2016	BNT	174	48	989001004580890	Walker Creek	Walker Creek
9/17/2016	BNT	175	48	989001004580892	Walker Creek	Walker Creek
9/17/2016	BNT	179	55	989001004580895	Walker Creek	Walker Creek
9/17/2016	BNT	167	44	989001004580896	Walker Creek	Walker Creek
9/17/2016	BNT	170	48	989001004580901	Walker Creek	Walker Creek
9/17/2016	BNT	142	26	989001004580904	Walker Creek	Walker Creek
9/17/2016	BNT	181	54	989001004580913	Walker Creek	Walker Creek
9/17/2016	BNT	181	61	989001004580920	Walker Creek	Walker Creek
9/17/2016	BNT	145	29	989001004580926	Walker Creek	Walker Creek
9/17/2016	BNT	159	36	989001004580930	Walker Creek	Walker Creek
9/17/2016	BNT	158	35	989001004580931	Walker Creek	Walker Creek
9/17/2016	BNT	162	39	989001004580933	Walker Creek	Walker Creek
9/17/2016	BNT	196	74	989001001953504	Walker Creek	Walker Creek
9/17/2016	BNT	211	91	989001001954348	Walker Creek	Walker Creek
9/17/2016	BNT	195	67	989001001955581	Walker Creek	Walker Creek
9/17/2016	BNT	204	83	989001001955651	Walker Creek	Walker Creek
9/17/2016	BNT	226	111	989001001955655	Walker Creek	Walker Creek
9/17/2016	BNT	180	64	989001001955684	Walker Creek	Walker Creek

Appendix B: Table 1. PIT tagged trout recaptured in Rush Creek sections, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/17/2016	BNT	166	42	989001004580936	Walker Creek	Walker Creek
9/17/2016	BNT	149	35	989001004580937	Walker Creek	Walker Creek
9/17/2016	BNT	180	58	989001004580938	Walker Creek	Walker Creek
9/17/2016	BNT	185	67	989001004580940	Walker Creek	Walker Creek
9/17/2016	BNT	160	37	989001004580943	Walker Creek	Walker Creek
9/17/2016	BNT	160	47	989001004580944	Walker Creek	Walker Creek
9/17/2016	BNT	154	35	989001004580951	Walker Creek	Walker Creek

Appendix B: Table 2. PIT tagged trout recaptured in Lee Vining Creek, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/16/2016	BNT	237	136	985121028055967	Main Channel	Main Channel
9/16/2016	BNT	210	96	989001001232519	Main Channel	Main Channel
9/16/2016	BNT	263	198	989001001242188	Main Channel	Main Channel
9/16/2016	BNT	203	73	989001001242901	Main Channel	Main Channel
9/16/2016	BNT	223	110	989001001355397	Main Channel	Main Channel
9/16/2016	BNT	230	136	989001001357596	Main Channel	Main Channel
9/16/2016	BNT	256	159	989001001357960	Main Channel	Main Channel
9/16/2016	BNT	216	107	989001001953527	Main Channel	Main Channel
9/16/2016	BNT	215	101	989001001954445	Main Channel	Main Channel
9/16/2016	BNT	162	41	989001004580453	Main Channel	Main Channel
9/16/2016	BNT	174	49	989001004580455	Main Channel	Main Channel
9/16/2016	BNT	170	54	989001004580456	Main Channel	Main Channel
9/16/2016	BNT	170	50	989001004580457	Main Channel	Main Channel
9/16/2016	BNT	176	58	989001004580469	Main Channel	Main Channel
9/16/2016	BNT	174	52	989001004580471	Main Channel	Main Channel
9/16/2016	BNT	170	45	989001004580472	Main Channel	Main Channel
9/16/2016	BNT	160	38	989001004580474	Main Channel	Main Channel
9/16/2016	BNT	161	37	989001004580480	Main Channel	Main Channel
9/16/2016	BNT	163	45	989001004580483	Main Channel	Main Channel
9/16/2016	BNT	187	64	989001004580487	Main Channel	Main Channel
9/16/2016	BNT	186	62	989001004580493	Main Channel	Main Channel
9/16/2016	BNT	173	52	989001004580495	Main Channel	Main Channel
9/16/2016	BNT	147	30	989001004580496	Main Channel	Main Channel
9/16/2016	BNT	159	38	989001004580500	Main Channel	Main Channel
9/16/2016	BNT	178	55	989001004580501	Main Channel	Main Channel
9/16/2016	BNT	166	48	989001004580503	Main Channel	Main Channel

Appendix B: Table 2. PIT tagged trout recaptured in Lee Vining Creek, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/16/2016	BNT	170	50	989001004580504	Main Channel	Main Channel
9/16/2016	BNT	182	62	989001004580505	Main Channel	Main Channel
9/16/2016	BNT	164	41	989001004580506	Main Channel	Main Channel
9/16/2016	BNT	167	47	989001004580508	Main Channel	Main Channel
9/16/2016	BNT	175	56	989001004580511	Main Channel	Main Channel
9/16/2016	BNT	163	37	989001004580515	Main Channel	Main Channel
9/16/2016	BNT	170	50	989001004580526	Main Channel	Main Channel
9/16/2016	BNT	180	55	989001004580530	Main Channel	Main Channel
9/16/2016	BNT	176	56	989001004580535	Main Channel	Main Channel
9/16/2016	BNT	161	41	989001004580538	Main Channel	Main Channel
9/16/2016	BNT	170	45	989001004580541	Main Channel	Main Channel
9/16/2016	BNT	187	63	989001004580543	Main Channel	Main Channel
9/16/2016	BNT	191	73	989001004580585	Main Channel	Main Channel
9/16/2016	BNT	181	57	989001004580589	Main Channel	Main Channel
9/16/2016	BNT	187	63	989001004580603	Main Channel	Main Channel
9/16/2016	BNT	170	46	989001004580605	Main Channel	Main Channel
9/16/2016	BNT	200	80	989001004580610	Main Channel	Main Channel
9/16/2016	BNT	168	46	989001004580622	Main Channel	Main Channel
9/16/2016	BNT	128	19	989001004580627	Main Channel	Main Channel
9/16/2016	BNT	190	67	989001004580631	Main Channel	Main Channel
9/16/2016	BNT	149	35	989001004581359	Main Channel	Main Channel
9/16/2016	BNT	154	34	989001004581372	Main Channel	Main Channel
9/16/2016	BNT	170	47	989001004581375	Main Channel	Main Channel
9/16/2016	BNT	172	51	989001004581398	Main Channel	Main Channel
9/16/2016	BNT	183	57	989001004581401	Main Channel	Main Channel
9/16/2016	BNT	182	54	989001004581403	Main Channel	Main Channel
9/16/2016	BNT	190	67	989001004581406	Main Channel	Main Channel
9/16/2016	BNT	167	46	989001004581407	Main Channel	Main Channel
9/16/2016	BNT	173	48	989001004581408	Main Channel	Main Channel
9/16/2016	BNT	174	56	989001004581426	Main Channel	Main Channel
9/16/2016	BNT	160	39	989001004581441	Main Channel	Main Channel
9/16/2016	BNT	160	38	989001004581445	Main Channel	Main Channel
9/16/2016	BNT	170	50	989001004580504	Main Channel	Main Channel
9/16/2016	BNT	182	62	989001004580505	Main Channel	Main Channel
9/16/2016	BNT	164	41	989001004580506	Main Channel	Main Channel
9/16/2016	BNT	167	47	989001004580508	Main Channel	Main Channel
9/16/2016	BNT	175	56	989001004580511	Main Channel	Main Channel
9/16/2016	BNT	163	37	989001004580515	Main Channel	Main Channel

Appendix B: Table 2. PIT tagged trout recaptured in Lee Vining Creek, September 2016.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
9/16/2016	BNT	173	49	989001004581446	Main Channel	Main Channel
9/23/2016	BNT	205	76	989001001231145	Main Channel	Main Channel
9/23/2016	BNT	217	90	989001001231194	Main Channel	Main Channel
9/23/2016	BNT	160	38	989001004580488	Main Channel	Main Channel
9/23/2016	BNT	186	62	989001004580490	Main Channel	Main Channel
9/23/2016	BNT	162	43	989001004580510	Main Channel	Main Channel
9/23/2016	BNT	157	38	989001004580522	Main Channel	Main Channel
9/23/2016	BNT	169	45	989001004580528	Main Channel	Main Channel
9/23/2016	BNT	170	48	989001004580529	Main Channel	Main Channel
9/23/2016	BNT	178	56	989001004580547	Main Channel	Main Channel
9/23/2016	BNT	176	55	989001004580580	Main Channel	Main Channel
9/23/2016	BNT	143	29	989001004580590	Main Channel	Main Channel
9/23/2016	BNT	181	60	989001004581371	Main Channel	Main Channel
9/23/2016	BNT	172	47	989001004581382	Main Channel	Main Channel
9/23/2016	BNT	180	56	989001004581420	Main Channel	Main Channel
9/16/2016	**RBT**	232	124	989001001242191	Main Channel	Main Channel
9/16/2016	**RBT**	242	173	989001001354122	Main Channel	Main Channel

Section 4

Monitoring Report
For RY 2016-17

RY2016
Geomorphic and Riparian Monitoring Report

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Introduction

The primary goal for RY2016 was to continue developing a long-term monitoring methodology capable of evaluating the ecological performance of the Synthesis Report's (2009) instream flow recommendations. In RY2015 (LADWP 2016), present stream channel morphology and past riparian plant stem growth were quantified within the Rush Creek Bottomlands. Given field experiences collecting and analyzing data, RY2016 focused on: (1) sampling stream channel morphology attributes that did not require fixed monitoring stations (except side-channel entrances) and (2) measuring RY2016 riparian tree stem lengths under varied geomorphic settings affecting water availability.

For efficient RY2016 fieldwork, two sets of maps were created using imagery from GoogleEarth: one for locating stream channel measurements and the other locating sampled riparian trees. Images were extracted from Google Earth and georeferenced using Esri's ArcMap, so they could be digitized into a Geographic Information System (GIS) to then determine, record, and calculate coordinates of each stream channel measurement and riparian tree measured. Original satellite images were captured on September 14, 2013. The first set contained 32 maps (scale 1:800) covering the area between Test Station Road and The Narrows. The second set contained 8 maps (scale 1:1,500) also encompassing the mainstem channel from Test Station Road up to The Narrows, but at the greater scale to include key floodplains throughout the Rush Creek Bottomlands.

RY2016 Fieldwork: Stream Channel Morphology

Two mainstem channel reaches in the Rush Creek Bottomlands were selected for RY2016 fieldwork: Lower Mainstem Rush Creek extended from the Ford upstream to the 10-Channel confluence and Upper Mainstem Rush Creek extended from the 8-Channel entrance upstream to approximately 1100 ft of the Narrows (Figure 1). These two were selected because both were primarily single-thread, yet distinctive, thus providing a good test as to whether the physical variables measured could cleanly differentiate the two.

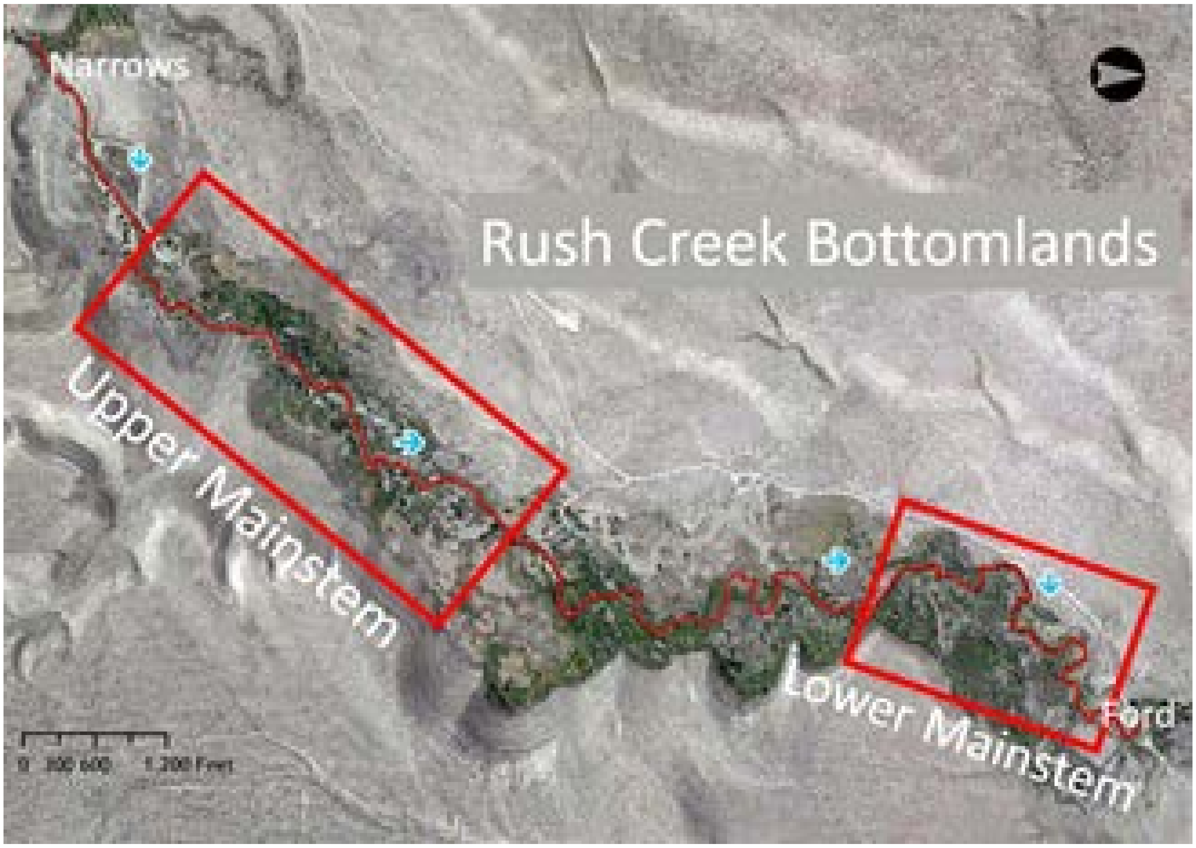

Figure 1. RY2016 mainstem Rush Creek sample reaches in the Rush Creek Bottomlands.

Decreasing baseflow and active channel widths, deepening riffle crest thalwegs (RCTs), and deepening pool/run depths will be primary geomorphic responses to gradual lower Rush Creek and Lee Vining Creek recovery. Analyses addressed two geomorphic objectives: (1) create a width exceedence probability curve (i.e., the probability of sampling a given width or greater) for baseflow, active, and floodpeak channel widths for the two mainstem reaches using a randomized, every 100 ft sampling protocol and (2) create similar width exceedence curves for width measurements taken only at riffle crests and at bend apexes. The overall objective will be to evaluate whether a stratified sampling plan for future monitoring (widths taken at riffle crests and/or bend apexes only) would be superior to sampling every 100 ft (i.e., which presumably creates greater variance).

Stream Channel Morphology: Measurement Protocol

Active, baseflow, and floodpeak channel widths were measured the second week of August 2016 within the two lower Rush Creek mainstem reaches (Figure 1). These widths were measured following two protocols. First, the three widths were measured every 100 ft up the channel centerline. Second, the three widths were measured at two distinct geomorphic locations: at riffle crests and at bend apexes. Channel widths were measured to the nearest 0.10 ft using a surveyor tape and stadia rod; streamflow depths were measured to the nearest 0.01 ft. Residual pool and run depths were measured by locating the greatest depth in each pool/run, and then subtracting this maximum depth from the riffle crest depth immediately downstream. All channel measurements were located on the 1:800 satellite images and entered into an Excel database. Robbie Di Paolo, Project Specialist for the Mono Lake Committee, provided invaluable assistant measuring channel widths and critically evaluating the methodology.

Stream Channel Morphology: Findings and Discussion

Four primary stream morphology findings in the Rush Creek Bottomlands are presented in Figures 2 through 5. Together, they differentiate distinctive channel morphologies without requiring surveyed cross-sections, or repeated measurements over multiple streamflows (though there would be added information if done so). All four do not require fixed location measurements, e.g., re-visiting cross-sections, thus avoiding the inevitable complications from channel migration and re-shaped bar features following significant floods. On their X-axes, the percent rank, or ‘P-value,’ is a cumulative exceedence estimate. For example, the percent rank in Figure 2 of P = 60% intersects the Lower Mainstem’s active channel width @ riffle crest at slightly greater than 30 ft. Therefore, approximately 60% of the active channel widths at riffle crests exceeded 30 ft, and alternatively 40% were narrower. This analytical strategy avoids use of the ‘average’ which does not exist in nature (or is very rare), instead treating channel widths, riffle crest depths, maximum pool depths, and riparian stem lengths (in the next section) probabilistically. Each figure offers a clear visual representation of the variability encountered. All four figures share similar outlier P-values. Back to Figure 2, active channel widths change uniformly between P-values of 15% and 85%, but the trend diverges noticeably for the greatest widths (i.e., below P = 15%) and narrowest widths (i.e., above P = 85%). Nature is attracted to novelty. Both active channel width extremes, really wide and really narrow, likely offer unique aquatic and riparian habitats.

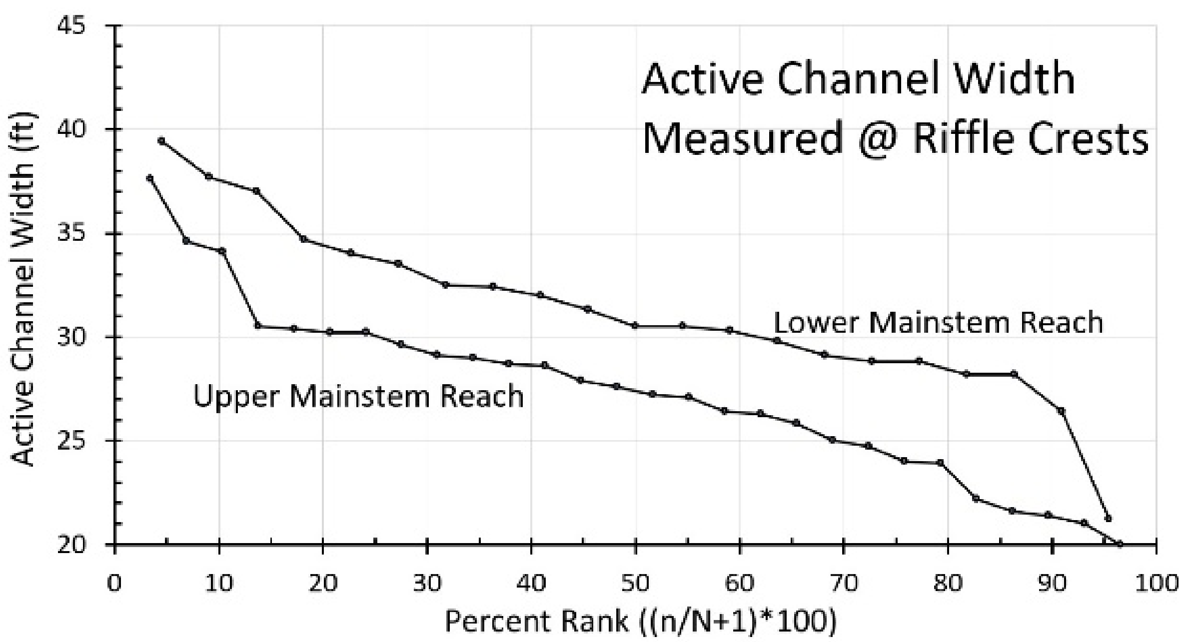

Figure 2. RY2016 active channel widths in Lower and Upper mainstem reaches measured only at riffle crests.

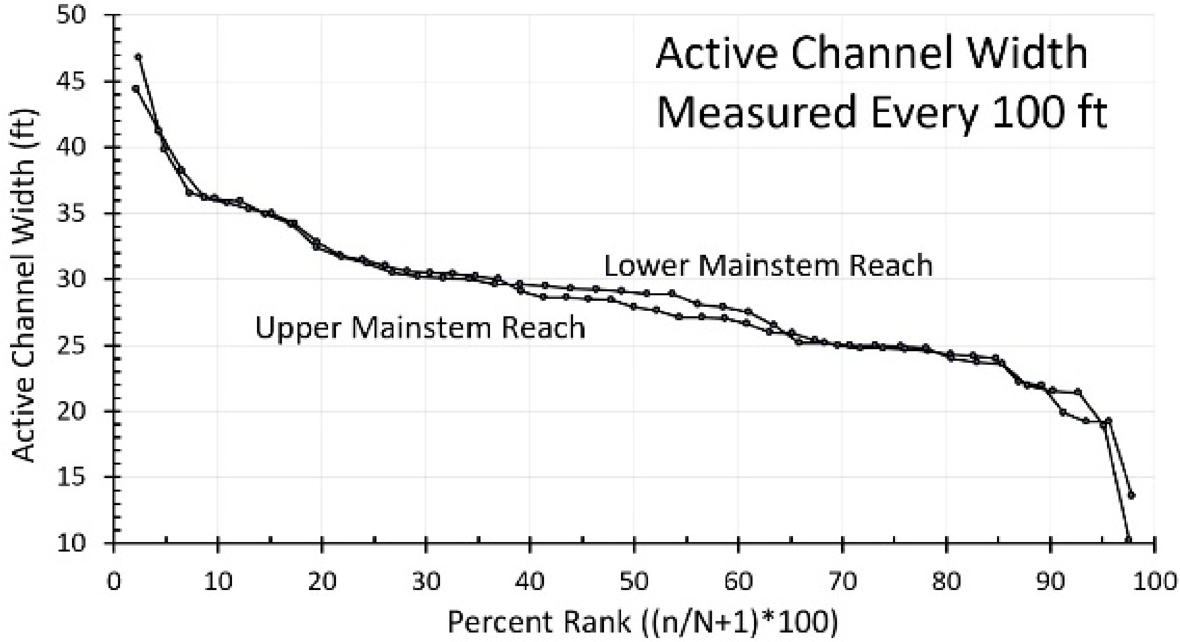

Figure 3. RY2016 active channel widths in Lower and Upper mainstem reaches measured every 100 feet.

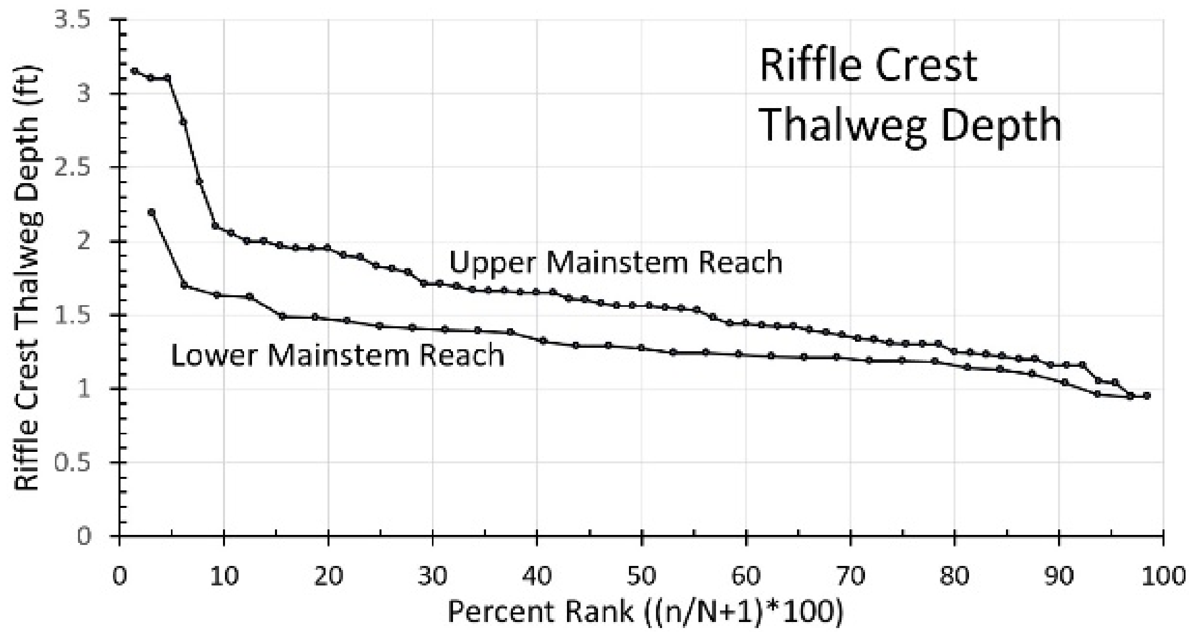

Figure 4. RY2016 riffle crest thalweg (RCT) depths in Lower and Upper mainstem reaches.

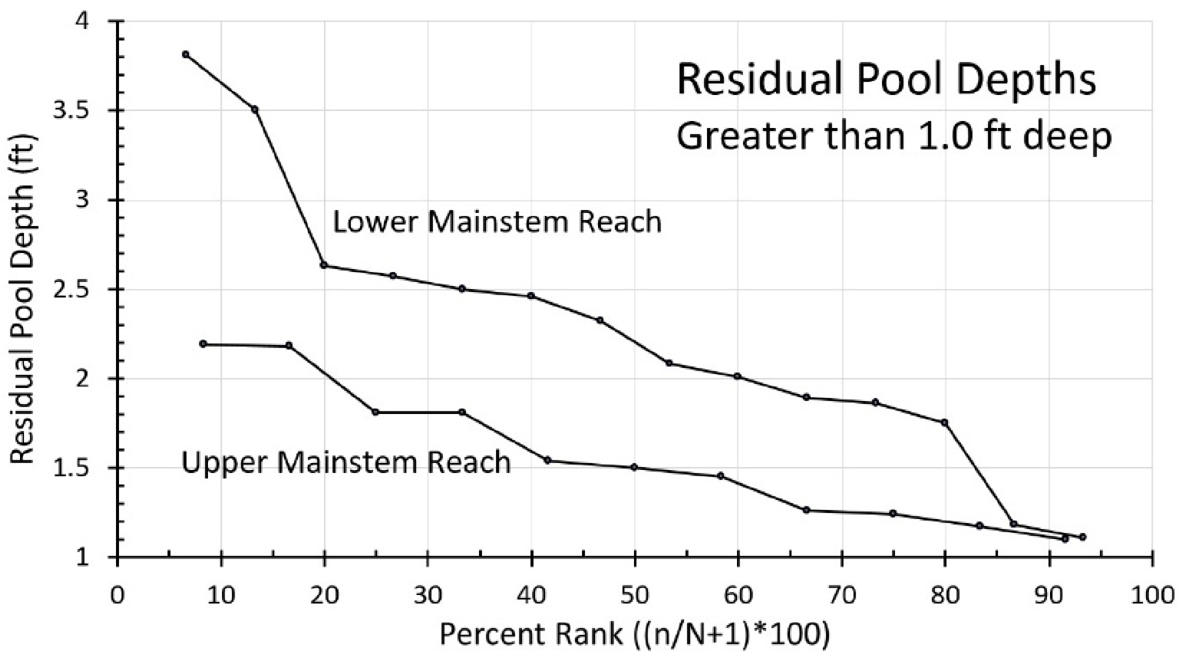

Figure 5. RY2016 residual pool depths in Lower and Upper mainstem reaches exceeding 1.0 ft.

The usefulness of Figures 2 through 5 can be demonstrated with Figure 6. Referring to the field notebook and Map No.14 (with the channel measurements locations documented) on August 11, 2016, the RCT depth was 1.27 ft. The active channel width at Riffle Crest No. 1 was 28.2 ft, the wetted width was 24.8 ft, and the floodplain width was 37.0 ft. The deepest location in the upstream pool, evident in Figure 6, was 3.90 ft, giving a residual pool depth of 2.63 ft (i.e., 3.90 ft – 1.27 ft). These stream channel measurements provide no reference point relative to the entire Lower Mainstem Reach. Was this a typical or unusual segment of the Lower Mainstem Reach? Figure 4 predicts that the 1.27 RCT depth had a P-value of 78%, (i.e., approximately 75% of riffle crest thalwegs were deeper). Riffle Crest No.1 was therefore relatively shallow. Figure 5 shows that a residual depth of 2.63 ft for the upstream pool was relatively deep (i.e., approximately 20% of residual pool depths were deeper). And last, Figure 2 shows that the active channel width of 28.2 ft was relatively narrow (i.e., approximately 82% of active channel widths at riffle crests were wider). The uniformity of active channel width also can be appreciated. A P-value of 20% in Figure 2 has an active channel width of 30.1 ft, only 1.90 ft wider. The stream segment in Figure 6, therefore, is somewhat unique: narrow and shallow, but with a deep pool immediately upstream. The physical variable not quantified is the radius of bend curvature. The upstream riffle, cascading toward the river-left bank enters the pool at nearly a right angle, creating significant scour to create/maintain the relatively deep pool. We are exploring how to measure radius of bend curvature simply from aerial photography.

Figure 6. Bill Trush locating the riffle crest thalweg with a stadia rod on August 11, 2016 in the Lower Mainstem Reach approximately 400 ft downstream of the inoperative stream gage (photo looking upstream)(photo credit: Robbie Di Paolo).

By targeting a geomorphically distinctive feature, W_{ACT} at riffle crests, the future monitoring program will perform better at detecting/documenting geomorphic change. As trees grow and floods build floodplains, the mainstem channel will continue to narrow. However not without simultaneously adjusting RCT depth, residual pool depth, and channel curvature as well. Figures 2 to 5 illustrate this well. The Lower Mainstem generates relatively wider W_{ACT} (Figure 2), deeper residual pool depths (Figure 5), and shallower RCT depths (Figure 4) for a given streamflow. The Lower Mainstem, with its greater sinuosity, behaves more as an alluvial channel than does the Upper Mainstem, and thus has been exercising its alluvial propensity by altering its channelbed, banks, and floodplains the last few decades. In contrast, the Upper Mainstem has been slow to change. Channel downcutting, measured by dropping RCT elevations (and not RCT depths), was evident in several locations. This may be the dominant geomorphic process for the immediate future rather than channel narrowing via woody riparian vegetation encroachment. A few, very-active channel headcuts (refer to RY2015 Report) endanger side-channel connectivity to the 4-Floodplain and possibly the 8-Floodplain during higher snowmelt baseflows. The Upper Mainstem will continue with a variable W_{ACT}, a minor increase in residual pool depths (immediately downstream of channel headcuts, around LWD/ jams, and associated with eroded yellow willow clumps), and an even less dramatic change in overall RCT depths (except at/below headcuts). Beaver dams remain a wildcard regarding widespread changes in channel morphology. However not in one geomorphic setting. In mainstem reaches with multiple channels (almost entirely missing from the Lower and Upper mainstem reaches), beaver dams may already be having impacts. For example, the complex, multiple channels immediately below the downstream confluence of the 8-Side Channel returning to the mainstem (Figure 7). This wide channel reduces flood water elevations while the dense willows offer dam ‘reinforcement’ (almost as rebar strengthens walls). These beaver dams can better survive floods. Geomorphically, patterns of fine-sediment flood deposition will be altered that will ultimately favor one channel over the others.

Figure 7. Portion of beaver dam immediately downstream of the 8-Side Channel LB return to the mainstem channel.

Residual pool depth is generally considered a physical ‘fish habitat’ variable. Greater residual depth, better fish habitat. But it can be considerably more useful, especially in the Rush Creek Bottomlands. Early photographs show narrow, trench-like mainstem channel segments. RCT depths would have been great due to the narrow rectangular channel, and relatively deep compared to the residual depth of the upstream run or pool. Much of the prime fish habitat occurred as deep under-cut banks and fallen trees forming log-jams. In RY2016, a greater than 1.0 ft residual depth threshold (Figure 5) was imposed on sampling. This was an error. For long-term monitoring, this simple ‘rule’ should apply: whenever measuring RCT depth, always measure maximum pool/run depth upstream. The frequency distribution of residual pool depths relative to associated RCT depths, over a wide range of streamflows, can be used as a fingerprint for identifying evolving channel morphologies, present and future. Finally, residual *pool* depth might not be the inclusive term desired; many upstream habitats will be runs and occasionally shallow riffles rather than pools.

RY2016 Fieldwork: Riparian Stem Length

Willms et al. (1998) concluded stem length is a hydrologically sensitive dendrological tool. Results from RY2015's annual branch length (ABI) measurements (REF) indicated likewise, offering a simple, but quantitative measure of annual cottonwood vigor suited to a long-term monitoring plan. Although measuring ABI back to RY2007 or earlier for a given cottonwood branch required expertise/practice, measuring only the current RY's ABI was considerably easier. By carefully selecting distinctive environmental settings within which to annually measure cottonwoods' ABI annually, the ecological performance of dam releases can be reasonably quantified/assessed without demanding a research project. In summer 2016, the following tasks were pursued: (1) sample ABIs within cottonwood stands/floodplains/terraces differing in environmental settings primarily with respect to water availability (i.e., RY2016 will be considered first sampling season) and (2) explore measuring RY2016 ABIs for white willow (and other species as well) (i.e., going back in time to measure ABI may not be feasible, but measuring future annual ABIs seems highly plausible), especially in the lower 4-Floodplain. We opted for a more straightforward terminology in RY2016, replacing 'annual branch length' (ABI) with simply 'stem length.' Subsequent analyses will address two objectives: (1) quantifying median RY2016 stem growth for black cottonwoods and yellow willows, as a quantitative measure of vigor, in each designated stand and (2) assessing stem length variability within species and between stands.

In RY2016 we prioritized measuring stem lengths over a wide range of environmental settings. Figures 8 and 9 locate the trees measured.

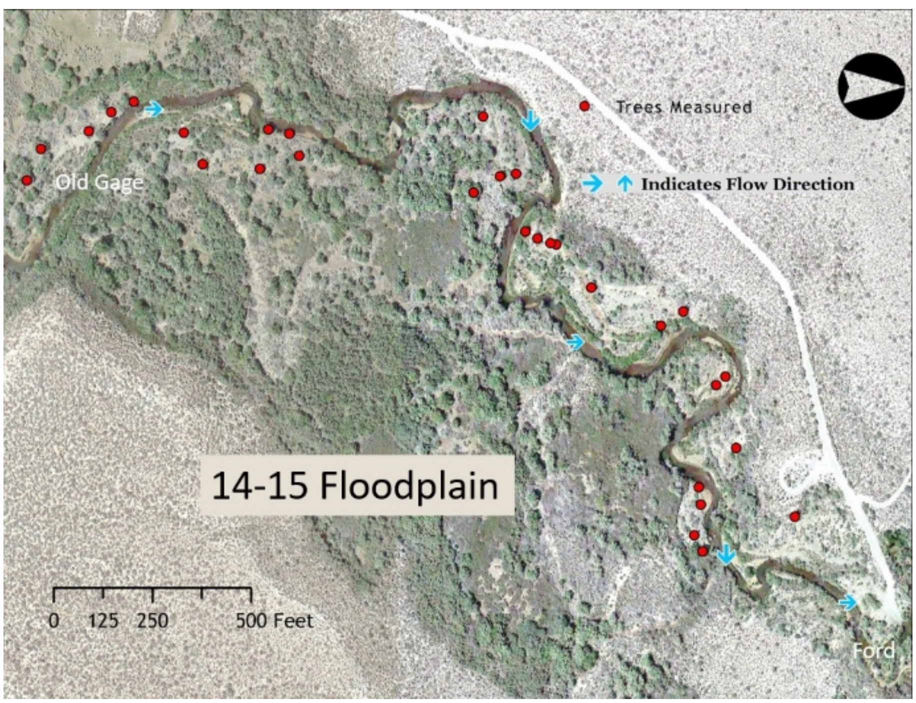

Figure 8. Lower Rush Creek mainstem tree locations for RY2016 (red dots signify trees measured).

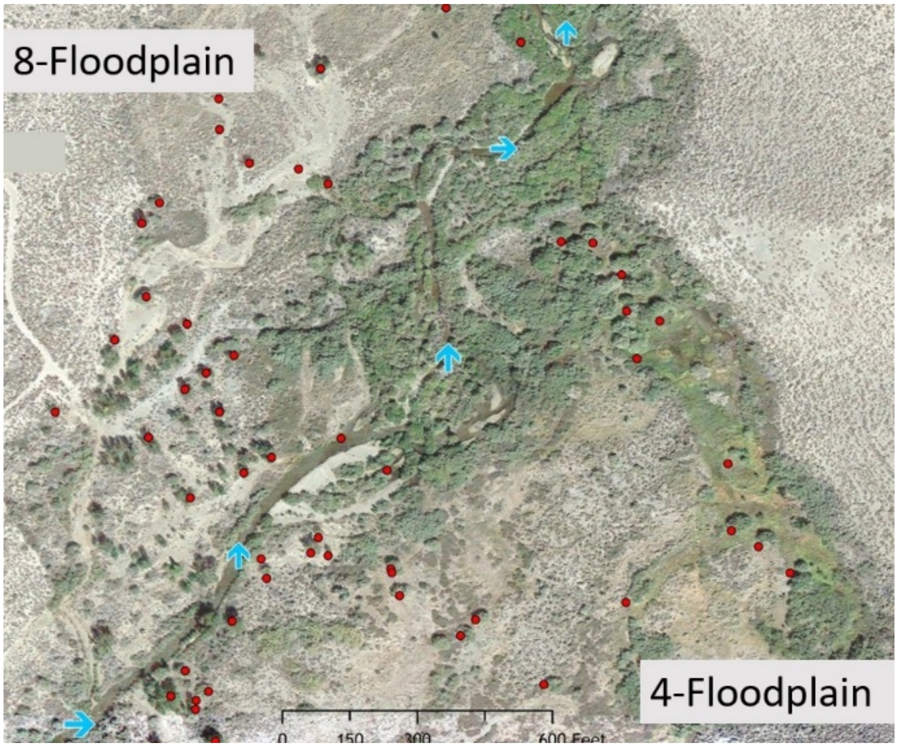

Figure 9. Upper Rush Creek mainstem tree locations for RY2016 (red dots signify trees measured).

Riparian Stem Length: Measurement Protocol

RY2016 stem growth was measured for black cottonwoods (*Populus balsamifera* spp *trichocarpa*) and yellow willows (*Salix lutea*) on September 8 through September 10, 2016 in the Rush Creek bottomlands. The most upstream location was the grove of mature yellow willows at Vestal Springs immediately below the Rush Creek Narrows on the left bank terrace. The most downstream was the LB floodplain immediately upstream of Test Station Road. Stem measurement data from fieldnotes, locations of measured trees/shrubs on the aerial images, and stand designations will be entered into an Excel database.

The number of RY2016 stem length measurements per tree ranged from 10 to 27. Stems were measured equally around each tree. Yellow willow stem lengths were considerably easier to measure than those of black cottonwood because branches were more numerous and closer to the ground. Given this was the first season measuring annual stem lengths, a significant portion of field time was spent selecting sample trees and locating them on the aerial photographs. Depending on (1) the understory, with dense Wood's rose (*Rosa woodsia*) being the most troublesome, and (2) general access to branches, most trees required 14 to 18 minutes to measure for a crew of two. General tree health, particularly variable leaf color/condition and early leaf abscission, was noted.

Riparian Stem Length: Findings and Discussion

Totals of 35 black cottonwoods and 65 yellow willows were measured between September 8 and September 11, 2016. Each sampled tree was located on the prepared satellite images. Spatial coordinates for each sampled tree were computed, and are available on request.

Individual trees were evaluated by first ranking measured stem lengths, then computing the exceedence value (P-value) for each stem measured. Ranking generates a cumulative distribution of stem lengths for each sampled tree more amendable to analysis and interpretation than assigning discrete size classes (of stem lengths) plotted as a histogram. With a focus on keeping the methodology simple, median RY2016 stem length was considered the primary response variable quantifying plant vigor. Stems growing vertically, rather than spreading laterally, oftentimes exhibited extreme RY2016 stem length. Vertical stem orientation was recorded, with these stems excluded from the analysis. Even with this precaution, most trees had a few extremely long RY2016 stem lengths that were included. These generally comprised exceedences (P-values) of 5% to 10%, and exerted minimal effect on median stem length.

We expected water to be less available in the 4-Floodplain Backwater than in the Lower 4-Floodplain (Figure 10) and also expected less water available in Central 4-Floodplain than in Lower Floodplain. But Central 4-Floodplain yellow willow had the longest P=50% stem lengths (Figures 11, 12, and 13). During peak runoff during summer 2016, surface streams may have reached Central 4-Floodplain and improved water availability though briefly. During our measurements, the yellow willows in Central 4-Floodplain were dropping in large numbers of yellowing leaves, whereas yellow willows in Backwater and Lower 4-Floodplain were bright green with no leaves dropping. Stem growth might have been rapid during actual snowmelt, but dropped-off quickly. Total annual stem length might be missing, or mischaracterizing, this process.

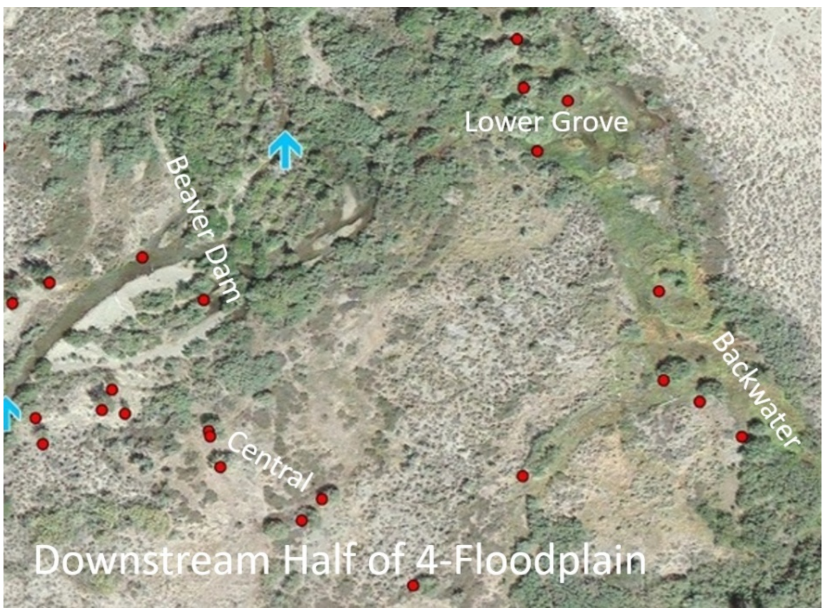

Figure 10. Close-up of lower half of the 4-Floodplain.

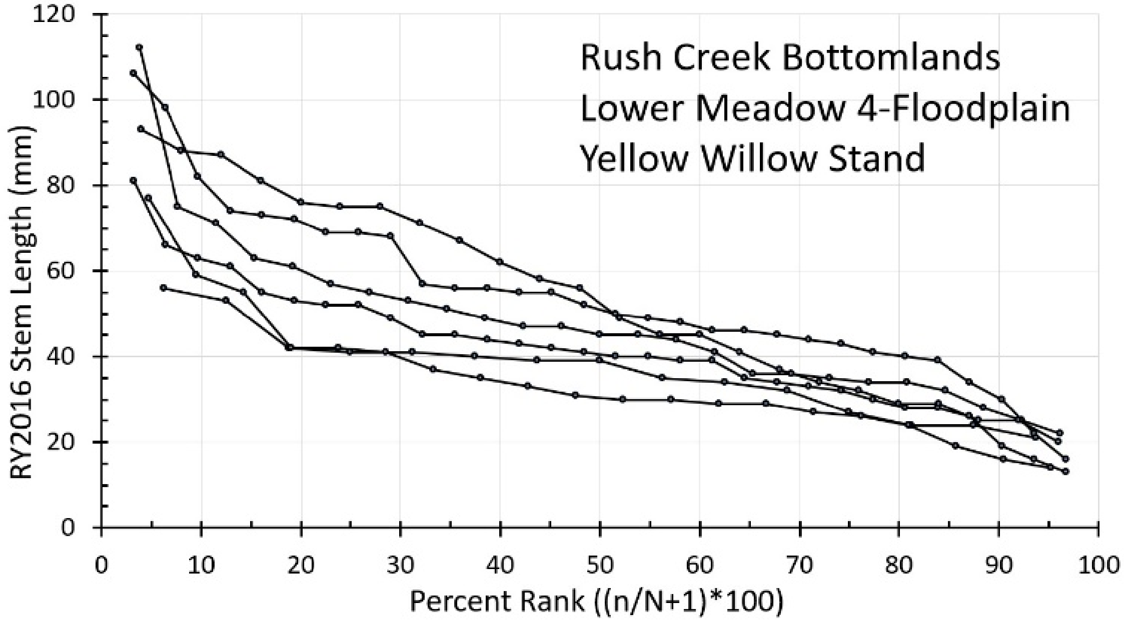

Figure 11. RY2016 annual stem lengths of mature yellow willows (n=6) in Lower 4-Floodplain.

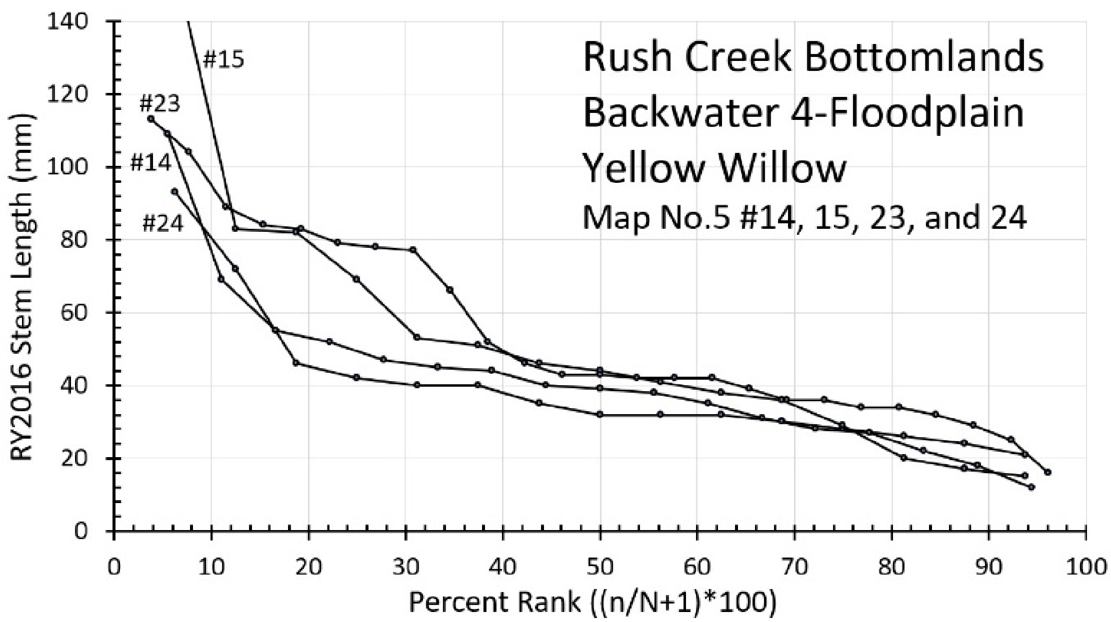

Figure 12. RY2016 annual stem lengths of mature yellow willows (n=4) in the 4-Floodplain Backwater.

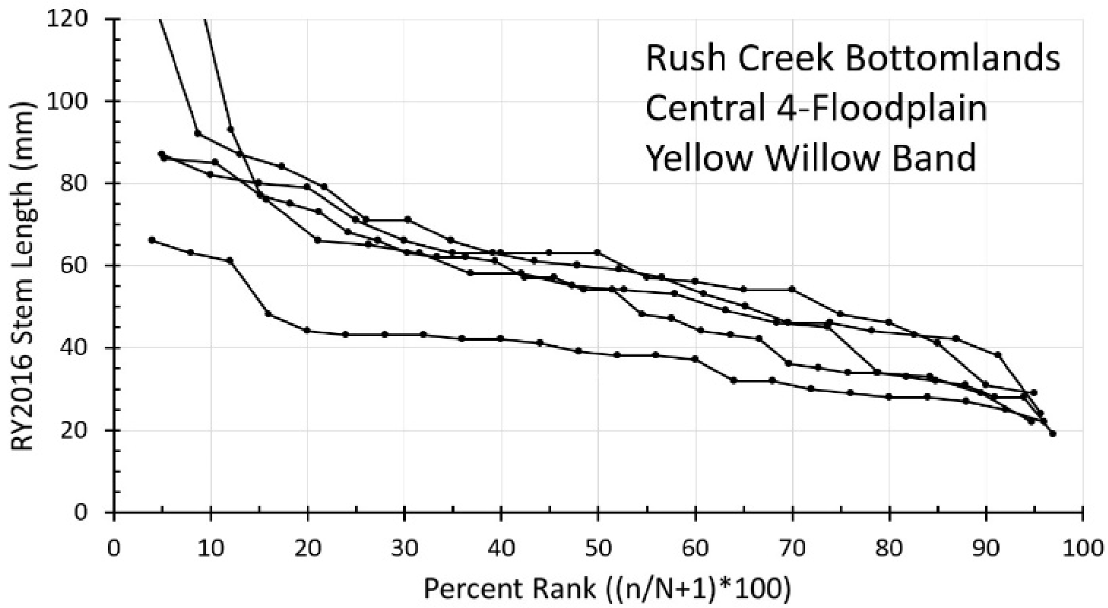

Figure 13. RY2016 annual stem lengths of mature yellow willows (n=5) in central 4-Floodplain.

In other locations, trees were measured to identify a causal mechanism. Three yellow willows were sampled along a contemporary floodplain (Figure 14) immediately upstream of a broad beaver dam. Trees #2 and #3 were situated on top an approximate 3yr-5yr abandoned floodplain; Tree #1, though close to the other two, was situated at a lower elevation, near the base of this abandoned floodplain and with access to the beaver dam's backwater. Median stem lengths differed sharply. A larger sample of upper and lower yellow willows would be necessary to conclusively attribute the beaver dam's backwater lasting into fall as the causal mechanism.

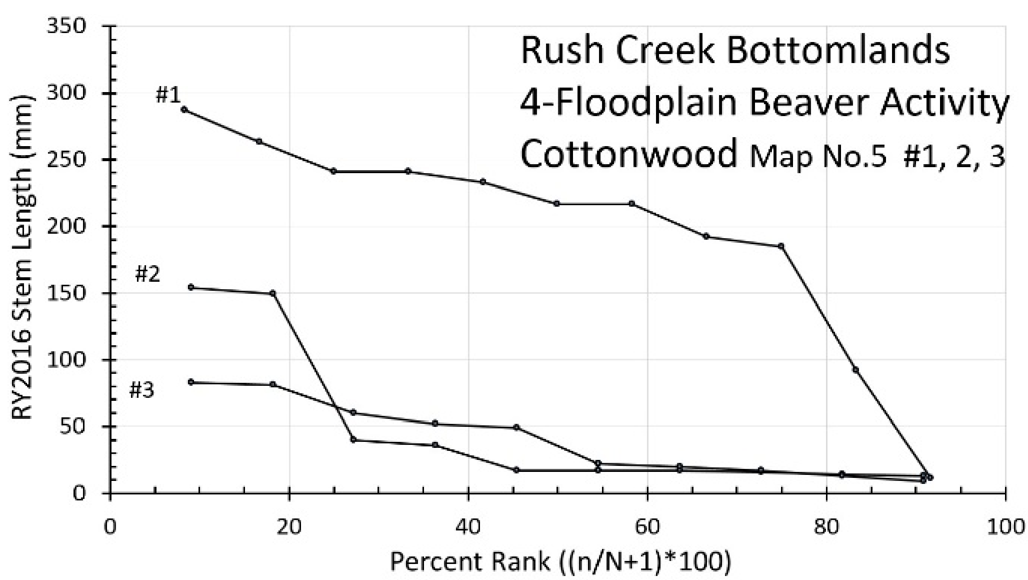

Figure 14. Stem lengths for three yellow willows along the mainstem channel of the 4-Floodpain immediately upstream of a beaver dam.

For comparison, the average stem length for every 10% increment in exceedence was plotted for six sampled locations (Figure 15). At a P-value of 50%, average stem length ranged from approximately 40 mm to 55 mm. Vestal Springs had the shortest P = 50% stem length of 39 mm and the mature grove on Lower 4-Floodplain had the longest at 55 mm (Figure 15). Initially, we considered stem lengths at Vestal Springs Grove might reflect good growth conditions (from experiencing continuously available water), serving as a baseline for future comparisons. However when visiting the site, the springs were not flowing (or even 'seeping'). RY2017 will provide the opportunity for measuring stem lengths under what should be a very favorable growing season.

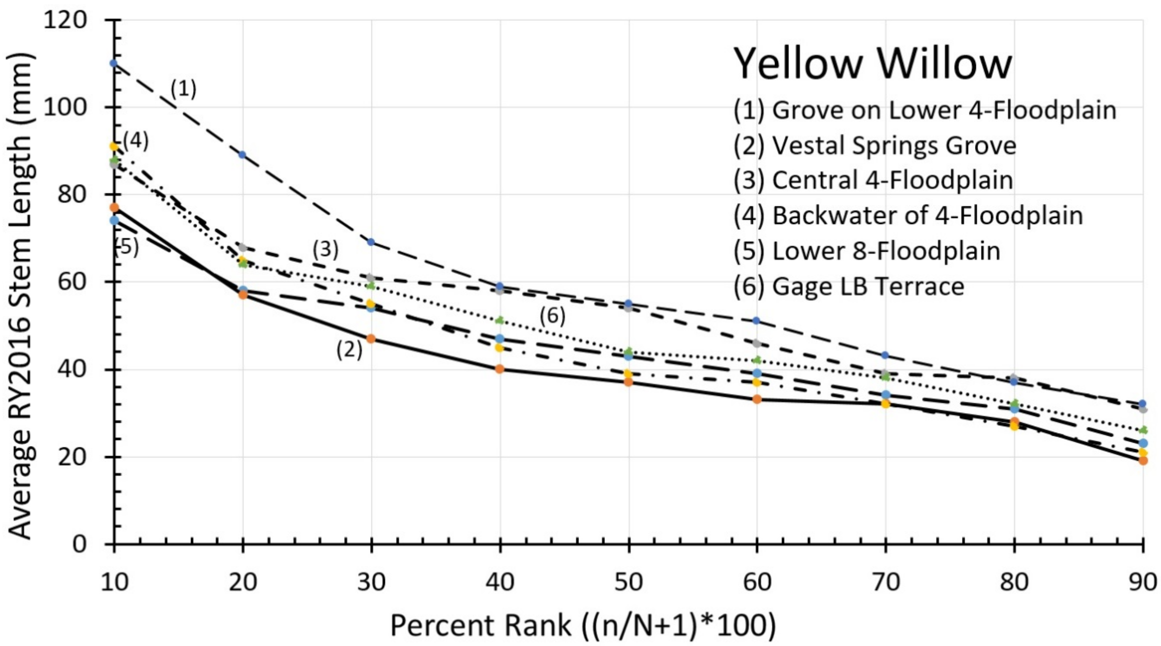

Figure 16. Compilation of average yellow willow stem lengths measured at six locations in RY2016.

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Section 5

Mono Lake Waterfowl and Limnology Monitoring
2016-17

Waterfowl Director Statement
Mono Lake Waterfowl Population Monitoring
Mono Lake Limnology Monitoring

Mono Basin Waterfowl Habitat Restoration Monitoring

2016 Mono Lake Compliance Report

In 2016 the Los Angeles Department of Water and Power (LADWP) conducted the following monitoring in compliance with the 1996 Mono Basin Waterfowl Habitat Restoration Plan (Plan) (LADWP 1996) and the reports are contained within:

- Summer waterfowl ground counts, brood surveys and documentation of habitat use
- Fall aerial waterfowl surveys at Mono Lake, Bridgeport Reservoir and Crowley Reservoir
- Still-image photography of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoir taken from a helicopter
- Lake limnology including meteorological, physical/chemical, phytoplankton, and brine shrimp population monitoring
- Surveillance for saltcedar (*Tamarix* spp.) during summer waterfowl surveys

Summary of Findings

The 2016 runoff year in the Mono Basin (April 1, 2016 - March 31, 2017) was a "dry/normal" year type with 79% of average runoff predicted. This was the fifth consecutive dry year, and the gradual decline in lake elevation that began in spring of 2012 continued due to ongoing drought. Mono Lake dropped a total of 1.2 feet in 2016 to a low of 6377.1 feet by December. In 2016 Mono Lake was at its lowest elevation since 1996 when the Mono Basin Waterfowl Restoration Plan was adopted.

Waterfowl

Over the last four years, the decline in lake elevation has resulted in the gradual drying of many seasonal and semi-permanent ponds used by breeding waterfowl. Conditions for breeding waterfowl in 2016 were not favorable in many lakeshore segments and all summer breeding waterfowl population indices were below the long-term 2002-2016 mean.

Although waterfowl numbers were below average at Mono Lake and Bridgeport, elevated use of Crowley Reservoir resulted in a Mono flyway count that did not differ from the long-term mean. There has been no trend in overall waterfowl numbers at the Mono flyway level or at the individual waterbodies, however data indicates a shift in use between the lakes by certain species. A significant reduction in use of Mono Lake and

Bridgeport by Ruddy Ducks has been accompanied by an increase in numbers of this species at Crowley. Data also indicate a shift in use of Northern Shoveler from Bridgeport to Crowley, and potentially to Mono Lake.

Total fall waterfowl numbers at Mono Lake and Crowley Reservoir are not related to lake elevation when evaluated on a lakewide scale; however additional analysis may reveal changes in spatial distribution in response to lake elevation at other spatial scales. Waterfowl use of Bridgeport has been negatively correlated with reservoir level.

Limnology

In 2016, Mono Lake experienced holomixis or complete autumnal mixing for the fifth year in a row. Mean adult *Artemia* abundance was 39% higher in 2016 compared to 2015 but still remained almost 50% below the long-term average. Peak adult abundance was similar to what observed in 2015. The declining trend of centroid was reversed in 2016 due to a broader peak of *Artemia* abundance as the centroid shifted from 185 days in 2015 to 220 days in 2016, 10 days above the long term average.

Epilimnionic water temperature was above normal between February and May but below normal for the rest of 2016 while hypolimnetic water temperature was above normal for all but one month and mostly lower than what observed in 2015. Summer water clarity remained very low as epilimnetic chlorophyll *a* levels were mostly above normal even though the levels were lower than what observed in 2015. Salinity continued to rise due to declining lake level.

Very low *Artemia* abundance in the past 3 years may be attributable to a combination of many factors, which include but are not limited to: 1) warmer hypolimnetic water temperature due to warmer ambient temperature, 2) higher salinity due to declining Mono Lake elevation, 3) lower than normal epilimnetic dissolved oxygen, 4) lower adult abundance in 2014 due to lower peak abundance during the breakdown in 2013 and higher reduction of 48% afterword, 5) progressively lower peak mean abundance during the breakdown of meromixis, and 6) weaker stratification due to decreased magnitude and/or duration of Mono Lake input. A temporal shift in peak occurrences of adult and instar abundance is most likely due to: 1) warmer hypolimnetic water temperature due to warmer ambient temperature, 2) higher food availability, and 3) possible changes in plankton communities. Despite these changing conditions brine shrimp reproductive strategies enable them to persist throughout both changing lake mixing regimes and periods of sometimes rapidly changing lake levels.

Recommendations

SWRCB Order WR 98-05 directed LADWP to implement restoration measures in the Plan and conduct monitoring to assess the success of waterfowl habitat restoration efforts. Under the Mono Basin Implementation Plan (LADWP 2000), waterfowl population monitoring in the Mono Basin was to continue until at least the year 2014, or until the targeted lake level (6,392 foot elevation) was reached and the lake cycled through a complete wet/dry cycle. Recovery of lake elevation to the target level is taking much longer than anticipated and predicted by previous models and Mono Lake has not yet reached the targeted lake elevation since implementation of the Plan.

In 2014, a recommendation was put forth that LADWP prepare a synthesis report incorporating monitoring data from all components of the 1996 Waterfowl Restoration Plan: hydrology, lake limnology and secondary producers, vegetation status in riparian and lake-fringing wetland habitat, and waterfowl population surveys and studies. This synthesis report was not completed, however the recommendation still stands. A synthesis of the data collected as part of the Waterfowl Restoration Plan will allow the State Water Resources Control Board, LADWP and interested parties the ability to evaluate the success of waterfowl habitat restoration efforts to date, and the efficiency and efficacy of the program at fulfilling both the requirements and intent of the Plan. Recommendations for modifications to the current program or for management of waterfowl habitat at Mono Lake should be addressed, if warranted.

Debbie House

Debbie House

Interim Mono Basin Waterfowl Monitoring Program Director

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MONO LAKE WATERFOWL POPULATION MONITORING

2016 Annual Report

PREPARED BY DEBBIE HOUSE
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PREPARED FOR STATE WATER RESOURCES CONTROL BOARD
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March 2017

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EXECUTIVE SUMMARY

Waterfowl populations were monitored in 2016 at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, as a component of the 1996 Mono Basin Waterfowl Habitat Restoration Plan. At Mono Lake, three summer ground surveys were conducted documenting species composition, habitat use and brood production. Six fall aerial surveys were conducted at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, providing an index of waterfowl numbers using each body of water during fall migration. The fall aerial surveys of Bridgeport and Crowley Reservoirs were conducted in order to provide data to determine whether or not long-term trends observed at Mono Lake are mirrored at neighboring Mono County lakes or are specific to Mono Lake.

The 2016 runoff year in the Mono Basin (April 1, 2016 - March 31, 2017) was a “dry/normal” year type with 79% of average runoff predicted. In 2016, Mono Lake was at its lowest level in 20 years, and from the 2016 high in July of 6378.3 feet, dropped an additional 1.2 feet to a low of 6377.1 feet by December.

Conditions for breeding waterfowl at Mono Lake in 2016 were not favorable as waterfowl numbers, total broods, and average brood size were all below the long-term mean. Total number of waterfowl summed over the three summer surveys (521) was below the 2002-2016 average. The four species that used the Mono Lake shoreline habitats for brooding were Canada Goose, Gadwall, Green-winged Teal, and Mallard. Total brood number (33) and average brood size (4.4) in 2016 were below the 2002-2016 mean. The habitats where waterfowl were observed most frequently were ria, mudflats, brackish ponds, and freshwater ponds.

The total of 108,624 waterfowl recorded at all three lakes during the six fall aerial surveys did not differ from the long-term mean. Fall aerial surveys of Mono Lake recorded 15,275 individuals and thirteen waterfowl species which was below the long-term mean. Data indicate a significant downward trend in Ruddy Duck use at Mono Lake coinciding with an upward trend in use of Crowley Reservoir. Fall waterfowl use was concentrated primarily in the Wilson and Mill Creek area along the northwest shore.

Bridgeport Reservoir supported 28,279 waterfowl which was below the long-term mean. As waterfowl use has been correlated with reservoir level at Bridgeport, the continuing drought and low water levels at this site may be a factor in the reduced use.

The total of 64,986 waterfowl recorded at Crowley Reservoir in 2016 was above the long-term mean.

At the restoration ponds, 47 waterfowl of four species and five broods were observed during summer ground counts. Fall aerial counts recorded 75 waterfowl of six species.

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population survey and study requirement set forth in compliance with the State Water Resources Control Board (SWRCB) Order No. 98-05. The waterfowl monitoring program consists of summer ground counts at Mono Lake, fall migration counts at Mono Lake, fall comparative counts at Bridgeport and Crowley Reservoirs, and photos of waterfowl habitats taken from the air. Three summer ground counts and six fall aerial surveys were conducted at Mono Lake in 2016. Six comparative fall aerial counts were completed at Bridgeport and Crowley Reservoirs. Photos of shoreline habitats were taken from a helicopter on December 20, 2016.

2016 Mono Lake Waterfowl Population Monitoring
Los Angeles Department of Water and Power
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INTRODUCTION

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

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

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

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

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

Summer ground surveys were conducted in order to determine the size of the breeding and/or summering population, species composition, spatial distribution and habitat use of waterfowl during the summer. Aerial surveys were conducted to document waterfowl abundance, species composition and spatial distribution at Mono Lake during fall migration. Fall waterfowl surveys were also conducted at Bridgeport and Crowley Reservoirs in order to provide data to evaluate whether long-term trends observed at Mono Lake are mirrored at neighboring Mono County lakes or are specific to Mono Lake.

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

DESCRIPTION OF SURVEY AREAS

Under the Mono Basin Waterfowl Restoration Plan, waterfowl surveys were conducted at Mono Lake and two nearby lakes - Bridgeport Reservoir and Crowley Reservoirs in Mono County, California (Figure 1). Just east of the town of Lee Vining, Mono Lake is almost centrally located in Mono County. Bridgeport Reservoir is approximately 36 km northwest of Mono Lake near the town of Bridgeport, while Crowley Reservoir is approximately 50km southeast of Mono Lake, and 20 km southeast of Mammoth Lakes.

Mono Lake

Mono Lake is the largest lake in Mono County with a surface area of approximately 223 km^2. Mono Lake is a terminal saline lake whose waters are more than twice as saline as ocean water. Mono Lake is fed by several perennial streams that originate from the eastern slope of the Sierra Nevada and flow into the west side of the lake, the largest of which are Rush Creek, Lee Vining Creek and Mill Creek. There are also numerous springs located throughout the basin and around the lakeshore that support the growth of wetland vegetation and create additional fresh and brackish water resources for waterfowl.

As a component of the Waterfowl Restoration Plan, lake-fringing vegetation has been mapped approximately every five years. Lake-fringing habitats at Mono Lake include streams, freshwater ponds, brackish ponds and hypersaline ponds, unvegetated areas (exposed playa or shoreline), wet meadow, alkaline wet meadow, marsh, riparian woodland and scrublands, and upland scrub. A description of the vegetation communities used for the most recent vegetation inventory conducted in 2014 can be found in Appendix 1.

The 2016 runoff year in the Mono Basin (April 1, 2016 - March 31, 2017) was a “dry/normal” year type (see Order WR 98-05) with a predicted runoff of 79% of the 1951-1990 average (Western Climate Center-Mono Lake/Lee Vining stations). During the 2016 runoff year, Mono Lake was at its highest in elevation in July, at 6,378.3 feet. The lake level steadily declined throughout the year after July, lowering an additional 1.2 feet to a low of 6377.1 feet in December (http://www.monobasinresearch.org/data/levelmonthly.php). In early summer (June) the lake level was 6378.2 feet, or 0.9 feet lower than it had been during the same time in 2015. The lake level continued to decline through the summer and at the start of fall surveys in September, the elevation was 6377.7 feet, which was 0.7 feet lower than September 2015.

Mono Lake Shoreline Segments

The Mono Lake shoreline was divided into 15 lakeshore segments in order to document the spatial use patterns of waterfowl (Figure 2). The segment boundaries are the same as those used by Jehl (2002), except for minor adjustments made in order to provide the observer with obvious landmarks that are easily seen from the air during fall aerial surveys. Coordinates forming the beginning of each segment were derived from the 2002 aerial photo of Mono Lake (2002 aerial image taken by I. K. Curtis, and processed by Air Photo, USA) and can be found in Appendix 2, along with the four-letter code for each lakeshore segment. Photos taken from a helicopter at all lakes on December 21, 2016 are used below to describe areas surveyed in 2016.

DeChambeau Creek (DECR)

DeChambeau Creek lies along the northwest shore. Flows in DeChambeau Creek are intermittent and do not reach the lakeshore, however freshwater resources are abundant as there are numerous springs in this area (Figure 3). Based on the most recent mapping in 2014, wet meadow, mudflat and riparian shrub with lesser amounts of marsh are the main vegetation types. Based on 2014 mapped conditions, approximately half the area is exposed playa. In 2016, the wet meadows, mudflats, and riparian shrub areas of DeChambeau Creek showed signs of drying, and many shrub willows in the meadow appeared to be very water-stressed. In 2016 the exposed playa in this area was also unusually dry, and appeared drier than in 2015. Downcutting along the spring channels continued to affect this area.

Mill Creek (MICR)

Mill Creek, Mono Lake's third largest tributary originates in Lundy Canyon. Mill Creek water has never been diverted for export, but creek flows have been diverted historically for hydropower, with return flows diverted to the Wilson Creek drainage. Diverted Mill Creek water has most recently been used by multiple water rights holders including Mono County, Bureau of Land Management and private land owners for fish-rearing and irrigation. Historically, water diversions have affected Mill Creek riparian vegetation. Under the Mono Lake Water Right Decision 1631, the State Water Resources Control Board indicated that the allocation of water between Mill Creek and Wilson Creek would be addressed with respect to restoration and protection of Mono Lake resources (SCE 2007). Following several years of negotiations between stakeholders, an amended Federal Energy Regulatory Commission License was issued to Southern California Edison (SCE) in which SCE proposed to install the necessary infrastructure needed to return desired flow to Mill Creek, downstream of the powerhouse (SCE 2011). This work has not yet been completed due to difficulties in obtaining necessary easements.

Unvegetated streambar areas primarily associated with the abandoned channel of Mill Creek are the most abundant habitat type in this area. In the vicinity of the active channel, riparian shrub, wet meadow, and barren shoreline are the dominant habitat types. In 2016, shoreline retraction seemed less apparent in the Mill Creek delta than other areas. Extensive beaver activity continues in the delta, creating waterfowl habitat suitable for brooding and feeding (Figure 4). There appeared to be additional die-off of the canopy of the shrub willows along Mill Creek in the vicinity of the beaver ponds as compared to last year. Heavy recruitment of willows and numerous tamarisk (*Tamarisk* sp.) seedlings were noted in the exposed delta soils. Tamarisk seedlings were pulled, and Dave Marquart, California State Park Ranger was notified.

Wilson Creek (WICR)

Wilson Creek is along the northwest shore. The Wilson Creek area supports the highest proportion of water features of any of the lakeshore segments. Meadow habitats including wet meadow, alkali meadow, and rabbitbrush meadow are the dominant vegetation types. Several significant springs also occur in this area, leading to the creation of mudflats at most lake elevations observed.

Significant changes were observed in the Wilson Creek area with the additional drop in lake elevation. The water level had receded to a point at which there was no longer a protected bay in this area (Figure 5). All of the springs in the Wilson Creek area continued to maintain connectivity with the lake. The small beaver dam near the outflow of Black Point Seep was still present but filling in with cattails and no waterfowl were observed using the pond in 2016. An outflow channel along western boundary of this area has significant downcutting, with the channel now at least 5 feet deep.

Black Point (BLPO)

Black Point is a volcanic hill on the northwest shore of Mono Lake. Existing alkali and wet meadow vegetation occurs primarily upgradient of the shoreline. Exposed shoreline comprises almost 60% of the area. In 2016, the Black Point shoreline area was dry and appeared to lack notable waterfowl resources (Figure 6).

DeChambeau Embayment (DEEM)

The DeChambeau Embayment area lies just east of the historic DeChambeau Ranch, and the DeChambeau and County Restoration ponds. Historically, conditions in this area may have been influenced by irrigation of DeChambeau Ranch. Vegetation in this area, dominated by alkali and wet meadow, is primarily confined to the inland portions of the embayment. Several small springs flow into the lake in this area, the largest of which is Perseverance Spring (Figure 7). The decrease in lake elevation over the last several years has resulted in large expanses of exposed playa and pumice blocks. The shoreline expansion in the DeChambeau Embayment area was minimal along the northern shore, and flow from all major springs in this part of the shoreline continued to reach the lake. From Perseverance Spring south, shoreline recession was similar to that observed in Northeast Shore and Bridgeport Creek, and a landbridge between the mainland and the large flat island northwest of Negit Island was present. The shoreline recession resulted in the unveiling of a hot spring source along a faultline on the north shore, approximately 1 km east of Perseverance Spring. A tall tufa tower was associated with this hot spring. The outflow area around this hot spring was attractive to waterfowl in the fall.

Bridgeport Creek (BRCR)

This shoreline area is at the terminus of the Bridgeport Creek drainage, however there is no surface flow in the creek near the lakeshore. A few small springs exist in this area, but with limited direct discharge to the lake and none in 2016. Alkali meadow, wet meadow, and barren playa are dominant, while open water resources are almost absent. The shoreline in the Bridgeport Creek area continued to recede substantially with decreasing lake levels. In 2016 there were no springs in the Bridgeport Creek area with direct connection to the lake (Figure 8).

Northeast Shore (NESH)

In the Northeast Shore area, groundwater too saline to support vegetation results in extensive areas of barren playa at most lake elevations. Barren playa currently comprises 99% of the Northeast Shore area, and only small amounts of alkali meadow are present. In 2016, a narrow band of water was present along much of the length of the Northeast Shore where groundwater was seeping up at the change in slope (Figure 9).

Warm Springs (WASP)

The Warm Springs area is located on the eastern shore of Mono Lake. The main feature of the Warm Springs area is the permanent brackish pond that is fed by the outflow of Pebble and Twin Warm Springs (referred to as “north pond”) (Figure 10). These and other springs in the area support extensive wet meadow, alkali meadow, and marsh vegetation, primarily around the pond and springheads. A quite notable change in the Warm Springs area from previous years was the drying of large areas of meadow habitat. The alkali and wet meadows in the Warm Springs area are typically inundated, but in 2016, standing water was confined to the brackish pond and the immediate area around the spring channels. The exposed playa at Warm Springs was dry throughout the summer and fall survey period.

Sammann’s Spring (SASP)

The Sammann’s Spring area includes the southeastern portion of the lakeshore. There are numerous springs in the Sammann’s Springs area, supporting large areas of wet meadow and marsh, and several small ephemeral and permanent ponds. The shoreline waterfowl habitat appears to change readily with lake elevation changes at Sammann’s Spring. The decline in lake elevation resulted in additional expansion of unvegetated shoreline. Due to incision as a result of downcutting in response to the drop in lake level, spring flow remained confined to channels in most of the Sammann’s Spring area. As a result, much of the exposed shoreline was dry, except in the vicinity of Abalos Spring, where incision had not taken place. The majority of waterbird activity in the Samman’s Spring area was centered around Abalos Spring. The broad area of exposed playa that existed at Sammann’s Springs in 2016 created conditions in which productive feeding areas on shore were far from nesting habitat for waterfowl (Figure 11). In addition, west of Sammann's Spring faultline, emergent vegetation encroaching on shallow fresh water ponds have decreased the available open water habitat in this area. Permanent to semi-permanent brackish water sources were present through the year just east of the Sammann's Spring faultline (Figure 12), however, the remainder of the Sammann's Springs shoreline to the east was dry. Interestingly, during the late-July survey, east of Samman's Spring (~1.5 km east), was one of the few places where large numbers of brine fly (*Ephydra* sp.) were encountered during June and July. Heavy bird activity was also observed where the brine fly concentration was including large numbers of American Avocet (*Recurvirostra americana*), California Gull (*Larus californicus*), and *Calidris* sandpipers.

South Shore Lagoons (SSLA)

The South Shore Lagoons area includes areas of permanent freshwater ponds supported by springs, and seasonal to semi-permanent ponds supported by groundwater, and ephemeral brackish ponds. The shoreline in this area seems to be particularly influenced by longshore currents transporting sands, forming littoral bars, resulting in the redirection of water resources, and changes in groundwater levels. Dominant community types include wet meadow, rabbitbrush scrub, eolian deposits, and marsh.

Habitat conditions appeared good for breeding waterfowl in the eastern South Shore Lagoons area around Goose Springs (Figure 13). The large freshwater pond noted in 2015 was still present. This large pond remained hydrologically connected through small channels to several smaller ponds closer to the springheads. Sand Flat Spring continued to provide a small amount of open water habitat for waterfowl (Figure 14). Sand Flat Spring supports two small permanent fresh water ponds at the spring source although the lower pond had filled in with vegetation. Fresh water no longer was seeping through the loose sand downgradient of the ponds, thus connectivity to the lake had been disrupted and the shoreline was drier than the last few years. Due to the decreased lake elevation, the westernmost semi-permanent brackish pond remained dry in 2016 (Figure 15). All other ephemeral, seasonal, and semi-permanent ponds in the South Shore Lagoons area were dry.

South Tufa (SOTU)

The South Tufa area is the primary visitor access point to the Mono Lake shoreline and includes a large display of tufa towers. Rabbitbrush scrub, upland scrub, and wet meadow are abundant.

Ephemeral to semi-permanent ponds are common in the eastern portion of this area near Navy Beach in some years. In the South Tufa area, the gradual decrease in lake elevation since 2012 resulted in an increase in exposed unvegetated shoreline. In the west portion of the South Tufa area exposed playa is typically fairly wet due to spring flow forming mudflats, however the exposed playa was fairly dry (see Figure 16) during the summer 2016 surveys, and no further expansion of wetland vegetation onto the playa was noted. To the east in the Navy Beach area (Figure 17), the shoreline is generally drier and sandier than the western portion of South Tufa. A brackish pond that developed in 2014 was still present throughout summer of 2016. By September, the lake level had declined another 0.6 feet and this brackish pond had dried resulting in a dry sandy beach during the fall period.

Rush Creek (RUCR)

Rush Creek, the largest stream in the Mono Basin, has primarily a snowmelt-driven hydrologic regime with peak stream flows occurring during the spring snowmelt season, and reduced flows the remainder of the year. Peak flows typically occur in June or July in any one year, but may also occur in April or May, particularly in dry years (Beschta 1994). There is a long history of water diversion of Rush Creek waters for irrigation dating back to the 1860s. Water diversion by LADWP began in 1941, resulting in a dry channel in the lower reaches of the creek in some years. Notable large runoff events occurring in 1967, 1969, and the early 1980s, caused substantial incision and scouring due to an absence of riparian vegetation to protect the banks and stabilize the soils. Incision of floodplains drained shallow groundwater tables and left former side channels stranded above the newly incised main stream channel (SWRCB 1994). Under Decision 1631, LADWP was required to develop a stream restoration plan and undertake projects to rehabilitate Rush Creek (LADWP 1996). Channel maintenance and flushing flows, referred to as “stream restoration flows” were established in order to mimic seasonal snowmelt runoff, with the magnitude based on the hydrological conditions for the year (SWRCB 1994).

The dominant vegetation types in the survey area are riparian shrub, streambar, wet meadow, and water. Following the release of stream restoration flows, the maximum flow observed in lower Rush Creek in 2016 was 263 cfs on June 13. During the stream restoration flows, downcutting was observed in the Rush Creek delta. This downcutting appeared to cut off flow to a small cross-channel in the delta that provided flow to a fresh water pond along the east side of the delta and these areas dried through the summer. The channel and fresh water pond were low velocity areas in the delta where waterfowl broods have frequently been encountered in previous years. Despite high flows in 2016, water appeared to be even more confined in the delta than in 2015, and much of the delta area quite dry (Figure 18).

Ranch Cove (RACO)

The Ranch Cove shoreline area is a relatively small area located between Rush Creek and Lee Vining Creek. The shoreline area is generally dry, supporting primarily riparian shrub, rabbitbrush, upland scrub, and barren playa. In 2016, the shoreline was dry in fall and supported limited waterfowl resources (Figure 19).

Lee Vining Creek (LVCR)

Lee Vining Creek is the second largest stream in the Mono Basin, has primarily a snowmelt-driven hydrologic regime with peak stream flows occurring during the spring snowmelt season, and reduced flows the remainder of the year. Peak flows typically occur in June or July in any one year, but may also occur in April or May, particularly in dry years. Water diversion by LADWP began in 1941, resulting in a dry channel in the lower reaches of the creek in some years. Most of the impacts to the creek as a result of LADWP diversions occurred downstream of Highway 395 (SWRCB 1994). Under Decision 1631, LADWP was required to develop a stream restoration plan and undertake projects to rehabilitate Lee Vining Creek (LADWP 1996). Channel maintenance and flushing flows, referred to as “stream restoration flows” were established in order to mimic seasonal snowmelt runoff, with the magnitude based on the hydrological conditions for the year (SWRCB 1994).

The dominant vegetation types in the survey area are wet meadow, riparian shrub and forest, and water. Following the release of stream restoration flows, the maximum flow observed in Lee Vining Creek in 2016 was 257.0 cfs on June 8. The entire delta area was flooded during stream restoration flow, however after a return to base flow, water remained confined to the main channel and significant drying of delta vegetation occurred (Figure 20).

West Shore (WESH)

The majority of the West Shore segment is located immediately east of Highway 395, along a steep fault scarp. Several fractured rock gravity springs (LADWP 1987) and two small drainages, Log Cabin Creek and Andy Thom Creek provide fresh water resources along the shoreline. The West Shore area (Figure 21) supports primarily wet meadow habitat with small amounts of riparian scrub and marsh. Minimal additional shoreline retraction was noted in this area resulting in only minor increases in the amount of exposed playa.

Restoration Ponds

The DeChambeau and County Ponds are artificial freshwater pond complexes developed initially in the 1940s. These ponds are flooded using deep artesian wells and water diverted from Mill Creek into Wilson Creek. Management of the restoration ponds is conducted by Inyo National Forest. Both County Ponds were flooded in 2016, however the water level in County Pond East was lower than normal and the water quite muddy. There was little open water visible at County Pond West due to the encroachment of emergent vegetation. DeChambeau Ponds 1 and 5 were dry in 2016, while ponds 2-4 were flooded.

Mono Lake Sectors

Each of these 15 segments was assigned into one of five Sectors, based on the type of sediments found in those sectors, and the mechanism of sediment deposition: streamflow, glacial action, lake deposits, or wind erosion (Loeffler 1977). Loeffler argues that the distribution of these sediment types is important for the understanding of groundwater flow in the basin.

Sector 1 is the western portion of the basin, where streamflow and glacial action have been the principal agents of deposition. Coarse sediments occur in this sector along current and former stream courses. The primary deposits are deltaic sands and gravels. The lakeshore segments in Sector 1 include Lee Vining Creek, West Shore, DeChambeau Creek, Mill Creek, Wilson Creek, and Black Point. There are numerous springs in Sector 1, creating wet shoreline conditions in many places at various lake elevations.

In Sector 2, streamflow and glacial action have been the principal agents of deposition; however, the area is much drier due to the greater distance from the eastern escarpment of the Sierra Nevada and a lack of springs. The shoreline segments included in this sector are Rush Creek and Ranch Cove. The major water source for Sector 2 is Rush Creek, which is the largest stream in the Mono Basin.

Sector 3 along the southern shore, is composed primarily of volcanic sands, deposited by winds and wave action. Shoreline segments in Sector 3 include South Tufa, South Shore Lagoons, and Sammann's Spring. Longshore currents transport sandy sediments in this Sector, contributing to the dynamic nature of shoreline ponds and wetland features.

Sector 4 in the eastern and northeastern portion of the lake is composed of fine lake sediments transported by lake water or wind, with a fine covering of sand transported by wind. Vegetation colonization of exposed playa areas in Sector 4 is limited. Lakeshore segments in Sector 4 are Warm Springs, Northeast Shore, and Bridgeport Creek.

Sector 5 was classified as a transition area composed of sand and silts. The only lakeshore segment in Sector 5 is DeChambeau Embayment.

Bridgeport Reservoir

Bridgeport Reservoir is located in Bridgeport Valley, at an elevation of 6,460 feet. Bridgeport Reservoir is a small reservoir with a surface area of approximately 12 km^2 and a storage capacity of 42,600 acre-feet. The reservoir is rather shallow with a mean depth of 4.6 meter and a maximum depth of 13.3 meters (Horne 2003). Bridgeport Reservoir captures flows from Buckeye Creek, Robinson Creek, and the East Walker River primarily for agricultural use in Nevada. Irrigated pastures border the south and southwestern portion of the reservoir; while Great Basin scrub is dominant along the north arm and east shore.

The three shoreline segments of Bridgeport Reservoir are North Arm, West Bay, and East Shore (Figure 22). The North Arm includes primarily sandy beaches bordered by upland vegetation (Figure 23). The West Bay receives fresh water inflows from Buckeye and Robinson Creeks and the East Walker River, creating extensive mudflat areas adjacent to these creek inflow areas, especially when the reservoir is at higher levels. The East Shore includes some mudflat and meadow areas in the vicinity of the East Walker River, but the majority of the East Shore area is bordered by Great Basin scrub or exposed reservoir bottom.

The water level of Bridgeport Reservoir continued to be well below the maximum storage capacity; however, the water level rose in 2016 and was slightly higher in fall 2016 as compared to 2015. In September 2016, Bridgeport Reservoir held 8,740 acre-feet (Department of Water Resources, California Data Exchange Center, (http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=BDP&d=today), more than doubling the storage present at the same time in 2015, but still well below storage capacity. The increased amount of water in the reservoir as compared to fall 2015 resulted in an increase in the amount of open water habitat primarily in the West Bay.

Crowley Reservoir

Crowley Reservoir is located in Long Valley, at an elevation of 6,780 feet. Crowley Reservoir is the second largest lake in Mono County, and the largest reservoir in the county, averaging 21.4 km^2. Crowley is much deeper than Bridgeport Reservoir with a mean depth of 10.6 meters and a maximum depth of 38 meters (California State Water Resources Control Board 1978). The storage capacity of Crowley Reservoir is 183,465 acre-feet. The major source of fresh water input at Crowley Reservoir occurs via the Owens River. Other fresh water input includes flow from McGee and Convict Creeks, Layton Springs, and subsurface flow from springs along the west shore. Vegetation communities immediately surrounding Crowley Reservoir include irrigated pasture, wet meadow, Great Basin scrub, alkali meadow, and exposed shoreline.

In early September, Crowley Reservoir held 94,649 acre-feet (Department of Water Resources, California Data Exchange Center, (http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=crw&d=today) which represents an 8% decrease in the number of acre-feet as compared to September 2015.

The shoreline of Crowley Reservoir was divided into seven segments (Figure 24, Appendix 2):

Upper Owens

The Upper Owens area includes large areas of exposed mudflats and reservoir bottom adjacent to the mouth of the Owens River. With declining reservoir levels, annual and perennial plant species have colonized areas of exposed reservoir bottom soils adjacent to the river channel in the Upper Owens area (Figure 25).

Sandy Point

Most of the length of Sandy Point area (Figure 26) is bordered by cliffs or upland vegetation. Small areas of meadow habitat occur in this area and limited freshwater input occurs at Green Banks Bay.

North Landing

The North Landing area is influenced by subsurface flows and supports meadow and wet meadow habitat, particularly near the western border (Figure 27).

McGee Bay

The McGee Bay shoreline area (Figure 28) supports vast mudflat areas immediately adjacent to wet meadow habitats. McGee Creek and Convict Creek are tributary to Crowley Reservoir in this shoreline area. Other sources of water include spring flow and subsurface flow from irrigation upgradient.

Hilton Bay

The Hilton Bay area includes Big Hilton Bay to the north and Little Hilton Bay to the south (Figure 29). The Hilton Bay area, surrounded by meadow and sagebrush habitat, receives small amounts of fresh water input from Hilton Creek and spring flow.

Chalk Cliffs

Chalk Cliffs (Figure 30) lacks fresh water inflow areas and wetland habitats, and is dominated by sandy beaches adjacent to steep, sagebrush-covered slopes.

Layton Springs

The Layton Springs shoreline area is bordered by upland vegetation and a large area of sandy beach (Figure 31). Layton Springs provides fresh water input at the southern border of this lakeshore segment.

METHODS

Summer Ground Surveys

Mono Lake

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

Shoreline locations surveyed were those identified in the Plan as current or historic waterfowl concentration areas, namely: South Tufa, South Shore Lagoon, Sammann's Spring, Warm Springs, Wilson Creek, Mill Creek, DeChambeau Creek Delta, Rush Creek Delta, and Lee Vining Creek, and delta. Surveys were also conducted at the restoration ponds north of the lake: DeChambeau and County Ponds.

Shoreline areas were surveyed by traversing the entire shoreline segment on foot, following the shoreline. In Rush Creek and Lee Vining Creek, the survey area included the creek channels from the County Road downstream to the deltas, and only the shoreline area within 100 meters on either side of the deltas. At the Restoration Ponds, observations were taken from stationary points that allowed full viewing of each pond. A minimum of five minutes was spent at each observation point at the DeChambeau and County Ponds.

All summer ground surveys began within one hour of sunrise and were completed within approximately six hours. The order in which the various sites were visited was varied in order to minimize the effect of time-of-day on survey results. Surveys were conducted by walking at an average rate of approximately 1.5 km/hr, depending on conditions, and recording waterfowl species as they were encountered. Total survey time was recorded for each area. The date and time of day for each survey during 2016, are provided in Appendix 3.

The following was recorded for each waterfowl observation: time of the observation; the habitat type being used; and an activity code indicating how the bird; or birds were using the habitat. Examples of activities recorded include resting, foraging, flying over, nest found, brooding, sleeping, swimming, and calling.

Brood Surveys

While conducting summer ground counts at Mono Lake, emphasis was placed on finding and recording all waterfowl broods. Because waterfowl are easily flushed, and females with broods are especially wary, the shoreline was frequently scanned well ahead of the observer in order to increase the probability of detecting broods. Information recorded for broods included species, size, GPS coordinates (UTM, NAD 83, Zone 11, CONUS), habitat use, and age. Broods were aged based on plumage and body size (Gollop and Marshall 1954).

Since summer surveys were conducted at three-week intervals, any brood assigned to Class I using the Gollop and Marshall age classification scheme (which includes subclasses Ia, Ib, and Ic), would be a brood that had hatched since the previous visit. Assigning an age class to broods allowed for the determination of the minimum number of "unique broods" using the Mono Lake wetland and shoreline habitats.

Habitat Use

The habitat being used by waterfowl was recorded in order to evaluate habitat selection by waterfowl at Mono Lake. The habitat categories generally follow the classification system found in Mono Lake Landtype Inventory, 2014 Conditions (LADWP 2014) (Appendix 1). 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 woodland, freshwater stream, ria, freshwater pond, brackish pond, hypersaline pond, and unvegetated. Salinity measurements of ponds were taken using an Extech EC400 Conductivity/TDS/Salinity probe in order to aid in the proper classification of fresh versus brackish ponds when recording habitat use. Ponds with a salinity of less than 500 ppm were classified as fresh. Ponds with vegetation present and a salinity of greater than 500 ppm were classified as brackish. Ponds with a measured salinity greater than 10 g/L (the maximum range of the probe) lacking vegetation and subsurface or surface freshwater inflow were classified as hypersaline. Two additional habitat types: open-water near-shore (within 50 meters of shore), and open-water offshore (>50 meters offshore), were added to the existing classification system in order to more completely represent areas used by waterfowl.

Fall Aerial Surveys

Overview of Methodology

Aerial surveys were conducted in the fall at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir using a small high-winged airplane. A total of six surveys were conducted at two-week intervals, with the first survey beginning during the first week of September, and the final fall survey occurring in the middle of November. In all cases, surveys of all three waterbodies were completed in a single flight by 1200 hours on the day of the survey. A summary of the fall survey schedule has been provided as Appendix 4.

LADWP contracted with Black Mountain Air Service to conduct fixed-winged aerial counts. Black Mountain Air Service has obtained a low-altitude flight waiver from the Federal Aviation Administration in order to conduct these flights. Aerial surveys were conducted in a Cessna 180 at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Observations were verbally recorded onto a handheld digital audio recorder and later transcribed by the observer. Two observers other than the pilot were present on all six flights.

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

Mono Lake

Aerial surveys of Mono Lake consisted of a perimeter flight of the shoreline and a set of fixed cross-lake transects. Waterfowl and shorebirds were censused, with the primary emphasis on counting waterfowl. Each aerial survey began at Mono Lake at approximately 0900 hours.

Shoreline surveys of the perimeter and cross-lake transects require approximately one and one-half hours. Shoreline surveys were conducted over water in a counterclockwise direction while maintaining a distance of approximately 250 meters from shore. The second observer sat on the same side of the plane as the primary observer during the perimeter flight and censused shorebirds and waterfowl.

Crosslake Transects

The cross-lake transects, conducted immediately after the shoreline census, cover open water areas of Mono Lake. The eight transects are spaced at one-minute (1/60 of a degree, approximately one nautical mile) intervals and correspond to those used by Boyd and Jehl (1998) for the monitoring of Eared Grebes during fall migration. The latitudinal alignment of each transect is provided in Appendix 5.

Each of the eight transects is further divided into two to four sub-segments of approximately equal length (Figure 32). The total length of each cross-lake transect was first determined from the 2002 aerial photo. These lengths were then sub-divided into the appropriate number of subsections to a total of twenty-five sub-segments, each approximately 2-km in length. This approach creates a grid-like sampling system that allows for the evaluation of the spatial distribution of species occurring offshore. The beginning and ending points for each subsection were determined using landscape features, or, when over open water, by using a stopwatch, since the survey aircraft's airspeed was carefully controlled and the approximate length of each subsection was known.

During the cross-lake transect counts, observers sat on the opposite sides of the plane and counted Ruddy Ducks and other waterfowl, and phalaropes occurring on the open water.
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. Although the flight path of the aircraft along the latitudinal transects effectively alternated the observer's hemisphere of observation in a North-South fashion due to the aircraft's heading on successive transects, the one-nautical-mile spacing between the transects worked in conjunction with the limited detection distance of the waterfowl (<< 0.5 nautical mile) to effectively prevent double-counting of birds on two adjacent transects.

Bridgeport Reservoir

At Bridgeport Reservoir, the second observer sat on the same side of the plane as the primary observer during the entire survey and assisted in waterfowl counts. The survey flights started at the dam at the north end of the reservoir and proceeded counterclockwise. The distance from shore, flight speed, and height above ground were the same as employed at Mono Lake. Adjustments were made as necessary depending on lighting, lake level, and waterfowl distribution. The reservoir was circumnavigated twice during each survey to allow for a second count of often large concentrations of mixed species flocks.

Crowley Reservoir

At Crowley, the second observer sat on the same side of the plane as the primary observer during the entire survey, and assisted in waterfowl counts. Each survey began at the mouth of the Owens River and proceeded over water in a counterclockwise direction along the shoreline. The distance from shore, flight speed, and height above the water were the same as at Mono Lake during most of each flight. Temporary diversions of distance from shore or height above ground were made by the pilot as necessary to avoid direct or low flight over float-tube recreationists or boats. Adjustments were also made as necessary depending on lighting, lake level and waterfowl distribution. The reservoir was circumnavigated twice during each survey to allow for a second count of often large concentrations of mixed species flocks.

DATA SUMMARY AND ANALYSIS

Summer Ground Count Data

Total waterfowl detections were summed for all three surveys, by individual survey, and lakeshore segment. Descriptive statistics were calculated for each of these indices including the long-term means for the time period 2002-2016. The number of individuals of each species was summed by survey. Spatial distribution patterns for 2016 were evaluated by summing the total waterfowl encountered in each lakeshore segment and comparing the distribution to that of the long-term mean.

The total number of broods by species, survey and lakeshore segment were summed for 2016. Descriptive statistics were calculated on brood data for the time period 2002-2016 including mean total lakewide broods and mean number of broods per lakeshore segment, and average brood size. Although a regular breeding species at Mono Lake, Canada Goose was excluded from the calculation of brood statistics. Canada Geese nest earlier than the other waterfowl species at Mono Lake, and their young broods appear to be highly mobile, raising the suspicion that the same broods are being encountered at multiple locations during any one survey period. Simple linear regression was used to evaluate the relationship between lake elevation and summer waterfowl abundance and total broods.

Waterfowl habitat observations were summed for all species except flyovers. Although a ">50 meter" category was used at the time of data collection, these observations will not be included in the final calculations unless the presence of waterfowl in the open-water offshore zone was determined to be due to observer influence (e.g., the observer sees that a female duck is leading her brood offshore and is continuing to swim away from shore).

The common names and scientific names for waterfowl species encountered can be found in Appendix 6.

Fall Aerial Count Data

Waterfowl survey data were summarized by survey, species, lake and "Mono flyway" (all three lakes combined). Descriptive statistics were calculated for each of these indices including the long-term means for the time period 2002-2016.

Although many factors likely affect waterfowl use of Mono Lake, the primary waterfowl habitat restoration goal identified in the Plan is to increase the level of Mono Lake to the target level of 6,392 feet. From 2002-2016, Mono Lake has experienced two periods of increasing lake elevation followed by decreases in lake elevation, and in 2016 Mono Lake was at the lowest level in 20 years. Waterfowl data were analyzed using simple linear regression to determine if there has been a response to lake elevation changes in this time period. Fall waterfowl populations at Mono Lake were evaluated for correlations between total waterfowl detections. This analysis was also conducted for Bridgeport and Crowley Reservoir as a comparison.

The spatial distribution of waterfowl at each lake was determined by calculating the proportion of all fall detections that occurred in each lakeshore segment. Waterfowl spatial distribution at Mono Lake was evaluated excluding Ruddy Duck.

RESULTS

Summer Ground Surveys

Shoreline waterfowl abundance, distribution and brood counts

A total of 521 waterfowl were recorded during summer surveys over the three surveys at all shoreline segments (Table 1). In contrast to most years when the number of waterfowl seen on the first survey is higher than the subsequent surveys, waterfowl numbers varied little during the summer. The number of waterfowl observed on survey 1 and survey 2 was below the long-term mean, however no decreases were observed when comparing the results of survey 3 (Figure 33). The total number of waterfowl observed summed over all three surveys in 2016 was below the 2002-2016 average of 961 +/-259SE.

Of the ten waterfowl species detected during summer lakeshore counts, (Table 1) breeding was confirmed for Canada Goose, Gadwall, Green-winged Teal and Mallard. Cinnamon Teal, Northern Pintail, and Ruddy Duck have nested around Mono Lake in previous years, but no evidence of nesting by these species was seen around the shoreline in 2016. Species encountered in 2016 which were transitory or over-summering individuals, included Redhead, Blue-winged Teal, Brant, and American Wigeon. The most abundant breeding species was Gadwall accounting for 43% of all detections (224/521). Other common species were Canada Goose (29%), Mallard (13%) and Green-winged Teal (8%).

The majority of waterfowl were found either in the Mill Creek area, South Shore Lagoons, or along the northwest shore in the DeChambeau Creek, and Wilson Creek areas (Figure 34). The fewest number of waterfowl were found at Warm Springs, Lee Vining Creek and Rush Creek. Waterfowl use was below the long-term mean in all shoreline areas except South Tufa (Figure 34).

Dabbling duck species breeding in the lake-fringing wetlands and creeks at Mono Lake in 2016 were Gadwall, Green-winged Teal, and Mallard (Table 2). In addition, up to seven Canada Goose broods were seen in 2016. The number of *Anas* species broods observed in 2016 at Mono Lake was below the 2002-2016 mean of 60.0 +/-5 SE. A total of 33 broods were found, the majority of which were Gadwall (19/33; 57%). Three Mallard and four Green-winged Teal broods were also found. Most waterfowl broods were found in the South Shore Lagoons area, primarily around Goose Springs (Figure 35). No broods were seen at Sammann's Springs, South Tufa or Warm Springs. The number of broods was below the long-term mean at all shoreline locations except South Shore Lagoons and Lee Vining Creek. Waterfowl with broods in the Lee Vining Creek area were seen to the south of the delta, while no broods were seen in the delta proper. The average brood size of 4.4 for dabbling ducks species in 2016 was below the long-term mean of 6.0 +/- 0.13 SEM.

Waterfowl use increases in summer as a function of increases in Mono Lake elevation in June ($r = 0.653$, $p = 0.008$, Figure 36). Waterfowl reproduction is also affected by lake elevation changes as the number (($r = 0.79$, $p < 0.01$) and size ($r = 0.754$, $p < 0.01$) of broods is positively correlated with lake elevation (Figure 37).

Habitat Use

The habitats waterfowl were observed in most frequently were ria (outflow areas of springs and creeks), mudflats, brackish ponds and freshwater ponds (Table 3). Broods were seen primarily in freshwater ponds and ria. Canada Goose were observed on mudflats with their broods, feeding on newly sprouted wetland vegetation. Most observations of waterfowl foraging were in ria, although mudflats, brackish ponds, and open water areas near shore were also used frequently. Ria was the main habitat type used for resting and sleeping.

Fall Aerial Surveys

Fall Aerial Survey Weather Conditions

Several wet weather systems affected Mono County in fall, bringing high winds, rain and snow to the mountains, and some flight delays. High winds associated with a cold front resulted in a two-day delay in conducting the second survey in September. In mid-October, a cold front with high winds and significant moisture affected the area a few days prior to the October 19 survey. No ice was evident in any of the areas surveyed during the mid-November flight.

Waterfowl Counts

A total of 108,624 waterfowl were recorded at the three lakes during the six fall counts. Although waterfowl numbers were below average at Mono Lake and Bridgeport, elevated use of Crowley Reservoir resulted in a Mono flyway count that did not differ from the long-term mean (Figure 38).

The fewest waterfowl species (13) and lowest number of total waterfowl (15,275) were observed at Mono Lake (Table 4). The majority of the waterfowl species at Mono Lake were the dabbling duck species Northern Shoveler (*Anas clypeata*) and Northern Pintail (*Anas acuta*) and the stiff-tailed Ruddy Duck (*Oxyura jamaicensis*). The numbers of geese and diving duck species at Mono Lake were low compared to the two reservoirs. Bridgeport Reservoir, supporting almost twice as many waterfowl as Mono Lake was more diverse with a large population of geese and a more diverse and abundant diving duck component. Dabbling ducks were also more diverse and abundant at Bridgeport than Mono Lake. The species composition differed as Gadwall was the most abundant, followed by Northern Shoveler, Green-winged Teal and Northern Pintail. Crowley Reservoir supported more than four times the number of waterfowl observed at Mono Lake. Similar to Bridgeport Reservoir, geese were abundant and diving ducks more abundant and diverse. Ruddy Duck was the most abundant waterfowl species at Crowley in 2016. Similar to Bridgeport, dabbling duck species were abundant and diverse, however species composition differed slightly as Northern Shoveler, Green-winged Teal, Northern Pintail and Mallard were most abundant.

Waterfowl numbers at Crowley were consistently higher throughout fall than either Mono Lake or Bridgeport Reservoir. Seasonal use of Mono Lake differed from the reservoirs in that use was highest early September and then decreased through fall (Figure 39). Waterfowl at Bridgeport tended to decline through fall, although a second smaller peak occurred in mid-November, while numbers at Crowley remained fairly high through November.

There has been no trend in overall waterfowl numbers at the Mono flyway level or at the individual waterbodies, however data indicates a shift in use between the lakes by certain species. Overall there has not been any trend in Ruddy Duck flyway numbers, however a decreasing trend in both the absolute number and proportional abundance of Ruddy Ducks at both Mono Lake ($r=0.674$, $p<0.01$) and Bridgeport ($r=0.667$, $p<0.1$) has been accompanied by significant increase in Ruddy Duck use of Crowley Reservoir ($r=0.746$, $p<0.01$)(Figure 40). Northern Shoveler flyway numbers have remained stable overall, however there has been a trend of decreasing use of Bridgeport ($r=0.620$, $p<0.1$). This use appears may have shifted primarily to Crowley Reservoir ($r=0.698$, $p<0.01$) as a there has been a trend toward increased proportion of flyway numbers. Visually, it appears that decreased use of Bridgeport has been accompanied by increased proportional use of Mono Lake by Northern Shovelers (Figure 41), however, this relationship was not statistically significant ($r=-.343$, $p=0.23$).

The elevation of Mono Lake and of the reservoirs could directly and indirectly affect waterfowl habitat availability and habitat quality. Although not statistically significant, there has been a tendency for Mono Lake to attract a greater proportion of the overall waterfowl with increasing lake elevation ($r=0.227$, $p=0.4$) (Figure 42). Waterfowl use of Bridgeport has been related to reservoir elevation as the proportion of all waterfowl found at Bridgeport has been significantly positively correlated to reservoir storage ($r=0.857$, $p<0.01$). Crowley tends to support a higher proportion of all waterfowl at lower levels, and decreasing amounts at higher elevations, but this relationship was not found to be significant.

Spatial Distribution

Shoreline use by fall waterfowl at Mono Lake was primarily in two areas - the northwest shore area (Sector 1) and the DeChambeau Embayment. Wilson Creek (Sector 1) continued to be a high use area and attracted over 68% of all waterfowl. Use of DeChambeau Embayment was above the long-term mean, and most waterfowl in this area were seen in the vicinity of hot spring newly exposed with declining lake elevation (photo). Use of the south shore (Sector 3) was reduced in 2016 (Figure 43).

Waterfowl distribution varies little at Bridgeport and 2016 was similar to previous years with the majority of all waterfowl occurring in the West Bay area. At Crowley Reservoir, the main areas of waterfowl use, McGee Bay and Upper Owens, attracted proportionally more waterfowl than usual.

Mono Lake Restoration Ponds

A total of four species and 47 waterfowl were detected at the Restoration Ponds during summer surveys (Table 7). Most of the waterfowl use was in DeChambeau Pond 4 and County Pond East. The most abundant species at the Restoration Ponds were Gadwall, Cinnamon Teal and Ruddy Duck. As was the case on the shoreline, a low number of broods were seen at the Restoration Ponds. The five broods observed at DeChambeau Pond 4 – two Gadwall, two Ruddy Duck, and one Cinnamon Teal was below the long-term mean of 9.1 +/0.96 SE) (Table 8).

A total of 84 waterfowl were recorded at the Restoration Ponds in fall (Table 9). This was well below the long-term mean of 363 +/- SEM 154. Waterfowl were seen primarily in DeChambeau Ponds 2, 3 and 4. County Pond East received very limited use, and no waterfowl were recorded at County Pond West.

SUMMARY

Based on waterfowl counts and field observations, conditions for breeding waterfowl at Mono Lake in 2016 were not favorable as waterfowl numbers, the total broods, and average brood size were all below the long-term mean. Declines in breeding waterfowl use at many lakeshore segment areas may be due in part to changes observed in habitat quality as a result of declines in lake elevation. At Mono Lake, waterfowl and their broods are most often observed feeding onshore at the outflow of creeks or springs around the lake, or in the somewhat limited and broadly-dispersed fresh water ponds. At higher lake elevations, these preferred feeding areas are in closer proximity to one another, and also closer to cover afforded by adjacent wetland vegetation. Shoreline retraction observed in many areas in 2016 has led to a notable increase in the distance between preferred feeding areas and vegetation for breeding and cover for adults and ducklings. Changes such as these have likely contributed to reductions in specific areas such as Sammann's Spring which has shown a decrease in breeding waterfowl use over the last four years, and an absence of broods in 2016.In some years, Sammann's has supported as many as 18 broods and 20% of all broods in a single year. Breeding waterfowl use of South Shore Lagoons area was maintained despite similar shoreline retraction. In this area, a series of open, freshwater ponds is present around Goose Springs, including a large freshwater pond that developed due to the formation of a large sandbar that is preventing direct spring flow to the lake. These freshwater ponds continued to support breeding waterfowl due to their open water nature, and adjacent cover that provide protection from predators and support invertebrate populations. Brooding female ducks generally select habitats that have high invertebrate populations and dense vegetative cover (Baldassarre and Bolen 1994) and seasonal wetland availability has been shown to have a positive effect on duckling survival (Pietz et al 2003). Near-shore ponds, when present, provide invertebrates required by ducklings for growth and development, and often dense vegetative cover nearby. Increasing distance between nesting areas, feeding areas, and protection from predators not only can increase exposure time of ducklings to predation, but can increase energetic costs to adults and ducklings alike.

Although the largest lake in Mono County, waterfowl use of Mono Lake continues to be lower on average than either Bridgeport or Crowley Reservoir and was below the long-term mean in 2016. Since implementation of the Mono Basin Waterfowl Habitat Restoration Plan, Mono Lake has undergone fluctuations in lake elevation, including substantial decreases in elevation over the last few years resulting in the lowest lake elevation in 2016 in 20 years. Increasing the water surface elevation is the primary means of restoring waterfowl habitat at Mono Lake. To date, no significant relationship has been observed in fall use by waterfowl in response to changes in Mono Lake elevation; however the limited range of elevations observed (6377 feet-6385 feet) may account for this in part. The lack of a direct relationship between fall use by waterfowl and Mono Lake elevation may be due to a few different factors. Dabbling duck use has been confined primarily to areas with fresh water influence, namely spring outflow areas, fresh water ponds and brackish ponds. Due to the dynamic nature of the Mono Lake shoreline, the abundance of these habitat types is not directly correlated with lake elevation. The varying effects of lake elevation changes, wind, erosion, and even variations in rainfall across the landscape lead to habitat conditions that change seasonally and yearly.

The fall comparison data suggests that waterfowl may be responding to local conditions in their choice of stopover location, however factors affecting habitat condition may vary between sites. Trends in fall results suggest that as conditions at Bridgeport have changed over the years (i.e. decreasing water levels), use of Crowley Reservoir by fall migratory waterfowl in the region has increased. The fluctuations in level of Bridgeport have not resulted in overall reductions in flyway waterfowl populations, but rather a possible shift in use to Crowley. Although water levels and conditions at both Bridgeport and Crowley Reservoirs have varied in response to climate and weather, the small size and shallowness of Bridgeport Reservoir as compared to Crowley may result in greater variability of surface area of waterfowl habitat in response to changes in water inputs to the reservoir. Fall waterfowl use of Bridgeport Reservoir has been influenced by water levels either directly or indirectly. Water levels at Bridgeport appear to influence waterfowl habitat primarily by affecting the amount of flooding at the south end of the reservoir, where the majority of waterfowl congregate. The south end of the reservoir is expected to have the best feeding areas for migratory waterfowl as these areas are adjacent to creek inflows, shallow areas preferred by most species of dabbling ducks, and seasonally-flooded irrigated pastures and meadows. Due to the gradient of the land at the south end of the reservoir, small increases in reservoir level can result in significant flooding. Changes in food quality or quantity or accessibility may also occur with lowered reservoir levels or reduced inflows.

Although no trend has been detected in the Ruddy Duck Mono flyway population, Ruddy Duck numbers at Mono Lake have been declining steadily since 2003, with a precipitous drop in numbers over the last four years. Conversely, Ruddy Duck populations have been increasing at Crowley Reservoir. These results suggest that Ruddy Duck numbers may not have been significantly decreased in the region, but are responding to conditions at Mono Lake in particular. A change in food resources at Mono Lake is one possible explanation for reduced numbers of Ruddy Ducks at Mono Lake. Johnson and Jehl (2002) state that alkali fly larvae appear to be the main food item of Ruddy Ducks at Mono Lake in fall. Although no data are available on alkali fly populations, I noted during summer surveys in 2016 what appeared to be greatly reduced numbers of adult alkaline flies on shore. Alkali flies require firm substrates such as pumice blocks, tufa, or beach rock (Jones and Stokes 1993) to attach their pupae to. Due to the decreases in lake elevation, many firm surfaces associated with shoreline areas such as pumice blocks in the DeChambeau Embayment and Wilson Creek delta area, delta beach rocks, and tufa formations have become exposed. The DeChambeau Embayment area in particular may tend to support higher concentrations of alkali fly in fall as it is shallow, sheltered from wind and waves, supports higher water temperatures and a longer growing season (Herbst 1993). The DeChambeau area has typically also supported the largest numbers of Ruddy Ducks at Mono Lake in fall.

The proportional abundance of waterfowl species at Mono Lake differs greatly from that of the nearby freshwater reservoirs as the fall waterfowl population at Mono Lake is dominated by Northern Shoveler and Ruddy Duck, while waterfowl populations at the reservoirs are much more diverse. The food resources of a fresh water reservoir differ greatly from those of Mono Lake, and thus waterfowl using Mono Lake encounter and are responding to a different set of environmental variables.

Migratory waterfowl populations that use Mono Lake are expected to be influenced by a multitude of factors. Short-term and long-term population trends will be affected by conditions on breeding grounds, wintering grounds, and along migratory routes. Mono Lake provides abundant food resources for the limited number of waterfowl species that are able to exploit those resources. Important waterfowl habitats at Mono Lake such as brackish and freshwater ponds are ephemeral in nature as the shoreline configuration is dynamic, changing as a result of lake elevation changes and the effect of wind on the shoreline.

RECOMMENDATIONS

Under the Mono Basin Implementation Plan (LADWP 2000a), the monitoring of waterfowl populations in the Mono Basin was to continue until at least the year 2014, or until the targeted lake level (6,392 foot elevation) was reached and the lake cycled through a complete wet/dry cycle. Recovery of lake elevation to the target level is taking longer than anticipated and predicted by previous models and Mono Lake has not yet reached the targeted lake elevation since implementation of the Plan. In addition, over the last five years, the lake elevation has dropped approximately 7 feet due to successive years of below-average precipitation. In 2010, Watercourse Engineering and LADWP reevaluated Mono Lake elevation predictions using a 31-year dataset (1980-2010). Based on reiterative runs of the model, the average length of time predicted for Mono Lake to reach the targeted lake level of 6,392 feet at that time was 17 years (range of 3-25 years).

Taking into consideration that the targeted lake elevation may not be reached for quite some time, it seems prudent to reevaluate the waterfowl monitoring program at this point. I recommend that the results of the waterfowl monitoring program from 2002-2016 be analyzed and synthesized in a report. The report will include a comparison of lake, local and regional trends, an analysis of the response of waterfowl to lake level, limnological and vegetation factors, an analysis of the efficiency of the program, and the efficacy of the program at fulfilling both the requirements and intent of the Plan. Recommendations for modifications to the current program or for management of waterfowl habitat at Mono Lake will also be addressed.

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Table 1. 2016 Summer Ground Count Data by Survey

Species	Survey 1	Survey 2	Survey 3	Total	Percent Detections
Canada Goose	65	59	28	152	29.2%
Cinnamon Teal	1	2	7	10	1.9%
Gadwall	74	95	55	224	43.0%
Green-winged Teal	14	12	18	44	8.4%
Mallard	14	16	41	71	13.6%
Redhead			1	1	0.2%
Ruddy Duck			12	12	2.3%
Blue-winged Teal	2	1		3	0.6%
Brant	2	1		3	0.6%
American Wigeon	1			1	0.2%
Total Waterfowl	173	186	162	521	

Table 2. 2016 Brood Data

Table shows the total number of broods by species per shoreline survey area

Total	Shoreline Segment	DECR	LVCR	MICR	RUCR	SASP	SOTU	SSLA	WASP	WICR	**Total**
	Canada Goose	2		3				2			**7**
	Gadwall	1	4	3	1			7		3	**19**
	Green-winged Teal				1			3			**4**
	Mallard							3			**3**
	Total broods per area	3	4	6	2	0	0	15	0	3	33

Table 3. 2016 Waterfowl habitat use

	Activity							
Habitat	Brooding	Calling	Flushed	Foraging	Nesting	Resting	Swimming	**Total**
Wet Meadow				30	9			39
Alkaline Meadow			1					1
Freshwater Stream	6	1	14			2	1	24
Ria	13		5	251		2		271
Freshwater Pond	17		15	35		13	43	123
Brackish Pond	7	1	10	94		63		175
Great Basin Scrub			1					1
Unvegetated						19		19
Open Water				7			35	42
Total by activity	43	2	46	417	9	99	79	695

Table 4. 2016 Summary of Fall Aerial Survey Count Data

English Name	Mono	Bridgeport	Crowley	Species Total
Geese and Swans				
Greater White-fronted Goose			50	50
Cackling Goose	33	8		41
Canada Goose	91	1230	1271	2592
Total Geese and Swans	**124**	**1238**	**1321**	**2683**
Dabbling Ducks				
Gadwall	79	6768	5815	12662
American Wigeon	2	50	141	193
Mallard	460	1967	7064	9491
Cinnamon Teal	13	2	19	34
Northern Shoveler	9744	4345	9888	23977
Northern Pintail	2175	4206	7086	13467
Green-winged Teal	138	4213	9108	13459
Unidentified Teal	25	1845	629	2499
Total Dabbling Ducks	**12636**	**23396**	**39750**	**75782**
Diving Ducks				
Canvasback		1	310	311
Redhead	2	91	164	257
Ring-necked Duck	5	1300	103	1408
Lesser Scaup		20	160	180
Surf Scoter			1	1
Bufflehead		142	908	1050
Common Goldeneye		1		1
Common Merganser	1	260	13	274
Ruddy Duck	2507	1830	22256	26593
Total Diving Ducks	**2515**	**3645**	**23915**	**30075**
Total Waterfowl	**15275**	**28279**	**64986**	**108540**

Table 5. 2016 Mono Lake Restoration Ponds - Total Summer Detections

Species	COPOE	COPOW	DEPO_1	DEPO_2	DEPO_3	DEPO_4	DEPO_5	Total
Cinnamon Teal	7					8		15
Gadwall	7				2	12		21
Green-winged Teal	2							2
Ruddy Duck	2				1	6		9
Pond Totals	18	0	0	0	3	26	0	47

Table 6. Mono Lake Restoration Ponds - Total Waterfowl Broods

Species	County Ponds	DeChambeau Ponds
Cinnamon Teal		1
Gadwall		2
Ruddy Duck		2
Total Broods	0	5

Table 7. Mono Lake Restoration Ponds - 2016 Fall Survey Counts

County Ponds	6-Sep	23-Sep	6-Oct	19-Oct	1-Nov	11-Nov	Total Fall Detections
Gadwall					3		3
Unidentified Teal	5			1			6
Total Waterfowl	5	0	0	1	3	0	9
DeChambeau Ponds	6-Sep	23-Sep	6-Oct	19-Oct	1-Nov	11-Nov	Total Fall Detections
Gadwall		12		1	4		17
Green-winged Teal				6			6
Mallard		2					2
Northern Shoveler	2						2
Ring-necked Duck					2		2
Ruddy Duck	2				10		12
Unidentified Teal	4	3	11	12		4	34
Total Waterfowl	8	17	11	19	16	4	75

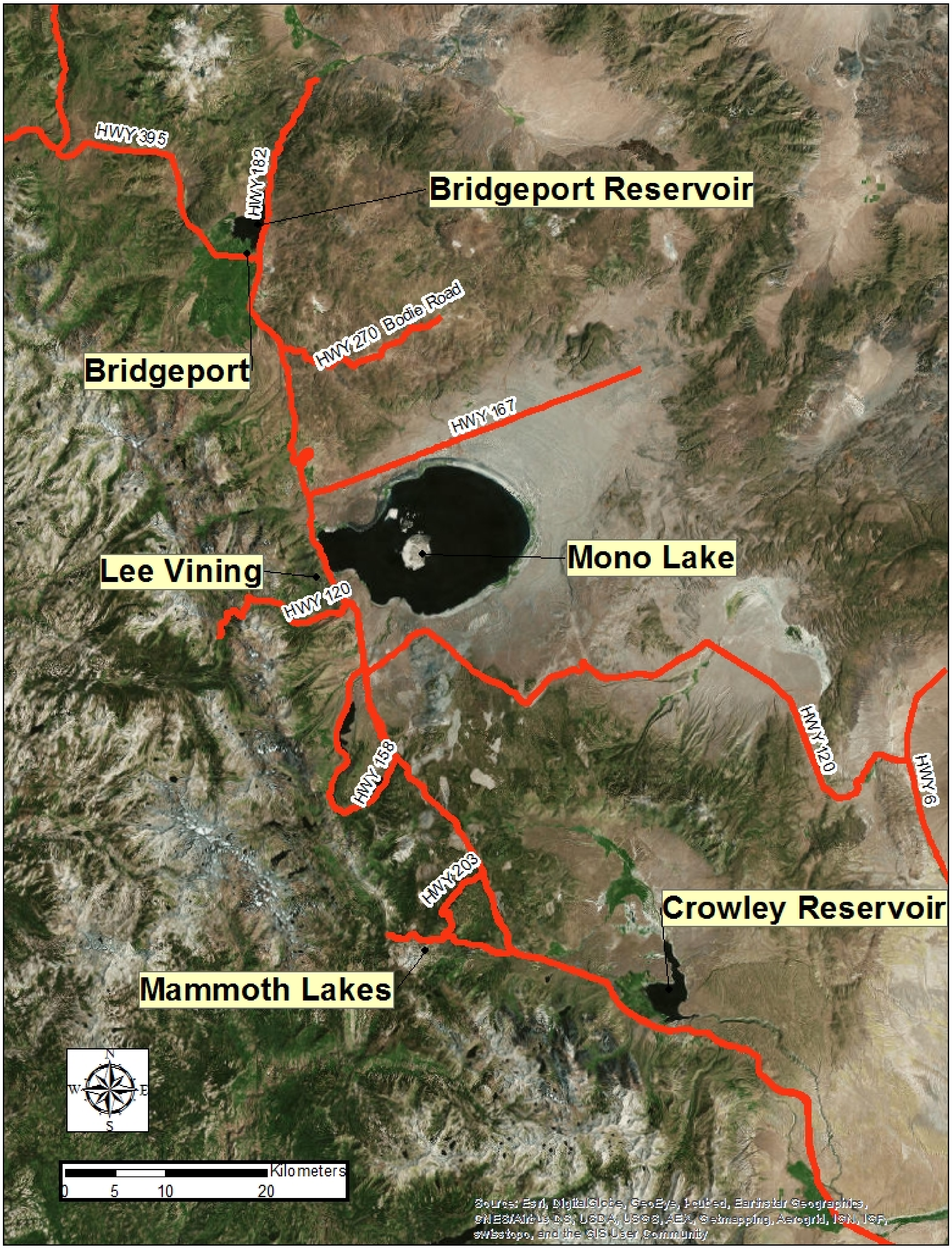

Figure 1. Lakes and Reservoirs Surveyed in 2016

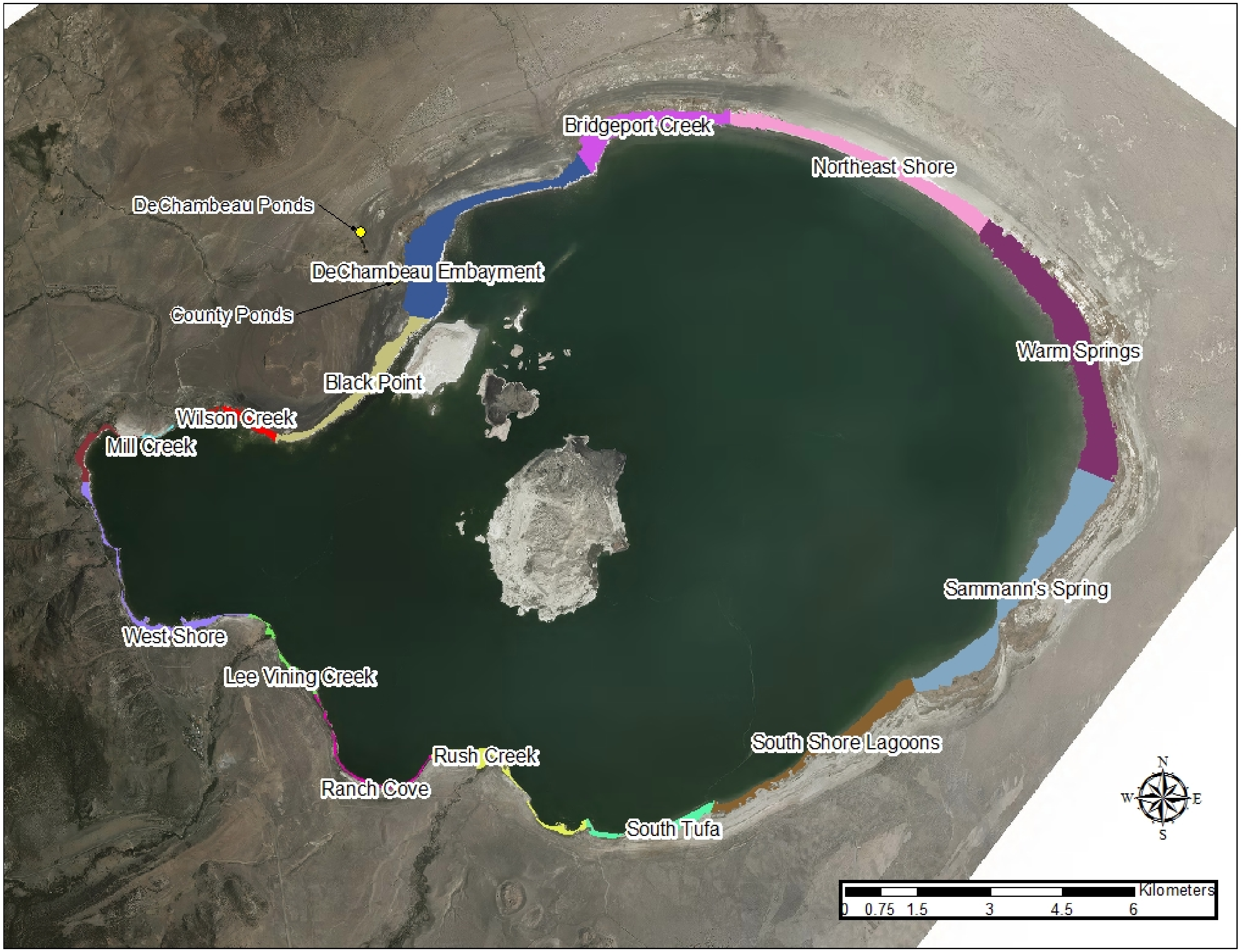

Figure 2. Mono Lake Lakeshore Segments

Figure 3. DeChambeau Creek Area

Figure 4. Mill Creek

Figure 5. Wilson Creek

Figure 6. Black Point

Figure 7. DeChambeau Embayment - Perseverence Spring

Figure 8. Bridgeport Creek

Figure 9. Northeast Shore

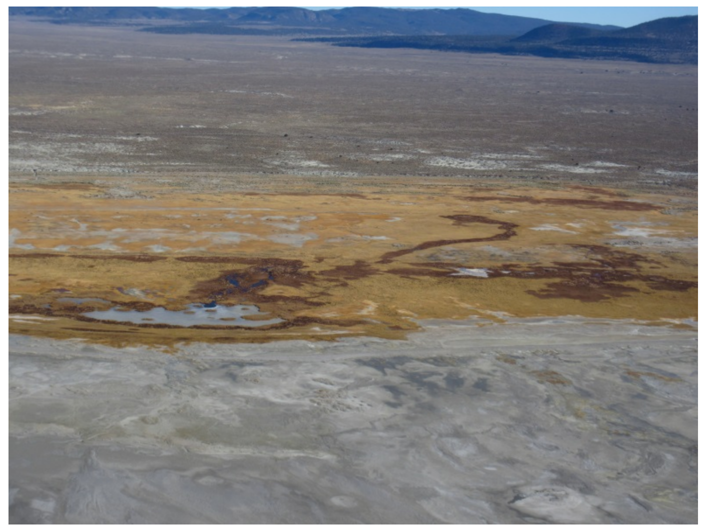

Figure 10. Warm Springs – North Pond

Figure 11. Sammann's Spring – west

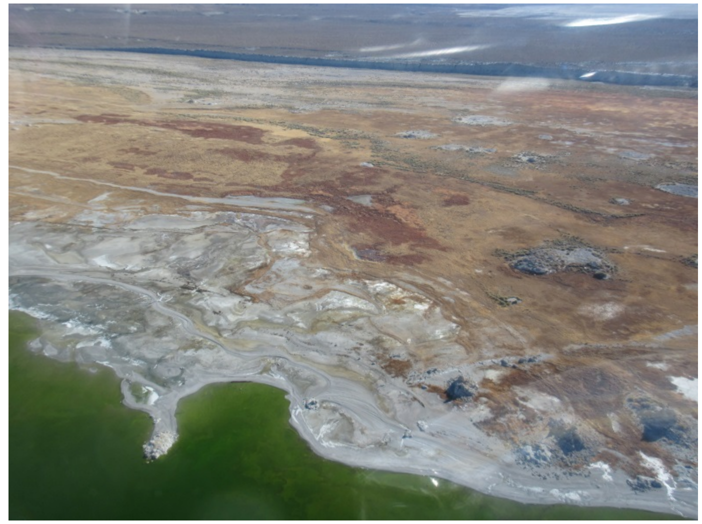

Figure 12. Sammann's Spring- east

Figure 13. South Shore Lagoons - Goose Springs

Figure 14. South Shore Lagoons - Sand Flat Spring

Figure 15. South Shore Lagoons

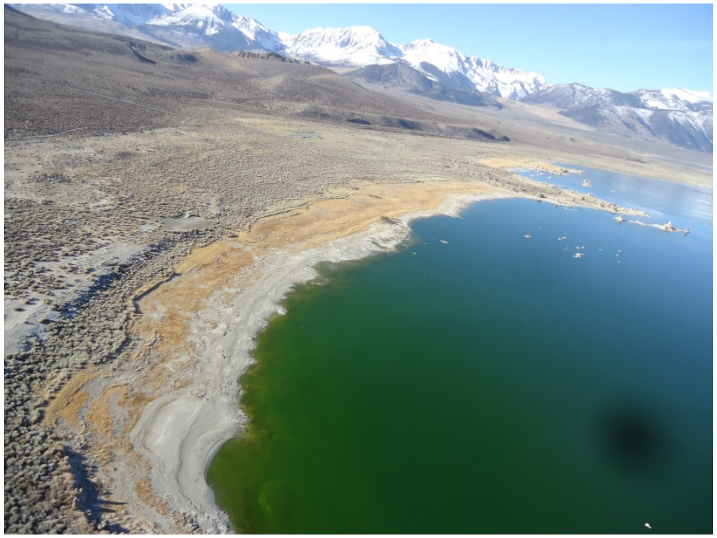

Figure 16. South Tufa Area

Figure 17. South Tufa – Navy Beach

Figure 18. Rush Creek delta

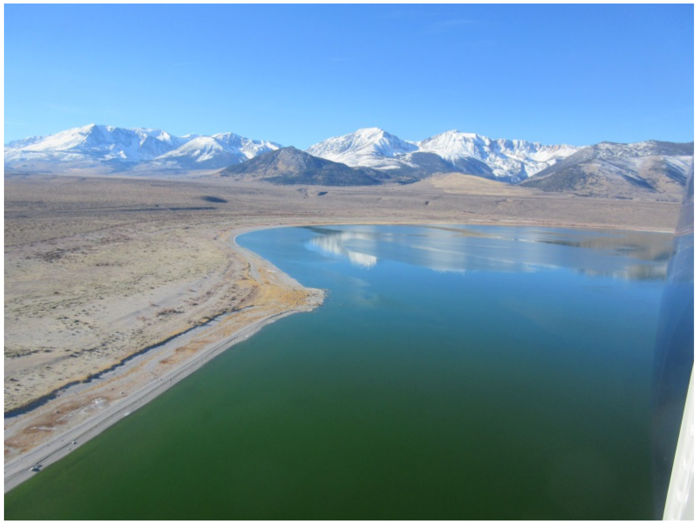

Figure 19. Ranch Cove

Figure 20. Lee Vining Creek Delta

Figure 21. West Shore

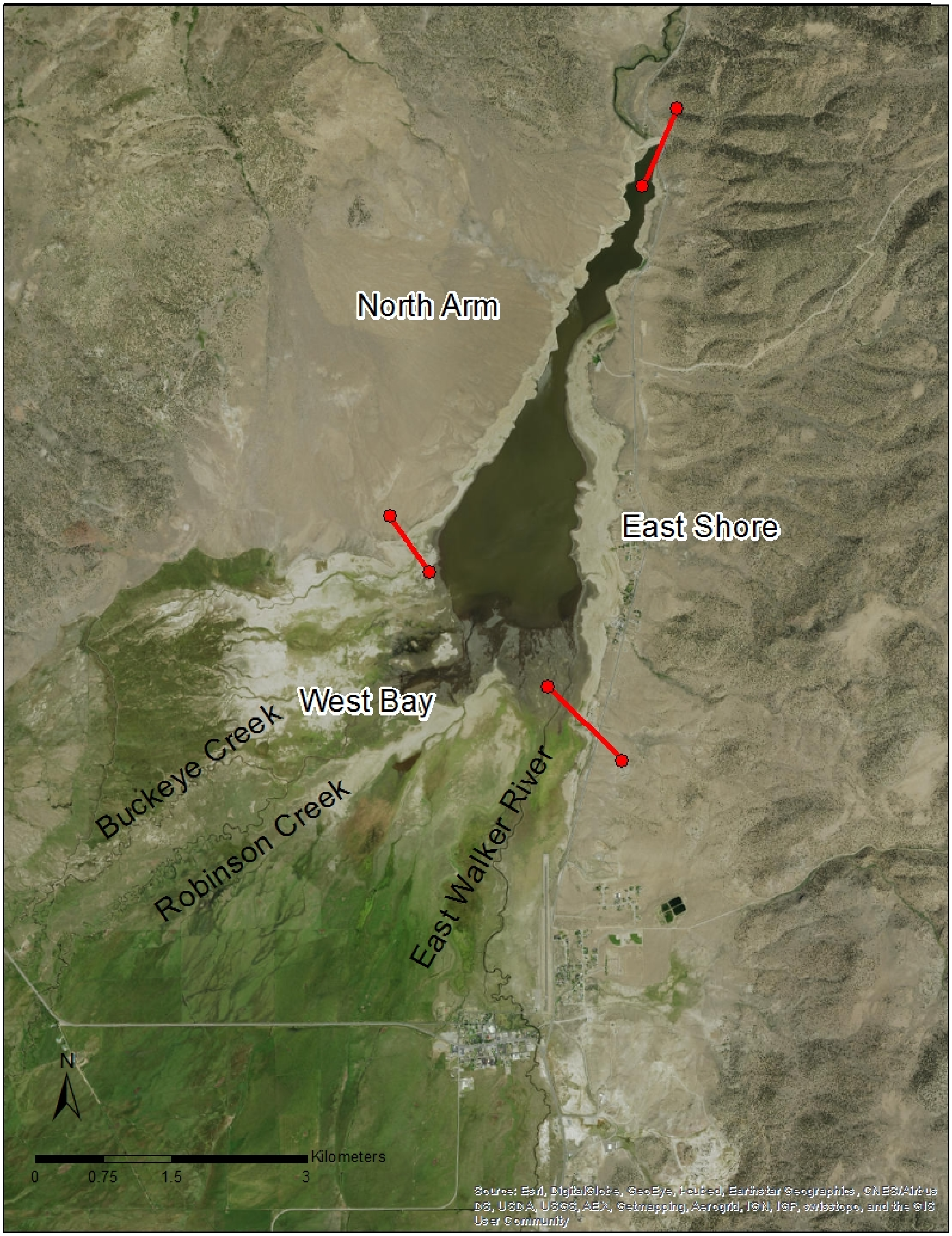

Figure 22. Bridgeport Reservoir Shoreline Segments

Figure 23. Photo of Bridgeport Reservoir, looking North
Photo shows the West Bay area and the south end of the East Shore area. The majority of waterfowl that use Bridgeport Reservoir in the fall congregate in this southern end of the reservoir.

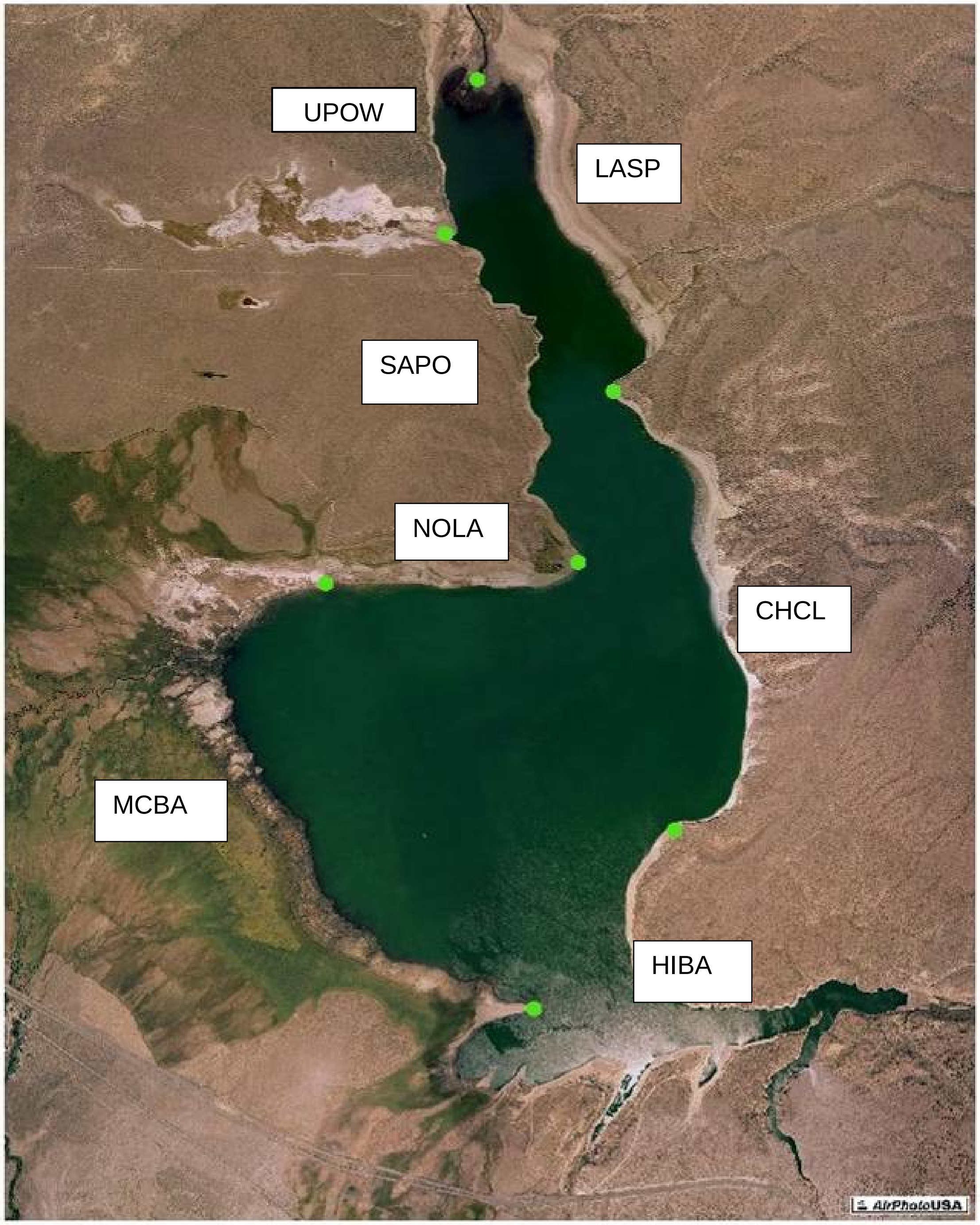

Figure 24. Crowley Reservoir Shoreline Segment Areas

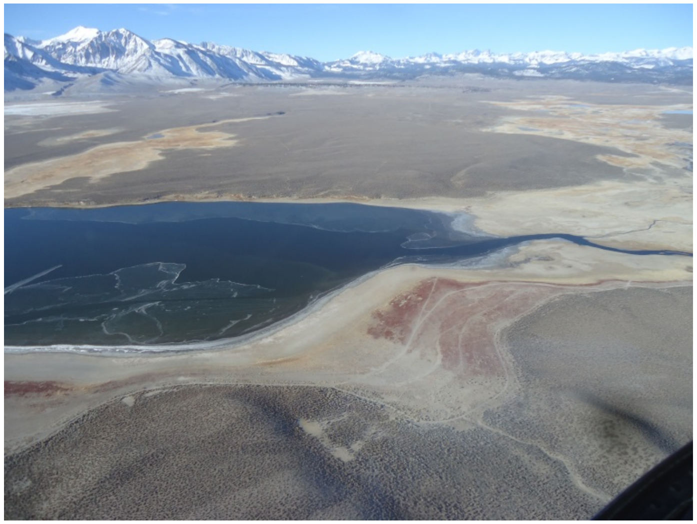

Figure 25. Crowley- Upper Owens River Delta

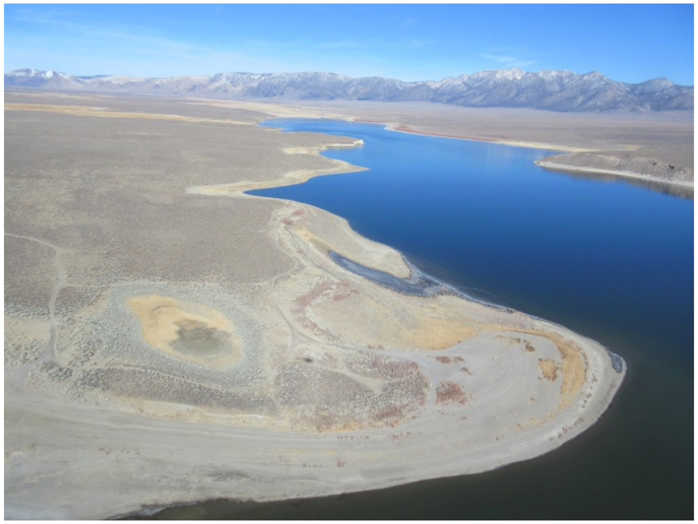

Figure 26. Crowley -Sandy Point Shoreline Area

Figure 27. Crowley - North Landing Shoreline Area

Figure 28. Crowley - McGee Bay

Figure 29. Crowley -Hilton Bay

Figure 30. Crowley - Chalk Cliffs

Figure 31. Crowley - Layton Springs

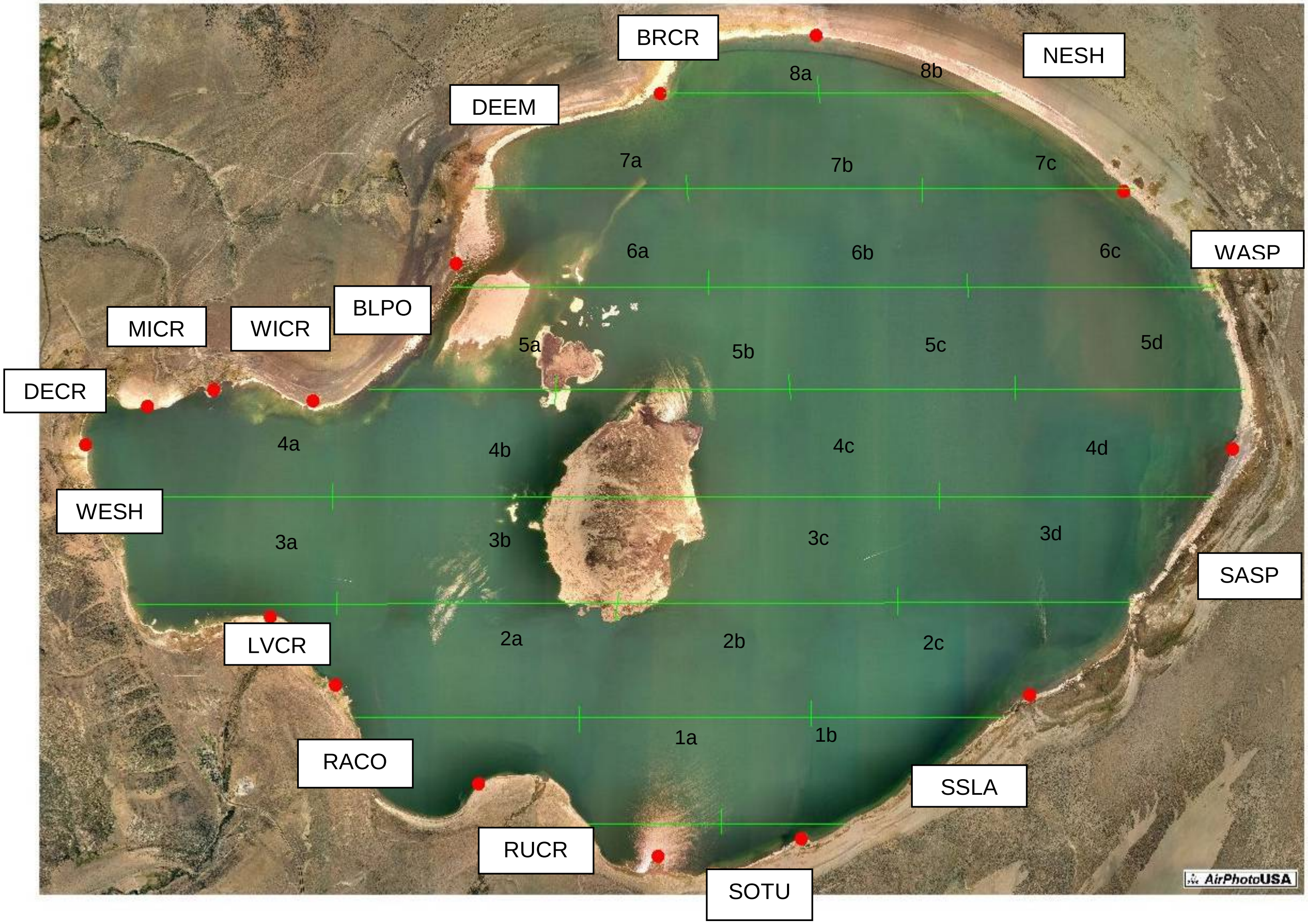

Figure 32. Mono Lake Fall Aerial Survey Cross-lake Transects and Shoreline Segments

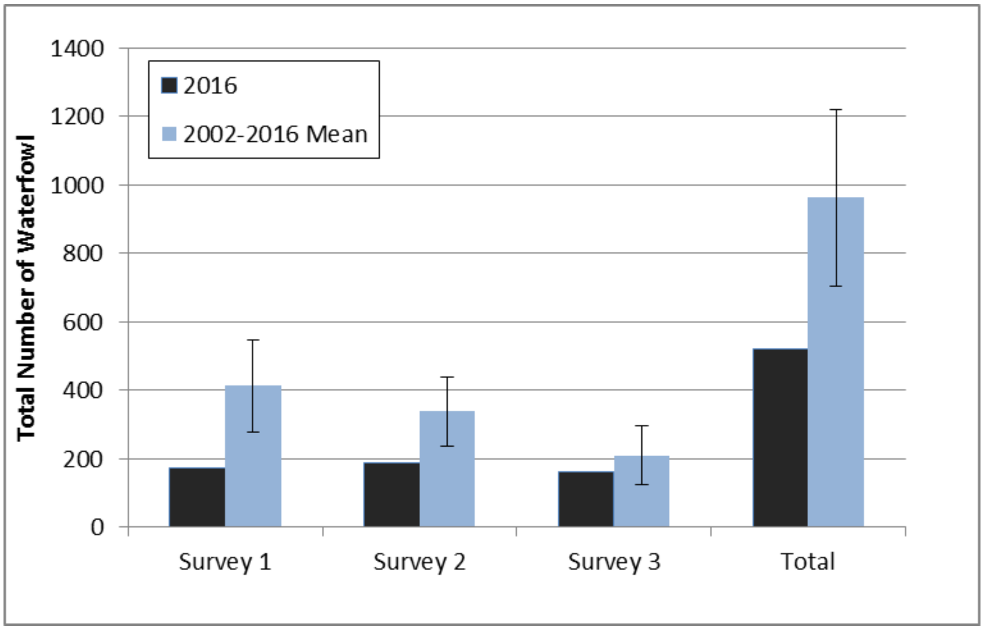

Figure 33. Mono Lake Summer Surveys – Total Waterfowl per Survey 2016 and 2002-2016 Mean. Error Bars Represent Standard Error of the Mean for 2002-2016.

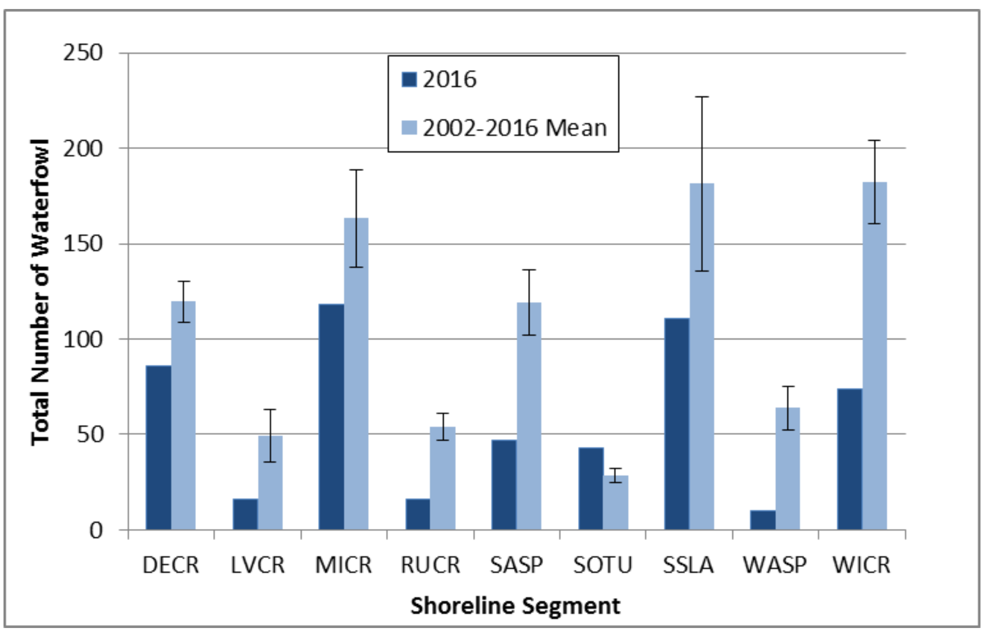

Figure 34. Spatial distribution of waterfowl during summer surveys 2016 and 2002-2016. Error Bars Represent Standard Error of the Mean for 2002-2016.

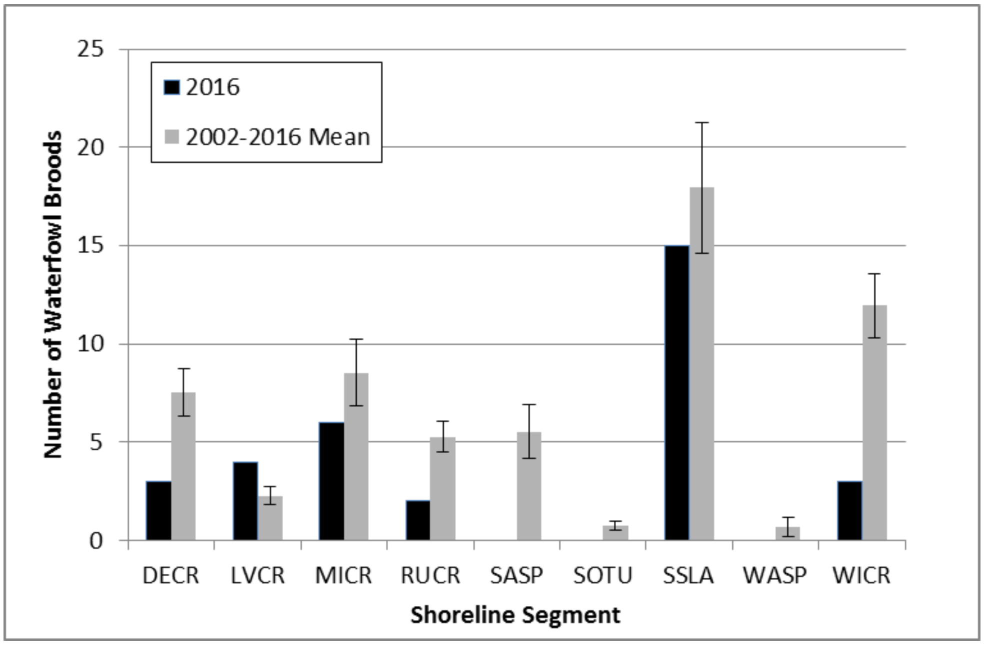

Figure 35. Spatial distribution of observed waterfowl broods during summer surveys 2016 and 2002-2016. Error Bars Represent Standard Error of the Mean for 2002-2016.

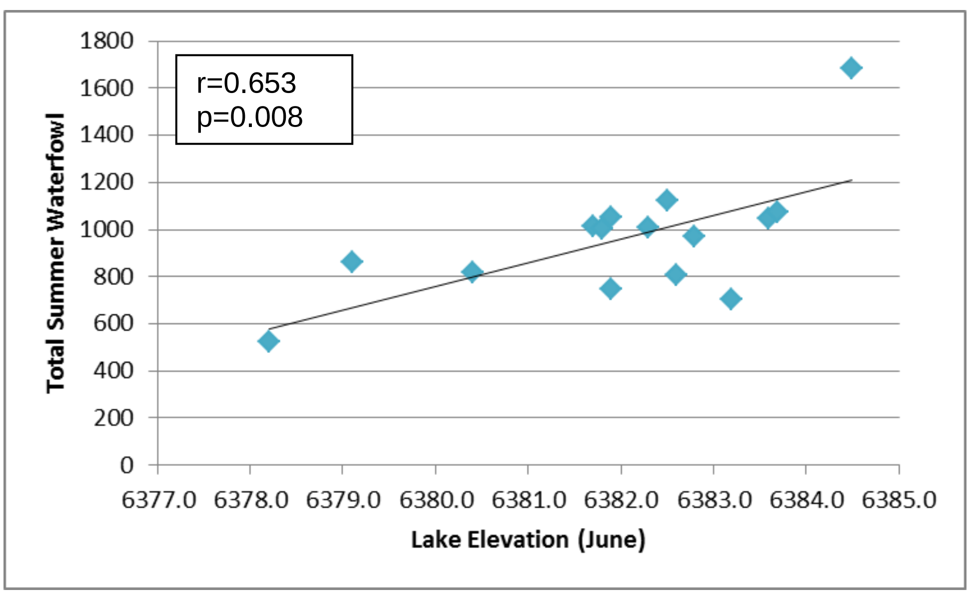

Figure 36. Total summer waterfowl counts are positively correlated with the elevation of Mono Lake in June

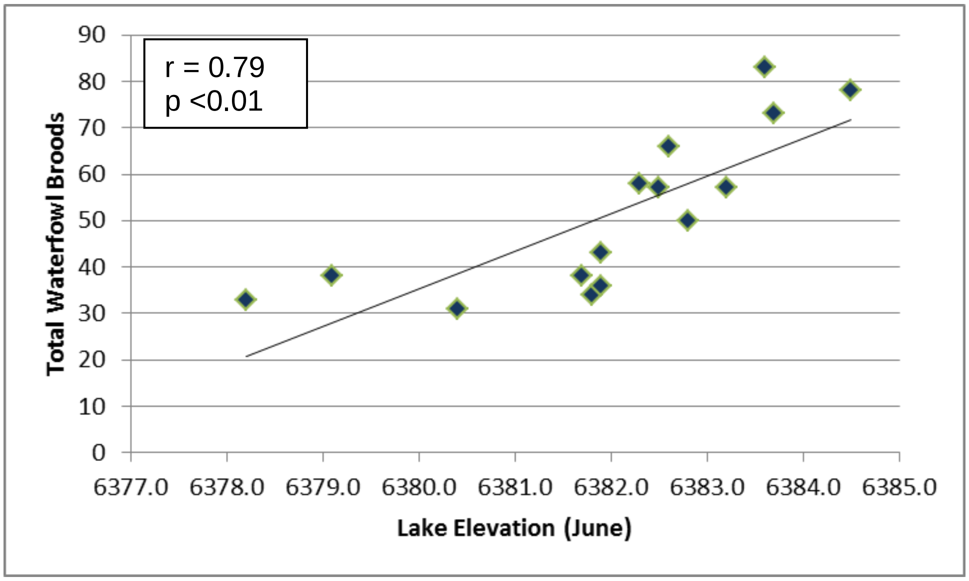

Figure 37. Total waterfowl broods are positively correlated with the elevation of Mono Lake in June

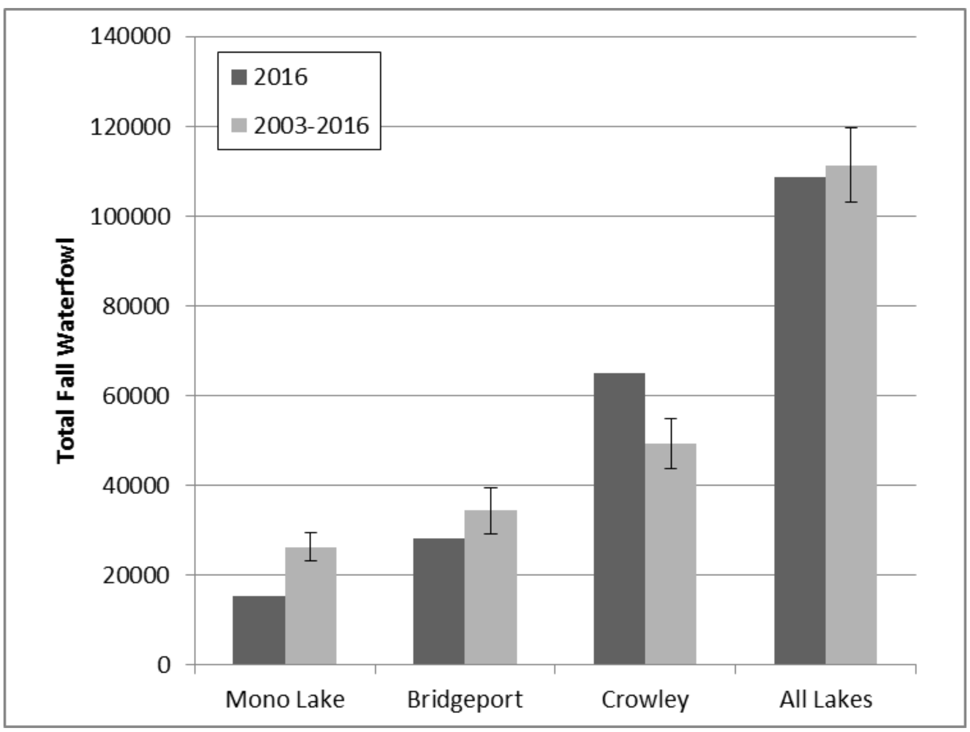

Figure 38. A comparison of total fall waterfowl in 2016 and 2003-2016 mean values for each waterbody and total Mono flyway. Error Bars Represent Standard Error of the Mean for 2002-2016.

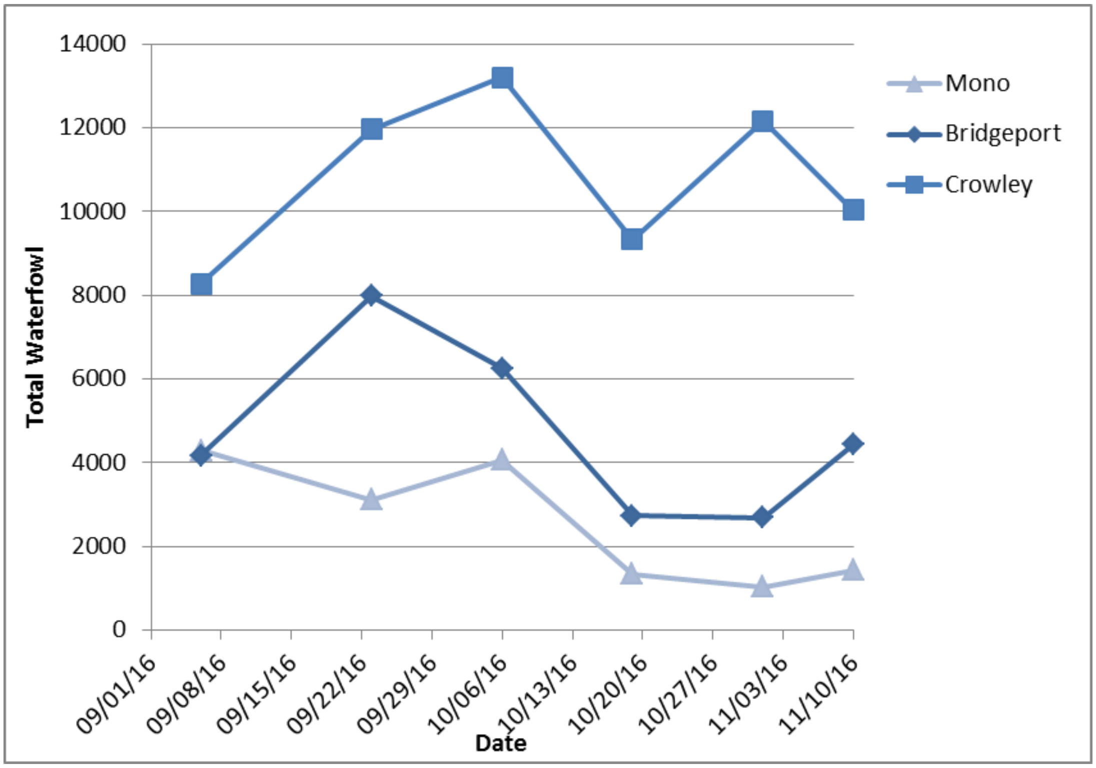

Figure 39. A comparison of seasonal abundance of waterfowl at Mono, Bridgeport and Crowley, 2016.

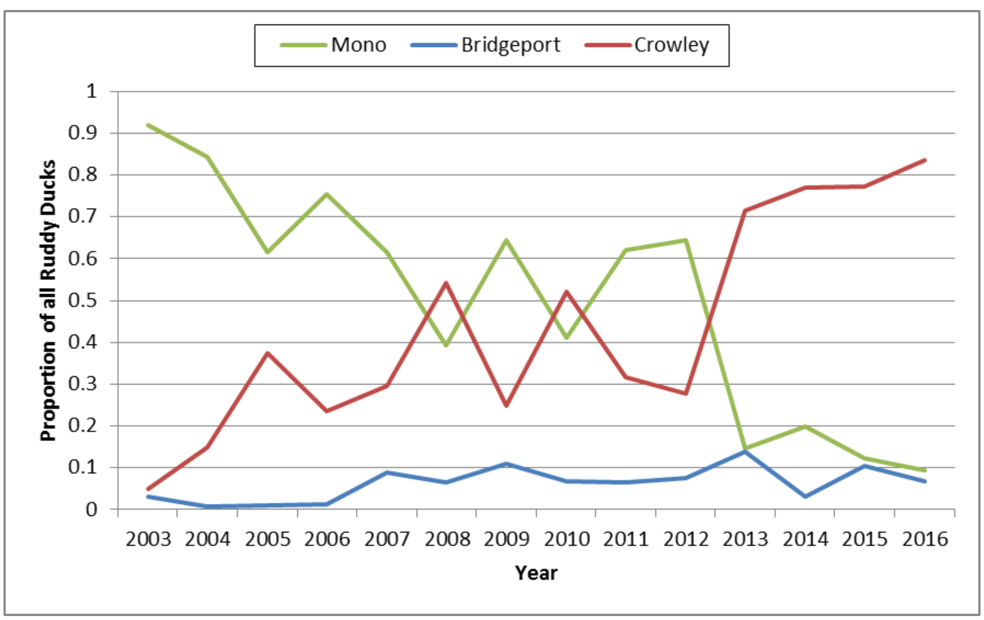

Figure 40. Proportion of Mono flyway Ruddy Ducks at each waterbody 2003-2016. Data indicate Ruddy Ducks in the Mono flyway have shifted use away from Mono Lake and to Crowley Reservoir.

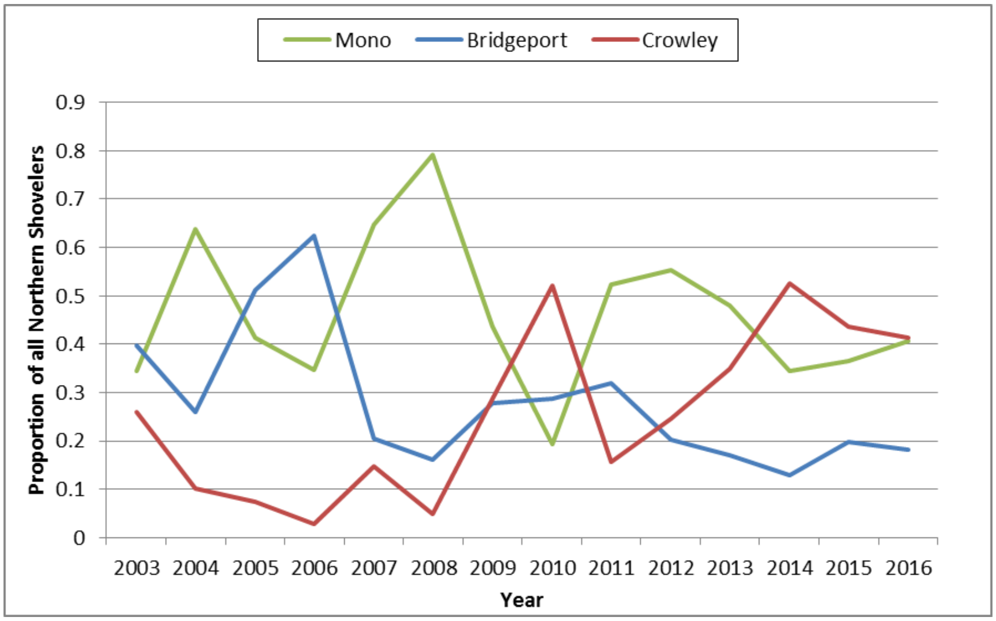

Figure 41. Proportion of Mono flyway Northern Shoveler at each waterbody 2003-2016. Data indicate Northern Shoveler in the Mono flyway have shifted use away from Bridgeport Reservoir and to Crowley Reservoir.

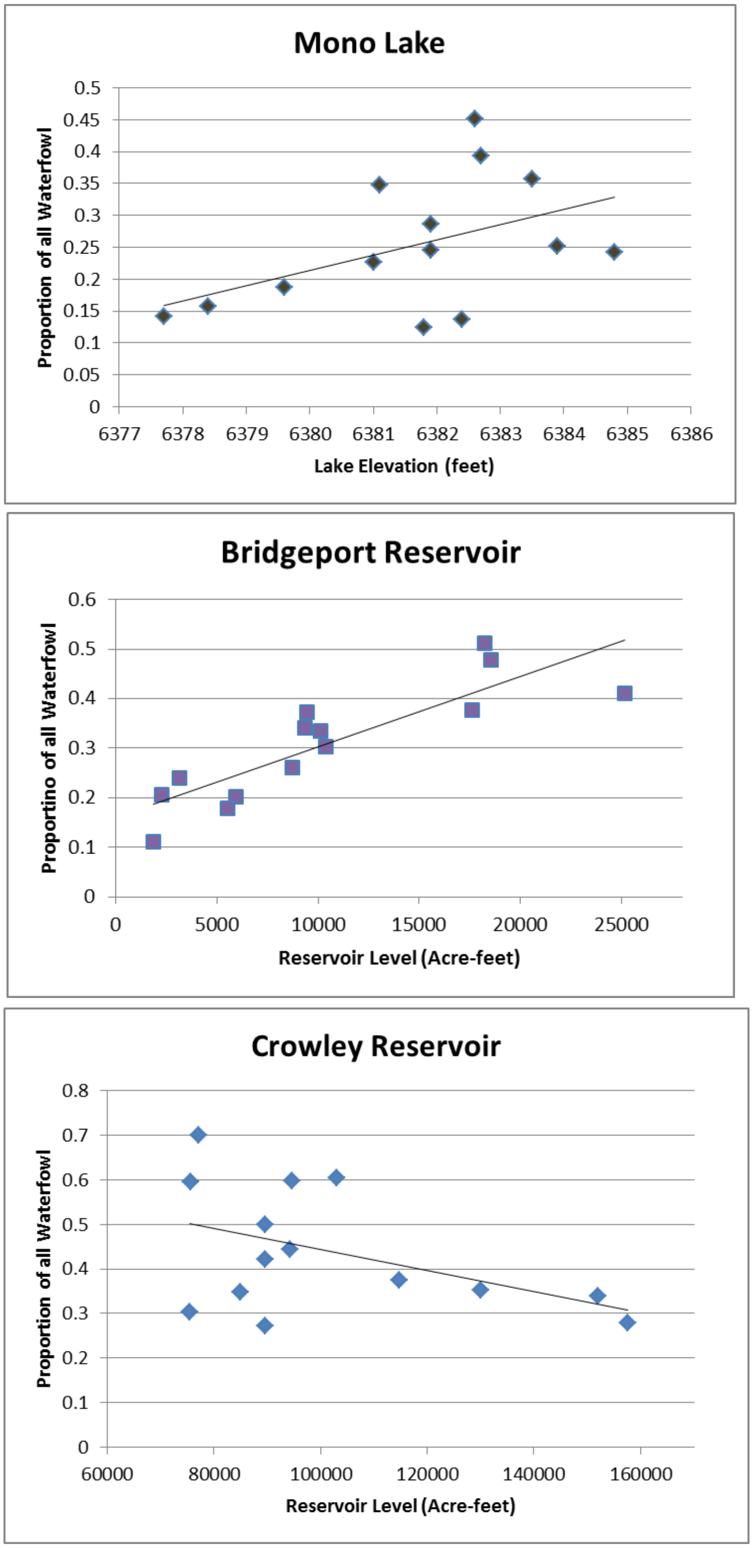

Figure 42. Relationship between total fall waterfowl and lake elevation at all three survey areas

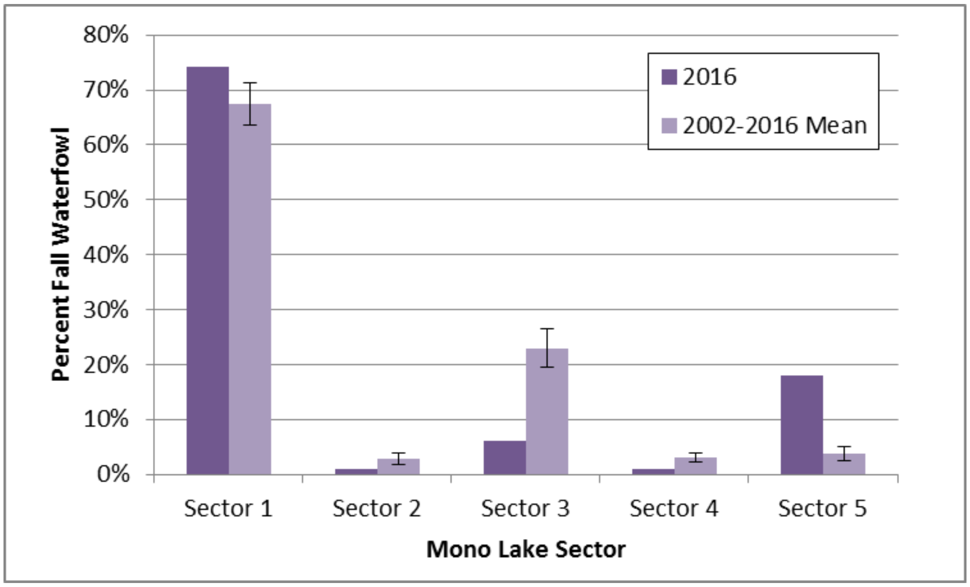

Figure 43. Spatial distribution of waterfowl at Mono Lake in fall.

APPENDICES

Appendix 1. Habitat Categories Used for Documenting Use by Waterfowl Species

(from Mono Lake Landtype Inventory, 2014 Conditions, LADWP 2014).

Marsh: Saturated and permanently flooded habitat dominated by obligate hydrophytic plant species. Prominent species include hard-stem bulrush (*Schoenoplectus acutus*), cattail (*Typha latifolia*), and three square (*Schoenoplectus americanus*). Marsh occurs in association with semi-permanently flooded wet meadow, seasonally flooded alkali wet meadow, and dry meadow/forb landtypes.

Wet Meadow: Semi-permanently flooded habitat dominated by obligate and facultative wetland plant species. Prominent species include rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), saltgrass (*Distichlis spicata*) and sedges (*Carex* spp.). Wet meadow occurs in association with marsh, alkali wet meadow, and dry meadow/forb landtypes.

Alkali Wet Meadow: Seasonally flooded habitat and areas with high water table dominated by facultative wetland plant species. Prominent species include saltgrass (*Distichlis spicata*) and Baltic rush (*Juncus arcticus*) with nearly total canopy cover. Alkali wet meadow occurs in association with marsh, wet meadow and dry meadow/forb.

Dry Meadow/Forb: Relatively dry habitat dominated by facultative wetland and facultative upland plant species.

Riparian shrub: Seasonally flooded areas dominated hydrophytic shrubs. Prominent plants include willow (*Salix* spp.), buffalo berry (*Shepardia argentea*) and Wood's rose (*Rosa woodsii*).

Riparian Woodland: Typically transitional from seasonally flooded riparian towards moist upland. Aspen (*Populus tremuloides*), and black cottonwood (*Populus balsamifera*) are typically prominent; Jeffrey pine (*Pinus jeffreyi*) is often present. Riparian woodland is prominent along Lee Vining Creek.

Great Basin scrub: Upland scrub dominated by sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) with scant understory. Occurs primarily on the upslope margin of the lake bed on terrace.

Rabbitbrush scrub: Upland scrub dominated by rabbitbrush (*Ericameria nauseosa*) with scant understory. Most areas of rabbitbrush were previously mapped as *unvegetated* or *Great Basin scrub*. Rabbitbrush occurs in association with barren lake bed and dry meadow/forb.

Eolian deposit: Low dunes and sand sheets, typically with a sparse scrub canopy and sparse saltgrass understory. It occurs in association with barren lake bed. It was included as *Great Basin scrub* or *unvegetated* in previous mapping

Unvegetated: Mostly barren lake bed, but also includes streambars near the mouths of streams. Unvegetated area increased between 1999 and 2009, mostly in response to declining lake elevation exposing barren lake bed. Prior to 2014, unvegetated areas included large areas of rabbitbrush scrub. The 2014 decline in unvegetated is mostly partly a response to delineating 1,913 acres of rabbitbrush scrub on the lake bed.

Freshwater Stream: Tributary streams flowing to Mono Lake. Includes lowest portions of Rush, Lee Vining, Dechambeau, Mill, and Wilson Creeks not shrouded by vegetation that are discernible on imagery.

Freshwater Pond: Ponds fed by springs within marsh areas or artificially with stream diversions (*e.g*. DeChambeau/County ponds).

Freshwater Ria: Surface water at the mouths of streams that likely has some salt/fresh water stratification. Only a few rias totaling less than 3 acres were identified in 1999, 2005 and 2009; but 72 areas totaling 39 acres were identified in 2014, including many small areas with direct connection to Mono Lake. Freshwater rias may not have been delineated consistently in 2014; they could not be spectrally distinguished from ephemeral brackish lagoon or hypersaline lagoon.

Ephemeral Brackish Ponds: Ponds separated from Mono Lake by littoral bars that receive drainage from upslope marsh and wet meadow sustained by springs. The area of this type decreased from 109 acres in 1999 to less than 15 acres in subsequent years. These features were not delineated consistently in 2014; they could not be spectrally distinguished from ria or ephemeral hypersaline pond.

Ephemeral Hypersaline Pond: Ponds separated from Mono Lake by littoral bars that appear to lack a freshwater source. These areas contain concentrated brine due to evaporation. The area of this type decreased from 111 acres in 1999 to 24 acres in 2005. It comprised less than an acre in 2009 and 2014. These features were not mapped consistently in 2014; they could not be distinguished from ria or ephemeral brackish pond.

Mud flat: Wet substrate, shallow water, and algae within recent drawdown zone along the lake margin. About 15 acres of this type was identified in 2014. Again, in was mapped somewhat inconsistently.

Appendix 2. Lakeshore Segment Boundaries
(UTM, Zone 11, NAD 83, CONUS)

Mono Lake	**Lakeshore Segment**	**Code**	**Easting**	**Northing**
	South Tufa	SOTU	321827	4201363
	South Shore Lagoons	SSLA	324470	4201876
	Sammann's Spring	SASP	328552	4204369
	Warm Springs	WASP	332240	4208707
	Northeast Shore	NESH	330050	4213640
	Bridgeport Creek	BRCR	324787	4216042
	DeChambeau Embayment	DEEM	321835	4215037
	Black Point	BLPO	318172	4211968
	Wilson Creek	WICR	315378	4209451
	Mill Creek	MICR	313690	4209742
	DeChambeau Creek	DECR	312630	4209468
	West Shore	WESH	311454	4208509
	Lee Vining Creek	LVCR	314833	4205764
	Ranch Cove	RACO	316216	4204134
	Rush Creek	RUCR	318624	4202827
Crowley Reservoir				
	Upper Owens	UPOW	346943	4167342
	Sandy Point	SAPO	345949	4167138
	North Landing	NOLA	346911	4164577
	McGee Bay	MCBA	344988	4164675
	Hilton Bay	HIBA	346329	4161198
	Chalk Cliff	CHCL	347613	4162620
	Layton Springs	LASP	347152	4165944
Bridgeport Reservoir				
	North Arm	NOAR	306618	4244297
	West Bay	WEBA	304401	4241152
	East Shore	EASH	305941	4240577

Appendix 3. 2016 Ground Count Survey Dates and Times

Survey 1

Survey Area	Survey Date and Time			
	6-Jun	7-Jun	8-Jun	9-Jun
RUCR	0616 - 0744 hrs			
SOTU	0848-0957 hrs			
SSLA	1000 - 1255 hrs			
DECR		0551 - 0648 hrs		
MICR		0647 - 0744 hrs		
WICR		0745 - 0832 hrs		
LVCR		1149 - 1239 hrs		
DEPO		1055-1110 hrs		
COPO		1040-1047 hrs		
SASP			0610 - 1012 hrs	
WASP				0708 - 0930 hrs

Survey 2

Survey Area	Survey Date and Time			
	27-Jun	28-Jun	29-Jun	30-Jun
RUCR		1244 - 1335 hrs		
SOTU		0528 - 0630 hrs		
SSLA		0632 - 1129 hrs		
DECR				0520 - 0623 hrs
MICR				0625 - 0747 hrs
WICR				0747 - 0821 hrs
LVCR				1021 - 1107 hrs
DEPO	1340 - 1410 hrs			
COPO	1325 - 1340 hrs			
SASP			0622 - 0852 hrs	
WASP	0745 - 1019 hrs			

Survey 3

Survey Area	Survey Date and Time			
	18-Jul	19-Jul	20-Jul	21-Jul
RUCR		0533 - 0725 hrs		
SOTU			0554 - 0645 hrs	
SSLA		0910 - 1120 hrs		
DECR				0551 - 0641 hrs
MICR				0641 - 0753 hrs
WICR				0754 - 0824 hrs
LVCR				1007 - 1100 hrs
DEPO	1315 - 1341 hrs			
COPO	1348 - 1420 hrs			
SASP			0820 - 1200 hrs	
WASP	0755 - 1025 hrs			

Appendix 4. 2016 Fall Aerial Survey Dates

Survey Number	1	2	3	4	5	6
Mono Lake	6-Sep	23-Sep	6-Oct	19-Oct	1-Nov	10-Nov
Bridgeport Reservoir	6-Sep	17-Sep	6-Oct	19-Oct	1-Nov	10-Nov
Crowley Reservoir	6-Sep	17-Sep	6-Oct	19-Oct	1-Nov	10-Nov

Appendix 5. Mono Lake Cross-Lake Transect Positions

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

Appendix 6. Common and Scientific Names for Species Referenced in the Document.

Common Name	Scientific Name
Greater White-fronted Goose	*Anser albifrons*
Cackling Goose	*Branta hutchinsii*
Canada Goose	*Branta canadensis*
Gadwall	*Anas strepera*
American Wigeon	*Anas americana*
Mallard	*Anas platyrhynchos*
Cinnamon Teal	*Anas cyanoptera*
Northern Shoveler	*Anas clypeata*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Unidentified Teal	*Anas (sp)*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Lesser Scaup	*Aythya affinis*
Surf Scoter	*Melanitta perspicillata*
Bufflehead	*Bucephala albeola*
Common Goldeneye	*Bucephala clangula*
Common Merganser	*Mergus merganser*
Ruddy Duck	*Oxyura jamaicensis*

2016 Annual Report

Mono Lake Limnology Monitoring

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Los Angeles Department of Water and Power

Bishop, CA.

Prepared for: State Water Resources Control Board

March 2017

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INTRODUCTION

Limnological monitoring was conducted in 2016 at Mono Lake as required under the State Water Resources Control Board Order No. 98-05. The limnological monitoring program at Mono Lake is one component of the Mono Basin Waterfowl Habitat Restoration Plan (LADWP, 1996). The purpose of the limnological monitoring program as it relates to waterfowl is to assess limnological and biological factors that may influence waterfowl use of lake habitat (LADWP 1996). The limnological monitoring program consists of four components: meteorological, physical/chemical, phytoplankton, and brine shrimp population data.

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

This report summarizes monthly field sampling for the year of 2016. Laboratory support including the analysis of ammonium and chlorophyll *a* in 2016 was provided by Environmental Science Associates (ESA), Davis, California.

METHODS

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

Meteorology

One meteorological station on Paoha Island provided weather data in 2016. The Paoha Island measuring station is located approximately 30 m from shore on the southern tip of the island. The base of the station is at 1,948 m above sea level, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten-minute averages or hourly values in a Campbell Scientific CR 1000 datalogger. Data are downloaded to a storage module which is collected periodically during field sampling visits.

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

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

In addition to the Paoha Island station, monthly total precipitation recorded at LADWP Cain Ranch since May 1931 and monthly average maximum and minimum temperature since October 1950 obtained from Western Regional Climate Center (www.wrcc.dri.edu) were analyzed to gain better insight to climatic trends. Winter temperature was calculated by averaging monthly average maximum (or minimum) temperature of December of the previous year and January and February of the year. More specifically, the monthly average from December 2015 was combined with the monthly average from January and February 2016 to obtain winter average for 2016. Summer temperature is an average monthly temperature between June and August. Annual precipitation is a sum of precipitation occurring within one calendar year

Field Sampling

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

Physical and Chemical

Sampling of the physical and chemical properties included lake transparency, water temperature, conductivity, dissolved oxygen, and nutrients (ammonium). Lake elevation data was obtained directly from LADWP database records. Annual lake elevation for year to year comparison was calculated based on average April (water year) daily measurements. Lake transparency was measured at all 12 stations using a Secchi disk. A high-precision conductivity temperature-depth (CTD) profiler (Seabird 19 plus V2) was used to record conductivity at nine stations (2, 3, 4, 5, 6, 7, 8, 10 and 12). During sampling, the Seabird CTD was initially lowered just below the surface of the water for 40 seconds during the pump delay time. The CTD was then lowered at a rate of ~0.5 meters/second with data collected at approximately 12.5 centimeter depth intervals. The Seabird CTD is programmed to collect data at 250 millisecond intervals.

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

Monitoring of ammonium in the epilimnion was conducted using a 9-meter integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. An ammonium profile was developed by sampling at station 6 from eight discrete depths (2, 8, 12, 16, 20, 24, 28, and 35 meters) using a vertical Van Dorn sampler. Samples for ammonium analyses were filtered through Gelman A/E glass-fiber filters and following collection, immediately placed onto dry ice and frozen in order to stabilize the ammonium content (Marvin and Proctor, 1965). Ammonium samples were transported on dry ice back to the laboratory transfer station. The ammonium samples were stored frozen until delivered to the University of California Davis Analytical Laboratory (UCDAL) located in Davis, California. Samples were stored frozen until analysis. The lower detection limit for ammonium was 2.8 µg/L.

Phytoplankton

Chlorophyll a sampling

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

Brine Shrimp

Artemia sampling

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

Laboratory Analysis

Ammonium

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

Chlorophyll a

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

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

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

Artemia Population Analysis and Biomass

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

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

Artemia Fecundity

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

Artemia Population Statistics

Calculation of long-term *Artemia* population statistics followed Jellison and Rose (2011). Daily values of adult *Artemia* between sampling dates were linearly interpolated in Microsoft Excel. The mean, median, peak and centroid day (calculated center of abundance of adults) were then calculated for the time period May 1 through November 30. Long-term values were determined by calculating the mean, minimum and maximum values for these parameters for the time period 1979-2016.

RESULTS

Meteorology

Wind Speed, relative humidity, air temperature and precipitation data from the weather station at Paoha Island are summarized daily for 2016.

Wind Speed and Direction

Mean daily wind-speed varied from 1.2 to 14.4 m/sec with an overall mean for this time period of 3.6 m/sec (Figure 2). The daily maximum 10-min averaged wind speed (5.6 m/sec) on Paoha Island averaged almost twice as much as the mean daily wind speed. The maximum recorded 10-min reading of 30.3 m/sec occurred the afternoon of March 10th. As has been the case in previous years, winds were predominantly from the south (mean 190.3 degrees).

Air Temperature

Daily air temperatures as recorded at Paoha Island ranged from a low of -12.9°C on January 1 to a high of 35.4°C on July 27th (Figure 3). Daily average winter temperature (January through February) ranged from -7.8°C to 7.9°C with an average maximum daily temperature of 8.6°C, much higher than previously recorded values. The average maximum daily summer temperature (June through August) was 28.1°C while the average minimum daily summer temperature was 11.8°C.

Relative Humidity and Precipitation

The mean relative humidity for the period between January 1st and December 19th, 2016 was 52% (Figure 4). The total precipitation measured at Paoha Island was 384 mm. Precipitation events were spread out throughout the year, with a somewhat dry period mid-July through September. The largest single day total precipitation of 160 mm was recorded on November 19th (Figure 5). In January and February, 43 mm of precipitation was recorded. Spring months produced 84 mm of precipitation followed by much lower summer month precipitation (20 mm). Fall produced precipitation increased to 216 mm due to the single event in November 19th. December precipitation was 20 mm. The month with the most frequent precipitation events (8) was January.

Long Term Trend

The winter of 2015-16 ranked 11th in average maximum and 10th in minimum temperature since the winter of 1950-51, and the preceding winter (2014-15) was the warmest winter since the winter of 1950-51. Since the summer of 1951, 2016 was ranked 5th and 13th in average summer maximum and minimum temperature, respectively. Annual precipitation in 2016 (9.4 in) ranked 48th in 85 years, and 90% of the long term average of 10.4 in.

There is no clear long-term trend for average summer and winter temperatures except for an increase in average summer minimum temperature ($r=0.55$, $p<0.0001$, $df=66$) (Figure 6, Figure 7). A combination of above long-term average summer minimum since 1995 and below long term average during the earlier part of the record (between 1962 and 1987) contributed to a significant positive trend of the average minimum summer temperature. For average minimum winter temperature the same trend was not found even though the average winter minimum temperature has been above the long term average (-6.1°C) for the past three years. The winter of 2014-15 was particularly warm as the highest average minimum since 1951 was recorded.

Since 1998, only 3 years show annual precipitation above the long term average of 85 years (10.4 in); 2005, 2006, and 2001 (Figure 8). The average annual precipitation of the past 10 years (2007 through 2016) excluding 2011 was 8.3 in, 75% of the long term average.

Physical and Chemical

Surface Elevation

The average monthly surface elevation of Mono Lake in January 2016 was 6377.6 feet, almost 1 foot (0.3 m) lower than the same time of 2015 at 6,378.5 feet. In spite of input from two major tributaries (Rush and Lee Vining Creeks) being slightly above 100% of the long-term average based on water years, the average monthly elevation rose only by 0.3 foot to 6,377.9 feet in June. Lake elevation declined after June to the lowest level at 6376.8 feet by November. A lake level of 6376.8 feet has not been recorded since June 1995. Figure 9 shows lake elevation from 1960 through 2016 and the mixing regime observed each year due to insufficient input from tributaries. As will be discussed below, Mono Lake continued to exhibit a monomictic mixing regime in 2016. For 2016 the greatest monthly change in surface elevation (0.3 feet) occurred in late summer from August to September.

Transparency

The lowest spring Secchi (average) depth was 0.34 m +/- 0.02 m in March (Table 2, Figure 10). As *Artemia* grazing reduced midsummer phytoplankton, lakewide transparency and Secchi depth increased through mid-July to a peak of 0.64 m +/- 0.03 m. Secchi depths began to decrease through the late summer and fall except a rather sharp increase in October (3.8 m). Overall Secchi depth transparency was reduced compared to previous years (Figure 11). Prior to 2014 average Secchi depth in July ranged between 4.31 m and 11.94 m averaging 8.2 m. Average Secchi depth in July for the past 3 years, however, were much lower and progressively decreasing each year; 1.5 m in 2014, 0.91 m in 2015 and finally 0.64 m in 2016.

Water Temperature

The water temperature data from Station 6 indicate that Mono Lake remained monomictic in 2016 as the lake was thermally stratified from late spring to early fall with turnover occurring once later in the fall (Table 3, Figure 12). By mid-May the thermocline formed at 4-5 m (as indicated by the greater than 1°C change per meter depth) and fluctuated between 5 and 13 m through September. By mid-November temperatures were isothermic from 1 m to 40 m indicating holomixis. Holomixis persisted throughout December as temperature data indicate little change with water temperatures between 5.8 and 6.0°C.

Average water temperature in the epilimnion was above normal throughout spring and below normal for the rest of the year in 2016 (Table 4a). The winter of 2014-15 was the warmest recorded since 1951 based on air temperature recorded at Lee Vining and Cain Ranch, but a trend of warming water started in fall of 2014 for the epilimnion and in fall of 2013 for the hypolimnion (Table 4c). For 7 consecutive months from October 2014 to May 2015, average water temperature in the epilimnion is approximately 2°C higher the 26 year average. Since 2011 (the end of the last meromixis), average water temperature in the hypolimnion was found above average 31 out 52 months. This warming trend is much stronger in two fall months (September and October) ($r = 0.66$ and $r = 0.69$, respectively).

Conductivity

Conductivity data was collected from the CTD field sampling device on a monthly basis. In situ conductivity measurements were corrected for temperature (25˚C) and reported at one meter intervals beginning at one meter in depth down to the lake bottom. The winter of 2016 marked the fifth consecutive year of monomixis at Mono Lake. Mono Lake surface elevation slowly increased in the beginning of 2016 and reached its peak in June due to freshwater inputs from snowmelt likely which contributed to vertical salinity stratification. As thermal and chemical stratification became more prominent in the summer months the greatest difference between epilimnetic and hypolimnetic specific conductivities were reported in June (Table 5, Figure 13). Specific conductivities for May ranged from 85.6 to 90.4 mS/cm above 14 meters and from 90.8 to 92.2 mS/cm below 14 meters. Difference in average specific conductivity between the epilimnion (87.5 mS/cm) and hypolimnion (90.5 mS/cm) remained at 3.5 mS/cm. The thermocline disappeared by October and the range of specific conductivity throughout the entire depth decreased to 1.5 mS/cm, and by November the lake experienced complete holomixis as the range of specific conductivity was 2.1 mS/cm.

Salinity

Salinity expressed as total dissolved solid (TDS in g/kg) was calculated based on the equation presented by Jellison in past compliance reports and presented in Table 6. Since 2013, the average salinity has remained above the 26-year average as was the case observed during the monomictic period in the early 90's. The lake level in 1991, however, was lower than the current level, yet current salinity level is higher than that of 1991. The highest salinity level since 1991 was observed in February of 2016 (93.4 g/kg) followed by the second highest in March (92.0 g/kg). The third highest salinity level was recorded in December (91.5 g/kg).

Dissolved Oxygen

Dissolved oxygen (DO) levels at Station 6 were indicative of historical limnological mixing patterns observed at Mono Lake. In 2016 Mono Lake had one period of fall turnover marking the 5th continuous year of monomictic conditions. DO concentration in winter months within the first 15 m of the water column remained relatively stable only ranging between 3.8 mg/l at 15 m and 6.6 mg/l at 2 m (Table 7, Figure 14). For comparison purposes the epilimnion refers to the first 14 m of the water column despite its movement from 8 m in early June to 10 m in October. Average epilimnetic DO levels were higher in spring months of March (4.2 mg/L) and April (5.3 mg/L) compared to early June (2.2 mg/L). Dissolved oxygen levels at Mono Lake are typically higher in spring months as phytoplankton blooms follow increased sunlight and temperature levels. In mid-June average DO levels in the first 6 m of the water column were about 6 times higher (4.8 mg/l) as 2014 levels (0.7 mg/l), but similar to 2015 level (5.2 mg/l). DO levels near the lake substrate (39 m) decreased from March to May (1.2 to 0.2 mg/l) prior to full onset of meromixis. In early June, Mono Lake was thermally stratified with meromictic conditions persisting through October. In 2016 DO levels in the middle of summer (June - August) ranged from 1.4 to 4.9 mg/L in the epilimnion. In October the thermocline began to slowly breakdown prior to holomixis. In the fall average epilimnetic DO concentrations slightly increased in November to 3.9 mg/l from 3.1 mg/l in October, but decreased to the lowest level in December (1.5 mg/l) as monomolimnetic hypoxic waters began to mix with epilimnetic waters. (Table 7, Figure 14). Mono Lake remained monomictic in December.

Average DO values between 1 m and 14 m ranged from 1.7 mg/l in December to 5.4 mg/l in April in 2016, and remained mostly below the long term average even though these values were within the historical range observed since 1994 (Table 8a). The range of values in 2016 was similar to what observed in 2015 (1.7 mg/l to 5.9 mg/l). Since the end of the last brief meromixis in 2011, average DO values were found high for two years. Average values were very high in 2013 with the highest value recorded in May (10.3 mg/l) since 1994. The year 2014 was very erratic with average values ranging from 0.5 mg/l in June to 10 mg/l in November. Average DO during summer months remained below 1 mg/l. During the meromixis between 1995 and 2001, DO values were mostly above the long-term average, but this trend was not found during the meromixis between 2005 and 2007.

Ammonium

Ammonium levels were uniform (12.2 – 15.0 µM) throughout the water column in February 2016 (Table 9a, Figure 15) due to holomixis that occurred in 2015. Ammonium above 15 m quickly depleted to below the detectable limit of 2.8 µM) in March except during summer months when epilimnetic ammonium levels slightly increased with onset of meromixis as *Artemia* abundance increased and excretion of fecal pellets raised the ammonium levels in the water column. The July through September period had large increases in the level of ammonium in the hypolimnion below approximately 20 m (11.6 to 24.4 µM). This increase, however, was smaller than what was observed in 2015. As holomixis progressed ammonium levels decreased below the detectable level throughout the water column by November. This reduction in ammonium levels throughout the water column coincides with holomixis and increased uptake by phytoplankton as predation pressure from *Artemia* decreases in winter months. Average epilimnetic ammonium concentrations from integrated 9-meter samples remained mostly just above or below the detectable level throughout the year except February and March (Table 9b).

Average ammonium values between 1 m and 14 m was mostly higher than the long-term average from February to August, but lower between September and December (Table 10a). Average epilimnetic ammonium was the highest on record in February and March. Due to the detection limit, precise values of ammonium are not known below 2.8 µm such that average values between 1 m and 14 m for June and between September and December could be lower than what is presented in the table. Since the summer of 2012, average ammonium tends to be higher than long term average for most months except the last four months of 2016. If not for release of a large amount of ammonium at the end of meromixis in 2003 and 2004, a positive linear trend would be much stronger for most months. To the contrary, average ammonium values in the hypolimnion have been lower than the long term average since the end of the last prolonged meromixis due to a lack of chemocline which causes buildup of ammonium in the hypolimnion. As a result a strong negative trend is observed for all months.

Phytoplankton

Seasonal changes were noted in the phytoplankton community, as measured by chlorophyll *a* concentration (Table 11a, Table 11b, Figure 16). On the February survey, epilimnetic chlorophyll a levels averaged 58.3 µg/L (Table 11a). Within the epilimnion, lakewide mean chlorophyll values decreased through the spring and reached their lowest point in July (15.4 µg/L, Table 11b). As the lake began to stratify in spring and zooplankton grazing increased, chlorophyll levels at the surface (2 m) declined from 63.6 µg/L in February, to 15.0 µg/L in June. In July, Station 6 chlorophyll concentrations varied from 15.0 µg/L at 2 m to 55.7 µg/L at 20 m in the hypolimnion. Mean epilimnetic chlorophyll levels steadily increased from August to December from 27.1 µg/L to 77.5 µg/L. By October as the water column began to mix the lakewide hypolimnionic average had increased and reached its peak in November at 80.6 µg/L. Overall both the lakewide trends and discrete sampling at Station 6 indicate changes in chlorophyll concentrations closely follow turnover conditions and fluctuations in grazing pressure from population changes of brine shrimp.

There is a trend of changes in chlorophyll *a* concentration in the epilimnion over time as average concentration was lower during the last prolonged meromixis, increased at the end of the meromixis and remained so until present (Table 12a). Peaks of average concentration vary among months. During spring months peaks are observed between 2003 and 2009 while peaks tend to occur later between 2014 and 2015 during summer to winter months. For instance, grazing used to reduce chlorophyll *a* concentration in July; however, chlorophyll *a* concentration for the past 3 years has been much higher than what was observed in the past. The average has doubled from 3.8 µg/L between 1994 and 2013 to 7.7 µg/L between 2014 and 2016. Dramatic decline in clarity in the terms of Secchi readings has been noted and coincides with changes in chlorophyll a concentration in the epilimnion.

A similar trend is found in average chlorophyll a concentration values in the hypolimnion even though a timing of peak occurrence differs slightly as peaks occur in 2009 from February to June while peaks occur in 2015 from July to December. Chlorophyll *a* concentration in the hypolimnion tends to decline during meromixis and tend to increase during monomixis (Table 12b). There appears to be 1 or 2 years of time lag between the end of meromixis and low chlorophyll *a* concentration; as a result peaks tend to occur 3 or 4 years after the brief trough. The year 2015 follows this pattern; however, average values are extremely high from late summer throughout fall. The average value in October of 2015 (101.5 µg/L) was highest recorded since 1994.

Brine Shrimp

Artemia Population Analysis and Biomass

Artemia population data is presented in Table 13a through Table 13c as lakewide means, sector means associated standard errors and percentage of population by age class. As discussed in previous reports (Jellison and Rose 2011), zooplankton populations can exhibit a high degree of spatial and temporal variability. In addition, when sampling, local convergences of water masses may concentrate shrimp above overall means. For these reasons, Jellison and Rose (2011) have cautioned that the use of a single level of significant figures in presenting data is inappropriate, and that the reader should always consider the standard error associated with *Artemia* counts when making inferences from the data.

Artemia Population

Hatching of overwintering cysts had already initiated by February as the mid-February sampling detected an instar lakewide mean abundance of 22,463 +/- 5,194/m^2. Almost all the instars in mid-February were instar age classes 1 and 2. Instar abundance increased through spring to a peak of 64.266 +/- 15,486/m^2. Between February and April adults continued to be essentially absent. The 2016 peak *Artemia* lakewide abundance of 69.779 +/-17,691/m^2 was recorded in April but almost the same value was recorded in May (69.235 +/-17,919/m^2). Adults started to mature in June as the proportion of adult increased from 4 % in May to 91% in August. The instar analysis indicated a diverse age structure of instars 1-7 and juveniles (instars 8-11) in April. In early June, females with cysts were first recorded. Females with cyst abundance peaked at 5,955 +/- 450/m^2 in July followed closely by August (5,785 +/- 886/m^2). By July reproduction decreased significantly, with instars and juveniles comprising only 24% of the population down from 55% in June. The greatest summer adult *Artemia* abundance occurred in June (18,498 +/- 3,094/m^2) and remained high through August (16,643 +/- 2,666/m^2) and relatively high in September and October (10,204 +/- 3,364/m^2 and 7,786 +/- 2,766/m^2). In November, adult *Artemia* abundance was still found above 1,000/m^2 and numbered 246 +/- 127/m^2, in December.

Instar Analysis

The instar analysis, conducted at seven stations, showed patterns similar to those shown by the lakewide and sector analysis, but provide more insight into *Artemia* reproductive cycles occurring at the lake (Table 14). Instars 1 were most abundant in February and March while instars 2 showed slight delay in peak abundance as they peaked in March and April as overwintering cysts were hatching. In April various age classes of instars 1-7 and juveniles were present and comprised approximately 96% of the *Artemia* population while adults comprised the remainder (4%). By June juvenile and instar abundance represented about 55% of the age structure population. The presence of late stage instars and juveniles indicate survival and recruitment into the population. Instar and juvenile abundance decreased to 23% in July and reached a low in August and September (9%) of the *Artemia* population. Adult abundance decreased from 91% in September to 12% in December while instar and juvenile age classes increased from 9% to near 88% over the same period. There was a large increase in instars 1 abundance in June compared to the previous month. Females with undifferentiated eggs were found in May indicating that the June spike was the hatching of the second generation. This spike in hatching did not result in the second peak in adult abundance; however, it should have helped to sustain high abundance of adult throughout summer.

Biomass

Mean lakewide *Artemia* biomass peaked at 17.4 g/m^2 in June, and remained at that level or slightly lower throughout summer (17.0 g/m^2 and 14.8 g/m^2 in July and August, respectively)

(Table 15). Mean biomass remained relatively high into October (8.19 g/m^2) and sharply declined in November to 1.62 g/m^2. Unlike 2015, peak mean biomass was higher in the east than in the west, and higher biomass in the east was observed for all monitored months except February.

Reproductive Parameters and Fecundity Analysis

By June, fecund females were plentiful enough to conduct fecundity analysis (Table 13c, Table 16, Figure 17). In mid-June approximately 69% of females were ovigerous, with 67% oviparous (cyst-bearing), 10% ovoviviparous (naupliar eggs) and 23% undifferentiated eggs (Table 13c). From July through December, over close to 90% of females were ovigerous with the majority (81-91%) oviparous.

The lakewide mean fecundity showed relatively small variation among four months during which fecundity was monitored (Table 16). The lakewide mean fecundity was initially 38.7 +/- 1.1 egg per brood in June, decreasing slightly to 32.4 +/- 1.1 eggs per brood in July and remaining at that level for August and September. Although fecund females were documented during population analysis in October, densities were too low to conduct fecundity analysis of females. The majority of fecund females (81-91%) were oviparous, while ovoviviparous females with naupliar eggs constituted the remainder. Little difference was observed in fecundity between the western and eastern sectors. Typically mean female lengths are positively correlated with mean eggs per brood; however, 2016 did not follow this pattern as in 2015. Mean lengths for June and September are almost identical yet the mean brood size in June was 6 more than that recorded in September. The largest mean females were found in August (9.9 mm) when the mean brood size was smallest (30.1 +/- 1.5 eggs per brood).

Artemia Population Statistics

The year 2016 marked the second consecutive year with very low calculated seasonal peak in adult *Artemia* (18,699/m^2 and 18,498/m^2 for 2015 and 2016, respectively) and 18,498/m^2 was the lowest peak recorded (Table 17). The mean and median were also below average (10,687 vs. 19,051/m^2 and 10,347 vs 10,347/m^2). These numbers were low but higher than what recorded during previous two years. Due to this continued trend of declining *Artemia* population, the 3 year average between 2014 and 2016 was lowest on record for mean and median. The centroid is the calculated center of abundance of adults. The centroid day, however, did not follow the declining trend; instead it rebounded to 220 days (August 7th), 35 days later than 186 days recorded in 2015 and 10 days later than the long term average of 210 days which corresponds to July 28th or 29th depending on whether a year is a leap year or not (Figure 18). The mean, median, peak and centroid data for 2015 was misreported in the 2015 annual report and has been corrected and reported in this document. The corrected mean, median and peak are higher by 12%, 4% and 21% respectively. Figure 19 shows daily lakewide mean adult *Artemia* values for 1982-2016. The year 2013 was the first year since the most recent episode of meromixis in 2011 that ammonium previously contained in the hypolimnion was fully available for phytoplankton. The year 2012 marked the 4th time that Mono Lake shifted from meromixis to monomixis during the period of record. There is data to suggest that years following the onset of monomixis have coincided with high adult *Artemia* abundance at Mono Lake (Figure 20). The long term data show 1989 and 2004 as the second and third highest adult density recorded from 1979-2016. The longest periods of meromixis, 1983-1987 and 1995-2002 ended just previous to these years (see Figure 9). Years such as 2014 that follow higher abundance years see a subsequent decline the following year of almost 50% (Table 17).

The examination of monthly average *Artemia* abundance reveals a shift in peak monthly abundance to earlier months for both adult and instars (Table 18 and Table 19). Bold numbers indicate monthly averages above the long term mean, and occurrences of these higher averages also has shifted from late summer and fall to spring and early summer. Table 18 can be broken down into three distinct periods: 1) between 1987 and 1994 (the period representing the end of the first recorded meromixis between 1983 and 1987, the breakdown of meromixis between 1988 and 1989, and after the breakdown), 2) between 1995 and 2003 (the period representing the second recorded meromixis between 1995 and 2002 and the first year of the breakdown in 2003), and 3) 2004 to present (mostly monomixitic state with two short meromixis. During the first period, the above average monthly abundance was mostly occurring between August and November. With onset of the meromixis in 1995, timing of the above average monthly abundance shifted slightly earlier to July and some years monthly abundance did not exceed their corresponding long term average value. Starting in 2004, the above average monthly abundance started to occur mostly between May and July. The last two years monthly abundance remained mostly below average. A similar trend is detected for monthly average instar abundance as above average monthly abundance was scattered throughout the year; however, the last 5 years these higher values were confined mostly between February and May (Table 19).

The data period of monthly average *Artemia* biomass available to LADWP is much shorter than *Artemia* population as it starts in 2000. Except the first three years the annual peak monthly biomass was found to occur mostly in June or July. The peak in 2015 was observed during the month of June due to postponement of May monitoring. A notable positive linear trend was found for February, March, and December between 2000 and 2016 ($r = 0.72$, 0.71, and 0.77, respectively). March in particular shows much higher monthly averages during the past 4 years: 0.1 g/m^2 between 2002 and 2012 compared 2.9 g/m^2 between 2013 and 2016. A notable negative trend was found for August as 6 out of 8 years showed the above average monthly biomass between 2000 and 2007 compared to only 2 of 9 years since then ($r = -0.72$). For February, March and August the observed trend in biomass seems to more accurately reflect the longer term trend when compared to both adult and instars abundance; however, much greater abundance was found in December between 1989 and 1992, such that the trend in biomass is a mere artifact of the sample period.

DISCUSSION

Since the beginning of the study, there have been four meromixis events; two lasted more than 4 years while two others lasted less than 2 years (Figure 9). More nutrients accumulate in the hypolimnion, and only during or after breakdown of meromixis the nutrients become available for phytoplankton (Table 10b). *Artemia* population tends to respond positively to the boost of primary production after meromixis as observed in 1989, 2004, 2009, and 2013 even though mean abundance for the latter 2 years is not as high as that of the first 2 years (34,202/m^{-2} compared to 26,002/m^{-2}) (Figure 20). The average mean abundance for the above mentioned 4 years is almost as twice as high at the rest of monitoring years, 30,102/m^{-2} compared to 16,871/m^{-2} (since 1983). After these spikes, *Artemia* population tends to decrease rather dramatically and consistently as the mean population is reduced by the average of 45%, 30,102/m^{-2} during peaks compared to 16,570/m^{-2} for years immediately following the peak. The reduction after the peak ranges from 43% to 48% averaging 45%.

In spite of generally lower abundance during non-peak years, it has been noted *Artemia* abundance has declined considerably in the past 3 years (Table 17). A large decline in 2014 is expected (48% decline from 26,033/m^{-2} to 13,467/m^{-2}), but the fact *Artemia* population has declined almost at the same rate at 43% in the following year has not been observed before.

The *Artemia* population has somehow rebounded in 2016 but remained low at 10,687/m^{-2}. Consequently, the average mean population between 2014 and 2016 is 10,610/m^{-2}, the lowest for any 3 year period on record, and the 2 lowest values on record are observed in 2015 and 2016. Instar abundance in March and April of 2014 was higher even in the historical context, 150,909/m^{-2} and 119,732/m^{-2} ranked 3rd and 4th highest since 1991, but very high instar abundance is not translated into higher adult abundance most likely due to extremely high population density which could lead to reduced food availability and dissolved oxygen. A similar collapse was observed in 1990 (peak instar abundance of 250,883/m^{-2}), but not in 1989 (peak instar abundance of 234,839/m^{-2}). A difference between 1989 and 1990/2014 is the former is the year of the meromixis breakdown while the latter is one year after the meromixis breakdown. During the breakdown, a large amount of ammonium is released from the hypolimnion and becomes available to the epilimnion, which, in turn, boosts primary productivity. Abundance of food sources in 1989 is most likely able to sustain the growth of instars into adults while resources could have been quickly depleted in 1990 and 2014. Instar abundance rapidly declines in 2014 after the peak. The instar collapse in 1990 is followed by a period of below normal adult *Artemia* abundance for 13 years until 2004 (16,312/m^{-2} between 1991 and 2003).

In addition, there is a clear temporal shift in peak abundance of instars and adults as peaks are occurring earlier in the year (Table 18 and Table 19), which are reflected on a strong linear negative trend of centroid days (calculated center of abundance of adults) in respect to monitoring years (Figure 18). There appear 3 distinct periods of adult abundance patterns; 1) later season occurrence between 1987 and 1994, 2) transition between 1995 and 2003, and 3) earlier season occurrence since 2004. The first period coincide with the breakdown of the first recorded meromixis and subsequent monomixis, and the transition period coincides with the second meromixis.

This section will be devoted to the two observations: low adult *Artemia* abundance in recent years and a temporal shift in monthly peak abundance for adult and instars and will relate these *Artemia* trends to physical and chemical parameters collected at or near Mono Lake.
It should be noted that limnological data collection conducted in Mono Lake is limited spatially and temporarily as noted previously. Monitoring is performed monthly except January at 12 stations covering the 41,977 acre area, such that it only captures a snapshot of the lake condition in the limited area and may not represent the entire lake. Further, water parameters collected at Station 6 mainly are used in this section because Station 6 has been sampled

consistently throughout the Mono Lake limnology monitoring. This further limits generalization of the results over the entire lake.

Lake Elevation and Input

In recent years, the Mono Lake level has fallen from 6,383.6 feet in April 2012 to 6,376.8 feet in October 2016 due to 5 consecutive years of below average runoff between 2012 and 2016 (Figure 22). Between 1934 and 2016, annual Mono Basin runoff averages 120,798 acre-feet; however, during the five year drought, it only averages 66,886 acre-feet (55% of Normal) with 2015 being the driest on record (44,805 acre-feet or 37% of normal). In spite of reduced runoff due to drought, total annual input from two main tributaries (Rush and Lee Vining Creeks) remains mostly above 60,000 acre-feet which is much higher than total annual input prior to 1990. Exports from the Mono Basin were halted in 1990 by a preliminary injunction in 1989 intended to stabilize Mono Lake elevation. Prior to 1990, input averaged 45,571 acre-feet when sporadic extremely wet years were excluded, compared to 96,623 acre-feet since 1990. Increased input since 1990 has resulted in rising lake level especially due to the wet period occurred in the second half of 1990s. Lake level has remained above 6,380 feet until the current drought.

Mono Lake experienced the largest single year of input on record in 1983 (250,479 acre-feet) during the first meromixis, which would have resulted in a quick and strong stratification of Mono Lake. The first meromixis has persisted until 1987. In contrast, during the second meromixis Mono Lake has stratified due to sustained high input rather a single large event as input has remained around 150,000 acre-feet for 4 years. The last 2 meromixis events are shorter and lack extremely high input. This is consistent with the general observation of the runoff pattern. The average runoff prior to 2000 is 131,810 acre-feet compared to 98,749 acre-feet since 2000, and runoff is above average for 11 of 21 years (52%) prior to 2000 compared to 4 out of 18 years (22%) since 2000. A longer period of high input and/or an extremely high input appear important for higher *Artemia* abundance, which, in turn, may affect *Artemia* abundance in subsequent years.

Salinity

Reduced input and declining Mono Lake level has resulted in higher salinity in recent years (Table 6). Salinity has been demonstrated to affect survival, growth, reproduction, and cyst hatching of *Artemia* (Starrett and Perry 1985, Dana and Lenz 1986). As of December 2016 salinity measured as total dissolved solid (or TDS) in g/kg at Station 6 is 91.5 g/kg, comparable to levels observed in the early 1990s in spite of annual Mono Lake elevation being 3 feet higher (6,377.7 feet) than that in 1991 (6374.6 feet). After breakdown of the meromixis in 1989, mean *Artemia* abundance declined sharply in 1990 and continued to decline in 1991 although slightly or much less pronounced than what observed in 2015. No rebounding may be attributable to higher salinity in 1991 and again in 1992. A continuous sharp decline in 2015 occurs under high salinity conditions as well although actual readings are not available during the first half of 2015 due to malfunctioning CTD. Concurrence of a sharp decline in *Artemia* abundance and high salinity may be responsible for continuous decline of *Artemia* abundance. In spite of high salinity levels, mean *Artemia* abundance rebounds from 7,676/m^{-2} in 2015 to 10,687/m^{-2} in 2016. This is somehow paradoxical, but in historical context mean *Artemia* abundance in 2016 is still low such that high salinity may be still affecting *Artemia* population.

Chlorophyll and Clarity

In addition to low *Artemia* abundance, clarity of Mono Lake has declined dramatically in the past 3 years (Figure 11). During a meromixis period, chlorophyll levels are lower throughout the year most likely due to limited nutrient availability (Table 10a) and persistent *Artemia* grazing while chlorophyll levels rise during the breakdown of meromixis. In July, during peak *Artemia* grazing, clarity generally improves even during years of high chlorophyll production; however, in the last 3 years clarity has failed to improve in July and Secchi readings have remained below 1 m all but one month. Declining clarity in summer coincides with much higher chlorophyll *a* concentration in the epilimnion (Table 12a). The average July value between 2014 and 2016 is 33.9 µM compared to 3.8 µM from 1994 and 2013. As mentioned previously, mean *Artemia* abundance has been much lower for the past 3 years than any other 3 year period since 1979 (Table 17).

Higher than normal chlorophyll levels, however, started developing in 2008, creating a positive linear trend of chlorophyll fluctuations with respect to monitoring years for most months. It is not clear, however, whether the observed linear trend is an artifact of the range of years during which data are available. The Station 6 data starts in 1994, just one year before the second meromixis. The 9-meter integrated data, available to 1987, supports a cyclic non-linear pattern for winter and spring but chlorophyll levels in summer and fall months are higher during later monitoring years (Table 12c). The levels observed in the past 3 years are much higher than the elevated levels in 1988. This is particularly true for July through December; chlorophyll levels are higher in later years than earlier years.

Continuingly reduced lake levels coupled with warm water temperatures and readily available nutrients may continue to support high concentrations of algal biomass. Excess algal biomass can result in self shading and reduce light attenuation throughout the water column inhibiting photosynthesis by plankton in a reduced euphotic zone. Increased senescence of light limited plankton may result in reduced oxygen availability throughout the water column. This is evident in the past 3 years as DO levels in the epilimnion are mostly below normal (Table 8). Potential abiotic factors such as increased sedimentation through wind erosion may be contributing to increased turbidity as the lake level continues to decline and regional scale drying patterns potentially contribute to reduced lake clarity.

As light availability reduces throughout the water column algal assemblages may be shifting towards phylogenies that thrive in more light limited conditions. Changes in algal assemblage type and distribution may result in less palatable food items for Mono Lake *Artemia* (Winkler 1977, Reeve 1963). The current chlorophyll sampling protocol does not allow detecting changes in plankton communities, but a failure for chlorophyll levels to decline in July and August in the past 3 years supports this hypothesis as the preferable food source is quickly depleted and non-palatable species are left throughout summer resulting in a shorter and narrower peak of *Artemia* abundance and in higher chlorophyll levels throughout summer and consequently into fall and winter. If this hypothesis is correct, chlorophyll levels should continue to rise; but results are more mixed. Fluctuations of chlorophyll concentration show more cyclic non-linear pattern and have dropped in 2016 compared to the previous two years during summer. High levels of chlorophyll in fall to December have resulted in elevated levels in February between 2014 and 2015 most likely due to the very warm winter, but the same pattern is not observed between 2015 and 2016. Further, *Artemia* abundance in 2016 shows a much broader peak than that observed in 2015, indicating brine shrimp continues to feed into summer. Fluctuations of chlorophyll levels, therefore, may be more responsive to the climatic condition and fluctuations of *Artemia* abundance. Data from 2017 will provide more insight into changes in plankton communities.

Studies have shown that spring generation *Artemia* raised at high food densities develop more quickly, begin reproducing earlier and that abundance of algae may likely affect year to year changes in *Artemia* abundance (Jellison and Melack, 1993). This appears to be the case when *Artemia* abundance (Table 18a) and chlorophyll levels (Table 12c) are compared. During the meromixic period between 1990 and 1994, a temporal shift in peak adult abundance is observed: September at 31,783/m^{-2} in 1991 to June at 24,986/m^{-2} in 1994. The temporal shift is halted with the onset of the second recorded meromixis in 1995, but resumes in 2004 with breakdown of the meromixis. Earlier completion of the life cycle due to higher food availability and a lack or reduced size of second generation may be responsible to higher chlorophyll levels later in the year resulting in low clarity of Mono Lake.

Dissolved Oxygen

Dissolved oxygen (DO) levels in the epilimnion are higher during two of three meromixis events which have occurred since 1994 simply because less saline water can hold more oxygen (Table 8a). The breakdown of the last meromixis event in 2013 shows concurrence of higher DO levels and peak mean *Artemia* abundance; however, this is not the case for 2003 and 2009. DO levels in the epilimnion for the past 3 years are lower than any other 3 year period; the average DO is 3.1 mg/L between 2014 and 2016, and only 7 out of 33 months show above average DO level. This is particularly true for 2014; the summer month average is 0.5 mg/L and if not for November's very high reading, the average DO would have been 1.9 mg/L. These values are much lower than the expected range of 2 to 6 mg/L in summer (NAS 1987).

DO in the epilimnion can originate from both abiotic (wind driven wave action) and biotic (photosynthesis) factors. Higher chlorophyll levels in the past 3 years are attributable to lower *Artemia* abundance, which, in turn, should result in higher DO levels assuming abiotic factors remain similar to previous years. DO saturation levels can be also determined by water temperature and salinity; warmer and more saline water holds less oxygen. Salinity has been steadily increasing for the past 3 years due to declining lake level while water temperature in the epilimnion shows a more mixed seasonal trend; water temperature has been higher during late winter and spring, lower during summer and early fall, and showing no trend in late fall to winter. Salinity, therefore, could be an important factor affecting DO levels in the epilimnion especially for the past 3 years. Lower DO levels in the epilimnion may have contributed to lower *Artemia* abundance in the past 3 years.

DO levels in the hypolimnion should be lower or become anoxic during meromixis and somewhat higher during monomixis due to reoxygenation due to complete mixing in late fall to winter. Low DO or anoxic condition negatively affects hatching of the cysts (Dana et al. 1988). The cysts, however, may remain viable for a number of years and may therefore hatch if sediments are reoxygenated in a later year (Jellison et al. 1989b). The relationship between instar abundance and DO levels in the hypolimnion, however, is not very clear as high instar abundance does not necessarily coincide with high hypolimnic DO levels or vice versa. This is most likely due to two factors: 1) a large discrepancy in instar abundance between eastern and western sectors, and 2) DO is monitored only at Station 6 where the depth exceeds 40 m whereas the average depth of stations in eastern sector is 24 m. Further DO reading at depths below 30 m either have not been routinely monitored or entered into the limnology database prior to 2013. This limits one's ability to relate hypolimnic DO levels to successful hatching or instar abundance.

Temperature

Ambient temperature greatly affects rates of development of Mono Lake brine shrimp and is a major determinant of seasonal variations in shrimp production (Jellison et al. 1989a; Jellison et al. 1990). Three of four temperature parameters show a warming trend or unusually warm temperatures in the past 3 years. Winter has been warm for the past 3 years in terms of maximum and minimum temperature (Figure 6). The winter of 2014-15 was particularly warm as average maximum temperature over 3 month period (December to February) was 10.3°C (50.6°F), or 4.6°C above the longer term average of 5.7°C. For summer temperature there is no clear trend of maximum temperature; however, minimum temperature shows a cyclic pattern; average to higher minimum temperature during 1950, below average throughout 1960s to most of 1980s, steadily climb between 1987 and 2002, and above average since then (Figure 7). When ambient temperature data are compared to water temperature data at Station 6, a strong linear relationship emerges for average water temperature in the epilimnion (Figure 21). There is no clear relationship between hypolimnion water temperature and air temperature because of time lag which could be variable depending on 1) season, 2) degree of chemical stratification, 3) meteorological factors (such as wind and cloud cover). When a time lag of 3 months is applied, the relationship improves statistically but becomes negative such that this type of comparison may not be applicable to gain insight into the relationship between ambient and hypolimnion water temperature due to the above mentioned reasons.

Cysts of Mono Lake brine shrimp require 3 months of dormancy in cold (<5°C) water to hatch (Dana 1981, Thun and Starrett 1986). Following this obligate period of dormancy, warmer water temperature is found to lead to shorter time required for hatching (Dana et al. 1988). Consistently above normal hypolimnic water temperature is found during the meromixis between 1995 and 2002 (Table 4b); however, a timing and duration of peak monthly instar abundance is more mixed most likely due to lower DO or anoxic in the hypolimnion and potentially low food availability. Since 2004, peak monthly instar abundance has occurred in April or earlier except 2 years (2008 and 2010) during which period hypolimnic water temperature has been below normal in spring. Cooler hypolimnic water temperature in 2016 could have resulted in more attenuated but broader peak mean abundance; consequently later occurrence of centroid. A combination of warmer hypolimnic water and higher food availability may have resulted in earlier hatching and faster development of *Artemia* instars, which, in turn, may have resulted in earlier peaking of the adult population.

Artemia Abundance

Peak mean Artemia abundance has been declining from 36,359/m^{-2} in 1989 to 26,033/m^{-2} in 2013; consequently after-peak mean *Artemia* abundance has declined from 20,005/m^{-2} in 1990 to 13,467/m^{-2} in 2014 due to consistent rates of population decline after the peak which averages 45% ranging from 43% to 48% (Table 17). Declining peaks are most likely due to weaker chemical stratification because of shorter period of above normal runoff and smaller magnitude of runoff especially for the last two meromixis. As a result, mean abundance in 2014 is lowest among four after-peak years and below the long term average. Higher salinity would have contributed to a continuing decline of *Artemia* abundance in 2015. Increase in mean abundance in 2016 seems puzzling but it is more due to width of the peak. Peak monthly abundance is very similar between 2015 and 2016, 18,699/m^{-2} and 18,498/m^{-2}, respectively, occurring in June. In 2015, monthly abundance drops quickly to 5,839/m^{-2} in August while above 10,000/m^{-2} is maintained until September in 2016. Because mean is based on the weighted average of DOY or day of year, mean is higher when higher or moderate monthly abundance continues later into the year; and in this regard peak monthly abundance has lesser influence on annual mean abundance. This would favor later peaks over earlier peaks and also broader peaks over narrower peaks.

SUMMARY

Very low *Artemia* abundance in the past 3 years, especially in 2015, may be attributable to a combination of many factors, which include but are not limited to: 1) warmer hypolimnion water temperature due to warmer ambient temperature, 2) higher salinity due to declining Mono Lake elevation, 3) lower than normal epilimnic dissolved oxygen, 4) lower adult abundance in 2014 due to lower peak abundance during the breakdown in 2013 and higher reduction of 48% afterword, 5) progressively lower peak mean abundance during the breakdown of meromixis, and 6) weaker stratification due to decreased magnitude and/or duration of Mono Lake input. A temporal shift in peak occurrences of adult and instar abundance is most likely due to: 1) warmer hypolimnion water temperature due to warmer ambient temperature, 2) higher food availability, and 3) possible changes in plankton communities. Despite these changing conditions brine shrimp reproductive strategies enable them to persist throughout both changing lake mixing regimes and periods of sometimes rapidly changing lake levels. Large influx of freshwater is expected in 2017 to initiate a longer period of meromixis which should closely resemble the first 2 meromixis events. The *Artemia* population is expected to rebound at the end of this meromixis even though magnitude of peak mean *Artemia* abundance following this meromixis depends on duration of this meromixis.

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Table 1. Mono Lake Limnology Sampling Dates for 2016.

MONTH	SAMPLING DATE
Feb	2/22/2016
Mar	3/17/2016
Apr	5/2/2016
May	5/18/2016
Jun	6/21/2016
Jul	7/27/2016
Aug	8/17/2016
Sep	9/19/2016
Oct	10/18/2016
Nov	11/28/2016
Dec	12/19/2016

Table 2. Secchi Depths (m); February – December 2016.

	SAMPLING DATE										
STATION	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western Sector											
1	0.5	0.2	0.5	0.4	0.45	0.55	0.6	0.5	0.3	0.6	0.4
2	0.4	0.4	0.4	0.4	0.4	0.5	0.55	0.45	0.3	0.5	0.4
3		0.3	0.4	0.4	0.45	0.8	0.55	0.5	0.5	0.5	0.4
4	0.45	0.4	0.4	0.3	0.5	0.6	0.5	0.5	0.45	0.5	0.3
5	0.4	0.45	0.35	0.4	0.5	0.6	0.45	0.5	0.5	0.5	0.5
6	0.45	0.3	0.45	0.3	0.5	0.6	0.6	0.5	0.5	0.5	0.5
AVG	0.44	0.34	0.42	0.37	0.47	0.61	0.54	0.49	0.43	0.52	0.42
SE	0.02	0.04	0.02	0.02	0.02	0.04	0.02	0.01	0.04	0.02	0.03
Eastern Sector											
7	0.45	0.3	0.4	0.4	0.5	0.7	0.6	0.6	0.35	0.6	0.5
8	0.4	0.4	0.45	0.3	0.45	0.5	0.65	0.4	0.3	0.6	0.5
9	0.5	0.3	0.35	0.5	0.5	0.7	0.65	0.55	0.35	0.5	0.4
10	0.45	0.4	0.5	0.4	0.5	0.9	0.7		0.3	0.5	0.5
11	0.35	0.3	0.4	0.4	0.4	0.6	0.6		0.35	0.5	0.4
12	0.45	0.3	0.35	0.4	0.45	0.6	0.65		0.4	0.5	0.3
AVG	0.43	0.33	0.41	0.40	0.47	0.67	0.64	0.52	0.34	0.53	0.43
SE	0.02	0.02	0.02	0.03	0.02	0.06	0.02	0.06	0.02	0.02	0.03
Total Lakewide											
AVG	0.44	0.34	0.41	0.38	0.47	0.64	0.59	0.50	0.38	0.53	0.43
SE	0.01	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.01	0.02

Table 3. Temperature (°C) at Station 6 between February and December in 2016.

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.9	5.3	9.7	15.2	17.4	21.8	20.9	17.4	11.5	7.8	5.8
2	3.1	5.3	9.4	15.1	16.5	20.8	21.0	17.4	11.5	7.8	5.8
3	3.1	5.3	9.4	13.8	16.1	20.5	21.2	17.1	11.4	7.8	5.8
4	3.1	5.3	9.2	13.6	15.8	20.2	21.4	17.1	11.4	7.9	5.9
5	3.2	5.2	9.1	11.3	15.1	19.4	21.4	17.0	11.4	7.9	5.9
6	3.1	5.0	9.0	9.4	14.2	19.2	19.9	16.8	11.4	7.9	5.9
7	3.0	4.8	8.8	8.8	14.0	18.7	19.3	16.8	11.4	7.9	5.9
8	2.9	4.7	8.8	8.2	13.5	17.5	18.0	16.4	11.4	7.9	5.9
9	2.7	4.6	7.7	7.3	12.3	14.0	16.5	16.8	11.4	7.9	5.9
10	2.7	4.4	7.2	7.0	9.7	12.4	13.6	16.8	11.4	7.9	5.9
11	2.7	4.2	6.9	6.7	8.5	9.8	10.9	13.5	11.4	7.9	5.9
12	2.7	4.0	6.5	6.5	7.6	8.0	8.8	10.8	11.4	7.9	5.8
13	2.7	3.9	6.1	6.4	6.8	7.4	8.1	9.2	11.4	7.9	5.8
14	2.6	3.9	5.8	6.1	6.7	7.0	7.4	8.6	11.4	7.9	5.8
15	2.6	3.8	5.6	5.7	6.6	6.8	7.2	7.7	11.4	7.9	5.8
16	2.6	3.8	5.2	5.5	6.5	6.5	6.8	7.5	11.2	7.9	5.8
17	2.6	3.8	5.1	5.3	6.3	6.4	6.5	7.4	11.1	7.9	5.8
18	2.5	3.8	4.8	5.2	6.2	6.3	6.3	7.0	11.1	7.9	5.8
19	2.5	3.7	4.6	5.0	6.0	6.2	6.2	6.7	10.9	7.9	5.8
20	2.5	3.7	4.6	4.8	5.8	6.0	6.1	6.5	10.8	7.9	5.8
21	2.5	3.7	4.5	4.7	5.7	5.9	6.1	6.5	10.6	7.9	5.8
22	2.5	3.6	4.4	4.7	5.6	5.8	6.1	6.3	10.5	7.9	5.8
23	2.5	3.4	4.3	4.7	5.4	5.8	6.0	6.2	10.3	7.9	5.8
24	2.6	3.4	4.3	4.6	5.3	5.7	5.9	6.1	10.2	7.8	5.8
25	2.6	3.4	4.2	4.5	5.2	5.7	5.8	6.1	10.1	7.8	5.8
26	2.5	3.3	4.1	4.5	5.2	5.6	5.8	6.0	9.5	7.8	5.8
27	2.5	3.2	4.0	4.4	5.1	5.5	5.7	5.9	9.0	7.8	5.8
28	2.5	3.2	4.0	4.3	5.0	5.5	5.6	5.8	8.6	7.8	5.8
29	2.5	3.1	4.0	4.3	4.9	5.4	5.5	5.8	8.5	7.8	5.8
30	2.5	3.0	3.9	4.2	4.9	5.3	5.5	5.8	8.3	7.8	5.8
31	2.5	3.0	3.9	4.2	4.9	5.3	5.5	5.7	8.2	7.8	5.8
32	2.5	2.9	3.9	4.1	4.8	5.3	5.5	5.7	8.2	7.7	5.8
33	2.5	2.9	3.8	4.1	4.8	5.2	5.5	5.7	8.2	7.7	5.8
34	2.5	2.8	3.8	4.1	4.8	5.2	5.5	5.6	8.0	7.7	5.8
35	2.5	2.8	3.8	4.1	4.8	5.2	5.5	5.6	7.9	7.7	5.8
36	2.5	2.8	3.8	4.1	4.7	5.2	5.4	5.6	7.9	7.7	5.8
37	2.5	2.8	3.8	4.1	4.7	5.2	5.4	5.5	7.9	7.7	5.8
38	2.5	2.8	3.8	4.1	4.7	5.2	5.4	5.5	7.8	7.7	5.8
39	2.6	2.9	-	-	-	-	-	-	-	7.7	5.9
40	-	-	-	-	-	-	-	-	-	-	-

Table 4a. Average water temperature (°C) between 1 m and 14 m at Station 6 since 1991. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	2.6	2.9	3.2	5.6	8.5	13.3	***17.3***	17.8		***16.2***	***9.9***	6.0
1992	2.9	***3.3***	***4.7***	***7.6***	***11.8***	***14.2***	17.0	***18.8***	17.1	***15.4***	***10.4***	5.5
1993	1.6		2.6	5.8	9.8	13.7		17.5	***17.5***	***15.2***	***11.7***	4.6
1994	3.1	2.3	***4.2***	***7.3***	10.3							
1995			***4.7***	5.5			14.8	17.6	17.1	***14.4***		***9.1***
1996		***3.8***	3.7	***6.9***	***11.7***	***15.2***	***18.0***	***19.0***			***9.7***	***6.6***
1997	3.9	***3.1***	***4.1***	***7.0***		13.4	16.0	17.4	16.3	11.5		***6.5***
1998		1.8	3.8	6.1	8.7	12.9	***17.7***	***18.5***	***17.7***	***14.0***		5.6
1999		2.1	***4.2***	5.2	9.3	12.9	***17.7***	18.0	***17.8***	***15.0***	***11.9***	***7.2***
2000		***3.3***	***4.9***	***7.7***	***10.7***	***15.6***	***18.2***	***19.3***	17.0	***14.7***		***6.2***
2001		1.5	2.6	5.6	***10.8***	***14.1***	***17.1***	***18.5***	***17.6***	***14.6***	***11.0***	***6.7***
2002		2.4	3.1	***7.3***	10.1	***15.2***	***18.6***	***18.9***	***17.3***	***14.1***	8.9	
2003	3.7	***3.4***	***5.2***	***6.9***	9.7	***14.0***	17.0	17.3	***17.6***	***15.5***	8.4	5.6
2004	3.1	2.8	3.8	***7.6***	***10.9***	***14.8***	***17.5***	***18.9***	***17.8***	***14.3***	8.2	5.4
2005			***4.3***	5.7	10.3	13.3	16.8	***18.6***	16.5	12.7	***9.6***	5.7
2006		***3.3***	3.0	6.5	***10.9***	13.5	***17.1***	17.7	16.4	13.4	9.1	4.7
2007		1.9	3.6	***6.9***	***11.2***	***14.2***	***18.8***	***20.2***	***20.0***	11.9	***9.9***	***6.5***
2008			3.3	***7.4***	***11.8***	***14.6***	***17.7***	***18.8***	***17.3***	12.2	9.5	
2009		2.9	***4.2***	6.2	***11.9***	13.6	***17.4***	17.7	***17.9***	12.2	8.7	4.7
2010			4.0	5.2	8.6	13.2	***17.4***	***18.8***	17.0	***15.2***	6.5	5.7
2011			***4.2***	5.9	8.6	12.4	15.7	18.1	***17.3***	13.8	***9.8***	3.8
2012				***6.8***	***11.1***		***18.5***	***20.4***	***19.8***	***15.8***	***10.4***	***6.5***
2013		2.0	3.9	***7.9***	***10.7***	***15.0***	17.0	17.6	17.0	11.6	8.4	***6.2***
2014		***4.3***	***5.2***	***7.3***	9.7	13.6	16.2	16.6	16.0	***14.9***	***10.5***	***8.1***
2015		***5.6***	***5.9***	***7.2***	***12.6***	13.0	14.0	15.3	15.4	13.7	***9.8***	5.4
2016		***3.0***	***4.7***	***8.2***	10.0	12.8	15.9	16.6	15.3	11.4	7.9	5.8
Average		2.9	4.0	6.7	10.4	13.9	17.1	18.2	17.2	13.9	9.5	6.0
Correlation		0.31	0.34	0.28	0.17	-0.20	-0.20	-0.22	-0.16	-0.42	-0.44	-0.13

Table 4b. Average water temperature between 15m and 38m at Station 6 since 1991. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	2.6	2.0	2.6	2.9	3.7	***4.8***	***5.3***	***5.5***		7.0	***9.0***	***5.9***
1992	2.9	2.5	2.6	2.8	3.2	3.5	4.4	4.4	5.1	6.3	***7.9***	5.5
1993	1.8		1.7	1.9	2.8	3.4		4.0	4.2	4.5	4.7	4.6
1994	2.9	2.5	2.5	2.8	3.1							
1995			3.0	3.1			4.1	4.6	4.6	4.7		4.9
1996		***4.9***	***4.9***	***4.9***	***5.0***	***5.3***	***5.7***	***5.7***			6.1	***5.7***
1997	5.1	***4.9***	***4.9***	***4.8***		***5.0***	5.2	5.3	5.5	5.7		***5.6***
1998		***4.4***	***4.3***	***4.4***	***4.4***	4.6	5.1	5.2	5.5	5.6		5.3
1999		***4.3***	***4.5***	***4.8***	***5.0***	***5.4***	***5.6***	***6.0***	***6.1***	6.8	6.5	***5.7***
2000		***4.4***	***4.4***	***4.6***	***5.3***	***5.6***	***5.9***	***6.2***	***6.5***	***7.0***		5.6
2001		3.4	***3.3***	3.4	3.6	3.7	4.0	4.1	4.5	5.2	5.4	5.2
2002		3.0	***3.3***	3.6	3.9	4.2	4.4	4.6	5.1	5.6	6.4	
2003	3.8	***3.5***	***3.5***	***3.8***	***4.7***	***5.0***	***5.3***	***5.5***	5.7	6.5	***8.7***	5.6
2004	3.0	2.7	2.7	3.0	3.6	4.1	4.7	5.0	5.4	6.7	***8.5***	5.3
2005			2.1	2.5	2.9	3.1	3.6	4.0	4.2	4.9	5.3	5.1
2006		***4.1***	***3.6***	***4.0***	4.2	4.4	4.8	4.9	5.0	5.1	5.3	5.2
2007		***3.7***	***3.4***	3.3	3.6	3.8	4.4	4.9	5.4	***8.2***	***9.9***	***6.5***
2008			1.7	2.6	***4.4***	4.5	***5.5***	***6.0***	***7.1***	***9.3***	***9.4***	
2009		2.5	2.9	3.5	***4.4***	***5.2***	***5.3***	***5.5***	***6.0***	***8.5***	***8.7***	4.9
2010			2.5	3.1	***4.3***	***5.5***	***5.7***	***6.4***	***6.3***	6.8	6.5	***5.9***
2011			2.7	3.3	***4.2***	***5.2***	***5.7***	***5.8***	***5.9***	5.9	6.0	***5.6***
2012				***4.7***	***6.0***		***7.7***	***8.0***	***8.6***	***9.8***	***10.0***	***6.5***
2013		1.7	2.1	2.6	3.0	3.6	4.0	4.3	***6.0***	***9.4***	***8.5***	***5.7***
2014		***3.5***	***3.7***	***4.1***	***4.8***	***5.6***	***5.7***	***6.3***	***7.9***	***9.9***	***10.3***	***8.0***
2015		***4.5***	***4.6***	***5.8***	***6.5***	***6.6***	***6.8***	***7.0***	***8.0***	***8.7***	***9.7***	5.4
2016		2.5	***3.3***	***4.3***	***4.5***	***5.3***	***5.7***	***5.9***	***6.2***	***9.4***	***7.8***	***5.8***
Average		3.4	3.2	3.6	4.2	4.7	5.2	5.4	5.9	7.0	7.7	5.6
Correlation		-0.10	-0.05	0.24	0.41	0.35	0.36	0.47	0.66	0.69	0.40	0.40

Table 5. Conductivity (mS/cm -1at 25°C) at Station 6 between June and December 2016.

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	91.8	91.1	88.6	86.8	86.3	85.9	86.6	87.6	89.0	90.7	92.0
2	92.8	91.2	88.7	86.4	86.1	86.2	86.7	87.5	88.8	90.7	92.0
3	93.0	91.1	88.8	86.8	86.4	86.4	86.8	87.6	89.1	90.7	92.0
4	93.0	91.2	88.8	86.6	86.4	86.1	86.9	87.6	89.1	90.7	92.0
5	92.9	91.1	89.0	85.6	86.6	86.1	86.8	87.5	89.1	90.7	91.9
6	92.8	91.3	88.9	88.6	86.7	86.5	85.9	87.6	89.1	90.7	92.0
7	93.2	91.5	89.1	89.0	86.9	86.0	86.7	87.6	89.2	90.7	92.0
8	93.2	91.6	89.0	88.7	87.0	85.1	85.4	87.6	89.1	90.7	92.0
9	93.4	91.6	88.9	89.5	87.1	85.9	86.3	87.9	89.1	90.7	92.0
10	93.4	91.8	89.8	90.3	88.4	86.2	86.1	87.7	89.1	90.7	92.0
11	93.4	91.8	89.8	90.1	89.0	86.5	87.1	86.8	89.2	90.7	92.0
12	93.5	92.2	90.3	90.4	89.7	89.0	88.9	87.5	89.1	90.7	92.0
13	93.5	92.3	90.4	90.4	90.1	89.7	89.1	89.1	89.1	90.7	92.0
14	93.5	92.3	90.7	90.4	90.2	90.1	89.8	89.1	89.1	90.7	92.0
15	93.5	92.4	90.7	90.8	90.3	90.2	89.8	89.4	89.1	90.7	92.0
16	93.6	92.4	91.1	91.1	90.3	90.3	90.0	90.1	89.0	90.7	92.0
17	93.6	92.4	91.2	91.2	90.5	90.5	90.4	89.7	89.2	90.7	92.0
18	93.7	92.4	91.4	91.3	90.5	90.5	90.4	90.1	88.9	90.7	92.0
19	93.7	92.5	91.7	91.3	90.7	90.6	90.6	90.2	89.2	90.7	92.0
20	93.7	92.5	91.8	91.6	90.8	90.7	90.6	90.4	89.1	90.7	92.0
21	93.7	92.5	91.8	91.7	90.9	90.7	90.7	90.5	89.2	90.7	92.0
22	93.7	92.6	91.9	91.7	91.0	90.8	90.7	90.5	89.3	90.7	92.0
23	93.7	92.7	91.9	91.7	91.1	90.9	90.7	90.4	89.3	90.7	92.1
24	93.7	92.8	92.0	91.8	91.2	90.9	90.8	90.7	89.4	90.7	92.1
25	93.7	92.8	92.1	91.8	91.2	90.9	90.8	90.7	89.1	90.8	92.1
26	93.7	92.9	92.2	91.9	91.3	91.0	90.9	90.7	88.8	90.8	92.1
27	93.7	92.9	92.2	91.9	91.4	91.0	90.9	90.7	89.6	90.8	92.1
28	93.7	93.0	92.3	91.9	91.5	91.1	91.0	90.8	89.7	90.8	92.1
29	93.8	93.0	92.3	92.0	91.5	91.1	91.1	90.9	89.9	90.8	92.1
30	93.8	93.1	92.3	92.0	91.5	91.2	91.1	90.9	89.9	90.8	92.1
31	93.8	93.2	92.4	92.1	91.6	91.2	91.1	90.9	90.0	90.8	92.1
32	93.8	93.3	92.4	92.2	91.6	91.3	91.1	91.0	90.1	90.8	92.1
33	93.8	93.3	92.4	92.2	91.6	91.3	91.1	91.0	89.9	90.8	92.1
34	93.8	93.5	92.4	92.2	91.6	91.3	91.1	91.0	90.1	90.8	92.1
35	93.8	93.4	92.4	92.2	91.6	91.3	91.2	91.0	90.2	90.8	92.1
36	93.8	93.5	92.4	92.2	91.6	91.3	91.2	91.0	90.3	90.8	92.1
37	93.8	93.5	92.4	92.2	91.7	91.3	91.2	91.2	90.3	90.9	92.1
38	93.8	93.5	92.4	92.2	91.7	91.4	91.2	91.1	90.3	90.9	92.1
39	69.2	68.3	-	-	-	-	-	-	-	67.1	67.2
40	-	-	-	-	-	-	-	-	-	-	-

Table 6. Average salinity or total dissolved solid (TDS) in g/kg between 1m and 38m at Station 6 since 1991. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	88.4	***88.2***	***88.1***	***88.2***	***88.4***	***88.7***	***88.8***	***89.1***		***89.6***	***90.0***	***90.0***
1992	89.3	***89.0***	***89.0***	***89.0***	***89.1***	***89.3***	***89.5***	***89.8***	***90.2***	***90.4***	***90.7***	***90.7***
1993	89.7		***89.1***	***89.0***	***89.1***	***89.4***		***89.0***	***89.1***	***89.2***	***89.2***	***88.8***
1994	88.4	***88.0***	***88.0***	***87.8***	***87.9***							
1995			***89.2***	***89.0***			***87.6***	***86.9***	***86.7***	***86.7***		***86.8***
1996		***85.9***	***85.5***	***85.2***	***84.7***	***84.6***	***84.1***	***84.1***			***84.2***	***84.1***
1997	81.5	***83.1***	***82.8***	***82.6***		***81.8***	***81.6***	***81.3***	***81.5***	81.4		81.5
1998		80.9	80.7	80.4	80.2	79.8	79.2	78.6	78.8	79.1		79.1
1999		78.0	78.1	77.7	77.6	76.6	77.9	77.9	78.4	77.8	78.6	78.7
2000		78.1	78.4	77.7	78.3	78.3	77.9	77.4	78.5	78.9		79.3
2001		79.2	79.3	79.1	79.0	78.8	78.8	78.6	79.0	78.8	79.4	79.5
2002		79.2	79.1	78.9	78.3	78.7	78.9	78.9	79.3	79.5	79.6	
2003	79.4	78.9	78.7	78.5	78.4	78.3	78.7	78.8	79.1	79.4	79.7	79.8
2004	80.0	79.6	79.3	79.3	79.3	79.2	79.1	79.5	79.8	80.3	80.6	80.6
2005			79.8	79.6	80.0	79.3	78.9	79.0	79.1	79.4	79.4	79.2
2006		78.5	78.1	77.8	77.4	77.0	76.3	76.2	76.5	76.6	76.6	76.6
2007		76.3	75.9	76.0	75.7	76.1	75.9	76.5	76.5	77.1	77.2	77.4
2008			76.9		77.1	77.0	74.4	73.9	75.9	77.4	78.1	
2009			78.2	78.1	78.1		76.8	77.2	77.7	78.9	79.2	79.3
2010			78.7	78.6	78.4	78.4	76.9	75.3	78.7	78.7	79.0	79.0
2011			78.4	78.1	77.8	77.7	76.9	76.1	76.8	77.0	76.9	76.7
2012								77.5	78.1	80.0	81.5	***83.7***
2013				***85.9***	***85.0***	***84.2***	***82.6***	***82.0***	***83.1***	***83.3***	***84.6***	***86.7***
2014			***87.7***	***86.8***	***85.4***	***85.0***	***82.1***	***83.0***	***82.6***			
2015						***86.8***	***86.6***	***85.7***	***85.7***	***86.3***	***87.2***	***90.6***
2016		***93.4***	***92.0***	***90.1***	***89.5***	***88.6***	***88.0***	***88.0***	***88.2***	***87.9***	***89.7***	***91.5***
Average		82.4	82.2	82.3	81.6	81.5	80.8	80.8	80.8	81.5	82.1	82.7

Table 7. Dissolved Oxygen* (mg/L) at Station 6 between February and December 2016.

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug†	Sep	Oct	Nov	Dec
1	6.4	4.9	6.4	3.8	4.9	2.9	3.4	2.8	5.8	5.4	3.8
2	6.6	5.1	6.4	3.6	4.9	2.8	3.2	2.7	4.0	5.3	1.7
3	6.6	4.8	6.2	3.3	4.9	2.7	3.1	2.6	5.2	5.0	1.4
4	6.2	4.7	6.0	3.2	4.9	2.6	3.1	2.6	5.0	4.6	1.4
5	5.6	4.5	5.8	3.1	4.7	2.6	3.1	2.4	4.4	4.4	1.4
6	5.3	4.3	5.6	3.0	4.5	2.5	3.1	2.2	4.0	4.3	1.4
7	5.1	4.2	5.5	2.7	4.3	2.4	3.0	2.7	3.9	4.2	1.3
8	4.8	4.1	5.4	2.6	4.2	2.3	3.0	2.5	2.1	3.9	1.3
9	4.6	4.0	5.3	2.2	4.1	2.3	2.9	2.4	1.5	3.8	1.2
10	4.5	3.9	5.2	1.7	3.9	2.0	2.7	2.7	1.5	3.4	1.2
11	4.4	3.9	4.8	1.5	3.7	1.8	2.6	2.9	1.6	3.2	1.2
12	4.3	3.7	4.5	1.4	3.5	1.7	2.3	1.5	2.0	3.0	1.2
13	4.2	3.6	4.2	1.3	3.3	1.6	**2.3**	1.1	1.8	2.8	1.2
14	3.9	3.5	4.0	1.2	3.1	1.5	**2.2**	1.1	1.8	2.7	1.2
15	3.8	3.5	3.9	1.1	2.9	1.4	**2.1**	1.0	1.9	2.5	1.1
16	3.7	3.5	3.6	1.1	2.7	1.4	**2.1**	1.0	1.8	2.4	1.1
17	3.6	3.5	3.3	1.0	2.6	1.3	**1.9**	1.0	1.6	2.1	1.1
18	3.6	3.5	3.1	0.9	2.4	1.3	**1.9**	1.0	1.5	1.8	1.1
19	3.6	3.5	2.8	0.8	2.3	1.2	**1.8**	0.9	1.5	1.7	1.1
20	3.5	3.5	2.6	0.8	2.1	1.1	**1.7**	0.9	1.0	1.6	1.1
21	3.4	3.5	2.5	0.7	1.9	0.9	**1.5**	0.8	0.5	1.5	1.1
22	3.4	3.4	2.4	0.6	1.6	0.8	**1.3**	0.7	0.3	1.3	1.1
23	3.3	3.4	2.3	0.6	1.5	0.8	**1.3**	0.7	0.2	1.1	1.1
24	3.2	3.4	2.2	0.6	1.4	0.7	**1.2**	0.6	0.1	1.0	1.1
25	3.1	3.4	2.2	0.5	1.3	0.7	**1.1**	0.6	0.1	0.9	1.0
26	3.0	3.3	2.1	0.5	1.1	0.6	**1.0**	0.5	0.3	0.7	1.0
27	3.0	3.2	2.1	0.4	1.1	0.6	**1.0**	0.4	0.4	0.7	1.0
28	2.8	3.1	1.9	0.4	0.9	0.6	**1.0**	0.4	0.4	0.6	1.0
29	2.7	3.1	1.9	0.3	0.8	0.5	**0.9**	0.4	0.4	0.6	1.0
30	2.5	3.0	1.8	0.3	0.7	0.5	**0.8**	0.4	0.2	0.6	1.0
31	2.3	3.0	1.6	0.3	0.6	0.4	**0.8**	0.4	0.2	0.6	0.9
32	2.0	3.0	1.5	0.2	0.6	0.4	**0.7**	0.4	0.1	0.5	0.9
33	1.8	2.9	1.4	0.2	0.6	0.4	**0.7**	0.4	0.1	0.5	0.8
34	1.8	2.7	1.3	0.2	0.6	0.4	**0.7**	0.4	0.1	0.5	0.8
35	1.8	2.6	1.2	0.2	0.6	0.4	**0.7**	0.4	0.2	0.5	0.8
36	1.7	2.5	1.1	0.2	0.5	0.4	**0.7**	0.5	0.2	0.5	0.8
37	1.7	2.4	1.1	0.2	0.5	0.4	**0.6**	0.4	0.2	0.5	0.8
38	1.7	2.4	1.1	0.2	0.5	0.3	**0.6**	0.5	0.2	0.5	0.8
39	2.1	2.3	1.1	0.2	0.5	0.3	**0.6**	0.5	0.2	0.5	0.7
40	0.8	2.2	1.1	0.2	0.5	0.3	**0.6**	0.5	0.2	0.5	0.7

*****YSI probe error (+/- 0.2 mg/L).
†Bold numbers indicate DO values estimated by the second order polynomial regression based on July readings.

Table 8a. Average dissolved oxygen (mg/L) at Station 6 between 2m and 14m since 1991. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1994						2.4	3.2	3.5	3.0	***6.2***		4.0	3.7
1995			***6.4***			3.6	3.4	***4.3***	3.9	***4.4***		3.7	4.2
1996		***5.7***	5.1	5.4	4.3	***4.9***	***4.2***	***4.3***	***4.2***		***6.1***	***5.5***	***5.0***
1997		***7.8***	5.8	5.5	***5.3***	***4.8***	***5.3***	***5.0***		***5.6***		***5.4***	***5.6***
1998		***6.7***	***7.8***	***7.1***	***5.8***	***5.0***	***5.2***	***5.1***	***5.1***	***4.8***		***5.4***	***5.8***
1999		***5.7***	***6.9***	***6.3***	***5.8***	***4.9***	***4.8***	***4.6***	***4.4***	***4.9***		***4.9***	***5.3***
2000			***6.4***	***6.4***	***4.9***	***4.8***	***4.7***	***4.7***	***4.8***	***5.7***	***4.9***	***5.5***	***5.3***
2001		***6.1***	***7.1***	***8.4***	4.7	***5.6***	***4.0***	4.0	***4.4***	***4.5***	***4.3***	2.5	***5.1***
2002		5.5	5.4	5.1	4.0	2.4	3.7	3.2	3.4	3.1	3.1		3.9
2003	0.7	3.8	4.4	3.7	***5.6***	***4.0***	***4.2***	3.7	4.0	***3.9***	0.2	1.8	3.6
2004	5.2	***6.7***	***6.4***	4.8	3.4	1.6	2.8	3.5	***4.2***	3.7	2.5	3.4	3.9
2005			***6.2***	5.5	4.3	3.7	3.1	***4.1***	***5.1***	***4.9***	***4.7***	***4.8***	***4.6***
2006		***6.4***	4.5	5.5	4.6	3.2	2.8	3.1	3.8	***3.9***	***4.0***	***4.6***	4.2
2007		5.3	5.9	5.5	***5.0***	3.2	3.1	3.7		1.6	2.2	4.0	3.9
2008			***6.7***	***6.2***	3.9	***3.8***	***4.0***	3.9	***4.1***	2.8	3.0		4.3
2009		5.0	***5.9***	***5.7***	4.2	2.6	3.1	3.9	3.6	2.9	2.4	***5.1***	4.0
2010			***6.6***	5.4	***6.0***	***4.5***	3.2	***4.6***	***4.4***	***4.5***	3.0	3.9	***4.6***
2011			5.9	***5.7***	4.3	***4.5***	3.7	***4.9***	***4.8***			3.7	***4.7***
2012				***6.1***	***5.5***		***5.0***	***5.1***	3.8	***4.3***	2.3	***5.2***	***4.7***
2013		***9.8***	***9.1***	***9.8***	***10.3***	***4.3***	***5.5***	***6.2***	***7.5***	2.5	0.9	0.6	***6.0***
2014		2.3	0.9	1.9	***4.9***	0.5	0.8	0.3	2.0	1.8	***9.5***	4.0	2.6
2015		2.9	5.6	3.4	1.7	***4.3***	***4.9***	3.2	4.0	2.2	1.8	1.9	3.3
2016		5.1	4.2	5.3	2.4	***4.1***	2.2	2.8	2.3	3.0	***3.9***	1.3	3.3
Average		5.7	5.9	5.6	4.8	3.8	3.8	4.0	4.1	3.9	3.5	3.9	4.4
Correlation		-0.32	-0.27	-0.21	-0.10	-0.22	-0.28	-0.24	-0.08	-0.73	-0.11	-0.48	-0.38

Table 8b. Average dissolved oxygen (mg/L) at Station 6 between 15m and 38m since 1991. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1994							0.4	0.5		***2.5***		***3.9***	***1.8***
1995			1.5				***0.8***	0.7	0.5	0.4		0.4	0.7
1996		0.5	0.3	0.3	0.4	0.5	***0.8***	0.8	***0.8***		0.6	***1.4***	0.6
1997		1.4	0.7	0.4	0.6	0.6	***1.0***			***1.5***		***1.5***	1.0
1998		2.5	1.6	1.7	0.7	***1.0***	***1.1***	***1.2***	***2.0***	***1.1***		***2.8***	***1.6***
1999		***3.4***	***3.6***	***3.3***	***2.3***	***1.5***	***1.9***	***2.2***	***1.4***	***2.5***		***3.9***	***2.6***
2000			***2.6***	1.2	***2.2***	***1.4***	***0.9***	***1.0***	***1.3***	0.7	***2.9***	***2.9***	***1.7***
2001		***4.2***	***2.8***	***1.7***	0.2	0.3	***0.7***	***1.3***	***1.0***	0.4	1.3	***3.0***	***1.5***
2002		***2.8***	2.3	1.0	0.3	0.3	0.5	0.3	0.2	0.5	1.3		0.9
2003	1.0	0.4	0.2	0.3	0.4	0.3	0.3	0.2	0.5	0.9	0.0	***1.7***	0.5
2004	3.4	***3.8***	2.2	0.9	0.7	0.4	0.4	0.6	0.1	***1.6***	1.2	***3.1***	1.4
2005			1.7	0.9	0.1	0.1	0.3	0.3	0.5	0.8	0.6	***3.1***	0.9
2006		1.6	***3.1***	***2.2***	0.8	0.2	0.4	0.8	***0.8***	0.3	0.2	***3.0***	1.2
2007		1.0	0.8	0.2	0.3	0.3	0.4	0.4		***1.3***	1.1	***3.8***	0.9
2008			***3.4***	1.6	0.7	0.2	0.3	0.3	0.3	0.4	***3.1***		1.1
2009		***5.3***	***4.6***	***2.7***	1.0	0.3	0.3	0.2	0.2	***1.2***	***3.4***	***4.8***	***2.2***
2010			***3.3***	***2.3***	***1.7***	***1.3***	0.2	0.1	0.1	0.2		***2.7***	1.3
2011			***4.7***	***3.5***	***2.0***	***1.3***		***2.3***	0.5			***2.9***	***2.4***
2012				***1.8***	***1.4***		0.3	***2.3***	0.4	0.7	1.3	***4.9***	***1.6***
2013		***8.7***	***6.2***	***4.7***	***4.0***	0.5	***0.8***	0.5	***1.6***	0.9	0.6	0.1	***2.6***
2014		2.0	0.1	0.6	***1.4***	0.0	0.3	0.0	0.1	0.1	***2.6***	***5.5***	1.2
2015		0.6	2.2	***1.8***	0.6	***0.8***	***0.8***	***1.2***	0.5	0.7	0.5	0.6	0.9
2016		2.7	***3.1***	***2.0***	0.5	***1.3***	***0.7***	***1.1***	0.6	0.5	1.0	1.0	1.3
Average		2.7	2.4	1.7	1.1	0.6	0.6	0.8	0.7	0.9	1.4	2.7	1.4
Correlation		0.24	0.41	0.39	0.26	-0.01	-0.38	0.03	-0.35	-0.48	0.07	0.07	0.18

Table 9a. Ammonium (µM) at Station 6 between February and December 2016.

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	15.0	11.1	<2.8	3.3	<2.8	2.8	2.8	<2.8	<2.8	<2.8	<2.8
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	13.3	10.5	3.3	3.9	<2.8	3.3	<2.8	<2.8	<2.8	<2.8	<2.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	11.6	12.8	3.9	3.9	2.8	7.2	9.4	2.8	<2.8	<2.8	<2.8
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	11.6	13.3	3.9	5.0	5.5	11.1	17.2	19.4	<2.8	<2.8	<2.8
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	12.2	13.3	4.4	4.4	5.5	11.6	20.0	24.4	3.9	<2.8	<2.8
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	12.2	14.4	4.4	4.4	6.7	11.1	21.6	18.8	5.5	<2.8	<2.8
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	12.2	13.3	3.9	5.5	7.2	14.4	23.8	18.3	11.1	2.8	<2.8

Laboratory detection limit of 2.8µm.

Table 9b. 9-meter integrated values for Ammonium (µm) between February and December 2016.

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	11.6	11.6	2.8	3.3	3.9	3.3	<2.8	<2.8	3.3	<2.8	<2.8
2	12.8	12.2	3.3	3.3	5.5	3.9	<2.8	<2.8	<2.8	<2.8	<2.8
5	13.9	12.2	4.4	3.9	3.3	4.4	2.8	<2.8	<2.8	<2.8	<2.8
6	15.0	11.6	2.8	3.9	<2.8	3.3	<2.8	<2.8	<2.8	<2.8	<2.8
7	14.4	12.8	3.3	2.8	3.9	2.8	<2.8	<2.8	<2.8	<2.8	<2.8
8	16.1	11.6	3.9	3.3	5.0	2.8	<2.8	<2.8	<2.8	<2.8	<2.8
11	12.2	10.5	3.9	3.3	5.0	3.9	<2.8	<2.8	<2.8	<2.8	<2.8
Mean	13.7	11.8	3.5	3.4	4.4	3.5	2.8	<2.8	3.3	<2.8	<2.8
SE	0.60	0.26	0.23	0.14	0.35	0.23	NA	NA	NA	NA	NA

Laboratory detection limit of 2.8µm.

Table 10a. Average Ammonium (µm) at Station 6 between 1 m and 14 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table. An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						***10.4***	***5.1***	3.0	***6.0***	0.7		***10.1***
1995			1.4			***7.8***	2.2	1.3	1.7	1.9		1.7
1996		1.1	0.7	0.8	***3.0***	1.6	2.4	1.3	1.8		1.1	0.8
1997		0.9	0.8	0.7	0.6	0.5	0.5	0.8	1.0	0.7		0.7
1998		0.7	0.6	0.8	0.9	1.6	0.8	0.6	0.7	0.7		0.6
1999		0.7	0.7	0.7	0.9	2.0	0.8	0.7	1.8	0.8		0.6
2000		0.5	0.8	0.8	0.6	1.5	0.3	0.9	0.8	0.7	0.6	0.9
2001		0.1	0.8	0.5	1.6	2.7	2.4	***4.4***	1.4	1.5	1.1	2.4
2002		1.7	0.9	0.8	1.6	***8.4***	3.0	2.8	1.5	***3.3***	1.2	
2003	10.7	***3.8***	***2.7***	***4.9***	1.5	2.9	0.4	***4.6***	***8.2***	0.7	***30.5***	
2004	17.6	***10.0***	***5.7***	0.4	***10.4***	***20.4***	***18.6***	***10.9***	1.5	2.3	***10.5***	***14.6***
2005			1.3	1.1	1.2	1.3	***4.5***	2.8	***3.2***	1.0	2.6	1.1
2006		1.0	0.6	0.9	1.0	1.8	***4.1***	2.6	0.9	0.1	1.1	1.2
2007		0.7	1.3	1.3	1.4	***6.0***	3.5	0.7	0.4	***5.6***	3.1	***6.4***
2008			1.2	0.4	1.3	2.9	2.3	1.1	0.8	1.1	0.8	
2009		1.3	***2.6***	0.2	1.5	3.7	***5.0***	2.8	0.7	***2.6***	***5.1***	1.6
2010			1.2	0.3	0.5	0.9	1.5	0.5	1.1	0.8	3.9	1.0
2011			0.4	0.5	0.9	0.6	1.8	0.3	1.0	1.1	0.9	2.0
2012		0.9	0.7	0.3	0.6	0.8	1.3	***4.7***	***4.7***	***7.3***	4.4	***4.7***
2013		***6.3***	***6.5***	***4.2***	***2.8***	***6.8***	***6.7***	***3.5***	***2.8***	***2.8***	2.8	2.8
2014		2.8				3.5	***3.9***	***4.7***	***3.5***	***3.4***	3.7	***5.4***
2015		***5.5***	***6.1***	***5.4***	***6.3***	***7.8***	***10.5***	***10.5***	***9.1***	***10.9***	***12.6***	***8.5***
2016		***13.3***	***11.5***	***3.1***	***3.7***	2.3	***4.4***	***4.7***	2.3	2.0	2.0	2.0
Average		3.0	2.3	1.4	2.1	4.3	3.7	3.1	2.5	2.4	4.9	3.5
Correlation		0.55	0.58	0.40	0.20	-0.10	0.26	0.37	0.18	0.51	-0.01	0.12

Table 10b. Average Ammonium (µm) at Station 6 between 15 m and 28 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table. An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						18.1	34.2	33.4	36.4	23.9		10.2
1995			10.5			37.9	40.0	41.9	38.7	55.7		56.9
1996		52.6	64.4	70.7	***76.5***	63.5	76.7	77.9	88.6		***113.3***	***108.3***
1997		***112.0***	***115.6***	***110.1***	***113.0***	***108.0***	***117.7***	***140.2***	***135.1***	***165.1***		***132.6***
1998		***186.9***	***158.2***	***163.3***	***186.2***	***188.8***	***159.5***	***204.9***	***168.6***	***168.8***		***199.4***
1999		***183.0***	***190.2***	***153.0***	***194.6***	***248.5***	***251.5***	***203.4***	***186.9***	***328.9***		***289.3***
2000		***199.1***	***258.1***	***254.1***	***137.1***	***168.2***	***159.2***	***124.3***	***164.7***	***190.8***	***258.0***	***354.0***
2001		***296.1***	***353.0***	***299.2***	***287.1***	***214.1***	***239.6***	***383.9***	***248.3***	***337.9***	***258.1***	***463.4***
2002		***225.3***	***186.6***	***241.5***	***243.8***	***238.3***	***204.9***	***329.2***	***306.9***	***250.5***	***212.6***	
2003	491.2	***200.6***	***121.9***	69.5	***73.3***	***99.9***	***98.6***	78.7	***120.5***	***96.5***	26.1	
2004	26.0	20.0	28.0	30.6	32.6	42.2	51.7	58.5	69.2	64.9	23.1	21.3
2005			25.8	24.4	30.4	39.2	53.4	53.5	58.0	57.8	***66.9***	40.6
2006		31.9	28.6	20.3	18.8	30.5	33.2	40.4	37.4	44.6	***65.1***	59.7
2007		52.2	51.6	64.5	62.5	***75.7***	65.3	71.5	68.1	42.2	8.4	6.2
2008			2.2	8.2	17.6	24.1	35.7	48.8	55.9	28.1	0.4	
2009		1.0	1.6	3.0	7.8	16.6	21.9	43.9	54.3	25.6	1.0	1.9
2010			4.6	6.4	6.6	9.3	26.7	40.8	51.3	63.5	4.2	3.7
2011			0.7	0.6	4.1	4.1	13.3	44.8	68.3	58.4	***68.6***	51.2
2012		24.9	9.6	2.6	7.9	16.5	32.5	32.9	36.1	33.9	4.5	4.7
2013		6.2	6.4	6.7	2.8	12.5	14.8	15.7	22.9	10.3	2.8	2.8
2014			2.8	4.4	6.1	9.2	14.0	23.7	20.5	15.5	3.3	3.8
2015		5.8	7.6	6.1	12.2	15.8	23.1	25.8	25.9	22.6	11.1	10.3
2016		12.1	13.6	4.2	4.9	6.2	12.1	20.7	20.2	5.6	2.2	2.0
Average		100.6	74.6	73.5	72.7	73.4	77.4	93.0	90.6	95.1	62.8	91.1
Correlation		-0.65	-0.57	-0.69	-0.71	-0.54	-0.56	-0.45	-0.49	-0.55	-0.69	-0.49

Table 11a. Chlorophyll a (µg /L) at Station 6 between February and December 2016.

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	63.6	55.5	40.7	36.1	26.6	15.0	17.5	32.1	56.1	65.6	74.9
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	55.5	43.9	41.0	37.6	29.6	21.1	16.1	33.4	51.8	73.3	80.7
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	56.6	50.2	43.4	36.1	47.1	51.9	47.7	39.3	52.5	87.5	76.9
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	58.6	41.7	44.6	45.9	63.7	55.4	59.0	59.3	55.4	78.2	65.4
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	58.9	44.9	46.1	49.9	70.7	55.7	58.6	60.2	58.7	81.8	63.3
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	71.9	49.3	46.5	49.4	62.9	43.3	57.4	57.2	56.5	76.7	50.6
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	58.3	53.1	46.9	42.7	63.6	53.0	60.4	61.3	57.5	85.5	61.9

Table 11b. 9-meter integrated values for chlorophyll *a* (µg/L) between February and December 2016.

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	57.1	54.2	49.3	38.9	30.5	16.0	20.4	34.5	76.7	72.7	70.5
2	50.4	53.2	45.9	35.8	29.0	18.1	17.3	30.0	71.8	81.6	80.6
5	59.5	58.8	40.9	33.2	25.7	15.6	16.8	32.2	53.1	71.9	86.9
6	63.5	57.6	44.3	26.4	23.4	8.7	15.3	33.5	62.8	78.4	70.6
7	41.0	48.4	44.2	40.3	34.6	13.8	13.4	33.7	67.5	91.3	58.8
8	54.9	54.6	43.2	38.1	33.8	18.7	17.2	33.7	75.2	80.5	57.1
11	61.3	58.6	46.9	43.0	26.5	17.0	18.7	34.5	72.3	79.9	53.3
Mean	55.4	55.1	45.0	36.5	29.1	15.4	17.0	33.2	68.5	79.5	68.2
SE	2.9	1.4	1.0	2.1	1.6	1.3	0.8	0.6	3.1	2.4	4.8

Table 12a. Average chlorophyll *a* (µg/L) at Station 6 between 1 m and 14 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						1.0	2.3	3.6	3.2	***47.5***		30.3
1995			***62.0***			9.0	1.1	1.4	2.9	13.2		13.5
1996		21.5	20.9	19.6	0.7	0.8	1.0	2.2	2.1		11.0	7.8
1997		35.0	21.6	7.4	1.0	1.5	0.7	0.6	1.3	22.6		7.8
1998		19.8	16.7	7.0	4.3	0.9	0.9	0.9	1.7	1.9		7.7
1999		12.0	17.0	16.2	7.1	1.1	1.5	1.9	1.5	4.3		25.6
2000		17.7	14.6	25.7	15.7	2.6	2.1	2.5	5.1	6.1	45.1	***54.2***
2001		36.9	35.8	21.8	27.0	3.0	0.8	1.4	2.2	6.9	27.7	***50.1***
2002		***69.9***	***60.0***	41.6	***34.6***	0.8	2.6	2.6	8.3	31.1	***80.0***	
2003	62.1	***67.0***	46.7	***63.9***	***81.3***	***54.5***	7.4	***26.6***	***22.2***	***48.6***	***56.2***	***54.6***
2004	59.3	***91.4***	***83.6***	***59.3***	14.4	1.5	1.6	3.0	3.5	***48.6***	***60.7***	***67.1***
2005			***64.5***	***75.7***	26.7	***21.0***	6.0	4.0	***14.4***	17.8	38.3	***61.1***
2006		***66.9***	***61.4***	***54.7***	***36.5***	4.4	2.1	2.7	6.9	8.6	11.4	28.5
2007		28.1	29.7	25.0	5.8	1.4	1.4	2.9	11.2	***45.9***	***68.1***	***55.7***
2008			***64.5***	39.1	23.0	12.4	***8.2***	***9.7***	***16.9***	***48.1***	***87.1***	
2009		***87.2***	***87.9***	***78.8***	***57.8***	***13.9***	4.0	6.6	12.6	***49.9***	***79.8***	***87.5***
2010			***68.1***	***67.4***	***68.0***	***25.8***	***10.2***	7.8	***16.4***	31.7	***66.4***	***79.5***
2011			***80.0***	***75.5***	***66.8***	***36.4***	***12.3***	3.1	5.4	6.6	15.0	43.6
2012		***56.7***	***65.7***	***69.3***	***53.5***	***18.0***	3.3	3.7	8.0	***45.2***	49.7	44.6
2013		47.2	40.7	38.0	29.8	6.6	6.1	***9.7***	***18.2***	***40.9***	51.1	***54.7***
2014		***53.5***	***54.2***	***60.4***	***32.6***	***21.9***	***22.3***	***34.6***	***51.8***	***70.9***	***92.0***	***95.4***
2015		***75.8***	***69.2***	***57.6***	***38.8***	***45.6***	***50.0***	***56.5***	***65.8***	***77.7***	***86.1***	***96.5***
2016		***58.6***	49.9	41.7	***36.6***	***34.4***	***29.3***	***27.1***	***34.9***	***53.4***	***75.5***	***77.5***
Average		49.7	50.7	45.0	31.5	13.9	7.7	9.4	13.8	33.1	55.6	49.7
Correlation		0.53	0.53	0.63	0.54	0.58	0.67	0.59	0.70	0.58	0.49	0.78

Table 12b. Average chlorophyll a (µg/L) at Station 6 between 15 m and 28 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						43.1	32.9	***45.8***	31.6	39.2		31.4
1995			42.6			28.7	20.4	26.8	38.6	***44.8***		38.1
1996		30.1	37.1	29.7	38.5	37.9	27.7	28.6	35.8		44.4	35.3
1997		46.6	46.9	32.1	33.2	42.0	35.5	32.6	21.6	24.5		27.1
1998		31.3	32.3	40.9	***54.9***	30.1	27.0	31.0	34.5	36.0		33.7
1999		25.3	25.0	26.1	23.7	44.7	31.7	23.1	34.5	23.2		30.8
2000		25.0	27.5	33.7	37.0	26.5	37.3	34.8	38.6	26.3	37.0	47.9
2001		39.6	35.2	35.4	32.1	38.1	15.5	13.2	16.7	21.2	24.9	45.6
2002		***65.3***	51.2	***54.6***	24.5	23.4	35.0	26.2	31.2	25.0	58.8	
2003	64.0	43.8	41.7	38.9	***50.4***	***53.5***		44.3	38.2	31.6	***61.6***	48.6
2004	47.0	***61.4***	***58.1***	***61.8***	***66.8***	***52.0***	33.3	33.9	41.0	39.4	53.5	***57.9***
2005			50.2	***58.1***	***56.7***	***53.9***	44.6	***47.0***	***50.7***	42.5	43.0	50.2
2006		48.4	***58.8***	***59.2***	***54.4***	***56.3***	42.9	40.5	***53.7***	***51.1***	48.7	41.2
2007		37.3	30.9	39.2	45.5	30.3	26.9	30.8	27.7	39.2	58.1	***67.1***
2008			***88.1***	***52.7***	42.4	45.2	43.0	***51.1***	39.8	***45.4***	***84.4***	
2009		***85.1***	***91.0***	***82.7***	***75.6***	***85.3***	***86.2***	***75.2***	***66.9***	***60.7***	***77.7***	***81.9***
2010			***69.6***	***67.8***	***73.4***	***69.0***	***75.6***	***67.0***	***68.2***	***59.2***	***66.2***	***75.8***
2011			***80.5***	***73.3***	***74.7***	***71.2***	***63.1***	***74.2***	***74.8***	***70.4***	***80.1***	50.7
2012		49.0	***59.5***	***69.1***	***52.2***	***52.6***	***56.3***	24.8	21.7	33.2	48.0	46.2
2013		47.6	39.4	37.7	36.4	42.9	42.2	***48.4***	44.8	43.2	50.6	***57.1***
2014		***66.1***	***56.8***	***59.0***	45.6	***59.8***	***74.5***	***86.6***	***74.8***	***69.8***	***87.0***	***96.1***
2015		***73.8***	***78.8***	***60.4***	***63.8***	***66.5***	***93.6***	***85.7***	***94.0***	***101.5***	***90.9***	***101.2***
2016		***61.9***	47.3	46.0	47.0	***65.2***	***51.8***	***58.8***	***59.5***	***57.0***	***80.6***	***60.3***
Average		49.3	52.2	50.4	49.0	48.6	45.3	44.8	45.2	44.7	60.9	53.5
Correlation		0.65	0.56	0.60	0.46	0.65	0.74	0.68	0.65	0.67	0.69	0.77

Table 12c. Average lakewide 9-meter integrated chlorophyll *a* (µg/L). Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.8	0.8	2.3	3.9	19.2	29.7
1988	24.7	***55.3***	31.1	10.9	0.6	***3.4***	***9.8***	***24.0***	***40.7***	***51.7***	40.8
1989	35.9	36.7	***63.3***	***47.2***	***29.0***	0.6	0.4	0.5	1.2	13.4	***46.2***
1990	***51.3***	***78.7***	***44.9***	15.0	2.2	1.1	1.5	1.6	***41.2***	21.7	32.5
1991	***65.5***	52.3	***51.9***	***32.5***	1.4	1.6	3.6	2.0	7.2	***55.7***	***72.4***
1992	***93.8***	***57.4***	23.1	0.4	1.5	1.4	1.3	2.9	16.5	38.1	***49.0***
1993		***109.3***	***87.9***	***24.8***	0.5	2.8	2.3	3.3	6.4	14.1	18.0
1994	***65.4***	***79.0***	39.0	3.9	0.4	1.3	1.9	6.3	***48.9***		28.5
1995		***65.5***			0.5	0.5	1.3	1.2	14.9		6.4
1996	16.2	11.7	7.3	0.6	0.9	1.2	1.4	2.4		12.3	7.8
1997	20.6	7.1	3.2	0.7	1.1	0.5	0.6	1.7	***48.3***		42.1
1998	15.8	11.8	0.9	1.9	0.7	0.9	1.0	2.3	2.2		7.4
1999	11.5	18.0	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
2000	16.5	12.2	20.4	4.0	1.6	1.3	1.5	3.1	7.2	43.7	***50.2***
2001		23.9	13.5	2.3	1.3	1.2	1.3	3.5	6.6	31.5	***53.0***
2002	***72.5***	***57.2***	22.3	10.3	0.7	1.1	4.2	***11.3***	***36.8***	***76.3***	
2003	***69.4***	48.4	***67.6***	***77.7***	***6.2***	***5.1***	3.3	***22.6***	***52.8***	***56.5***	***53.5***
2004	***101.4***	***97.5***	***60.8***	14.7	0.4	1.4	2.1	4.3	***48.9***	***63.3***	***69.9***
2005		***60.4***	***73.5***	18.8	4.1	1.0	2.2	3.5	18.1	40.7	
2006	***61.1***	***63.6***	***53.6***	***26.8***	1.9	2.0	2.1	3.2	8.3	11.3	25.8
2007	21.8	18.7	18.1	1.8	0.9	1.1	2.4	10.8	***45.3***	***71.1***	
2008		49.1	40.5	20.1	***6.8***	***3.6***	3.2	***17.7***	***48.5***	***91.5***	
2009	***86.3***	***84.1***	***69.8***	***35.2***	2.9	1.9	***4.7***	9.7	***54.0***	***78.7***	
2010		***66.4***	***66.8***	***64.2***	***13.0***	2.5	3.6	***13.8***	28.3	***67.1***	***79.1***
2011		***77.2***	***71.3***	***58.5***	***29.1***	1.6	1.9	3.2	4.8	14.6	40.1
2012	***58.2***	***63.5***	***69.7***	***40.6***	***8.8***	2.3	3.2	6.6	***39.6***	48.0	***47.1***
2013	47.4	34.8	39.2	18.1	3.3	1.6	3.1	***14.4***	***42.6***	***51.1***	***55.5***
2014	***57.7***	***52.8***	***54.4***	***31.3***	***13.7***	***8.5***	***24.2***	***50.9***	***64.7***	***86.6***	***97.7***
2015	***72.4***	***71.4***	***56.6***	***28.7***	***18.4***	***15.4***	***30.5***	***65.1***	***71.1***	***98.2***	***97.1***
2016	***55.4***	***55.1***	***45.0***	***36.5***	***29.1***	***15.4***	***17.0***	***33.2***	***68.5***	***79.5***	***68.2***
Average	50.9	52.4	43.2	21.8	6.1	2.8	4.6	11.0	30.4	49.4	45.7
Correlation	0.25	0.09	0.28	0.41	0.43	0.54	0.50	0.56	0.53	0.59	0.56

Table 13a. *Artemia* lakewide and sector means (per m^2) in 2016.

	Instars				Adult	Ad Female Ovigery Classification				
	1-7	8-11	Adult Total	Adult Males	Female Total	empty	undif	cysts	naup	Total *Artemia*
Lakewide										
Feb	22,463	0	0	0	0	0	0	0	0	22,463
Mar	59,643	0	0	0	0	0	0	0	0	59,643
Apr	64,266	5,513	0	0	0	0	0	0	0	69,779
May	40,664	25,567	3,005	2,978	27	0	27	0	0	69,235
Jun	14,567	7,780	18,498	12,609	5,889	1,797	939	2,723	429	40,845
Jul	3,573	1,657	17,393	10,158	7,234	271	410	5,955	599	22,623
Aug	744	983	16,643	9,346	7,297	970	139	5,785	403	18,370
Sep*	449	503	10,204	6,071	4,133	470	151	3,117	395	11,157
Oct	844	200	7,786	3,973	3,813	167	161	3,238	247	8,830
Nov	1,701	295	1,338	520	818	33	50	638	96	3,334
Dec	1,616	194	246	124	121	14	5	90	13	2,056
Western Sector										
Feb	15,663	0	0	0	0	0	0	0	0	15,663
Mar	41,132	0	0	0	0	0	0	0	0	41,132
Apr	32,649	1,261	0	0	0	0	0	0	0	33,910
May	39,490	24,950	2,012	1,958	54	0	54	0	0	66,452
Jun	8,746	7,378	18,296	13,280	5,017	1,476	966	2,173	402	34,420
Jul	3,277	1,374	14,343	8,785	5,558	239	252	4,575	492	18,994
Aug	1,008	920	11,444	7,058	4,386	265	189	3,592	340	13,372
Sep*	484	510	6,209	2,915	3,293	185	136	2,643	329	7,203
Oct	731	199	6,248	2,663	3,586	120	117	3,167	183	7,178
Nov	429	47	164	85	79	9	16	50	3	640
Dec	476	3	19	16	3	0	0	0	3	498
Eastern Sector										
Feb	28,129	0	0	0	0	0	0	0	0	28,129
Mar	78,155	0	0	0	0	0	0	0	0	78,155
Apr	95,882	9,765	0	0	0	0	0	0	0	105,647
May	41,838	26,184	3,997	3,997	0	0	0	0	0	72,019
Jun	20,389	8,182	18,699	11,938	6,761	2,119	912	3,273	456	47,270
Jul	3,869	1,941	20,443	11,532	8,911	302	567	7,335	706	26,253
Aug	479	1,046	21,842	11,633	10,209	1,676	88	7,978	466	23,367
Sep*	391	492	16,864	11,331	5,533	945	176	3,907	504	17,746
Oct	958	202	9,324	5,284	4,039	214	205	3,308	312	10,483
Nov	2,974	542	2,511	955	1,557	57	85	1,226	189	6,028
Dec	2,757	384	473	233	239	28	9	180	22	3,614

* Due to strong wind last four stations (3, 10 to 12) were not sampled.

Table **12a.** Average chlorophyll *a* (µg/L) at Station 6 between 1 m and 14 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						1.0	2.3	3.6	3.2	***47.5***		30.3
1995			***62.0***			9.0	1.1	1.4	2.9	13.2		13.5
1996		21.5	20.9	19.6	0.7	0.8	1.0	2.2	2.1		11.0	7.8
1997		35.0	21.6	7.4	1.0	1.5	0.7	0.6	1.3	22.6		7.8
1998		19.8	16.7	7.0	4.3	0.9	0.9	0.9	1.7	1.9		7.7
1999		12.0	17.0	16.2	7.1	1.1	1.5	1.9	1.5	4.3		25.6
2000		17.7	14.6	25.7	15.7	2.6	2.1	2.5	5.1	6.1	45.1	***54.2***
2001		36.9	35.8	21.8	27.0	3.0	0.8	1.4	2.2	6.9	27.7	***50.1***
2002		***69.9***	***60.0***	41.6	***34.6***	0.8	2.6	2.6	8.3	31.1	***80.0***	
2003	62.1	***67.0***	46.7	***63.9***	***81.3***	***54.5***	7.4	***26.6***	***22.2***	***48.6***	***56.2***	***54.6***
2004	59.3	***91.4***	***83.6***	***59.3***	14.4	1.5	1.6	3.0	3.5	***48.6***	***60.7***	***67.1***
2005			***64.5***	***75.7***	26.7	***21.0***	6.0	4.0	***14.4***	17.8	38.3	***61.1***
2006		***66.9***	***61.4***	***54.7***	***36.5***	4.4	2.1	2.7	6.9	8.6	11.4	28.5
2007		28.1	29.7	25.0	5.8	1.4	1.4	2.9	11.2	***45.9***	***68.1***	***55.7***
2008			***64.5***	39.1	23.0	12.4	***8.2***	***9.7***	***16.9***	***48.1***	***87.1***	
2009		***87.2***	***87.9***	***78.8***	***57.8***	***13.9***	4.0	6.6	12.6	***49.9***	***79.8***	***87.5***
2010			***68.1***	***67.4***	***68.0***	***25.8***	***10.2***	7.8	***16.4***	31.7	***66.4***	***79.5***
2011			***80.0***	***75.5***	***66.8***	***36.4***	***12.3***	3.1	5.4	6.6	15.0	43.6
2012		***56.7***	***65.7***	***69.3***	***53.5***	***18.0***	3.3	3.7	8.0	***45.2***	49.7	44.6
2013		47.2	40.7	38.0	29.8	6.6	6.1	***9.7***	***18.2***	***40.9***	51.1	***54.7***
2014		***53.5***	***54.2***	***60.4***	***32.6***	***21.9***	***22.3***	***34.6***	***51.8***	***70.9***	***92.0***	***95.4***
2015		***75.8***	***69.2***	***57.6***	***38.8***	***45.6***	***50.0***	***56.5***	***65.8***	***77.7***	***86.1***	***96.5***
2016		***58.6***	49.9	41.7	***36.6***	***34.4***	***29.3***	***27.1***	***34.9***	***53.4***	***75.5***	***77.5***
Average		49.7	50.7	45.0	31.5	13.9	7.7	9.4	13.8	33.1	55.6	49.7
Correlation		0.53	0.53	0.63	0.54	0.58	0.67	0.59	0.70	0.58	0.49	0.78

Table 12b. Average chlorophyll a (µg/L) at Station 6 between 15 m and 28 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						43.1	32.9	***45.8***	31.6	39.2		31.4
1995			42.6			28.7	20.4	26.8	38.6	***44.8***		38.1
1996		30.1	37.1	29.7	38.5	37.9	27.7	28.6	35.8		44.4	35.3
1997		46.6	46.9	32.1	33.2	42.0	35.5	32.6	21.6	24.5		27.1
1998		31.3	32.3	40.9	***54.9***	30.1	27.0	31.0	34.5	36.0		33.7
1999		25.3	25.0	26.1	23.7	44.7	31.7	23.1	34.5	23.2		30.8
2000		25.0	27.5	33.7	37.0	26.5	37.3	34.8	38.6	26.3	37.0	47.9
2001		39.6	35.2	35.4	32.1	38.1	15.5	13.2	16.7	21.2	24.9	45.6
2002		***65.3***	51.2	***54.6***	24.5	23.4	35.0	26.2	31.2	25.0	58.8	
2003	64.0	43.8	41.7	38.9	***50.4***	***53.5***		44.3	38.2	31.6	***61.6***	48.6
2004	47.0	***61.4***	***58.1***	***61.8***	***66.8***	***52.0***	33.3	33.9	41.0	39.4	53.5	***57.9***
2005			50.2	***58.1***	***56.7***	***53.9***	44.6	***47.0***	***50.7***	42.5	43.0	50.2
2006		48.4	***58.8***	***59.2***	***54.4***	***56.3***	42.9	40.5	***53.7***	***51.1***	48.7	41.2
2007		37.3	30.9	39.2	45.5	30.3	26.9	30.8	27.7	39.2	58.1	***67.1***
2008			***88.1***	***52.7***	42.4	45.2	43.0	***51.1***	39.8	***45.4***	***84.4***	
2009		***85.1***	***91.0***	***82.7***	***75.6***	***85.3***	***86.2***	***75.2***	***66.9***	***60.7***	***77.7***	***81.9***
2010			***69.6***	***67.8***	***73.4***	***69.0***	***75.6***	***67.0***	***68.2***	***59.2***	***66.2***	***75.8***
2011			***80.5***	***73.3***	***74.7***	***71.2***	***63.1***	***74.2***	***74.8***	***70.4***	***80.1***	50.7
2012		49.0	***59.5***	***69.1***	***52.2***	***52.6***	***56.3***	24.8	21.7	33.2	48.0	46.2
2013		47.6	39.4	37.7	36.4	42.9	42.2	***48.4***	44.8	43.2	50.6	***57.1***
2014		***66.1***	***56.8***	***59.0***	45.6	***59.8***	***74.5***	***86.6***	***74.8***	***69.8***	***87.0***	***96.1***
2015		***73.8***	***78.8***	***60.4***	***63.8***	***66.5***	***93.6***	***85.7***	***94.0***	***101.5***	***90.9***	***101.2***
2016		***61.9***	47.3	46.0	47.0	***65.2***	***51.8***	***58.8***	***59.5***	***57.0***	***80.6***	***60.3***
Average		49.3	52.2	50.4	49.0	48.6	45.3	44.8	45.2	44.7	60.9	53.5
Correlation		0.65	0.56	0.60	0.46	0.65	0.74	0.68	0.65	0.67	0.69	0.77

Table 12c. Average lakewide 9-meter integrated chlorophyll *a* (µg/L). Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.8	0.8	2.3	3.9	19.2	29.7
1988	24.7	***55.3***	31.1	10.9	0.6	***3.4***	***9.8***	***24.0***	***40.7***	***51.7***	40.8
1989	35.9	36.7	***63.3***	***47.2***	***29.0***	0.6	0.4	0.5	1.2	13.4	***46.2***
1990	***51.3***	***78.7***	***44.9***	15.0	2.2	1.1	1.5	1.6	***41.2***	21.7	32.5
1991	***65.5***	52.3	***51.9***	***32.5***	1.4	1.6	3.6	2.0	7.2	***55.7***	***72.4***
1992	***93.8***	***57.4***	23.1	0.4	1.5	1.4	1.3	2.9	16.5	38.1	***49.0***
1993		***109.3***	***87.9***	***24.8***	0.5	2.8	2.3	3.3	6.4	14.1	18.0
1994	***65.4***	***79.0***	39.0	3.9	0.4	1.3	1.9	6.3	***48.9***		28.5
1995		***65.5***			0.5	0.5	1.3	1.2	14.9		6.4
1996	16.2	11.7	7.3	0.6	0.9	1.2	1.4	2.4		12.3	7.8
1997	20.6	7.1	3.2	0.7	1.1	0.5	0.6	1.7	***48.3***		42.1
1998	15.8	11.8	0.9	1.9	0.7	0.9	1.0	2.3	2.2		7.4
1999	11.5	18.0	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
2000	16.5	12.2	20.4	4.0	1.6	1.3	1.5	3.1	7.2	43.7	***50.2***
2001		23.9	13.5	2.3	1.3	1.2	1.3	3.5	6.6	31.5	***53.0***
2002	***72.5***	***57.2***	22.3	10.3	0.7	1.1	4.2	***11.3***	***36.8***	***76.3***	
2003	***69.4***	48.4	***67.6***	***77.7***	***6.2***	***5.1***	3.3	***22.6***	***52.8***	***56.5***	***53.5***
2004	***101.4***	***97.5***	***60.8***	14.7	0.4	1.4	2.1	4.3	***48.9***	***63.3***	***69.9***
2005		***60.4***	***73.5***	18.8	4.1	1.0	2.2	3.5	18.1	40.7	
2006	***61.1***	***63.6***	***53.6***	***26.8***	1.9	2.0	2.1	3.2	8.3	11.3	25.8
2007	21.8	18.7	18.1	1.8	0.9	1.1	2.4	10.8	***45.3***	***71.1***	
2008		49.1	40.5	20.1	***6.8***	***3.6***	3.2	***17.7***	***48.5***	***91.5***	
2009	***86.3***	***84.1***	***69.8***	***35.2***	2.9	1.9	***4.7***	9.7	***54.0***	***78.7***	
2010		***66.4***	***66.8***	***64.2***	***13.0***	2.5	3.6	***13.8***	28.3	***67.1***	***79.1***
2011		***77.2***	***71.3***	***58.5***	***29.1***	1.6	1.9	3.2	4.8	14.6	40.1
2012	***58.2***	***63.5***	***69.7***	***40.6***	***8.8***	2.3	3.2	6.6	***39.6***	48.0	***47.1***
2013	47.4	34.8	39.2	18.1	3.3	1.6	3.1	***14.4***	***42.6***	***51.1***	***55.5***
2014	***57.7***	***52.8***	***54.4***	***31.3***	***13.7***	***8.5***	***24.2***	***50.9***	***64.7***	***86.6***	***97.7***
2015	***72.4***	***71.4***	***56.6***	***28.7***	***18.4***	***15.4***	***30.5***	***65.1***	***71.1***	***98.2***	***97.1***
2016	***55.4***	***55.1***	***45.0***	***36.5***	***29.1***	***15.4***	***17.0***	***33.2***	***68.5***	***79.5***	***68.2***
Average	50.9	52.4	43.2	21.8	6.1	2.8	4.6	11.0	30.4	49.4	45.7
Correlation	0.25	0.09	0.28	0.41	0.43	0.54	0.50	0.56	0.53	0.59	0.56

Table **13**b. Standard errors (SE) of *Artemia* sector means (from

Table **12a.** Average chlorophyll *a* (µg/L) at Station 6 between 1 m and 14 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						1.0	2.3	3.6	3.2	***47.5***		30.3
1995			***62.0***			9.0	1.1	1.4	2.9	13.2		13.5
1996		21.5	20.9	19.6	0.7	0.8	1.0	2.2	2.1		11.0	7.8
1997		35.0	21.6	7.4	1.0	1.5	0.7	0.6	1.3	22.6		7.8
1998		19.8	16.7	7.0	4.3	0.9	0.9	0.9	1.7	1.9		7.7
1999		12.0	17.0	16.2	7.1	1.1	1.5	1.9	1.5	4.3		25.6
2000		17.7	14.6	25.7	15.7	2.6	2.1	2.5	5.1	6.1	45.1	***54.2***
2001		36.9	35.8	21.8	27.0	3.0	0.8	1.4	2.2	6.9	27.7	***50.1***
2002		***69.9***	***60.0***	41.6	***34.6***	0.8	2.6	2.6	8.3	31.1	***80.0***	
2003	62.1	***67.0***	46.7	***63.9***	***81.3***	***54.5***	7.4	***26.6***	***22.2***	***48.6***	***56.2***	***54.6***
2004	59.3	***91.4***	***83.6***	***59.3***	14.4	1.5	1.6	3.0	3.5	***48.6***	***60.7***	***67.1***
2005			***64.5***	***75.7***	26.7	***21.0***	6.0	4.0	***14.4***	17.8	38.3	***61.1***
2006		***66.9***	***61.4***	***54.7***	***36.5***	4.4	2.1	2.7	6.9	8.6	11.4	28.5
2007		28.1	29.7	25.0	5.8	1.4	1.4	2.9	11.2	***45.9***	***68.1***	***55.7***
2008			***64.5***	39.1	23.0	12.4	***8.2***	***9.7***	***16.9***	***48.1***	***87.1***	
2009		***87.2***	***87.9***	***78.8***	***57.8***	***13.9***	4.0	6.6	12.6	***49.9***	***79.8***	***87.5***
2010			***68.1***	***67.4***	***68.0***	***25.8***	***10.2***	7.8	***16.4***	31.7	***66.4***	***79.5***
2011			***80.0***	***75.5***	***66.8***	***36.4***	***12.3***	3.1	5.4	6.6	15.0	43.6
2012		***56.7***	***65.7***	***69.3***	***53.5***	***18.0***	3.3	3.7	8.0	***45.2***	49.7	44.6
2013		47.2	40.7	38.0	29.8	6.6	6.1	***9.7***	***18.2***	***40.9***	51.1	***54.7***
2014		***53.5***	***54.2***	***60.4***	***32.6***	***21.9***	***22.3***	***34.6***	***51.8***	***70.9***	***92.0***	***95.4***
2015		***75.8***	***69.2***	***57.6***	***38.8***	***45.6***	***50.0***	***56.5***	***65.8***	***77.7***	***86.1***	***96.5***
2016		***58.6***	49.9	41.7	***36.6***	***34.4***	***29.3***	***27.1***	***34.9***	***53.4***	***75.5***	***77.5***
Average		49.7	50.7	45.0	31.5	13.9	7.7	9.4	13.8	33.1	55.6	49.7
Correlation		0.53	0.53	0.63	0.54	0.58	0.67	0.59	0.70	0.58	0.49	0.78

Table 12b. Average chlorophyll a (µg/L) at Station 6 between 15 m and 28 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						43.1	32.9	***45.8***	31.6	39.2		31.4
1995			42.6			28.7	20.4	26.8	38.6	***44.8***		38.1
1996		30.1	37.1	29.7	38.5	37.9	27.7	28.6	35.8		44.4	35.3
1997		46.6	46.9	32.1	33.2	42.0	35.5	32.6	21.6	24.5		27.1
1998		31.3	32.3	40.9	***54.9***	30.1	27.0	31.0	34.5	36.0		33.7
1999		25.3	25.0	26.1	23.7	44.7	31.7	23.1	34.5	23.2		30.8
2000		25.0	27.5	33.7	37.0	26.5	37.3	34.8	38.6	26.3	37.0	47.9
2001		39.6	35.2	35.4	32.1	38.1	15.5	13.2	16.7	21.2	24.9	45.6
2002		***65.3***	51.2	***54.6***	24.5	23.4	35.0	26.2	31.2	25.0	58.8	
2003	64.0	43.8	41.7	38.9	***50.4***	***53.5***		44.3	38.2	31.6	***61.6***	48.6
2004	47.0	***61.4***	***58.1***	***61.8***	***66.8***	***52.0***	33.3	33.9	41.0	39.4	53.5	***57.9***
2005			50.2	***58.1***	***56.7***	***53.9***	44.6	***47.0***	***50.7***	42.5	43.0	50.2
2006		48.4	***58.8***	***59.2***	***54.4***	***56.3***	42.9	40.5	***53.7***	***51.1***	48.7	41.2
2007		37.3	30.9	39.2	45.5	30.3	26.9	30.8	27.7	39.2	58.1	***67.1***
2008			***88.1***	***52.7***	42.4	45.2	43.0	***51.1***	39.8	***45.4***	***84.4***	
2009		***85.1***	***91.0***	***82.7***	***75.6***	***85.3***	***86.2***	***75.2***	***66.9***	***60.7***	***77.7***	***81.9***
2010			***69.6***	***67.8***	***73.4***	***69.0***	***75.6***	***67.0***	***68.2***	***59.2***	***66.2***	***75.8***
2011			***80.5***	***73.3***	***74.7***	***71.2***	***63.1***	***74.2***	***74.8***	***70.4***	***80.1***	50.7
2012		49.0	***59.5***	***69.1***	***52.2***	***52.6***	***56.3***	24.8	21.7	33.2	48.0	46.2
2013		47.6	39.4	37.7	36.4	42.9	42.2	***48.4***	44.8	43.2	50.6	***57.1***
2014		***66.1***	***56.8***	***59.0***	45.6	***59.8***	***74.5***	***86.6***	***74.8***	***69.8***	***87.0***	***96.1***
2015		***73.8***	***78.8***	***60.4***	***63.8***	***66.5***	***93.6***	***85.7***	***94.0***	***101.5***	***90.9***	***101.2***
2016		***61.9***	47.3	46.0	47.0	***65.2***	***51.8***	***58.8***	***59.5***	***57.0***	***80.6***	***60.3***
Average		49.3	52.2	50.4	49.0	48.6	45.3	44.8	45.2	44.7	60.9	53.5
Correlation		0.65	0.56	0.60	0.46	0.65	0.74	0.68	0.65	0.67	0.69	0.77

Table 12c. Average lakewide 9-meter integrated chlorophyll *a* (µg/L). Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.8	0.8	2.3	3.9	19.2	29.7
1988	24.7	***55.3***	31.1	10.9	0.6	***3.4***	***9.8***	***24.0***	***40.7***	***51.7***	40.8
1989	35.9	36.7	***63.3***	***47.2***	***29.0***	0.6	0.4	0.5	1.2	13.4	***46.2***
1990	***51.3***	***78.7***	***44.9***	15.0	2.2	1.1	1.5	1.6	***41.2***	21.7	32.5
1991	***65.5***	52.3	***51.9***	***32.5***	1.4	1.6	3.6	2.0	7.2	***55.7***	***72.4***
1992	***93.8***	***57.4***	23.1	0.4	1.5	1.4	1.3	2.9	16.5	38.1	***49.0***
1993		***109.3***	***87.9***	***24.8***	0.5	2.8	2.3	3.3	6.4	14.1	18.0
1994	***65.4***	***79.0***	39.0	3.9	0.4	1.3	1.9	6.3	***48.9***		28.5
1995		***65.5***			0.5	0.5	1.3	1.2	14.9		6.4
1996	16.2	11.7	7.3	0.6	0.9	1.2	1.4	2.4		12.3	7.8
1997	20.6	7.1	3.2	0.7	1.1	0.5	0.6	1.7	***48.3***		42.1
1998	15.8	11.8	0.9	1.9	0.7	0.9	1.0	2.3	2.2		7.4
1999	11.5	18.0	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
2000	16.5	12.2	20.4	4.0	1.6	1.3	1.5	3.1	7.2	43.7	***50.2***
2001		23.9	13.5	2.3	1.3	1.2	1.3	3.5	6.6	31.5	***53.0***
2002	***72.5***	***57.2***	22.3	10.3	0.7	1.1	4.2	***11.3***	***36.8***	***76.3***	
2003	***69.4***	48.4	***67.6***	***77.7***	***6.2***	***5.1***	3.3	***22.6***	***52.8***	***56.5***	***53.5***
2004	***101.4***	***97.5***	***60.8***	14.7	0.4	1.4	2.1	4.3	***48.9***	***63.3***	***69.9***
2005		***60.4***	***73.5***	18.8	4.1	1.0	2.2	3.5	18.1	40.7	
2006	***61.1***	***63.6***	***53.6***	***26.8***	1.9	2.0	2.1	3.2	8.3	11.3	25.8
2007	21.8	18.7	18.1	1.8	0.9	1.1	2.4	10.8	***45.3***	***71.1***	
2008		49.1	40.5	20.1	***6.8***	***3.6***	3.2	***17.7***	***48.5***	***91.5***	
2009	***86.3***	***84.1***	***69.8***	***35.2***	2.9	1.9	***4.7***	9.7	***54.0***	***78.7***	
2010		***66.4***	***66.8***	***64.2***	***13.0***	2.5	3.6	***13.8***	28.3	***67.1***	***79.1***
2011		***77.2***	***71.3***	***58.5***	***29.1***	1.6	1.9	3.2	4.8	14.6	40.1
2012	***58.2***	***63.5***	***69.7***	***40.6***	***8.8***	2.3	3.2	6.6	***39.6***	48.0	***47.1***
2013	47.4	34.8	39.2	18.1	3.3	1.6	3.1	***14.4***	***42.6***	***51.1***	***55.5***
2014	***57.7***	***52.8***	***54.4***	***31.3***	***13.7***	***8.5***	***24.2***	***50.9***	***64.7***	***86.6***	***97.7***
2015	***72.4***	***71.4***	***56.6***	***28.7***	***18.4***	***15.4***	***30.5***	***65.1***	***71.1***	***98.2***	***97.1***
2016	***55.4***	***55.1***	***45.0***	***36.5***	***29.1***	***15.4***	***17.0***	***33.2***	***68.5***	***79.5***	***68.2***
Average	50.9	52.4	43.2	21.8	6.1	2.8	4.6	11.0	30.4	49.4	45.7
Correlation	0.25	0.09	0.28	0.41	0.43	0.54	0.50	0.56	0.53	0.59	0.56

Table **13**a) in 2016.

	Instars		Adult	Adult	Adult Female	Ad Female Ovigery Classification				Total
	1-7	8-11	Total	Males	Total	empty	undif	cysts	naup	*Artemia*
Lakewide										
Feb	5,194	0	0	0	0	0	0	0	0	5,194
Mar	12,775	0	0	0	0	0	0	0	0	12,775
Apr	15,486	2,326	0	0	0	0	0	0	0	17,691
May	10,428	7,568	734	742	27	0	27	0	0	17,919
Jun	2,408	1,224	3,094	2,305	913	327	205	450	133	5,316
Jul	533	256	1,968	1,055	1,077	65	101	886	143	2,444
Aug	166	121	2,666	1,310	1,428	281	47	1,130	99	2,758
Sep*	45	109	3,364	2,495	944	280	29	606	90	3,378
Oct	242	71	2,766	1,507	1,381	64	54	1,204	87	3,020
Nov	533	97	630	267	366	14	16	297	44	1,222
Dec	622	92	127	60	68	7	5	53	7	797
Western Sector										
Feb	7,474	0	0	0	0	0	0	0	0	7,474
Mar	12,316	0	0	0	0	0	0	0	0	12,316
Apr	3,823	382	0	0	0	0	0	0	0	3,935
May	9,523	8,708	901	919	54	0	54	0	0	17,716
Jun	1,713	2,360	6,010	4,448	1,638	580	355	755	136	9,521
Jul	506	274	2,197	1,202	1,350	104	117	1,205	117	2,826
Aug	233	211	1,540	637	1,051	70	80	856	147	1,799
Sep*	63	163	1,372	581	844	30	28	720	87	1,493
Oct	430	143	4,111	1,584	2,541	98	71	2,287	93	4,652
Nov	72	13	30	14	22	6	6	15	3	99
Dec	148	3	13	10	3	0	0	0	3	143
Eastern Sector										
Feb	6,894	0	0	0	0	0	0	0	0	6,894
Mar	20,721	0	0	0	0	0	0	0	0	20,721
Apr	25,311	4,052	0	0	0	0	0	0	0	29,103
May	19,679	13,267	1,079	1,079	0	0	0	0	0	33,102
Jun	3,002	975	2,447	1,850	826	307	241	449	244	4,142
Jul	979	425	2,915	1,642	1,468	87	146	1,113	267	3,609
Aug	197	136	4,254	2,249	2,116	378	49	1,722	141	4,500
Sep*	55	153	7,993	5,903	2,091	739	67	1,098	202	8,023
Oct	261	40	3,976	2,607	1,382	86	83	1,071	152	4,171
Nov	774	129	1,093	488	609	23	24	501	72	1,913
Dec	1,076	149	223	105	123	12	9	96	14	1,343

* Due to strong wind last four stations (3, 10 to 12) were not sampled.

Table **12a.** Average chlorophyll *a* (µg/L) at Station 6 between 1 m and 14 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						1.0	2.3	3.6	3.2	***47.5***		30.3
1995			***62.0***			9.0	1.1	1.4	2.9	13.2		13.5
1996		21.5	20.9	19.6	0.7	0.8	1.0	2.2	2.1		11.0	7.8
1997		35.0	21.6	7.4	1.0	1.5	0.7	0.6	1.3	22.6		7.8
1998		19.8	16.7	7.0	4.3	0.9	0.9	0.9	1.7	1.9		7.7
1999		12.0	17.0	16.2	7.1	1.1	1.5	1.9	1.5	4.3		25.6
2000		17.7	14.6	25.7	15.7	2.6	2.1	2.5	5.1	6.1	45.1	***54.2***
2001		36.9	35.8	21.8	27.0	3.0	0.8	1.4	2.2	6.9	27.7	***50.1***
2002		***69.9***	***60.0***	41.6	***34.6***	0.8	2.6	2.6	8.3	31.1	***80.0***	
2003	62.1	***67.0***	46.7	***63.9***	***81.3***	***54.5***	7.4	***26.6***	***22.2***	***48.6***	***56.2***	***54.6***
2004	59.3	***91.4***	***83.6***	***59.3***	14.4	1.5	1.6	3.0	3.5	***48.6***	***60.7***	***67.1***
2005			***64.5***	***75.7***	26.7	***21.0***	6.0	4.0	***14.4***	17.8	38.3	***61.1***
2006		***66.9***	***61.4***	***54.7***	***36.5***	4.4	2.1	2.7	6.9	8.6	11.4	28.5
2007		28.1	29.7	25.0	5.8	1.4	1.4	2.9	11.2	***45.9***	***68.1***	***55.7***
2008			***64.5***	39.1	23.0	12.4	***8.2***	***9.7***	***16.9***	***48.1***	***87.1***	
2009		***87.2***	***87.9***	***78.8***	***57.8***	***13.9***	4.0	6.6	12.6	***49.9***	***79.8***	***87.5***
2010			***68.1***	***67.4***	***68.0***	***25.8***	***10.2***	7.8	***16.4***	31.7	***66.4***	***79.5***
2011			***80.0***	***75.5***	***66.8***	***36.4***	***12.3***	3.1	5.4	6.6	15.0	43.6
2012		***56.7***	***65.7***	***69.3***	***53.5***	***18.0***	3.3	3.7	8.0	***45.2***	49.7	44.6
2013		47.2	40.7	38.0	29.8	6.6	6.1	***9.7***	***18.2***	***40.9***	51.1	***54.7***
2014		***53.5***	***54.2***	***60.4***	***32.6***	***21.9***	***22.3***	***34.6***	***51.8***	***70.9***	***92.0***	***95.4***
2015		***75.8***	***69.2***	***57.6***	***38.8***	***45.6***	***50.0***	***56.5***	***65.8***	***77.7***	***86.1***	***96.5***
2016		***58.6***	49.9	41.7	***36.6***	***34.4***	***29.3***	***27.1***	***34.9***	***53.4***	***75.5***	***77.5***
Average		49.7	50.7	45.0	31.5	13.9	7.7	9.4	13.8	33.1	55.6	49.7
Correlation		0.53	0.53	0.63	0.54	0.58	0.67	0.59	0.70	0.58	0.49	0.78

Table 12b. Average chlorophyll a (µg/L) at Station 6 between 15 m and 28 m since 1994. Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						43.1	32.9	***45.8***	31.6	39.2		31.4
1995			42.6			28.7	20.4	26.8	38.6	***44.8***		38.1
1996		30.1	37.1	29.7	38.5	37.9	27.7	28.6	35.8		44.4	35.3
1997		46.6	46.9	32.1	33.2	42.0	35.5	32.6	21.6	24.5		27.1
1998		31.3	32.3	40.9	***54.9***	30.1	27.0	31.0	34.5	36.0		33.7
1999		25.3	25.0	26.1	23.7	44.7	31.7	23.1	34.5	23.2		30.8
2000		25.0	27.5	33.7	37.0	26.5	37.3	34.8	38.6	26.3	37.0	47.9
2001		39.6	35.2	35.4	32.1	38.1	15.5	13.2	16.7	21.2	24.9	45.6
2002		***65.3***	51.2	***54.6***	24.5	23.4	35.0	26.2	31.2	25.0	58.8	
2003	64.0	43.8	41.7	38.9	***50.4***	***53.5***		44.3	38.2	31.6	***61.6***	48.6
2004	47.0	***61.4***	***58.1***	***61.8***	***66.8***	***52.0***	33.3	33.9	41.0	39.4	53.5	***57.9***
2005			50.2	***58.1***	***56.7***	***53.9***	44.6	***47.0***	***50.7***	42.5	43.0	50.2
2006		48.4	***58.8***	***59.2***	***54.4***	***56.3***	42.9	40.5	***53.7***	***51.1***	48.7	41.2
2007		37.3	30.9	39.2	45.5	30.3	26.9	30.8	27.7	39.2	58.1	***67.1***
2008			***88.1***	***52.7***	42.4	45.2	43.0	***51.1***	39.8	***45.4***	***84.4***	
2009		***85.1***	***91.0***	***82.7***	***75.6***	***85.3***	***86.2***	***75.2***	***66.9***	***60.7***	***77.7***	***81.9***
2010			***69.6***	***67.8***	***73.4***	***69.0***	***75.6***	***67.0***	***68.2***	***59.2***	***66.2***	***75.8***
2011			***80.5***	***73.3***	***74.7***	***71.2***	***63.1***	***74.2***	***74.8***	***70.4***	***80.1***	50.7
2012		49.0	***59.5***	***69.1***	***52.2***	***52.6***	***56.3***	24.8	21.7	33.2	48.0	46.2
2013		47.6	39.4	37.7	36.4	42.9	42.2	***48.4***	44.8	43.2	50.6	***57.1***
2014		***66.1***	***56.8***	***59.0***	45.6	***59.8***	***74.5***	***86.6***	***74.8***	***69.8***	***87.0***	***96.1***
2015		***73.8***	***78.8***	***60.4***	***63.8***	***66.5***	***93.6***	***85.7***	***94.0***	***101.5***	***90.9***	***101.2***
2016		***61.9***	47.3	46.0	47.0	***65.2***	***51.8***	***58.8***	***59.5***	***57.0***	***80.6***	***60.3***
Average		49.3	52.2	50.4	49.0	48.6	45.3	44.8	45.2	44.7	60.9	53.5
Correlation		0.65	0.56	0.60	0.46	0.65	0.74	0.68	0.65	0.67	0.69	0.77

Table 12c. Average lakewide 9-meter integrated chlorophyll *a* (µg/L). Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.8	0.8	2.3	3.9	19.2	29.7
1988	24.7	***55.3***	31.1	10.9	0.6	***3.4***	***9.8***	***24.0***	***40.7***	***51.7***	40.8
1989	35.9	36.7	***63.3***	***47.2***	***29.0***	0.6	0.4	0.5	1.2	13.4	***46.2***
1990	***51.3***	***78.7***	***44.9***	15.0	2.2	1.1	1.5	1.6	***41.2***	21.7	32.5
1991	***65.5***	52.3	***51.9***	***32.5***	1.4	1.6	3.6	2.0	7.2	***55.7***	***72.4***
1992	***93.8***	***57.4***	23.1	0.4	1.5	1.4	1.3	2.9	16.5	38.1	***49.0***
1993		***109.3***	***87.9***	***24.8***	0.5	2.8	2.3	3.3	6.4	14.1	18.0
1994	***65.4***	***79.0***	39.0	3.9	0.4	1.3	1.9	6.3	***48.9***		28.5
1995		***65.5***			0.5	0.5	1.3	1.2	14.9		6.4
1996	16.2	11.7	7.3	0.6	0.9	1.2	1.4	2.4		12.3	7.8
1997	20.6	7.1	3.2	0.7	1.1	0.5	0.6	1.7	***48.3***		42.1
1998	15.8	11.8	0.9	1.9	0.7	0.9	1.0	2.3	2.2		7.4
1999	11.5	18.0	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
2000	16.5	12.2	20.4	4.0	1.6	1.3	1.5	3.1	7.2	43.7	***50.2***
2001		23.9	13.5	2.3	1.3	1.2	1.3	3.5	6.6	31.5	***53.0***
2002	***72.5***	***57.2***	22.3	10.3	0.7	1.1	4.2	***11.3***	***36.8***	***76.3***	
2003	***69.4***	48.4	***67.6***	***77.7***	***6.2***	***5.1***	3.3	***22.6***	***52.8***	***56.5***	***53.5***
2004	***101.4***	***97.5***	***60.8***	14.7	0.4	1.4	2.1	4.3	***48.9***	***63.3***	***69.9***
2005		***60.4***	***73.5***	18.8	4.1	1.0	2.2	3.5	18.1	40.7	
2006	***61.1***	***63.6***	***53.6***	***26.8***	1.9	2.0	2.1	3.2	8.3	11.3	25.8
2007	21.8	18.7	18.1	1.8	0.9	1.1	2.4	10.8	***45.3***	***71.1***	
2008		49.1	40.5	20.1	***6.8***	***3.6***	3.2	***17.7***	***48.5***	***91.5***	
2009	***86.3***	***84.1***	***69.8***	***35.2***	2.9	1.9	***4.7***	9.7	***54.0***	***78.7***	
2010		***66.4***	***66.8***	***64.2***	***13.0***	2.5	3.6	***13.8***	28.3	***67.1***	***79.1***
2011		***77.2***	***71.3***	***58.5***	***29.1***	1.6	1.9	3.2	4.8	14.6	40.1
2012	***58.2***	***63.5***	***69.7***	***40.6***	***8.8***	2.3	3.2	6.6	***39.6***	48.0	***47.1***
2013	47.4	34.8	39.2	18.1	3.3	1.6	3.1	***14.4***	***42.6***	***51.1***	***55.5***
2014	***57.7***	***52.8***	***54.4***	***31.3***	***13.7***	***8.5***	***24.2***	***50.9***	***64.7***	***86.6***	***97.7***
2015	***72.4***	***71.4***	***56.6***	***28.7***	***18.4***	***15.4***	***30.5***	***65.1***	***71.1***	***98.2***	***97.1***
2016	***55.4***	***55.1***	***45.0***	***36.5***	***29.1***	***15.4***	***17.0***	***33.2***	***68.5***	***79.5***	***68.2***
Average	50.9	52.4	43.2	21.8	6.1	2.8	4.6	11.0	30.4	49.4	45.7
Correlation	0.25	0.09	0.28	0.41	0.43	0.54	0.50	0.56	0.53	0.59	0.56

Table **13**c. Percentage in different classes for *Artemia* sector means (from Table 13a) in 2016.

	Instars		Instar	Adult	Adult	Adult Female	Ad Female Ovigery Classification				Ovigerous
	1-7	8-11	%	Total	Males	Total	empty	undif	cysts	naup	Female%
Lakewide											
Feb	100	0	100	0	0	0	0	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	92	8	100	0	0	0	0	0	0	0	0
May	59	37	96	4	4	0.04	0	100	0	0	100
Jun	36	19	55	45	31	14	31	23	67	10	69
Jul	16	7	23	77	45	32	4	6	86	9	96
Aug	4	5	9	91	51	40	13	2	91	6	87
Sep*	4	5	9	91	54	37	11	4	85	11	89
Oct	10	2	12	88	45	43	4	4	89	7	96
Nov	51	9	60	40	16	25	4	6	81	12	96
Dec	79	9	88	12	6	6	12	4	84	12	88
Western Sector											
Feb	100	0	100	0	0	0	0	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	96	4	100	0	0	0	0	0	0	0	0
May	59	38	97	3	3	0.1	0	100	0	0	100
Jun	25	21	47	53	39	15	29	27	61	11	71
Jul	17	7	24	76	46	29	4	5	86	9	96
Aug	8	7	14	86	53	33	6	5	87	8	94
Sep*	7	7	14	86	40	46	6	4	85	11	94
Oct	10	3	13	87	37	50	3	3	91	5	97
Nov	67	7	74	26	13	12	12	23	73	5	88
Dec	96	1	96	4	3	1	0		0	100	100
Eastern Sector											
Feb	100	0	100	0	0	0	0	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	91	9	100	0	0	0	0	0	0	0	0
May	58	36	94	6	6	0	0	0	0	0	100
Jun	43	17	60	40	25	14	31	20	71	10	69
Jul	15	7	22	78	44	34	3	7	85	8	97
Aug	2	4	7	93	50	44	16	1	94	5	84
Sep*	2	3	5	95	64	31	17	4	85	11	83
Oct	9	2	11	89	50	39	5	5	86	8	95
Nov	49	9	58	42	16	26	4	6	82	13	96
Dec	76	11	87	13	6	7	12	4	85	10	88

* Due to strong wind last four stations (3, 10 to 12) were not sampled.

Table 14. Lakewide *Artemia* instar abundance analysis in 2016.

	Instars									
	1	2	3	4	5	6	7	8-11	Adults	Total
Mean										
Feb	10,222	7,497	11	0	0	0	0	0	0	17,731
Mar	20,547	42,694	1,458	0	0	0	0	0	0	64,700
Apr	1,587	23,685	14,004	3,817	4,047	2,736	2,552	2,644	0	55,073
May	966	3,576	7,014	11,302	13,625	9,497	4,507	32,975	1,840	85,300
Jun	2,506	5,174	4,047	713	184	345	552	9,497	21,891	44,909
Jul	65	540	1,242	1,048	248	86	22	1,275	15,470	19,996
Aug	11	151	97	162	97	0	119	983	17,555	19,175
Sep*	6	158	113	101	19	25	50	536	7,770	8,778
Oct	135	300	194	65	32	81	27	211	9,931	10,976
Nov	354	389	275	178	97	54	70	246	872	2,536
Dec	348	637	332	100	11	14	27	100	122	1,691
Standard Error										
Feb	3,535	3,197	11	0	0	0	0	0	0	6,386
Mar	5,442	9,900	678	0	0	0	0	0	0	15,267
Apr	409	4,046	3,404	1,686	2,208	1,338	1,015	1,093	0	11,218
May	444	630	1,211	4,619	6,519	4,019	1,656	12,447	906	29,371
Jun	882	1,635	1,356	198	138	268	207	1,555	4,636	7,405
Jul	26	177	359	282	82	86	22	251	2,285	2,987
Aug	11	17	67	65	36	0	59	200	3,827	3,963
Sep*	6	33	48	39	13	13	23	138	1,031	1,098
Oct	81	147	101	26	21	42	21	120	1,031	1,098
Nov	101	199	159	112	49	23	29	110	392	1,123
Dec	158	371	255	91	11	14	27	94	109	1,125
Percentage in different age classes										
Feb	32	66	2	0	0	0	0	0	0	
Mar	58	42	0.1	0	0	0	0	0	0	
Apr	3	43	25	7	7	5	5	5	0	
May	1	4	8	13	16	11	5	39	2	
Jun	6	12	9	2	0.4	1	1	21	49	
Jul	0.3	3	6	5	1	0.4	0.1	6	77	
Aug	0.1	1	1	1	1	0	1	5	92	
Sep*	0.1	2	1	1	0.2	0.3	1	6	89	
Oct	1	3	2	1	0.3	1	0.2	2	90	
Nov	14	15	11	7	4	2	3	10	34	
Dec	21	38	20	6	1	1	2	6	7	

* Due to strong wind last four stations (3, 10 to 12) were not sampled.

Table 15. *Artemia* mean biomass (g/m^2) recorded in 2016.

Month	Lakewide	Western Sector	Eastern Sector
Feb	1.02	1.14	0.94
Mar	4.21	2.21	6.20
Apr	3.16	0.74	5.58
May	7.51	6.53	8.49
Jun	17.0	16.0	18.1
Jul	17.4	13.9	21.0
Aug	14.8	10.8	18.9
Sep*	9.79	6.75	14.9
Oct	8.19	7.35	9.03
Nov	1.62	0.42	2.83
Dec	0.39	0.14	0.64

* Due to strong wind last four stations (3, 10 to 12) were not sampled.

Table 16. *Artemia* fecundity summary recorded in 2016.

	#of eggs/brood				Female Length (mm)		
	Mean	SE	%cysts	%indented	Mean	SE	n
Lakewide							
Jun	38.7	1.4	95.7	45.7	9.7	0.10	7
Jul	32.4	1.1	100	51.4	9.2	0.08	7
Aug	30.1	1.5	100	64.3	9.9	0.10	7
Sep	33.4	2.0	82.9	37.1	9.8	0.09	6
Western Sector							
Jun	41.6	1.7	54.3	24.3	9.7	0.12	4
Jul	31.4	1.5	57.1	24.3	9.1	0.13	4
Aug	30.1	1.9	57.1	40.0	9.9	0.15	4
Sep	33.4	2.6	57.1	24.3	9.9	0.12	4
Eastern Sector							
Jun	34.8	2.2	41.4	21.4	9.7	0.17	3
Jul	33.7	1.5	42.9	27.1	9.4	0.09	3
Aug	30.1	2.4	42.9	24.3	9.8	0.13	3
Sep	33.5	2.7	25.7	12.9	9.8	0.13	2

"n" represents number of stations sampled. 10 individuals were sampled at each station with the exception of 9 individuals on June 20th at Station 11 and Sept 19th at Station 7 due to undifferentiated egg types.

Table 17. Summary Statistics of Adult *Artemia* Abundance between May 1st and November 30th since 1979.

Year	Mean	Median	Peak	Centroid
1979	14,118	12,286	31,700	216
1980	14,643	10,202	40,420	236
1981	32,010	21,103	101,670	238
1982	36,643	31,457	105,245	252
1983	17,812	16,314	39,917	247
1984	17,001	19,261	40,204	212
1985	18,514	20,231	33,089	218
1986	14,667	17,305	32,977	190
1987	23,952	22,621	54,278	226
1988	27,639	25,505	71,630	207
1989	36,359	28,962	92,491	249
1990	20,005	16,775	34,930	230
1991	18,129	19,319	34,565	226
1992	19,019	19,595	34,648	215
1993	15,025	16,684	26,906	217
1994	16,602	18,816	29,408	212
1995	15,584	17,215	24,402	210
1996	17,734	17,842	34,616	216
1997	14,389	16,372	27,312	204
1998	19,429	21,235	33,968	226
1999	20,221	21,547	38,439	225
2000	10,550	9,080	22,384	210
2001	20,031	20,037	38,035	209
2002	11,569	9,955	25,533	200
2003	13,778	12,313	29,142	203
2004	32,044	36,909	75,466	180
2005	17,888	15,824	45,419	192
2006	21,518	20,316	55,748	186
2007	18,826	17,652	41,751	186
2008	11,823	12,524	27,606	189
2009	25,970	17,919	72,086	181
2010	14,921	7,447	46,237	191
2011	21,343	16,893	48,918	194
2012	16,324	11,302	53,813	179
2013	26,033	31,276	54,347	196
2014	13,467	7,602	42,298	194
2015*	7,676	5,786	18,699	185
2016	10,687	10,347	18,498	220
Mean	19,051	17,732	44,179	210
Min	7,676	5,786	18,498	179
Max	36,643	36,909	105,245	252

***** Value for 2015 were recalculated using correct parameters; thus, these values differ from one reported in 2015.

Table 18a. Monthly Average Adult *Artemia* Abundance based on Stations 1 to 12 since 1987.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				7934	24733	**41366**	**39313**	**27179**	**18366**	**11579**	
1988	3			11378	**71292**	**33277**	**33580**	**21108**	**14915**	3231	
1989				1312	11273	21097	**67268**	**92491**	**38991**	**26455**	**10673**
1990	**21**		77	14181	13841	27472	**30753**	**31783**	**16775**	**9985**	**7930**
1991				710	20920	28758	**32629**	**23061**	**13974**	**6492**	**1826**
1992			256	**19590**	22724	29513	**26789**	**20426**	**14467**	**7917**	**6064**
1993				11983	21896	18383	18106	16104	**11747**	**9945**	11
1994			22	14761	24986	24957	19952	17145	**10686**		31
1995					18716	26077	17106	17099	5555		34
1996	15			11531	25462	**34242**	**29098**	**17326**		**5496**	24
1997	4			14706	18321	24891	**31791**	13576	35		22
1998	2			88	22228	29603	**37556**	**29735**	**16119**		121
1999					17077	**37227**	22892	**29281**	**9991**	3055	25
2000				5022	15664	22384	18940	9131	4901	116	60
2001				11945	23971	**38035**	**37800**	**20299**	6444	23	30
2002	7			2614	24909	21853	25533	4961	79	10	
2003	2			9379	26065	21834	25136	10908	3042		
2004			**22052**	**63528**	**73883**	**47338**	**36412**	9215	2245	122	40
2005		3	3	**25902**	**41247**	**37840**	**26838**	13058	3073	189	40
2006	**35**	**22**	5	**35381**	**47480**	**41355**	25124	14148	2316	18	7
2007				**21180**	**40107**	**38353**	24165	3799	939	22	10
2008				**20418**	27606	20366	16777	4992	89	20	
2009	**35**	**17**		**43099**	**72086**	**45231**	18645	9058	2981	235	20
2010				1462	**39933**	**46237**	11714	4732	773	92	55
2011			3	**19524**	**48918**	**48491**	19296	14088	5540	266	27
2012	3		2	**53813**	**31375**	10288	13920	11224	5312		104
2013	**27**			**31415**	**39759**	**54347**	**45152**	12449	2349	35	44
2014	6			832	**33535**	**42298**	10776	4019	553	106	66
2015	**32**	3	396	14782	18699	17406	5839	2289	239	44	38
2016				3005	18498	17393	16643	10204	**7786**	1338	246
Average	15	11	2535	16838	31240	31597	26185	17163	7596	3616	1102
Correlation	0.37	-0.38	0.03	0.31	0.26	0.17	-0.53	-0.58	-0.70	-0.70	-0.55

Table 18b. A comparison of monthly average Adult *Artemia* Abundance between earlier and later seasons based on Stations 1 to 12 since 1987.

	Average		Propotion	
Year	May-Jul	Aug-Nov	May-Jul	Aug-Nov
1987	24678	24109	43%	57%
1988	38649	18208	61%	39%
1989	11227	56301	13%	87%
1990	18498	22324	38%	62%
1991	16796	19039	40%	60%
1992	23943	17400	51%	49%
1993	17420	13976	48%	52%
1994	21568	15928	58%	42%
1995	22396	13253	53%	47%
1996	23745	17307	58%	42%
1997	19306	15134	56%	44%
1998	17306	27803	38%	62%
1999	27152	16305	45%	55%
2000	14357	8272	57%	43%
2001	24650	16141	53%	47%
2002	16459	7646	62%	38%
2003	19092	13029	59%	41%
2004	61583	11998	79%	21%
2005	34997	10790	71%	29%
2006	41405	10402	75%	25%
2007	33214	7231	78%	22%
2008	22796	5469	76%	24%
2009	53472	7730	84%	16%
2010	29211	4328	84%	16%
2011	38978	9797	75%	25%
2012	31825	10152	76%	24%
2013	41840	14996	68%	32%
2014	25555	3863	83%	17%
2015	16962	2103	86%	14%
2016	12965	8993	52%	48%
Average	26735	14334	61%	39%
Correlation	0.31	-0.66	0.76	-0.76

Table 19. Monthly average instar *Artemia* abundance based on Stations 1 to 12 since 1987.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	3274	22280	18455	**33650**	13325	5925	1717	453	**1999**	**9234**	
1988	355	**50215**	**46799**	26918	24703	5709	**4834**	1339	**2624**	1157	
1989	32	17849	9274	2894	**250883**	7136	990	172	875	1477	**5099**
1990	2016	7520	12020	**89708**	**234839**	**12393**	**7100**	1137	**1875**	**3600**	**8755**
1991	5653	**33584**	26635	31953	39478	**18016**	3556	953	1411	**3831**	**3559**
1992	6601	14832	26507	28901	14298	5429	**6057**	**1956**	**3373**	**9640**	**15292**
1993		12093	20130	12534	**67073**	**22433**	**10842**	**4178**	**5111**	**9281**	**1864**
1994	6117	18246	29263	13192	**45758**	**13839**	**7540**	**3737**	**3684**		598
1995		14805			20867	**20106**	**8312**	**1767**	**1860**		465
1996	**12224**	24888	**73528**	26955	10009	3073	2349	768		1888	1002
1997	6846	11268	34988	33174	11868	5436	**3914**	1127	882		587
1998	**11195**	21950	**49570**	**53763**	18043	4236	2473	1456	659		1251
1999	**27123**	**32557**	33291	**54655**	11436	5619	1942	1482	1112	1637	501
2000	**12458**	14168	19382	24515	**93119**	**9512**	2916	**2559**	**2056**	340	513
2001	3400	3245	30129	**36009**	23085	7760	3293	**2458**	**2795**	288	404
2002	909	20696	36881	18312	**66237**	**9968**	2425	1559	218	96	
2003	3167	4398	15307	6619	**90316**	**42364**	**8756**	**2255**	1198		13
2004	**47324**	**68746**	**49108**	20711	15225	5674	3427	**2410**	857	233	256
2005		**31791**	33588	9893	15480	**11522**	**6895**	**2881**	**2559**	1261	282
2006	**13707**	**46843**	**92894**	10110	12237	**10060**	3611	**2218**	869	349	879
2007	2713	14375	**51898**	**45667**	24936	**10429**	2830	1135	624	104	101
2008	1097	10651	26663	13410	**83541**	**13551**	**6834**	**2269**	193	34	60
2009	**19308**	**43317**	**54145**	27311	11107	6948	2354	**2592**	1522	599	483
2010		**31387**	**64588**	**67005**	9188	3957	2760	**2161**	723	223	280
2011		**39946**	**110160**	**97512**	15686	4715	2126	**2990**	**2188**	440	724
2012	**12928**	**31185**	40216	29567	18390	1157	1167	1266	**1633**		800
2013	1461	28106	**81355**	30181	11858	3579	1336	1103	985	219	807
2014	**35352**	**150909**	**119732**	**60416**	3783	555	712	476	521	44	148
2015	10098	18530	**66841**	24856	19088	2193	826	573	178	148	354
2016	**22463**	**59643**	**64266**	**40664**	14567	3573	744	449	844	1701	1616
Average	10713	30001	46125	33485	43014	9229	3821	1729	1566	1993	1729
Correlation	0.40	0.39	0.65	0.16	-0.40	-0.27	-0.42	-0.01	-0.49	-0.63	-0.51

Table 20. Monthly average female *Artemia* abundance based on Stations 1 to 12 since 1987.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				3095	9932	**13501**	**9873**	**7909**	**4719**	**2970**	
1988	2			5289	**34414**	**13430**	**10541**	3489	**3544**	**1487**	
1989				682	4683	9779	**33720**	**44480**	**17336**	**11010**	**5348**
1990	4		1	6152	5623	7776	9387	**9298**	**5495**	**3171**	**2904**
1991				688	10380	12334	**12536**	**7187**	**4200**	**2377**	**678**
1992			201	**9165**	10254	11948	8940	5239	**4314**	**2726**	**2489**
1993				3388	8379	7113	6026	**6483**	**3644**	**3620**	
1994				3823	10141	10536	7690	5124	**3666**		11
1995					7426	10404	7192	**6943**	1824		16
1996				3892	9482	12511	**12885**	**7551**		**2466**	11
1997				6087	7361	11224	**13536**	5866	7		5
1998				59	7712	9695	**14531**	**9409**	**4931**		84
1999					6965	**15394**	7596	**8582**	**3185**	682	5
2000				1755	6261	7004	5262	1660	428	40	17
2001				6579	9604	10637	8350	4051	630	8	17
2002	2			926	9390	6113	5594	632	15	3	
2003				4868	12057	7292	7966	2316	610		
2004			**14889**	**29806**	**30731**	**19142**	**11100**	2098	443	45	20
2005			3	**13327**	**19705**	**16479**	**10436**	3498	614	117	30
2006	**12**	**12**	3	**18377**	**21844**	**18120**	**9897**	4733	956	2	7
2007				**11545**	**19249**	**15547**	8585	1066	253	8	
2008				**9707**	13467	7334	5184	1828	8	13	
2009	**17**	12		**23528**	**34554**	**20268**	8283	2832	1269	94	
2010				1375	**20456**	**22093**	5785	1846	221	42	25
2011			2	**13803**	**26077**	**24628**	9105	5651	2017	86	20
2012			2	**31076**	**15305**	4534	5698	4946	1849		17
2013	**9**			**10141**	11938	**22586**	**20487**	5287	866	6	11
2014	6			80	7834	**15729**	5029	2031	224	36	19
2015	3			3192	7203	6932	2596	1011	32	5	5
2016				27	5889	7234	7297	4133	**3813**	818	121
Average	7	12	2157	7944	13477	12577	9703	5906	2452	1326	539
Correlation	0.41	-1.00	0.05	0.32	0.20	0.26	-0.34	-0.43	-0.55	-0.64	-0.55

Table 21. Monthly Average *Artemia* Biomass based on Stations 1 to 12 since 2000.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000				8.1	18.4	**22.9**	**30.3**	**11.0**	**6.2**	**0.4**	0.1
2001				8.9	19.9	**31.1**	**32.5**	2.8	**8.3**	0.0	0.0
2002	0.0	0.1	0.3	2.4	15.2	14.6	17.1	7.3	0.1	0.0	
2003	0.0	0.0	0.2	8.0	**28.1**	17.1	**22.1**	**14.0**	**4.5**		0.0
2004	0.1	0.3	**13.9**	**28.5**	**33.0**	20.3	**26.2**	**12.0**	2.8	0.1	0.0
2005		0.2	0.6	**14.0**	**27.8**	**22.7**	**20.0**	**17.1**	**3.9**	0.1	0.0
2006	0.1	0.6	0.4	11.3	20.9	21.0	17.5	**13.1**	2.7	0.0	0.0
2007	0.0	0.0	1.0	10.9	15.2	**24.6**	**21.2**	5.9	1.1	0.0	0.0
2008		0.0	0.2	**16.1**	19.3	14.3	15.1	6.4	0.1		
2009	0.1	0.1	0.4	**17.3**	**37.2**	19.9	14.9	**12.2**	**4.7**	0.2	
2010		0.1	0.3	3.7	19.1	**22.4**	8.4	5.2	0.8	0.1	
2011		0.1	0.7	9.8	20.3	**24.8**	10.1	**9.7**	**5.7**	**0.3**	0.0
2012	0.0	0.1	0.2	**19.9**	17.7	19.6	**18.4**	**13.4**	**9.6**	**0.4**	**0.4**
2013	0.1	**1.8**	**17.2**	**13.8**	**23.2**	**28.6**	**23.8**	**15.0**	3.6	0.2	**0.2**
2014	**1.4**	**3.8**	**3.9**	**17.1**	**28.7**	**28.2**	7.7	5.1	0.9	**0.5**	**0.2**
2015	**0.8**	**1.7**	**10.1**	**32.3**	15.2	14.1	6.8	3.1	0.4	0.3	**0.3**
2016	**1.0**	**4.2**	3.2	7.5	17.0	17.4	14.8	**9.8**	**8.2**	**1.6**	**0.4**
Average	0.3	0.9	3.5	13.5	22.1	21.4	18.0	9.6	3.7	0.3	0.1
Correlation	0.72	0.71	0.27	0.34	-0.10	-0.06	-0.72	-0.12	-0.03	0.55	0.77

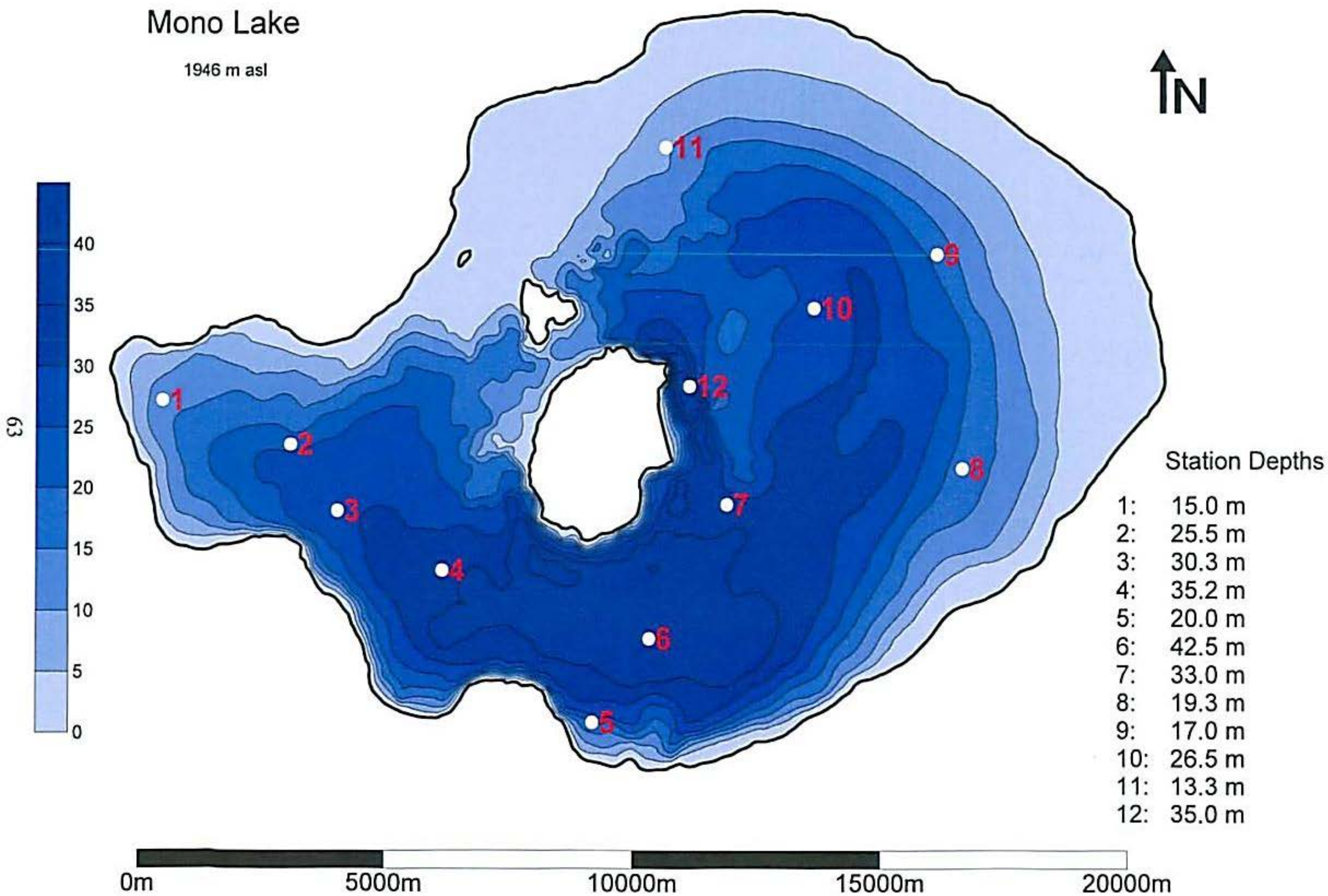

Figure 1. Sampling Stations at Mono Lake and Associated Station Depths.

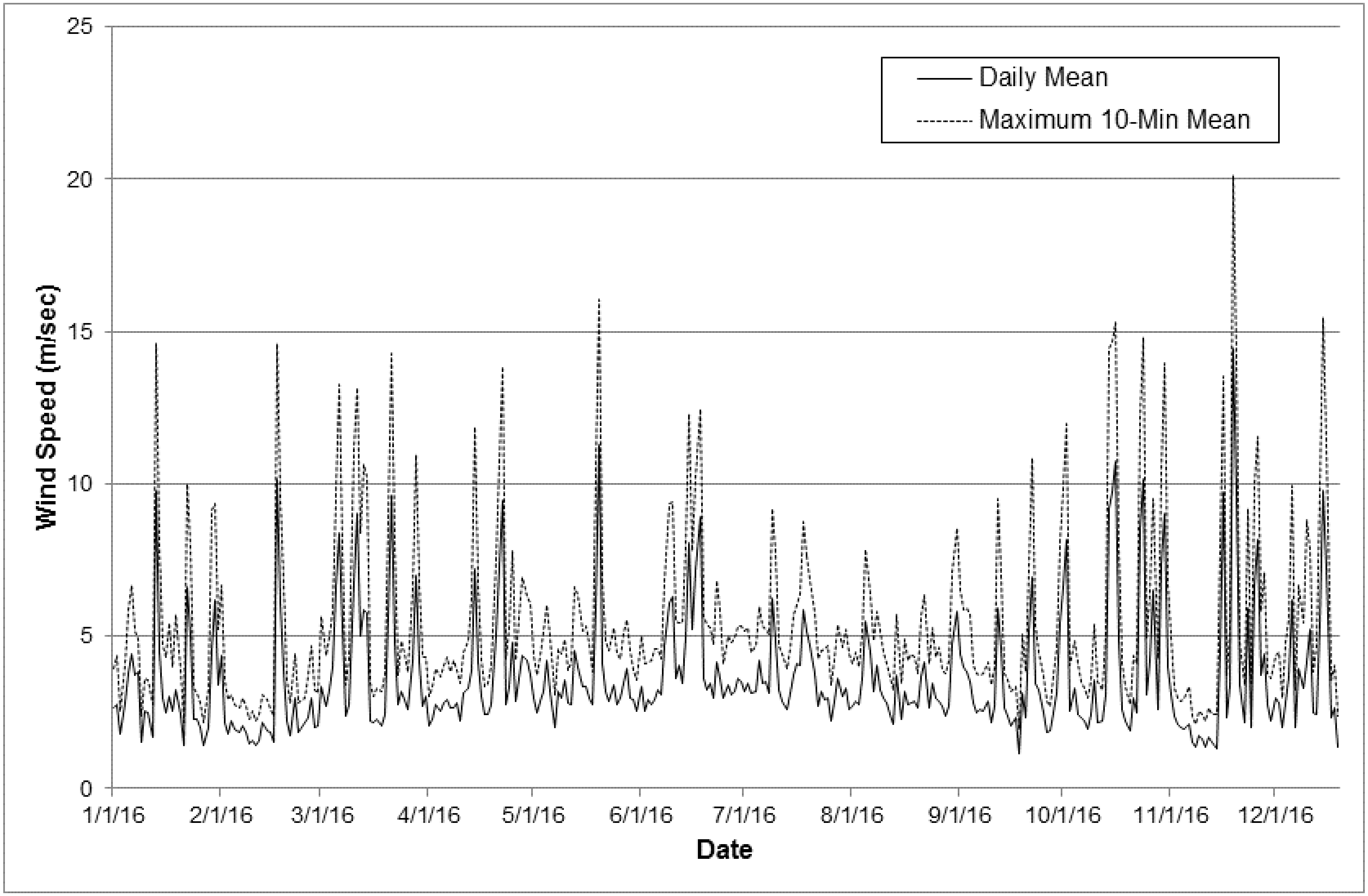

Figure 2. Mean daily wind speed and mean maximum 10-minute wind speed as recorded at Paoha Island from January 1 to December 19, 2016.

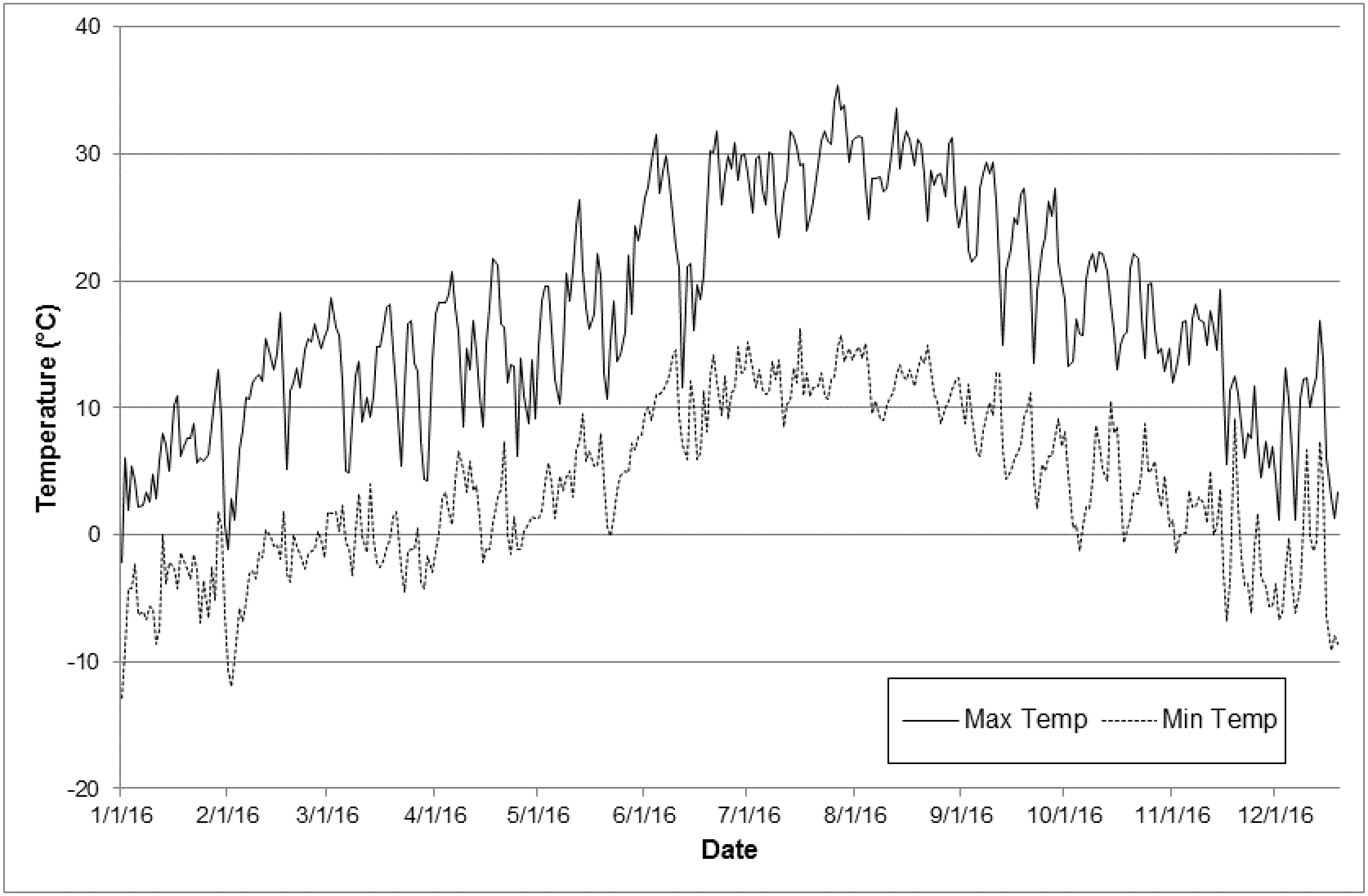

Figure 3. Minimum and maximum daily temperature (°C) as recorded at Paoha Island from January 1 to December 19, 2016.

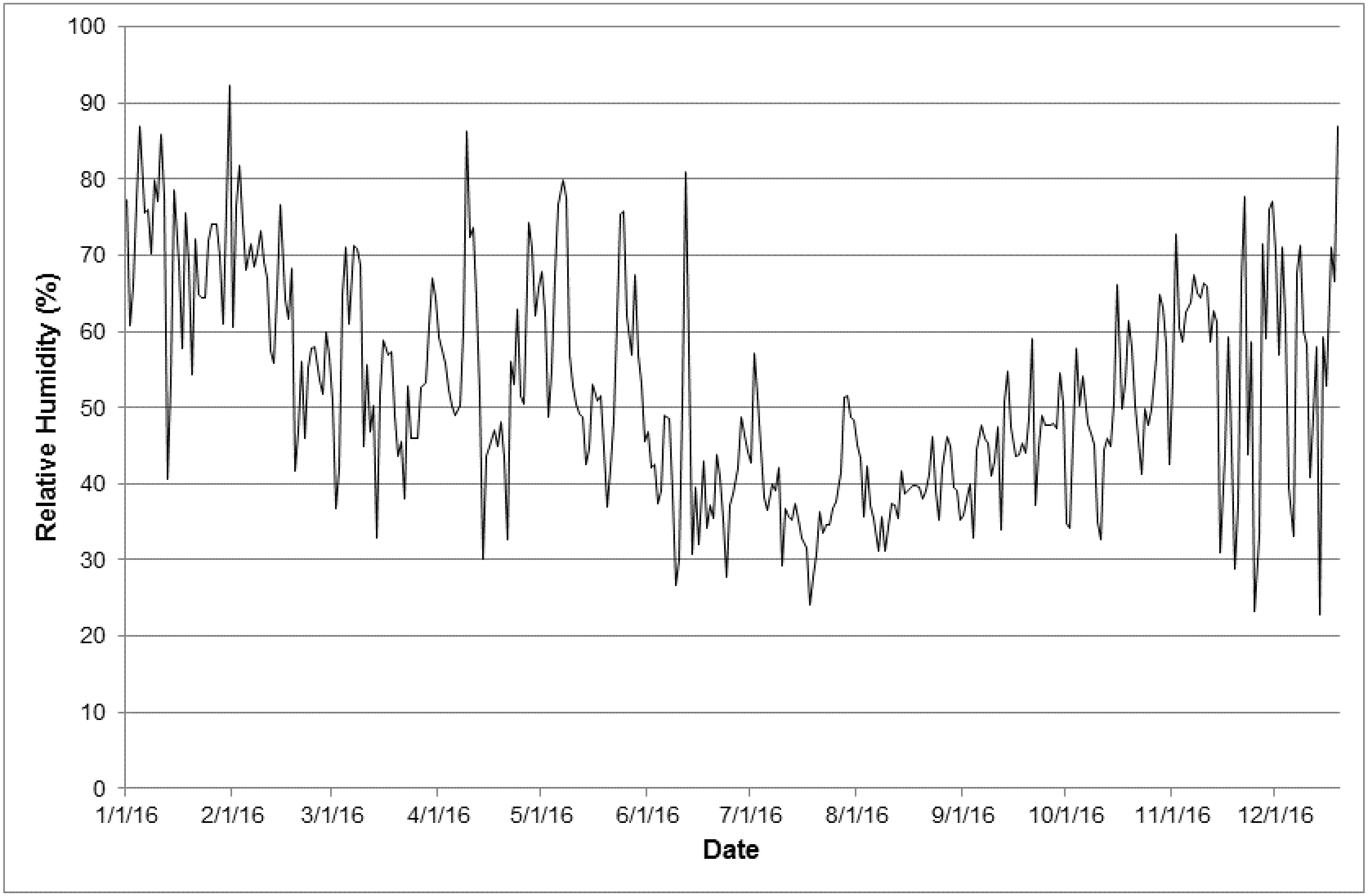

Figure 4. Mean relative humidity (%) as recorded at Paoha Island from January 1 to December 19, 2016.

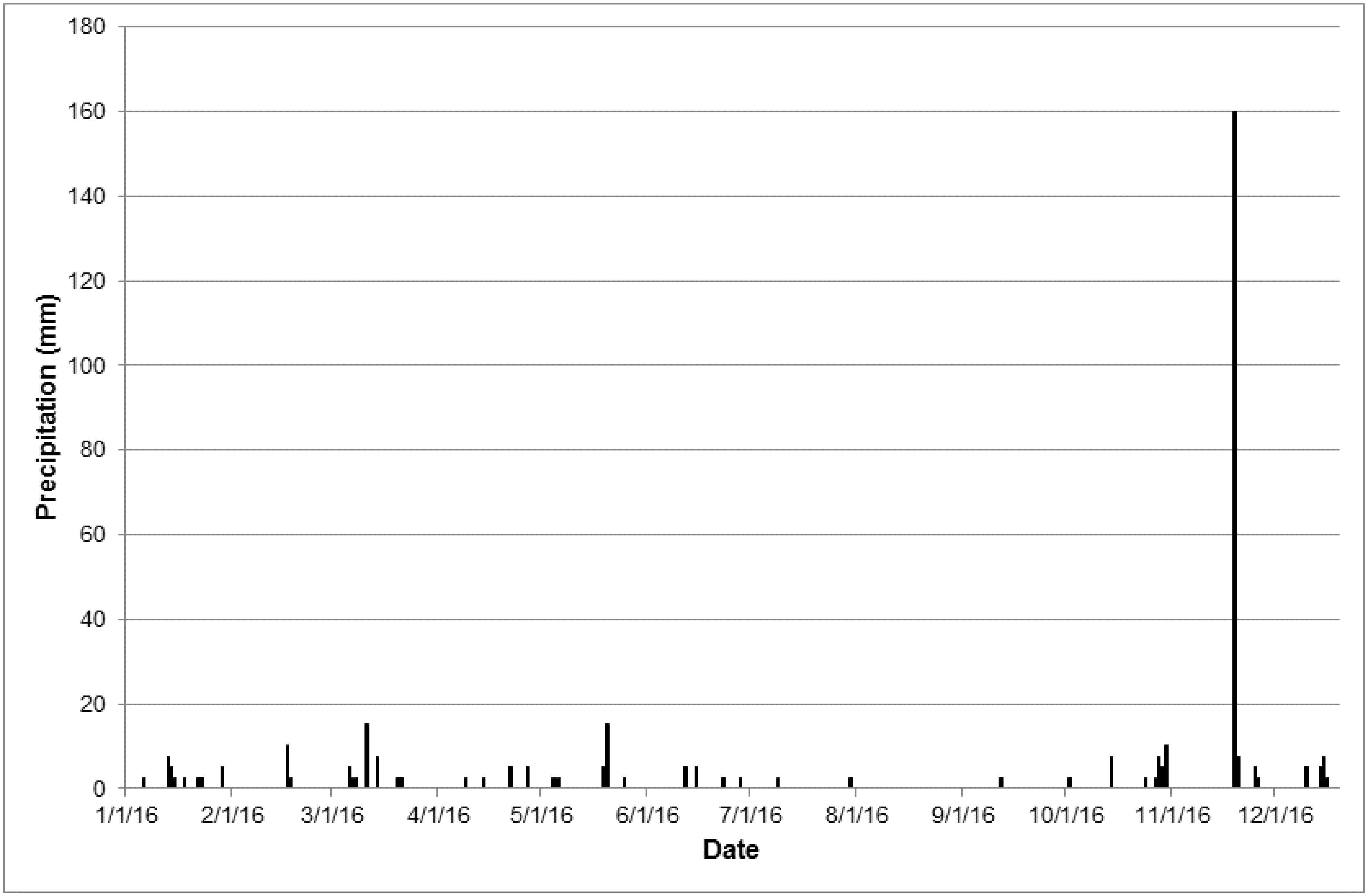

Figure 5. Precipitation (mm) as recorded at Paoha Island from January 1 to December 19, 2016.

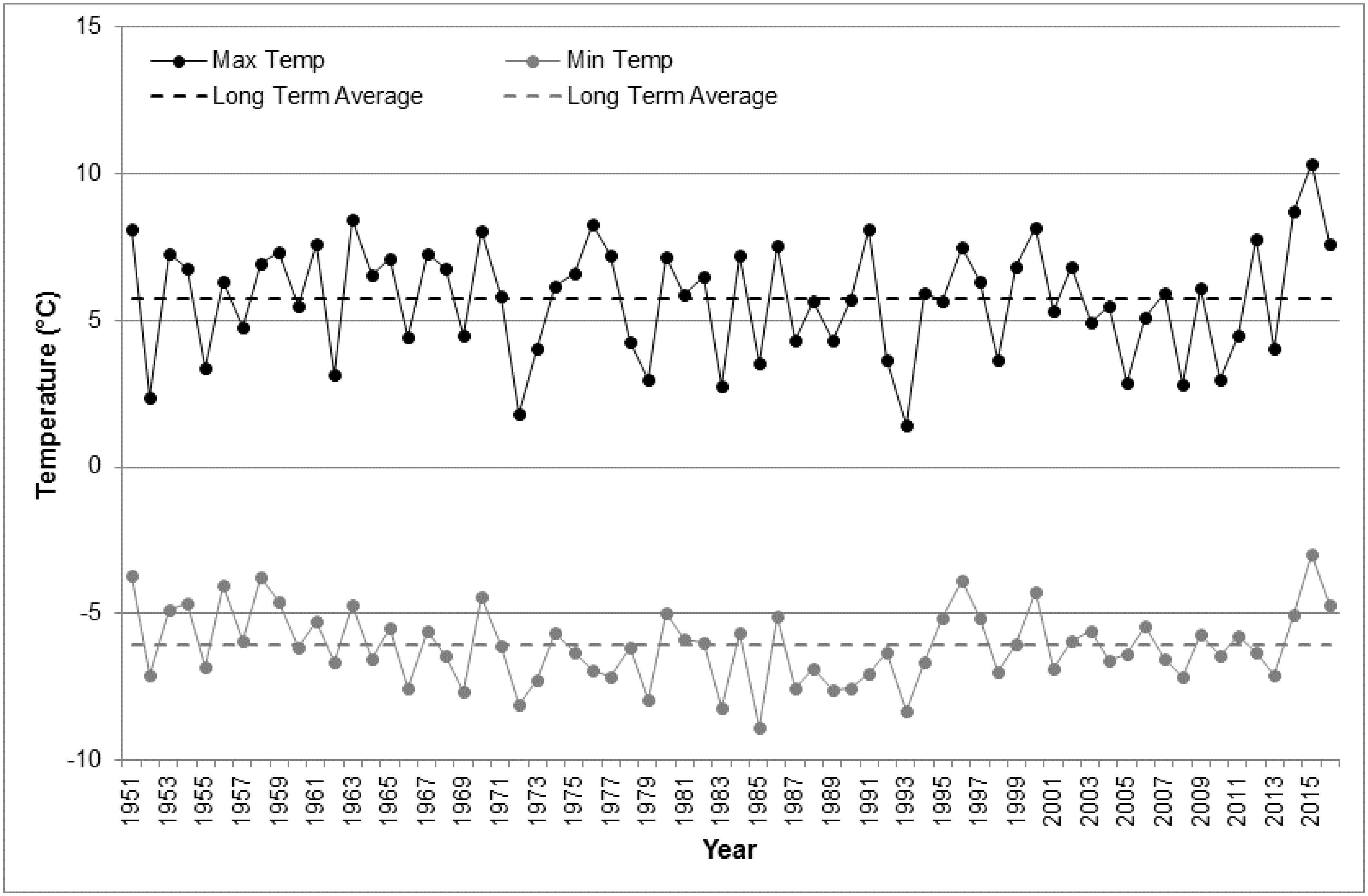

Figure 6. Average temperature during winter months (December through February) as recorded at Mono Lake (Station Number 045779-3 obtained from Western Regional Climate Center) between 1951 and 1988 and at LADWP Cain Ranch Weather Station since 1989.

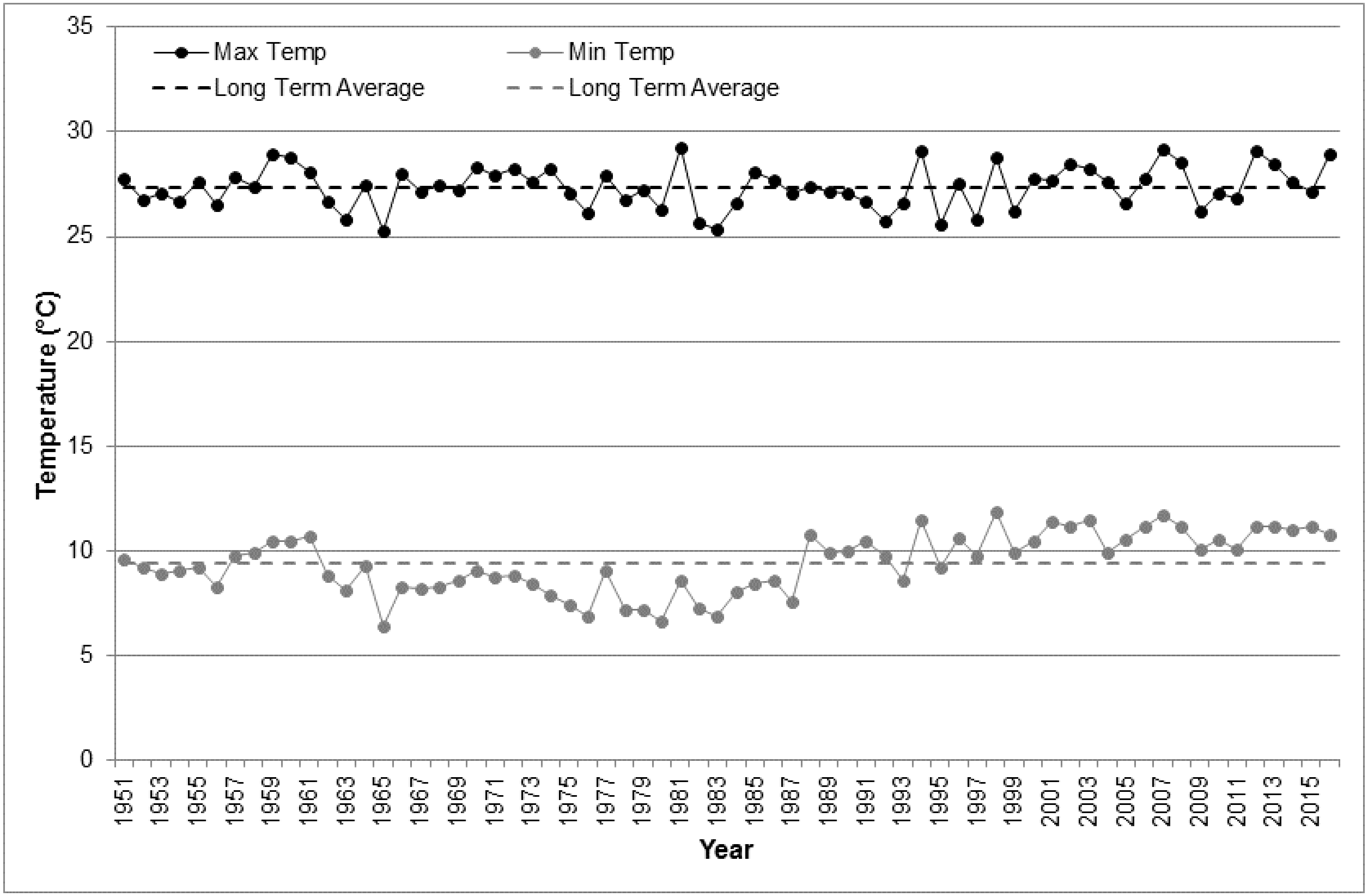

Figure 7. Average temperature during summer months (June through August) as recorded at Mono Lake (Station Number 045779-3 obtained from Western Regional Climate Center) between 1951 and 1988 and at LADWP Cain Ranch Weather Station since 1989.

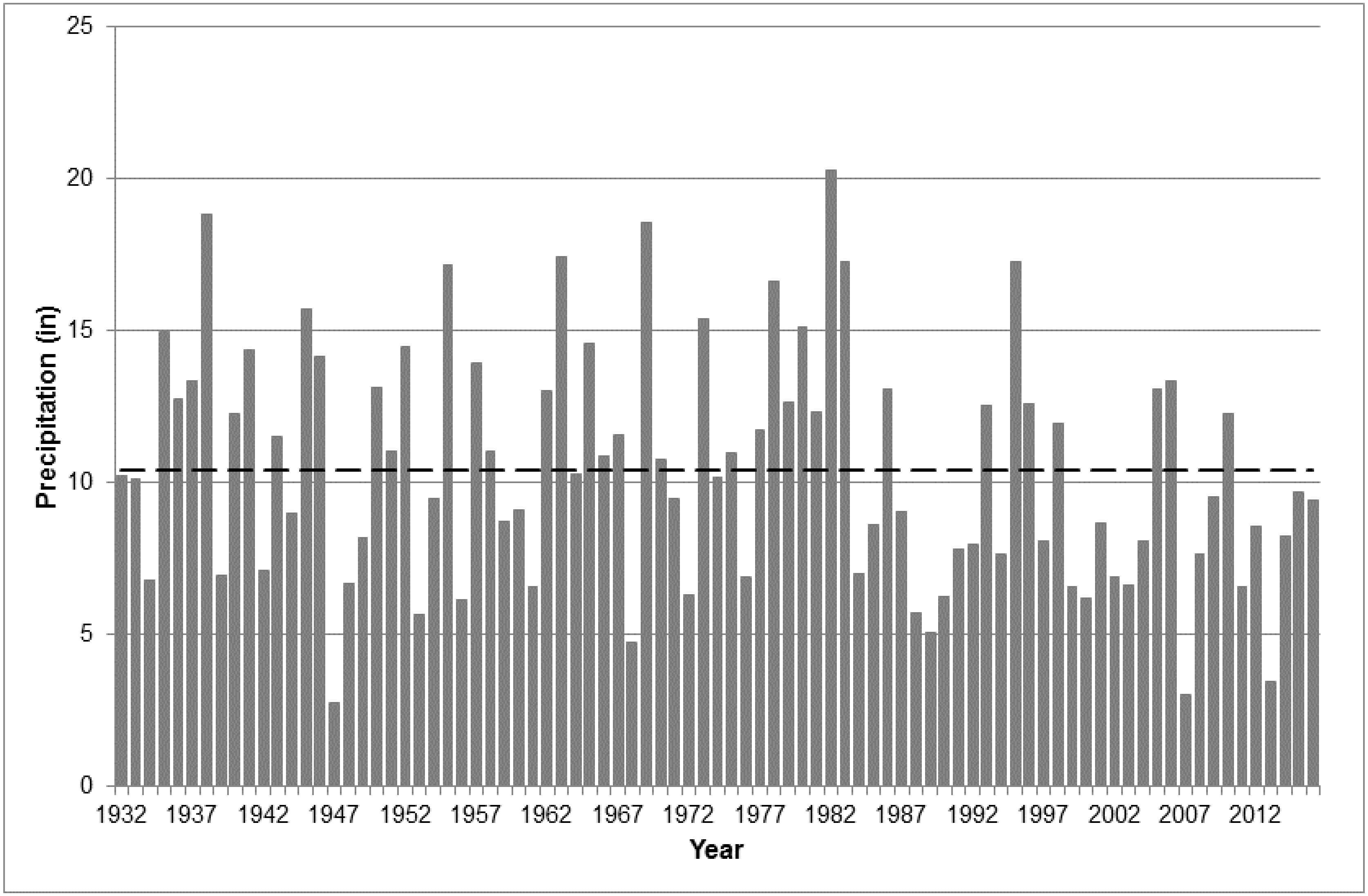

Figure 8. Total annual precipitation recorded at LADWP Cain Ranch..

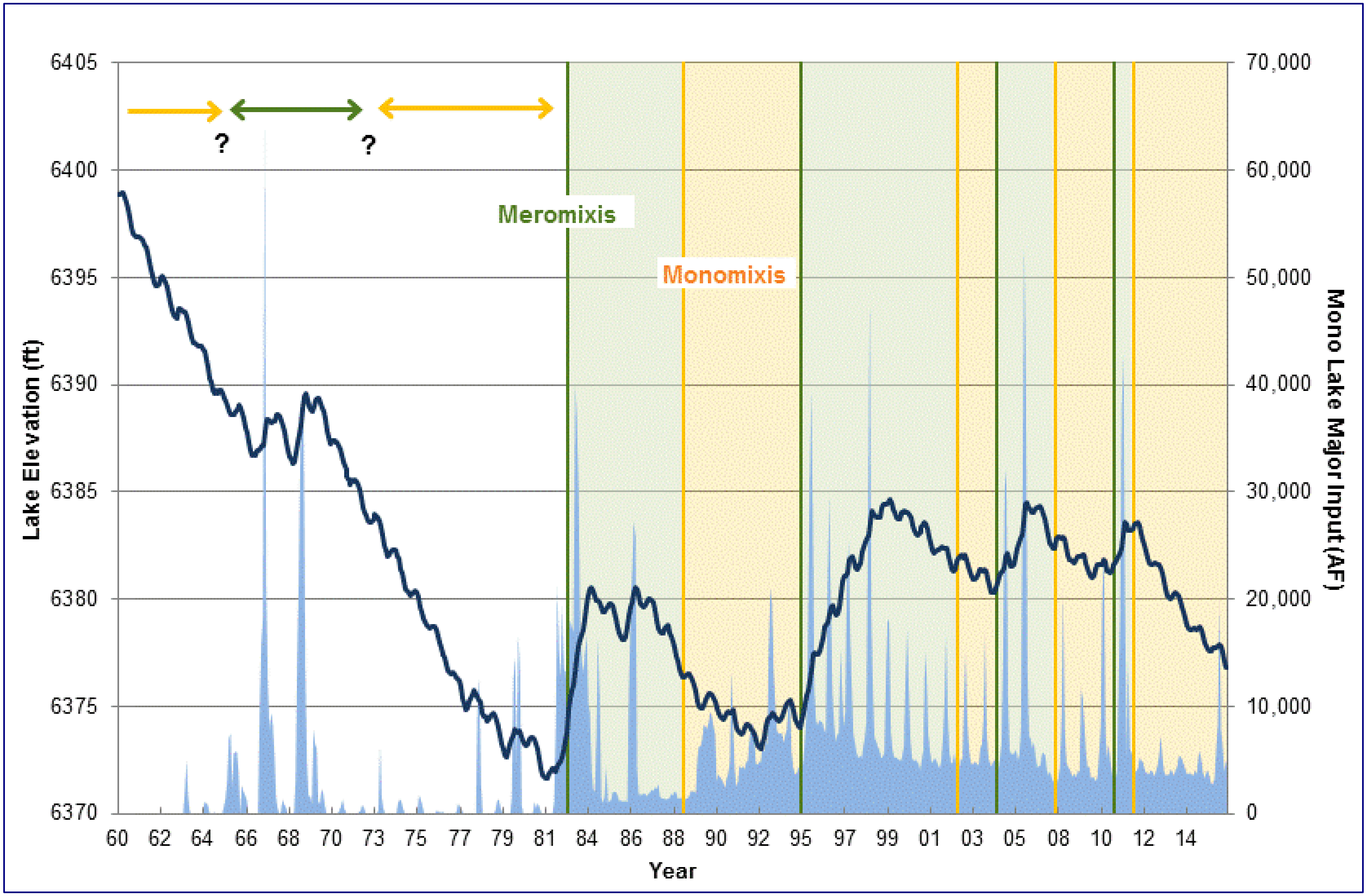

Figure 9. Surface elevation of Mono Lake and combined inflow of Rush and Lee Vining creeks since 1960 and mixing regime. The first meromictic regime was recorded in 1983. Green indicates meromixis while orange indicates monomixis.

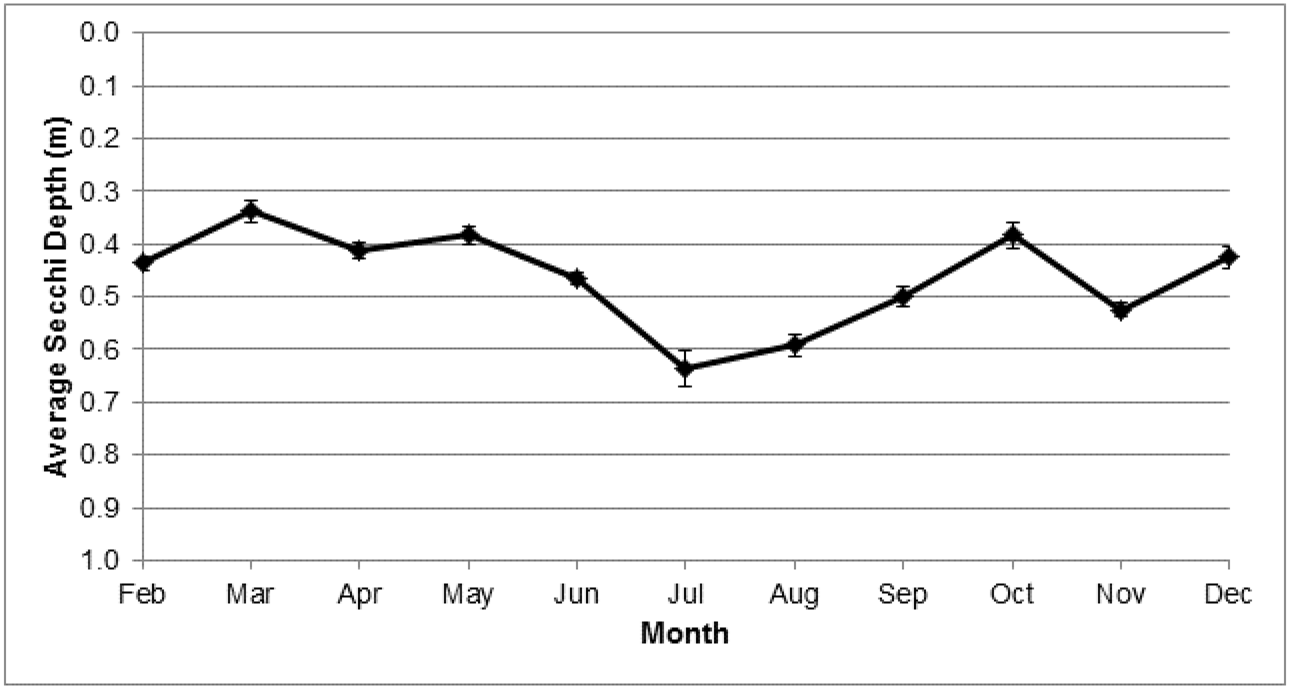

Figure 10. Lakewide average of Secchi depths (meters) and standard error for 2016.

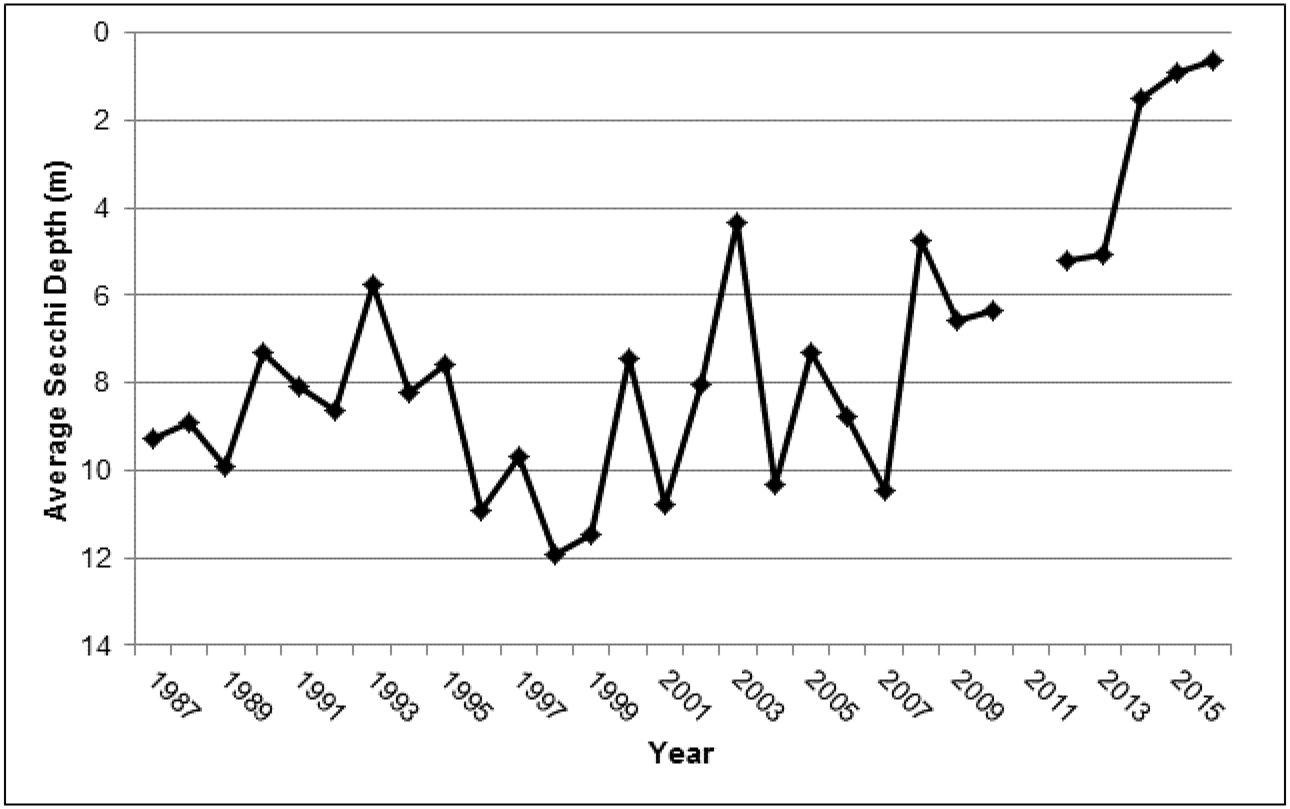

Figure 11. July lakewide average of Secchi depths (meters) since 1987.

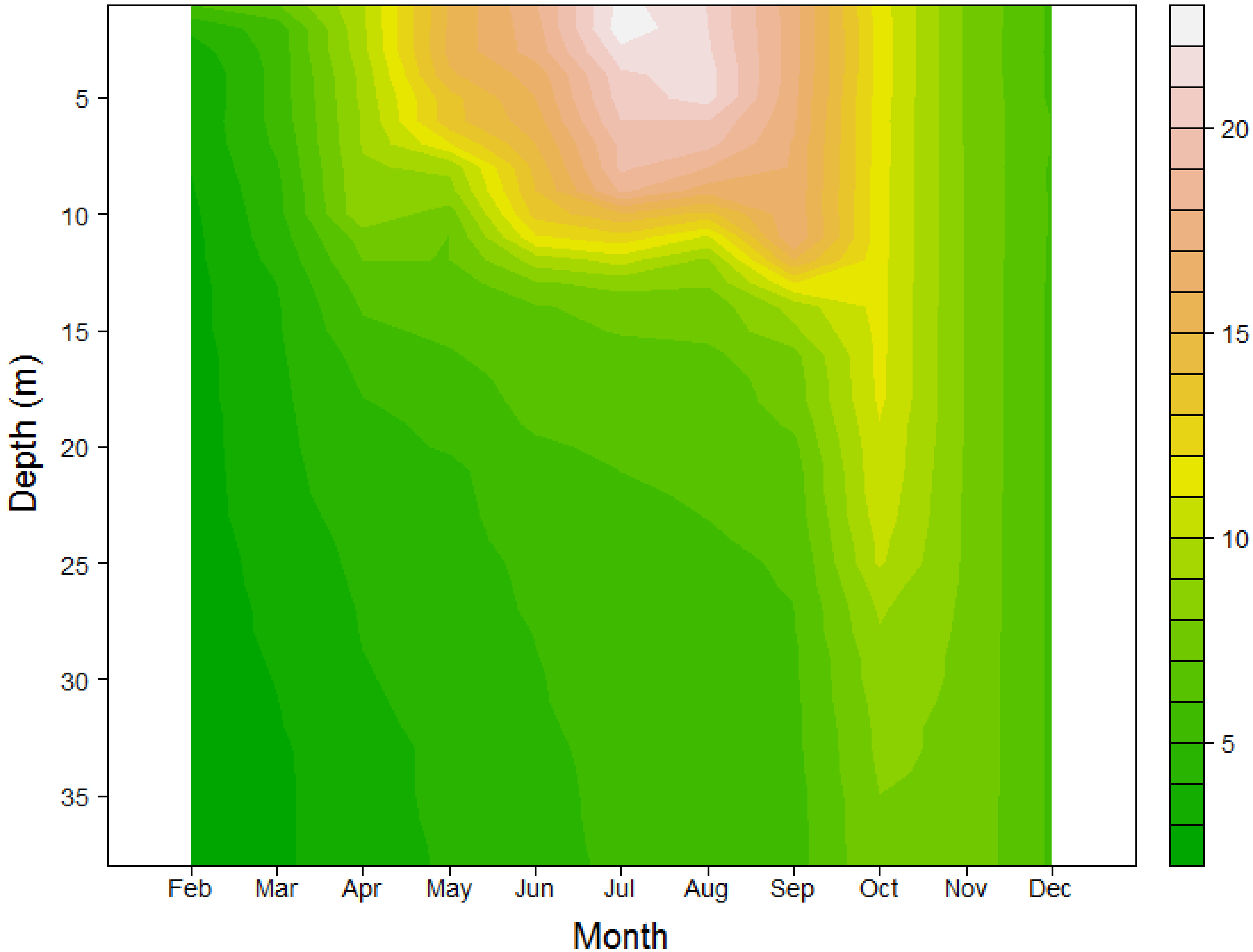

Figure 12. Temperature profiles (°C) at Station 6 between February and December in 2016.

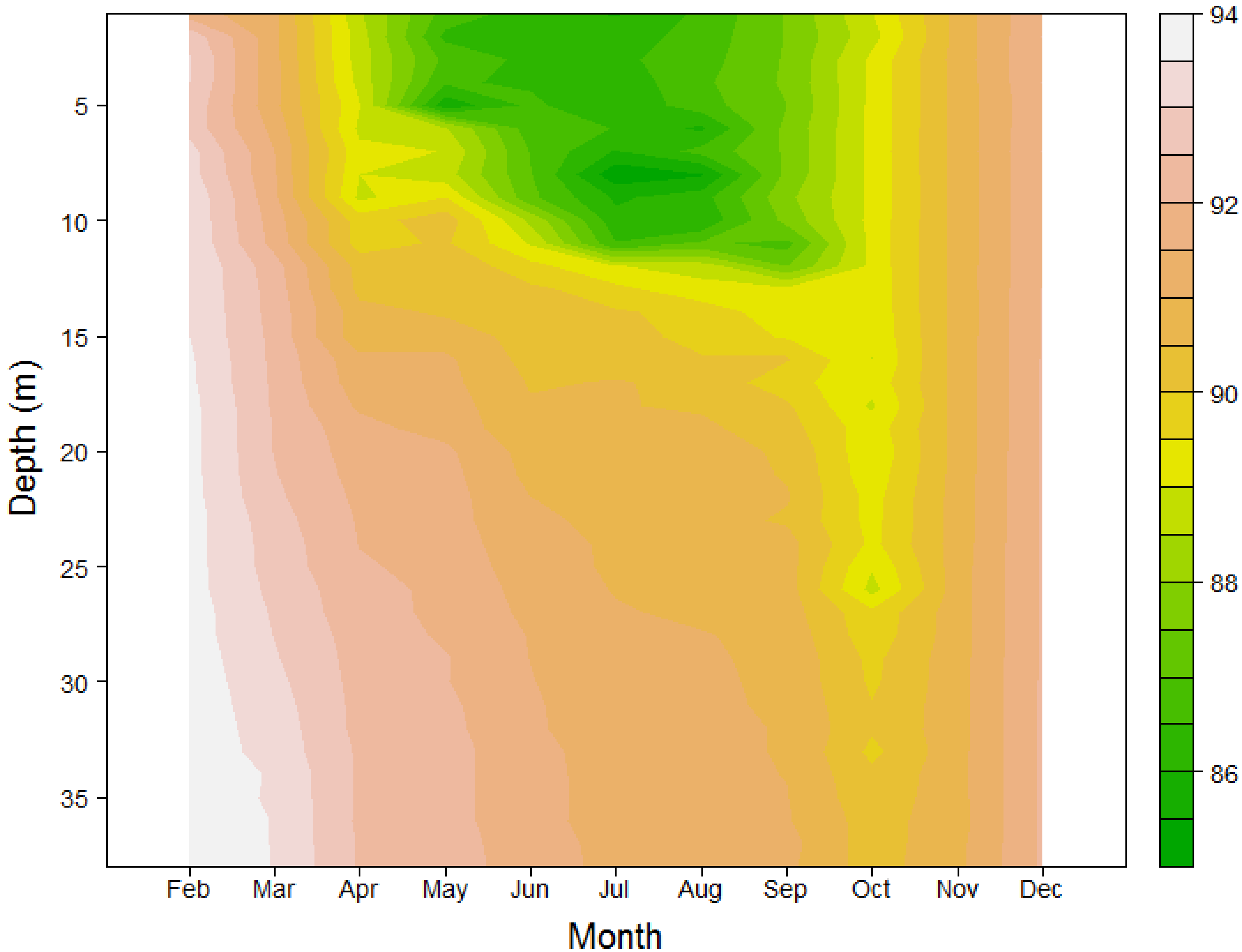

Figure 13. Conductivity (mS/cm) profiles at Station 6 between February and December in 2016.

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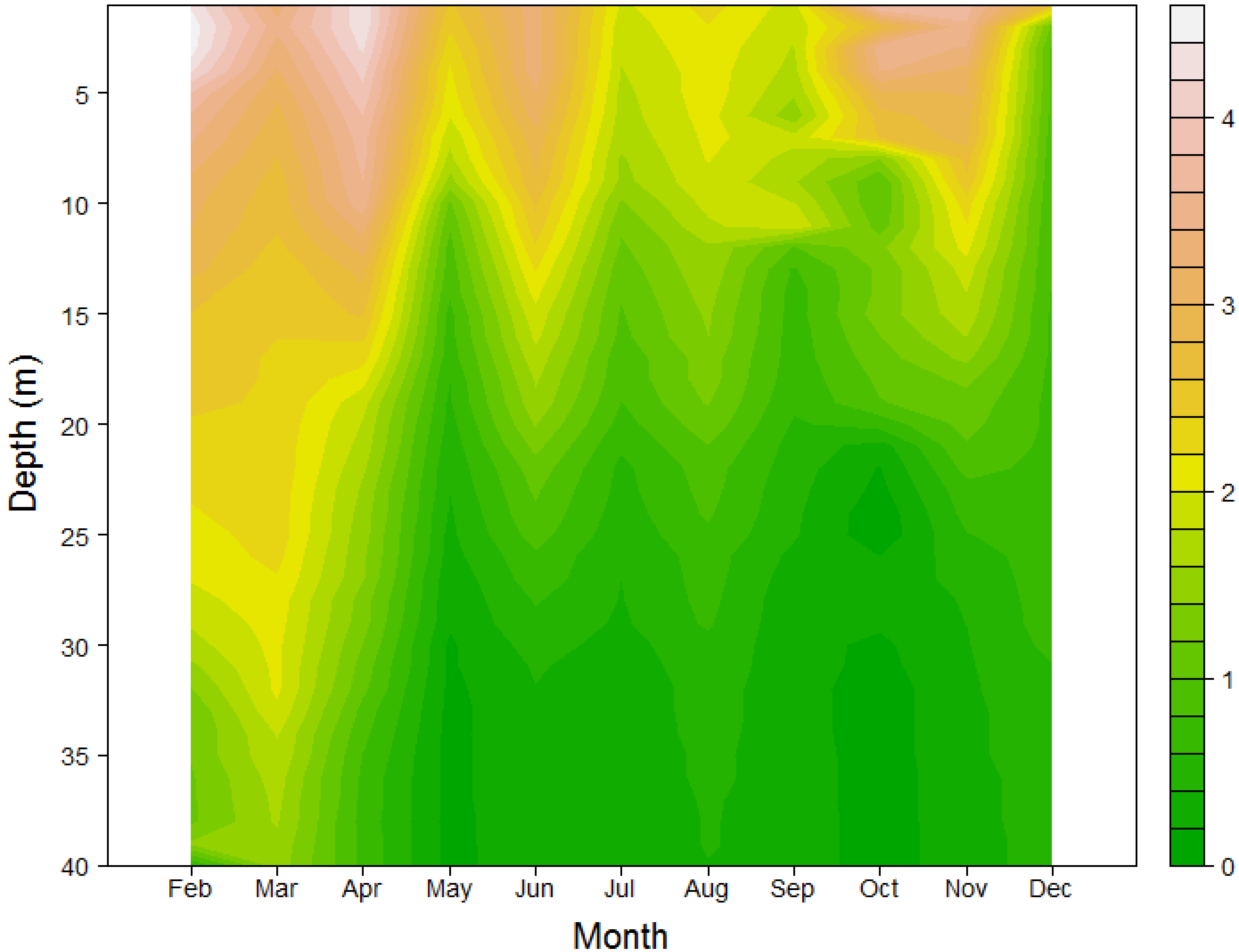

Figure 14. Dissolved oxygen (mg/l) profiles at Station 6 between February and December in 2016.

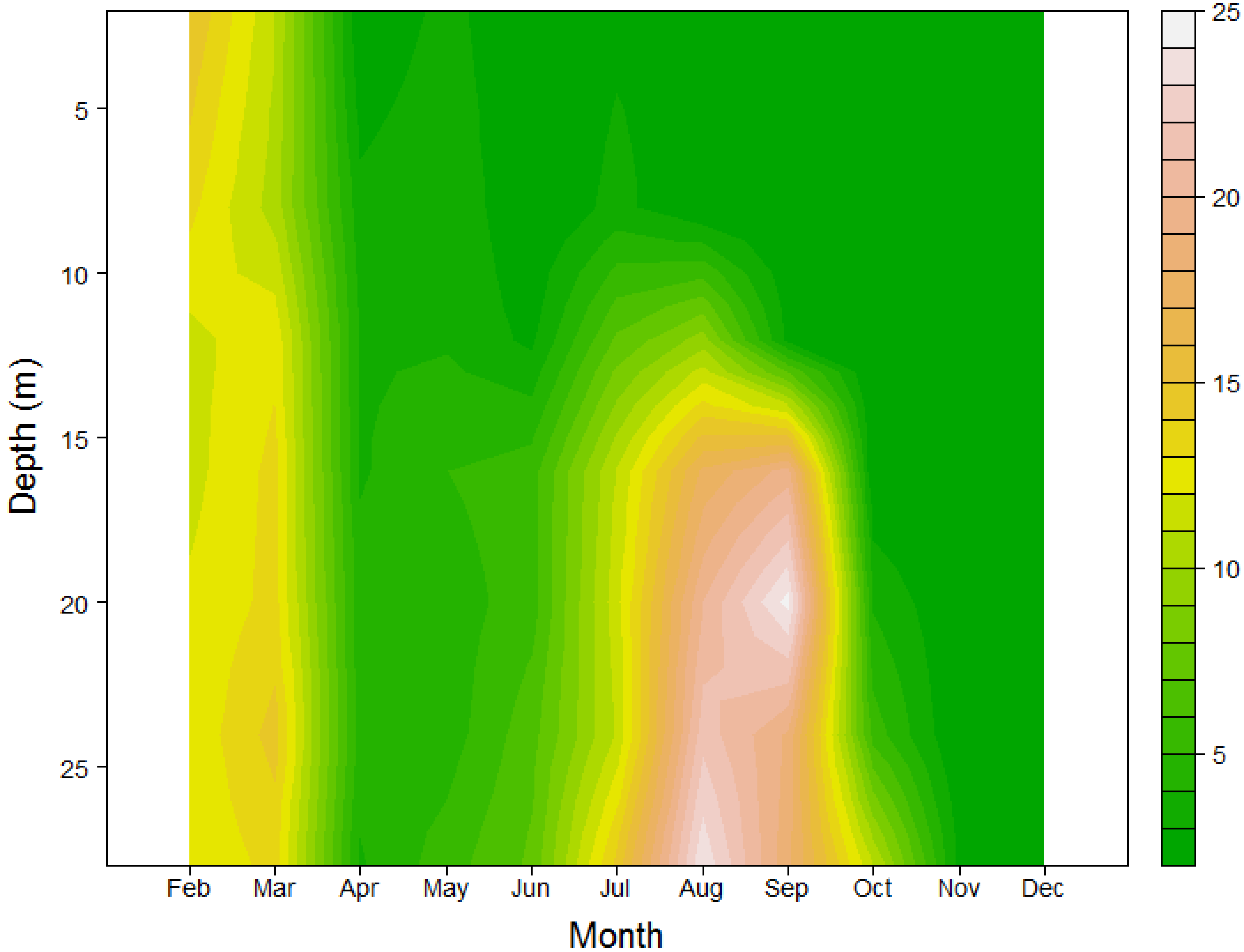

Figure 15. Ammonium (µm) profiles Station 6 between February and December in 2016.

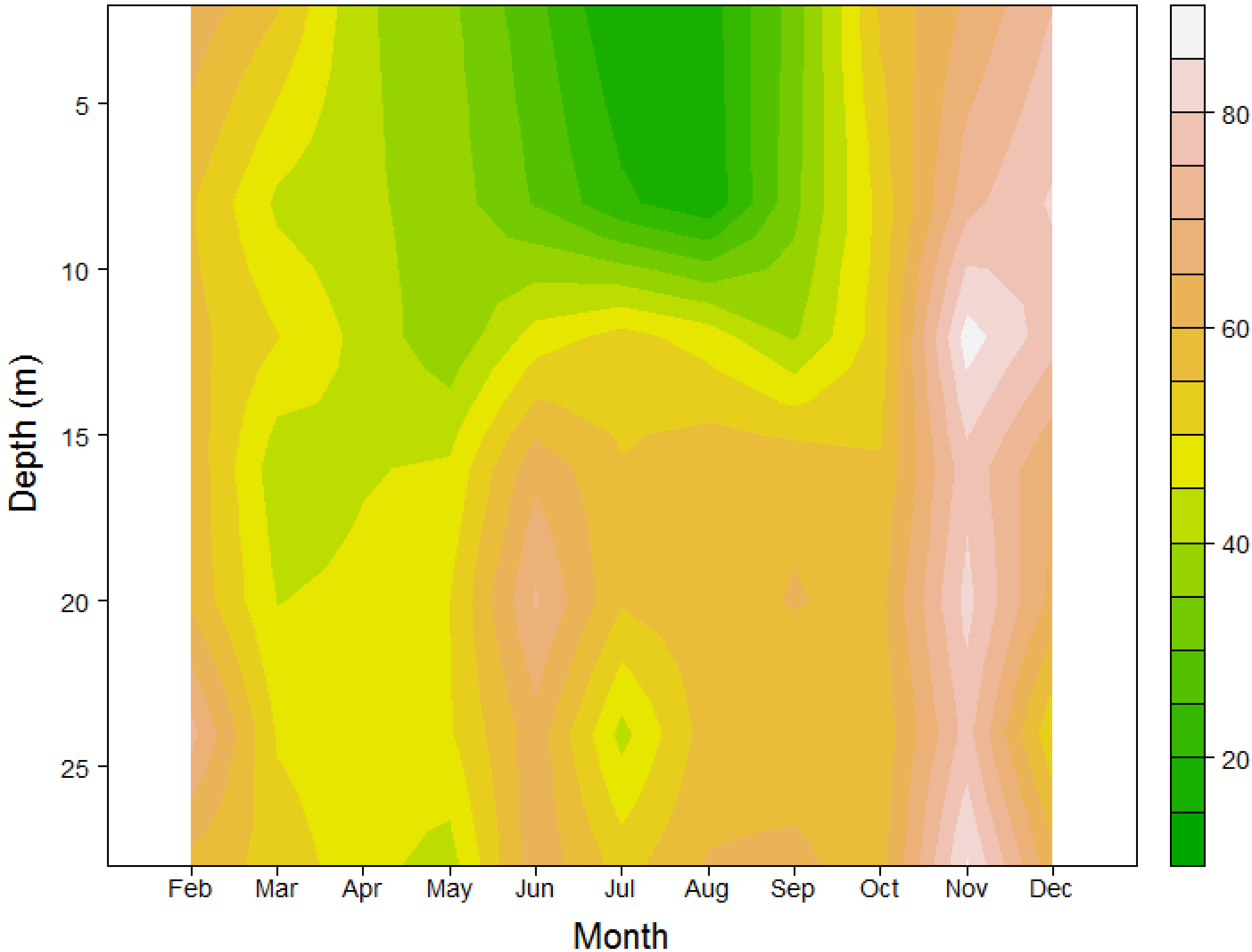

Figure 16. Chlorophyll *a* (µg/L) profiles at Station 6 between February and December in 2016.

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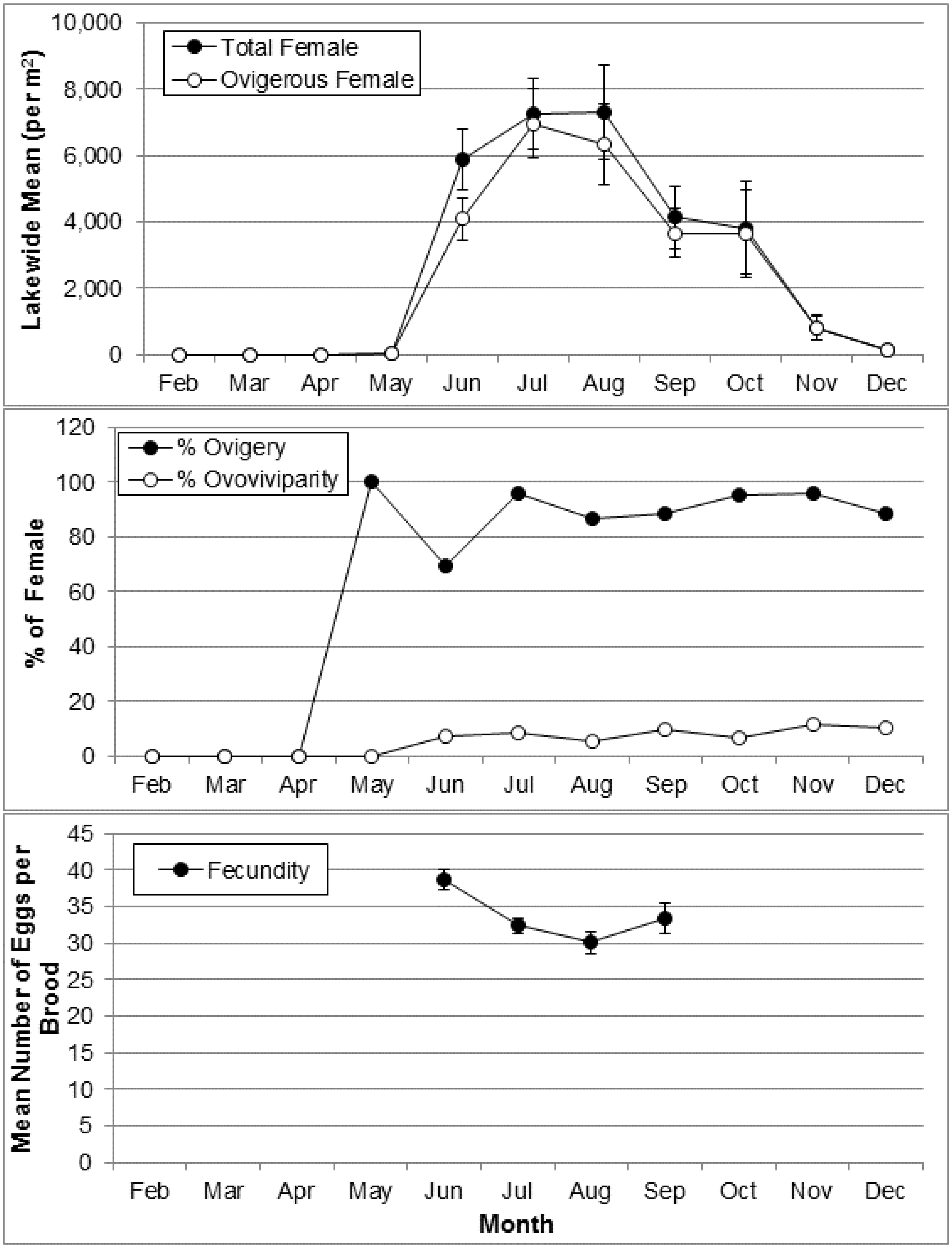

Figure 17. *Artemia* reproductive parameter and fecundity between June and September in 2016.

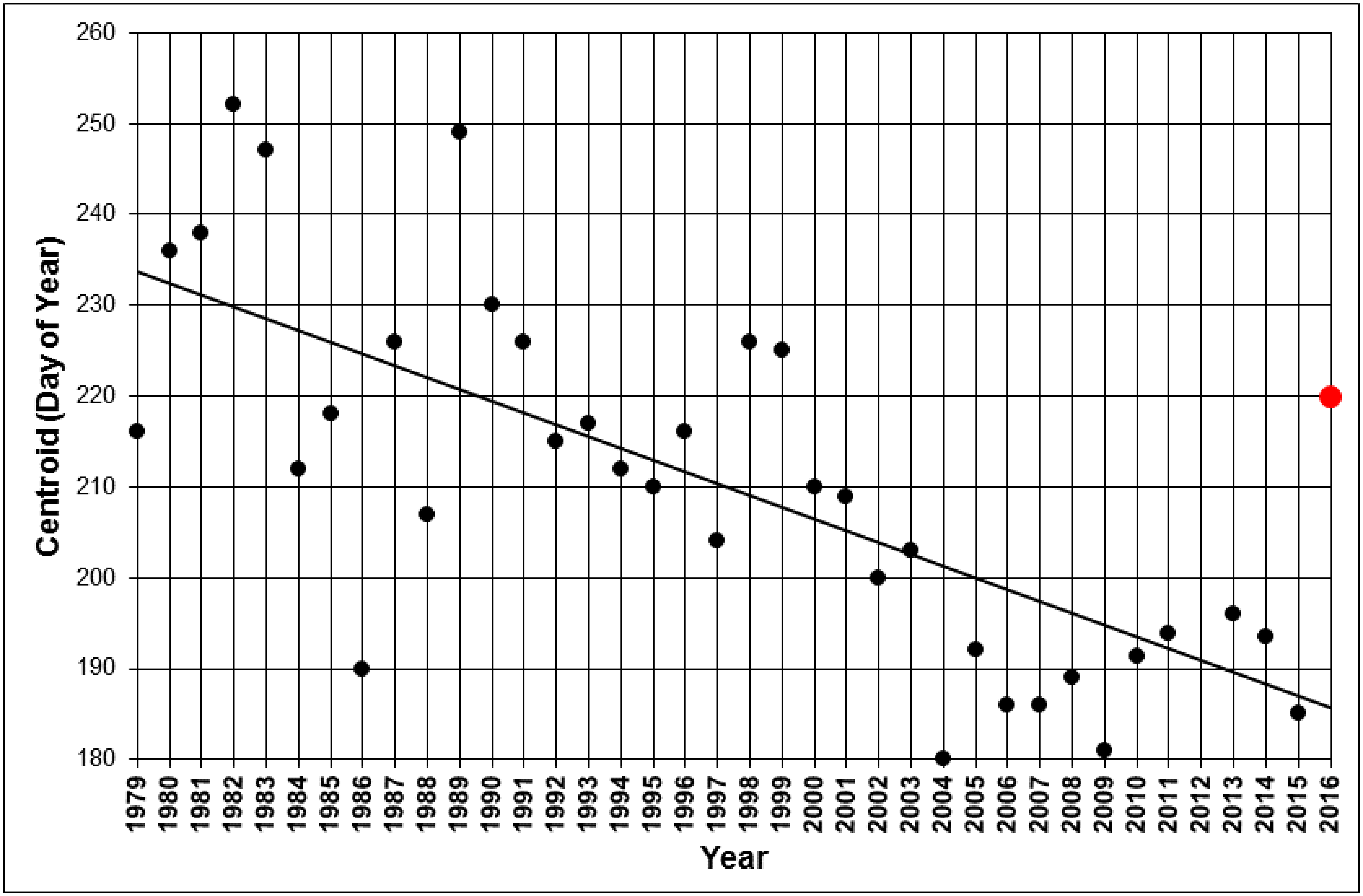

Figure 18. Adult Artemia population centroid since 1987. A red dot indicates a value from 2016.

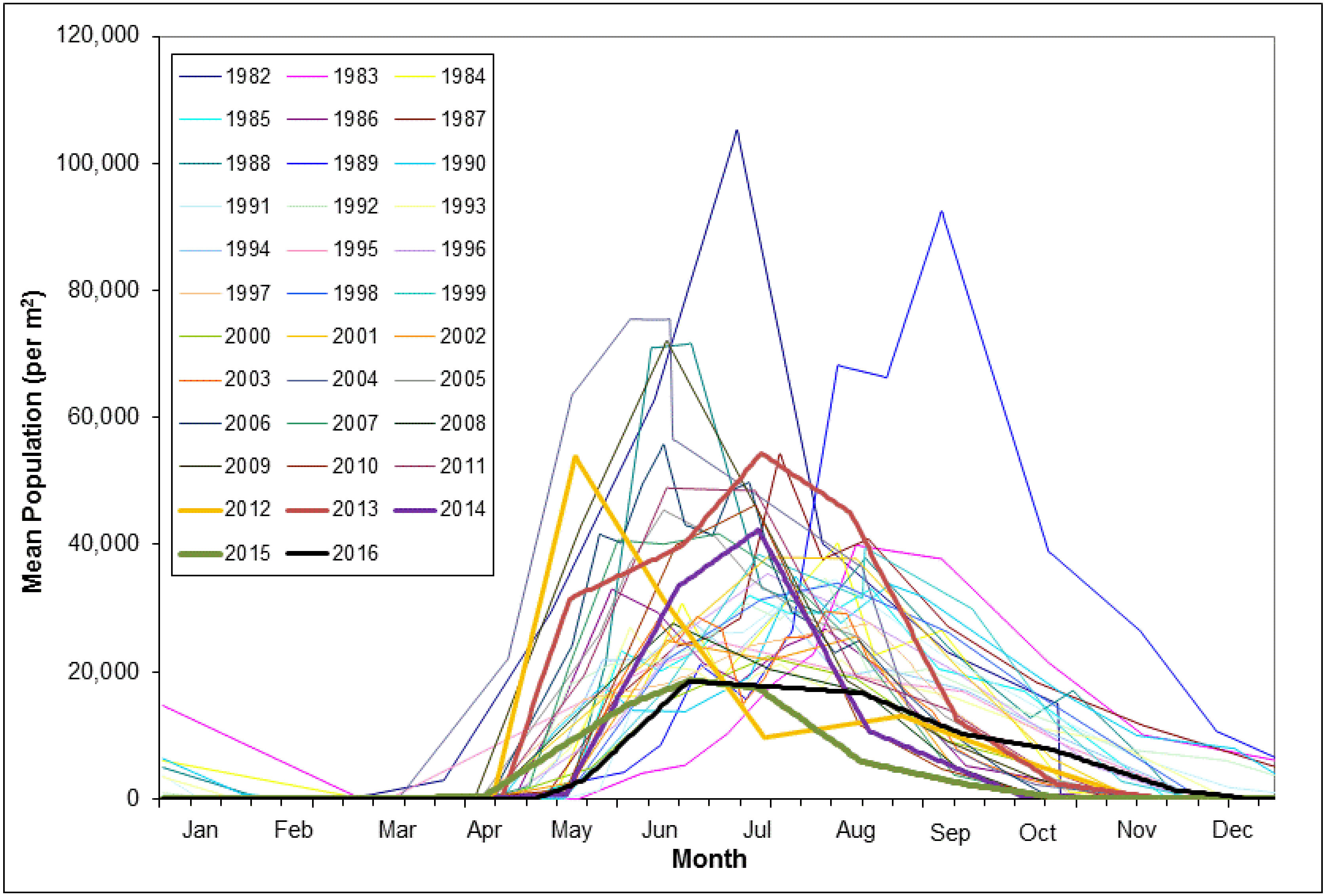

Figure 19. Mean lakewide adult *Artemia* population (per m^2) between 1982 and 2016.

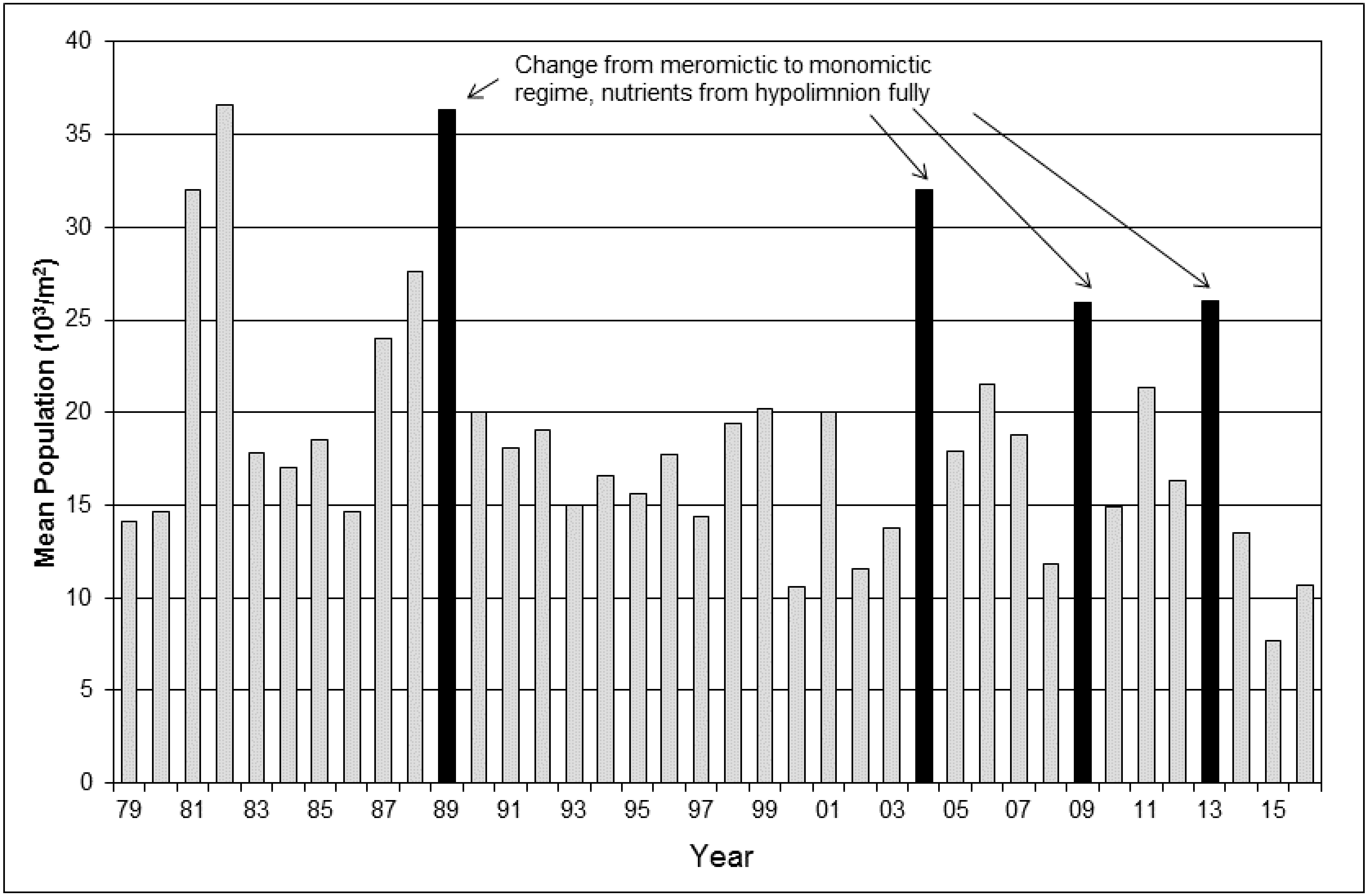

Figure 20. Mean lakewide adult *Artemia* population (per m^2) between May and November from 1979 to 2016. Years with a darker color indicates years subsequent to onset of monomixis.

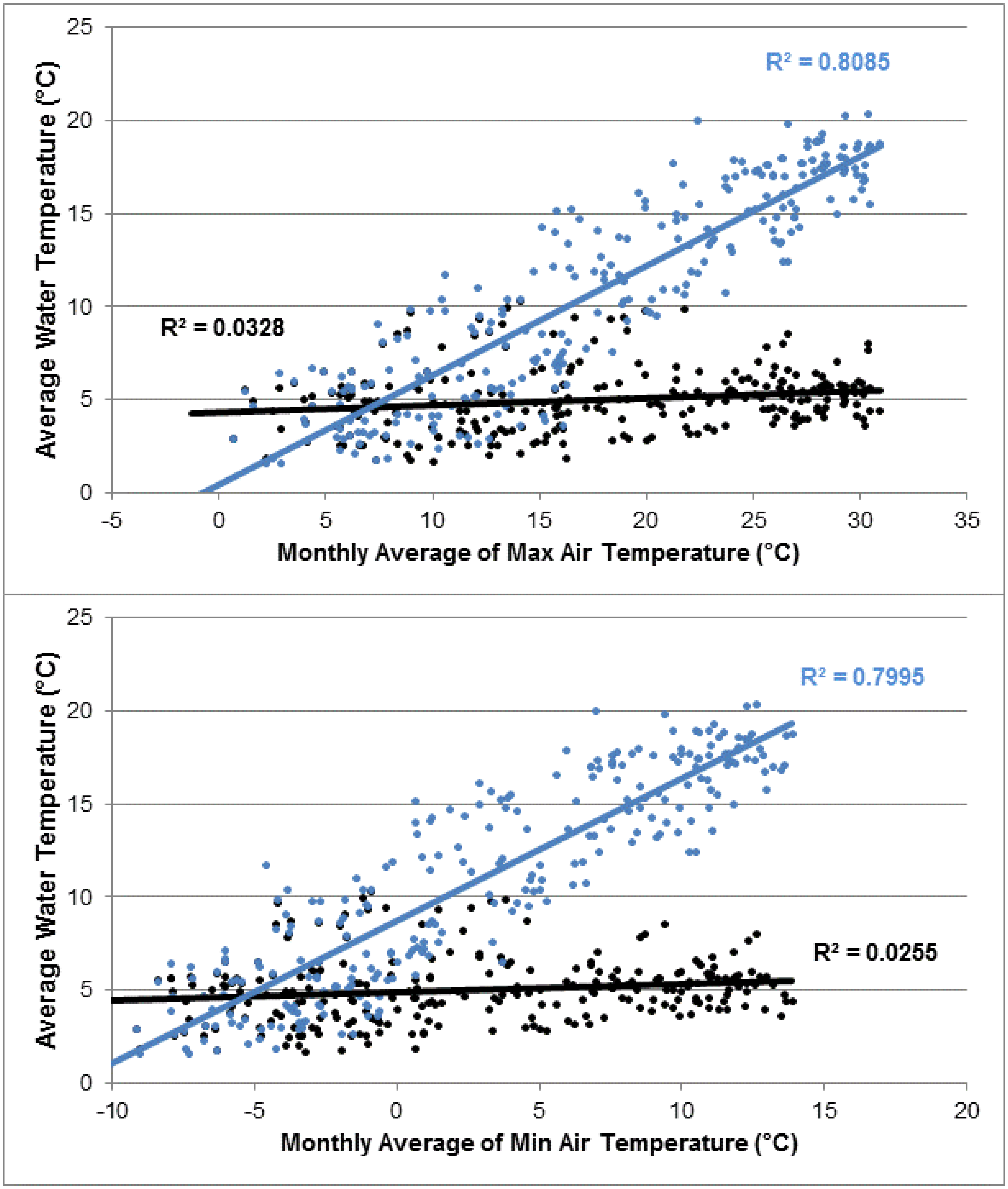

Figure 21. Relationships between monthly average air temperature and mono lake water temperature at different depths. Blue indicates water temperature averaged in the epilimnion (1 to 14m of depth) while black indicates water temperature averaged in the hypolimnion (15 to 38m of depth) at Station 6.

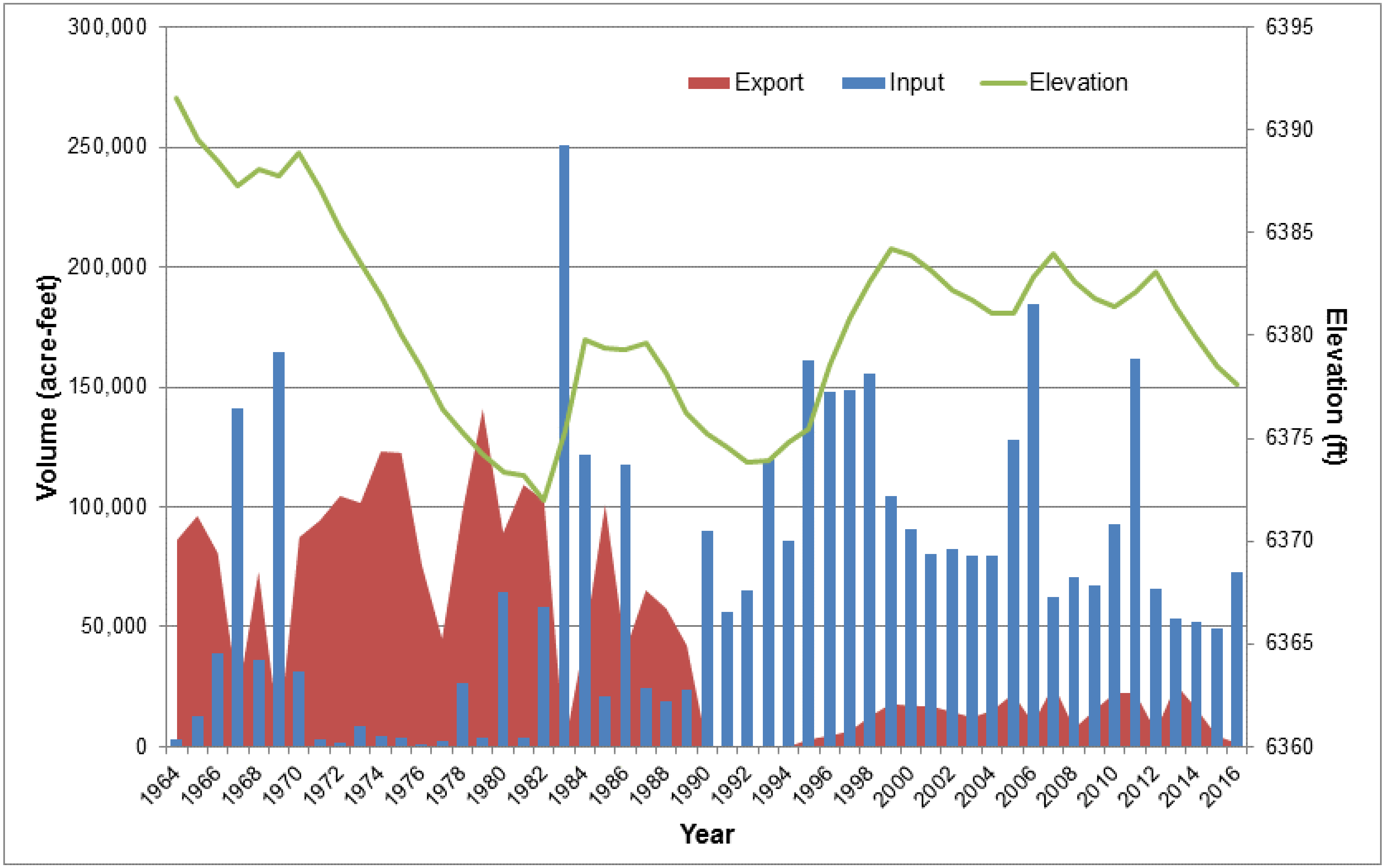

Figure 22. Annual export of water from Mono Lake tributaries, input to Mono Lake from two major tributaries and surface elevation from 1963-2016 reported in acre feet per water year (October-September). Annual input from two major tributaries is only available after May of 1964 when recording has begun at Parker below Lee Vining Conduit (STAID 5003) and Walker below Lee Vining Conduit (STAID 5002).