LA DWP Los Angeles Department of Water & Power

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May 12, 2020

Mr. Erik Ekdahl, Deputy Director
Division of Water Rights
State Water Resources Control Board
1001 I Street, 14th Floor
Sacramento, California 95814

Dear Mr. Ekdahl:

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

Pursuant to the State Water Resources Control Board (SWRCB) Decision No. 1631 and Order Nos. 98-05 and 98-07 (Orders) and in accordance with the terms and conditions of the Los Angeles Department of Water and Power (LADWP) Mono Basin Water Rights License Nos. 10191 and 10192, enclosed is a compact disc (CD) containing a submittal, "Compliance Reporting May 2020", which contains the following four reports required by the Orders. Please note that for Runoff Year (RY) 2019-2020, Mono Basin Operations followed the Temporary Urgency Change Petition (TUCP) and its subsequent renewal as approved by the SWRCB, and supported by the Mono Basin interested parties. The reports are as follows:

- Section 2: Mono Basin Operations: RY 2019-2020 and Planned Operations for RY 2020-2021. The planned operations through September 30, 2020 will follow the renewed TUCP (2nd renewal) as expected to be approved by your agency in early May 2020.
- Section 3: Mono Basin Fisheries Monitoring Report: Rush, Lee Vining, Parker, and Walker Creeks for RY 2019-2020
- Section 4: Stream Monitoring Report RY 2019-2020
- Section 5: Mono Basin Waterfowl Habitat and Population Monitoring for RY 2019-2020, including a statement by the Waterfowl Director, Ms. Debbie House

In addition to these reports, the submittal also includes Section 1: the RY 2019-2020 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 2019-2020 as set forth in Decision 1631 and the Orders, as well as the original and renewed TUCP.

Electronic copies of the 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 Dr. Paul C. Pau, Eastern Sierra Issues Supervisor, at (213) 367-1187.

Sincerely,

Anselmo G. Collins
Director of Water Operations

PCP:mt
Enclosures
c/enc: Mono Basin Distribution List
Dr. Paul C. Pau

Mono Basin Distribution List
Runoff Year 2019-20

Mr. Erik Ekdahl Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Mr. Scott McFarland Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814
Ms. Amanda Montgomery Division of Water Rights State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Mr. Geoffrey McQuilkin Mono Lake Committee P.O. Box 29 Lee Vining, CA 93541
Mr. Bartshe Miller Mono Lake Committee P.O. Box 29 Lee Vining, CA 93541	Dr. Eric Huber 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, Suite 801 Berkeley, CA 94704-1229
Mr. Ross Taylor 1254 Quail Run Court McKinleyville, CA 95519	Ms. Stacey Simon 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
Mr. Dan Shaw California State Parks P.O. Box 266 Tahoma, CA 96142	Mr. Doug Smith Grant Lake Reservoir Marina P.O. Box 21 June Lake, CA 93529
Mr. Matt Green California State Parks P.O. Box 266 Tahoma, CA 96142	Mono County Board of Supervisors c/o Clerk of the Board P.O. Box 715 Bridgeport, CA 93517

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 Habitat & Population Monitoring

May 2020
Los Angeles Department of Water and Power

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NO. 1 Status of Restoration Compliance Report (SORC)

NO. 2 Mono Basin Operations
RY2019-20
RY2020-21

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NO. 4 Stream Monitoring Report for RY 2019-20

NO. 5 Mono basin Waterfowl Habitat Restoration

2019 Compliance Report with Recommendations

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 2020

Los Angeles Department of Water and Power

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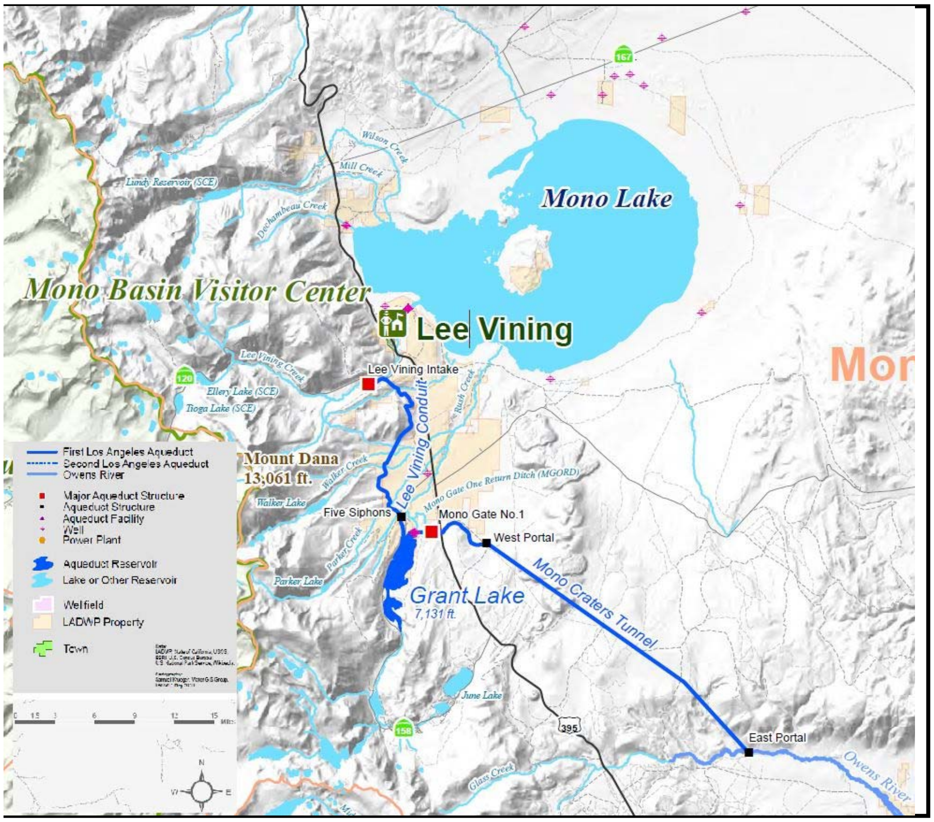
Introduction

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, 2020. 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 2020 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, 2019, there has been no change to the report and Section 4, the Plans for Runoff Year RY2019-20, will apply to RY2020-21.

4. Plans for the Upcoming Runoff Year:

During the upcoming runoff year, RY2020-21, LADWP plans to:

1. Continue with all requirements listed under Category A – Ongoing Items, as needed based on the runoff year.
2.

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. On occasions, the requirements could be deviated through special permission granted by the SWRCB, such as in a Temporary Urgency Change Petitions (TUCP). Such activities are reported in the Annual Compliance Report. 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.

Category A – Ongoing Items

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

Category B – Completed Items

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

Category C – In-Progress Items

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.

Category D – Incomplete Items

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 2019. 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 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. 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". 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". 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 will 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

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

May 2020

Los Angeles Department of Water and Power

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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 2019-20 Operations

For the majority of RY 2019-2020, Mono Basin operated under the Temporary Urgency Change Petition (TUCP) and the subsequent renewed TUCP (Attachments 1 & 2 respectively) approved by the SWRCB, pursuant to Water Code Section No. 1435. The TUCP allowed LADWP to temporarily deviate from the Stream Restoration Flow requirements as outlined in the SWRCB Order 98-05, and instead to follow the Stream Ecosystem Flows (SEFs) recommended by the SWRCB-appointed stream scientist in the 2010 Synthesis of Instream Flow Recommendations to the SWRCB and LADWP.

A. Rush Creek

The runoff from Rush Creek was approximately 78,170 AF which amounts to the total water delivered to Grant Lake Reservoir (GLR)'s 'Damsite'. The highest flow of 497.08 cfs occurred on June 14, 2019.

Rush Creek flows below 'the Narrows', which consist of Rush Creek releases (Return Ditch, Spill, and 5-Siphons augmentation) combined with Parker and Walker Creeks flows, had an approximate total of 86,359 AF. This flow terminated into Mono Lake.

RY 2019 was forecasted as a WET year and followed principally the Temporary Urgency Change Petition (TUCP) and the subsequent renewed TUCP requirements, as approved by the SWRCB in April, and October, 2019, respectively.

Rush Creek flows were generally implemented in accordance with Table 1B of Attachment 1. As noted in the TUCP, the current infrastructure may not allow LADWP to deliver the magnitude of flows and duration as specified in Table 1B, especially for the snowmelt peak flow of 650 cfs for 5 days. However, from June 18, 2019 to July 10, 2019, flows (Mono Gate One Return Ditch (MGORD) + GLR spill flows) were in the range of 415 – 472 cfs, vs. the 650 cfs for 5 days. For the recession phase, slight deviations from Table 1 B were made in order to prevent GLR from early spilling in late winter/early spring 2020. Early spill would be detrimental to the fisheries hatching period. Also, on August 20, 2019, LADWP informed SWRCB through email that the flows for Rush Creek and Lee Vining would be set at 30, and 25 cfs for the fish monitoring activities from September 16 - 26, 2019.

Under the renewed TUCP, Rush Creek flows were implemented in accordance with Table 1B of Attachment 2 starting in October 2019 through March 31, 2020.

1. Rush Creek Augmentation

To meet high flow targets for lower Rush Creek, LADWP must at times employ facilities in addition to the 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.

5-Siphons Bypass
Under the TUCP, the 5-Siphons were not utilized.

Grant Reservoir Spill
Grant spilled from June 14, 2019 through July 16, 2019.

B. Lee Vining Creek

Under the TUCP, Lee Vining Creek flows were generally implemented in accordance with Table 2A of Attachment 1. One key aspect of Table 2A is to bypass all inflows when they exceed or equal 251 cfs. From June 5 through 25, 2019, all flows were bypassed as they exceeded 251 cfs except for 2 days. Again, to prevent early GLR spills, Lee Vining Creek was operated as flow through in August. Lee Vining flows were set at 25 cfs for the fish monitoring activities from September 16 - 26, 2019.

Lee Vining Creek had its highest flow on June 20, 2019 at 415 cfs. Total runoff for the year was approximately 62,525 AF.

Under the renewed TUCP, Lee Vining Creek flows were implemented in accordance with Section 2.2.2 of Attachment 2 for “WET” year starting in October 2019 through March 31, 2020.

C. Dry Cycle Channel Maintenance Flows

RY 2019 was forecasted as a WET year type, therefore dry cycle channel maintenance flows (CMF) were not required in accordance with Decision 1631, and separately, with the TUCP.

D. Parker and Walker Creeks

Under the TUCP and the renewed TUCP, Parker and Walker were operated as pass through for RY 2019.

Parker Creek had its highest flow on June 20, 2019 at 69.60 cfs. Total runoff for the year was approximately 11,575 AF.

Walker Creek had its highest flow on June 20, 2019 at 42.84 cfs. Total runoff for the year was approximately 6,179 AF.

E. Grant Lake Reservoir

GLR began the runoff year at approximately 28,041 AF (7,110.95 ft AMSL). The reservoir spilled between June 14, 2019 and July 16, 2019. Final storage volume by the end of the RY of March 31, 2020 was approximately 26,920 AF (7,109.7 ft AMSL).

F. Exports during RY 2019-20

During RY 2019, Mono Lake elevations were within the 6,382 ft – 6,383 ft range, allowing for up to 16,000 AF of exports per Decision 1631. LADWP exported 15,958 AF total from the Mono Basin, which is below the allowed 16,000 AF.

G. Mono Lake Elevations during RY 2019-20

In RY 2019, Mono Lake elevations were as shown in the following table. The Lake elevation was at 6,382.1 ft AMSL at the beginning of the runoff year, and ended the runoff year at 6,382.6 ft AMSL.

RY 2019-20 Mono Lake Elevation Readings

April 1, 2019	6,382.1
May 1, 2019	6,382.1
June 1, 2019	6,382.2
July 1, 2019	6,382.7
August 1, 2019	6,383.1
September 1, 2019	6,383.1
October 1, 2019	6,382.7
November 1, 2019	6,382.5
December 1, 2019	6,382.5
January 1, 2020	6,382.5
February 1, 2020	6,382.6
March 1, 2020	6,382.6
April 1, 2020	6,382.6

B. Proposed Mono Basin Operations Plan RY 2020-21

A. Forecast for RY 2020-21

The Mono Basin Operations Plan for RY 2020-21 from early May to September 30, 2019 will follow the TUCP (Renewal II) for a “Dry-Normal I” year category, as expected to be approved by the SWRCB in early May 2020. Flow requirements are shown in **Attachment 3.** The Mono Basin’s April 1st forecast for Runoff Year (RY) 2020 for April to March period is 85,000 acre-feet (AF), or 71 percent of average using the 1966-2015 long term mean of 119,103 AF (**Attachment 4**). This value puts the year type within the “Dry-Normal I” category. Mono Basin operations follow Decision 1631 requirement until the TUCP is approved.

LADWP will submit a timely TUCP renewal application, as necessary, to the SWRCB for the Mono Basin Operations Plan from October 1, 2020 to March 31, 2020.

The following forecasts are subjected to change as operations for the second-half of the runoff year have not been defined.

B. Grant Lake Reservoir

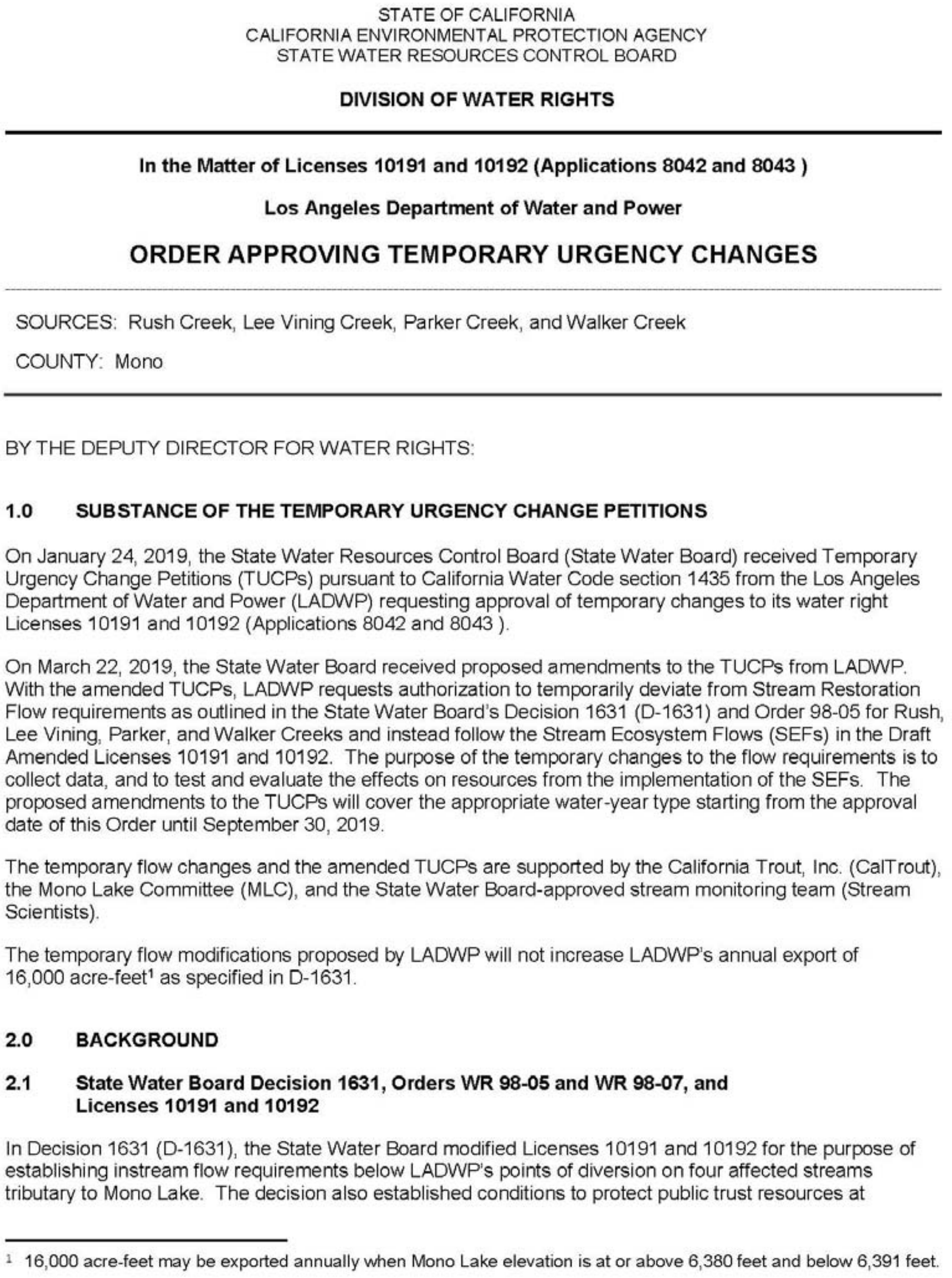
GLR storage volume was 27,009 AF, corresponding to a surface elevation of 7,109.8 feet above mean sea level (AMSL) at the start of the runoff year. Using the closest available representative historical inflow data (2002 runoff year at 72.8 percent of normal), and above specified flows, GLR’s profile is projected to be as shown in **Attachment 5**. 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.

C. Projected Mono Lake Elevations during RY 2020-21

Mono Lake began this runoff year at 6,382.6 ft AMSL where it is projected to the runoff year at approximately 6,382.0 ft AMSL (**Attachment 6**).

ATTACHMENTS

Attachment 1



STATE OF CALIFORNIA
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
STATE WATER RESOURCES CONTROL BOARD

DIVISION OF WATER RIGHTS

In the Matter of Licenses 10191 and 10192 (Applications 8042 and 8043)

Los Angeles Department of Water and Power

ORDER APPROVING TEMPORARY URGENCY CHANGES

SOURCES: Rush Creek, Lee Vining Creek, Parker Creek, and Walker Creek

COUNTY: Mono

BY THE DEPUTY DIRECTOR FOR WATER RIGHTS:

1.0 SUBSTANCE OF THE TEMPORARY URGENCY CHANGE PETITIONS

On January 24, 2019, the State Water Resources Control Board (State Water Board) received Temporary Urgency Change Petitions (TUCPs) pursuant to California Water Code section 1435 from the Los Angeles Department of Water and Power (LADWP) requesting approval of temporary changes to its water right Licenses 10191 and 10192 (Applications 8042 and 8043).

On March 22, 2019, the State Water Board received proposed amendments to the TUCPs from LADWP. With the amended TUCPs, LADWP requests authorization to temporarily deviate from Stream Restoration Flow requirements as outlined in the State Water Board's Decision 1631 (D-1631) and Order 98-05 for Rush, Lee Vining, Parker, and Walker Creeks and instead follow the Stream Ecosystem Flows (SEFs) in the Draft Amended Licenses 10191 and 10192. The purpose of the temporary changes to the flow requirements is to collect data, and to test and evaluate the effects on resources from the implementation of the SEFs. The proposed amendments to the TUCPs will cover the appropriate water-year type starting from the approval date of this Order until September 30, 2019.

The temporary flow changes and the amended TUCPs are supported by the California Trout, Inc. (CalTrout), the Mono Lake Committee (MLC), and the State Water Board-approved stream monitoring team (Stream Scientists).

The temporary flow modifications proposed by LADWP will not increase LADWP's annual export of 16,000 acre-feet[1] as specified in D-1631.

2.0 BACKGROUND

2.1 State Water Board Decision 1631, Orders WR 98-05 and WR 98-07, and Licenses 10191 and 10192

In Decision 1631 (D-1631), the State Water Board modified Licenses 10191 and 10192 for the purpose of establishing instream flow requirements below LADWP's points of diversion on four affected streams tributary to Mono Lake. The decision also established conditions to protect public trust resources at

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[1] 16,000 acre-feet may be exported annually when Mono Lake elevation is at or above 6,380 feet and below 6,391 feet.

Mono Lake. State Water Board Orders WR 98-05 and WR 98-07 (Orders) amended D-1631. Pursuant to D-1631 and the subsequent Orders, LADWP is required to conduct fisheries studies and stream monitoring activities until the program (or elements thereof) is terminated by the State Water Board. LADWP has been conducting fisheries studies and stream monitoring for over 20 years. These activities are conducted by the Stream Scientists who: (a) oversee implementation of the stream monitoring and restoration program, and (b) evaluate the results of the monitoring program and recommend modifications as necessary. In the Stream Scientists' April 30, 2010 *Synthesis of Instream Flow Recommendations Report* (Synthesis Report), they recommended modification of the flow regime and other aspects of the Mono Basin stream monitoring and restoration program.

2.2 Description of the Temporary Urgency Changes

The basis of temporary changes to the flow requirements is to allow LADWP to collect data, and to test and evaluate the effects on resources from the implementation of the SEFs, as identified in the *Mono Basin Operations Plan Under The Amended TUCP*, dated March 22, 2019. The TUCPs request the following temporary changes:

1. Rush Creek - The Mono Basin's April 1st forecast for Runoff Year (RY) 2019-2020 is projected to be either an Extreme-Wet, Wet, or Wet/Normal water-year type. Rush Creek's SEFs will be set to the appropriate water-year type and follow either Table 1A for an Extreme-Wet, Table 1B for a Wet, or Table 1C for a Wet/Normal water-year type (see Tables on pages 6-8).
2. Lee Vining Creek – The SEFs for Lee Vining Creek will follow Table 2A for an Extreme-Wet, Wet, or Wet/Normal water-year type (see Table on page 9).
3. Parker Creek – All flow will be continuously bypassed.
4. Walker Creek - All flow will be continuously bypassed.

It has been noted that the current infrastructure may not allow LADWP to deliver the magnitude of flows and duration for Rush Creek's SEFs listed in Tables 1A, 1B, and 1C when flows exceed 380 cubic feet per second (cfs). LADWP also acknowledged that Lee Vining Creek's flows listed in Table 2A will be implemented to the extent that the current infrastructure and upstream operations allows and operate to ensure flows in Lee Vining Creek do not drop below the minimum specified flows as outlined in Table 2A. An exception to the flows in Table 2A will be made in September 2019 during fish monitoring activities where Lee Vining Creek flows will be set to 28 cfs for up to two weeks in order to ensure the safety of the Stream Scientists and LADWP biologists performing the fish monitoring activities.

LADWP will communicate with Mono Basin parties (MLC, CalTrout, California Department of Fish and Wildlife), the Stream Scientists, and the State Water Board during the TUCP's authorized period to coordinate and gain input as SEFs proceed. Specifically, a conference call will be scheduled within a reasonable time of the April runoff forecast to discuss final water year type, operations plan, address questions, and Stream Scientist input that may result from the operations plan. LADWP will also provide reasonable communication to update parties, answer questions, and address unforeseen challenges as SEFs are delivered according to the April 1 forecast for RY 2019-20.

3.0 COMPLIANCE WITH CALIFORNIA ENVIRONMENTAL QUALITY ACT

LADWP, as Lead Agency pursuant to the California Environmental Quality Act (CEQA), prepared a Notice of Exemption for the *Mono Basin Temporary Operation Petition to State Water Resources Control Board* on January 3, 2019. LADWP found that the change is categorically exempt from CEQA, as the project is for the use of existing facilities with negligible or no expansion of existing use, for the purpose of maintaining fish and wildlife habitat areas, maintaining stream flows, and protecting fish and wildlife resources. (14 Cal. Code Regs. § 15301(i).).

The State Water Board has reviewed the information submitted by LADWP and has determined that the petitions qualify for an exemption under CEQA. The State Water Board will issue a Notice of Exemption for the temporary urgency change petitions.

4.0 PUBLIC NOTICE OF TEMPORARY URGENCY CHANGE PETITIONS

On April 5, 2019, the State Water Board issued a public notice of the temporary urgency changes pursuant to Water Code section 1438, subdivision (a). The comment period expires on May 6, 2019. Pursuant to Water Code section 1438, subdivision (b)(1), LADWP is required to publish the notice in a newspaper having a general circulation and published within the counties where the points of diversion are located. LADWP published the notice on April 4, 2019 in the Mammoth Times. The State Water Board posted the notice of the temporary urgency changes and the TUCPs (and accompanying materials) on its website and distributed the notice through its electronic notification system. Pursuant to Water Code section 1438(a), the State Water Board may issue a temporary urgency change order in advance of the required notice period.

5.0 COMMENTS REGARDING THE TEMPORARY URGENCY CHANGE PETITIONS

On January 22, 2019, LADWP copied the initial TUCPs to interested parties including the California Department of Fish and Wildlife, CalTrout, MLC, and the Stream Scientists. On February 1, 2019, MLC commented on the proposed TUCPs. MLC recommended that the State Water Board approve implementation of the interim SEFs for 180 days with the option for renewal. MLC also recommended that all elements of draft Licenses 10191 and 10192 terms and conditions 11 (Stream Ecosystem Flows) including tables, 12 (Grant Lake Operations), and 15 (Annual Operations Plan) including the collaborative planning, Stream Scientists input, and monthly reporting elements be implemented. MLC stated that interim implementation of the SEFs in 2019 will benefit the restoration of Rush, Lee Vining, Walker, and Parker Creeks and help with Grant Lake Reservoir management as well.

On February 6, 2019, a Mono Lake stakeholders meeting/conference call was held at the State Water Board's office which initiated the discussion on the TUCPs and action items for the coordination and resubmittal of amended TUCPs. On March 14, 2019, LADWP discussed the proposed amendments to the TUCPs in a conference call with the MLC, CalTrout, and Stream Scientists and there was a consensus to support the amended TUCPs. On March 22, 2019, LADWP submitted the amended TUCPs to the State Water Board.

6.0 CRITERIA FOR APPROVING THE PROPOSED TEMPORARY URGENCY CHANGES

Water Code section 1435 provides that a permittee or licensee who has an urgent need to change the point of diversion, place of use, or purpose of use from that specified in the permit or license may petition for a conditional temporary change order. The State Water Board's regulations set forth the filing and other procedural requirements applicable to TUCPs (Cal. Code Regs., tit. 23, §§ 805, 806.) The State Water Board's regulations also clarify that requests for changes to permits or licenses other than changes in point of diversion, place of use, or purpose of use may be filed, subject to the same filing and procedural requirements that apply to changes in point of diversion, place of use, or purpose of use. (*Id.*, § 791, subd. (e))

Before approving a temporary urgency change, the State Water Board must make the following findings:

1. The Petitioner has an urgent need to make the proposed change;
2. The proposed change may be made without injury to any other lawful user of water;
3. The proposed change may be made without unreasonable effect upon fish, wildlife, or other instream beneficial uses; and
4. The proposed change is in the public interest.

(Wat. Code, § 1435, subd. (b)(1-4).)

6.1 Urgency of the Proposed Change

Under Water Code section 1435, subdivision (c), an "urgent need" means "the existence of circumstances from which the State Water Board may in its judgment conclude that the proposed temporary change is necessary to further the constitutional policy that the water resources of the state be put to beneficial use to the fullest extent of which they are capable and that waste of water be prevented . . . ." However, the State Water Board shall not find the need urgent if it concludes that the petitioner has failed to exercise due diligence in petitioning for a change pursuant to other appropriate provisions of the Water Code. (Ibid.)

In this case, there is an urgent need for the proposed change in the license conditions regarding fish flows for the purpose of furthering protection of public trust resources.

6.2 No Injury to Any Other Lawful User of Water

There are no known lawful users of water that will be affected by the proposed changes to instream flows. Accordingly, granting these TUCPs will not result in injury to any other lawful users of water

6.3 No Unreasonable Effect upon Fish, Wildlife, or Other Instream Beneficial Uses

As described above, MLC have indicated that the temporary urgency will benefit the restoration of Rush, Lee Vining, Walker, and Parker Creeks and help with Grant Lake Reservoir management. No other fish or wildlife resources are implicated by the proposed change; accordingly, the proposed change will not have unreasonable effects upon fish and wildlife resources.

6.4 The Proposed Change is in the Public Interest

The proposed change would assist LADWP in maintaining the fishery resources in good condition. Maintenance of the fishery is in the public interest.

In light of the above, I find in accordance with Water Code section 1435, subdivision (b)(4) that the proposed change is in the public interest, including findings to support change order conditions imposed to ensure that the change is in the public interest.

Pursuant to Water Code section 1439, the State Water Board shall supervise diversion and use of water under this temporary change order for the protection of all other lawful users of water and instream beneficial uses.

7.0 STATE WATER BOARD DELEGATION OF AUTHORITY

On June 5, 2012, the State Water Board adopted Resolution 2012-0029, delegating to the Deputy Director for Water Rights the authority to act on petitions for temporary urgency change. This Order is adopted pursuant to the delegation of authority in section 4.4.1 of Resolution 2012-0029.

8.0 CONCLUSIONS

The State Water Board has adequate information in its files to make the evaluation required by Water Code section 1435.

I conclude that, based on the available evidence:

1. The Petitioner has an urgent need to make the proposed changes;
2. The proposed changes will not operate to the injury of any other lawful user of water;

3. The proposed changes, with conditions set forth in this Order, will not have an unreasonable effect upon fish, wildlife, or other instream beneficial uses; and

4. The proposed changes are in the public interest.

ORDER

NOW, THEREFORE, IT IS ORDERED THAT: the petitions filed by the LADWP for temporary urgency changes in Licenses 10191 and 10192 are approved, and this approval is effective from the date of this Order to September 30, 2019. All existing terms and conditions in Licenses 10191 and 10192 remain in effect, except as temporarily amended by the following terms.

1. For protection of fish in Rush and Lee Vining Creeks, LADWP shall bypass flow below the point of diversion at the flows specified in the tables below for the appropriate water year type. The SEFs provided under this requirement shall remain in the stream channel and not be diverted for any other use.

2. LADWP shall submit to the Deputy Director for Water Rights on a monthly basis a written report that summarizes all activities conducted to ensure compliance with the requirements of this Order. The first monthly report is due at the end of the first complete month of this Order. LADWP shall submit a final report summarizing overall compliance with this Order no later than November 1, 2019.

3. This Order does not authorize any act that results in the taking of a threatened or endangered species, or any act that is now prohibited, or becomes prohibited in the future, under either the California Endangered Species Act (Fish and Game Code sections 2050 to 2097) or the federal Endangered Species Act (16 U.S.C.A. sections 1531 to 1544). If a "take" will result from any act authorized under this Order, the licensee shall obtain authorization for an incidental take permit prior to construction or operation. Licensee shall be responsible for meeting all requirements of the applicable Endangered Species Act for the temporary urgency change authorized under this Order.

4. The State Water Board shall supervise the diversion and use of water under this Order for the protection of legal users of water and instream beneficial uses and for compliance with the conditions. Petitioner shall allow representatives of the State Water Board reasonable access to the project works to determine compliance with the terms of this Order.

5. The State Water Board reserves jurisdiction to supervise the temporary urgency changes under this Order, and to coordinate or modify terms and conditions, for the protection of vested rights, fish, wildlife, instream beneficial uses and the public interest as future conditions may warrant.

6. The temporary urgency changes authorized under this Order shall not result in creation of a vested right, even of a temporary nature, but shall be subject at all times to modification or revocation in the discretion of the State Water Board. The temporary urgency changes approved in this Order shall automatically expire September 30, 2019, unless earlier revoked.

STATE WATER RESOURCES CONTROL BOARD

ORIGINAL SIGNED BY:

Erik Ekdahl, Deputy Director
Division of Water Rights

Dated: APR 16 2019

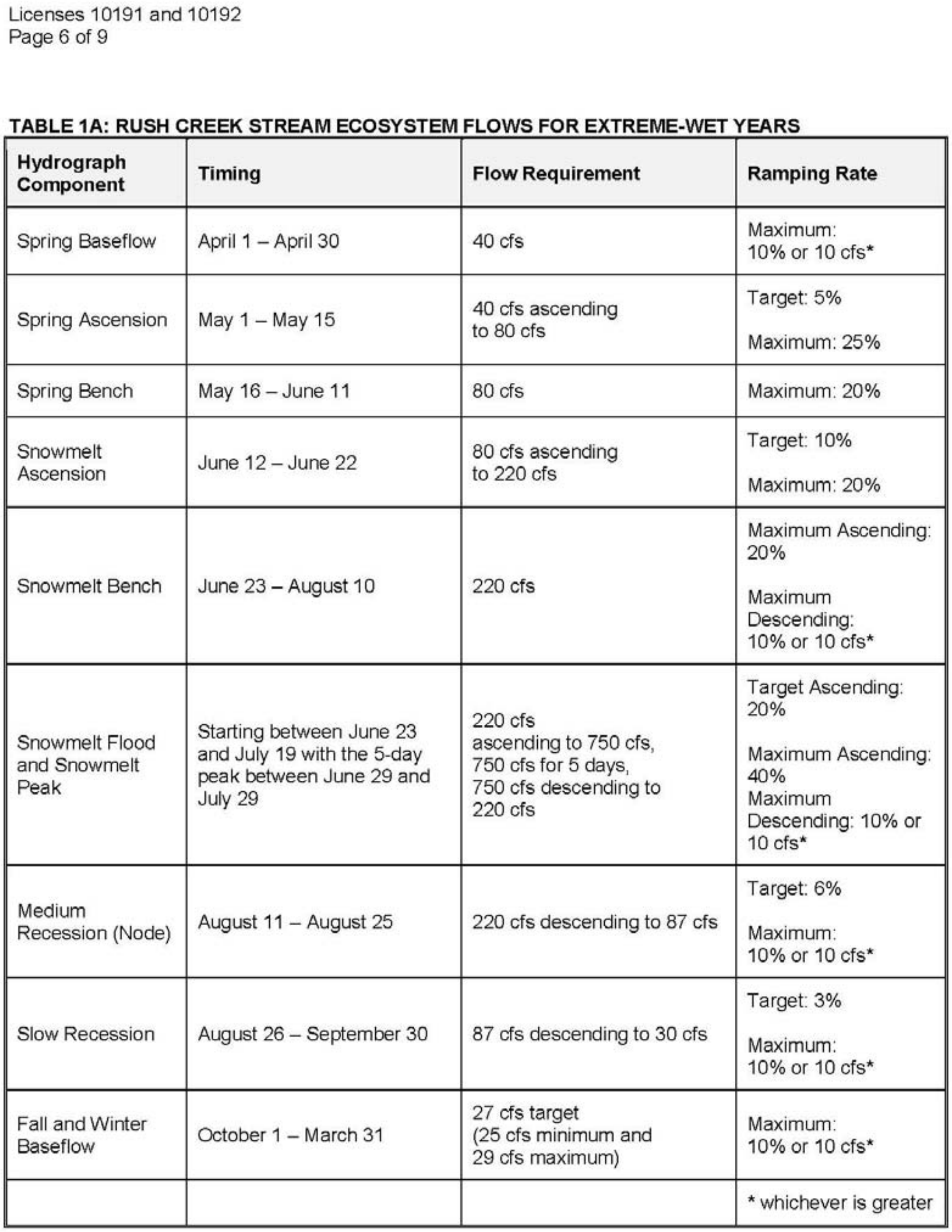
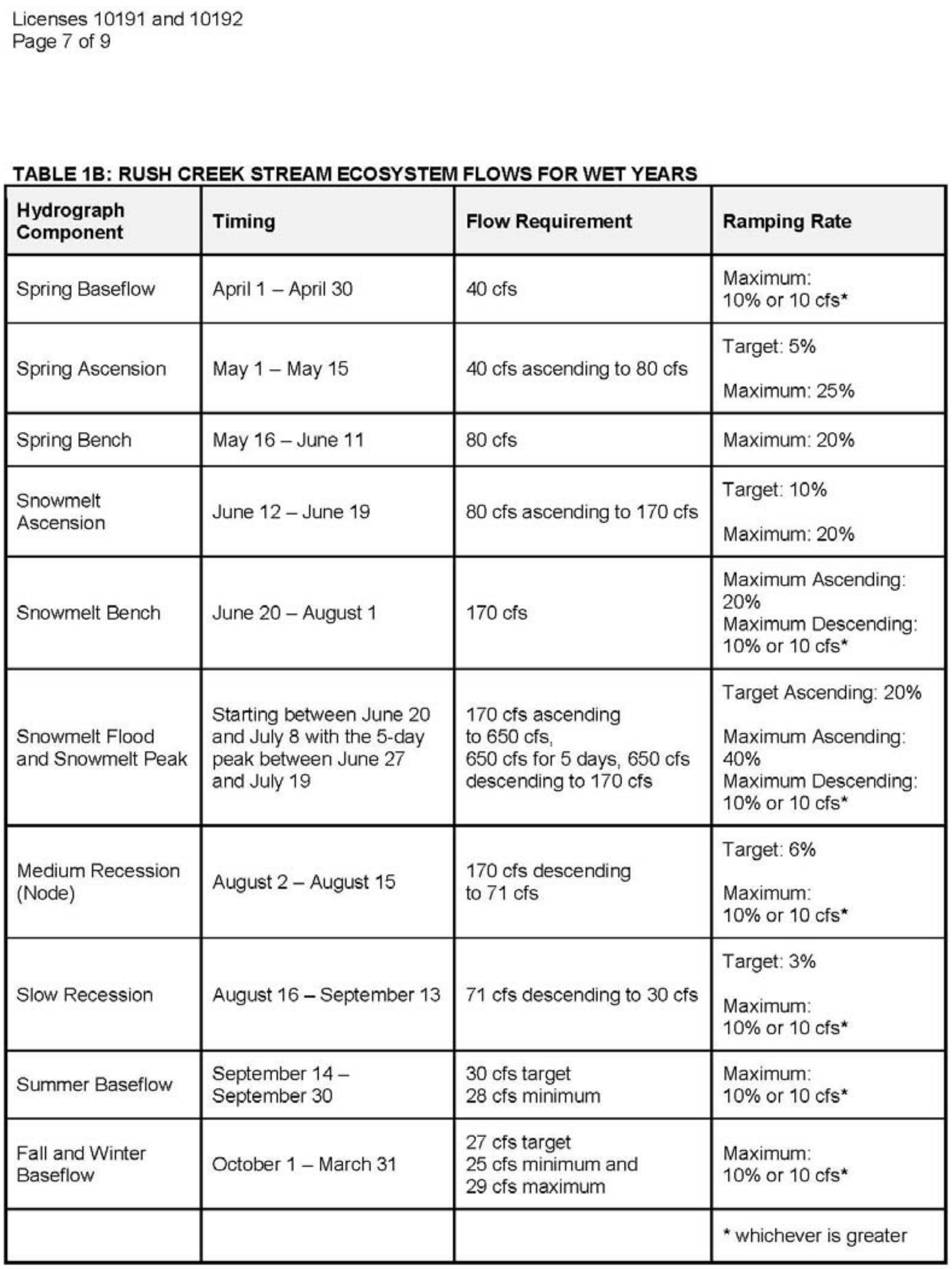


TABLE 1A: RUSH CREEK STREAM ECOSYSTEM FLOWS FOR EXTREME-WET YEARS

Hydrograph Component	Timing	Flow Requirement	Ramping Rate
Spring Baseflow	April 1 – April 30	40 cfs	Maximum: 10% or 10 cfs*
Spring Ascension	May 1 – May 15	40 cfs ascending to 80 cfs	Target: 5% Maximum: 25%
Spring Bench	May 16 – June 11	80 cfs	Maximum: 20%
Snowmelt Ascension	June 12 – June 22	80 cfs ascending to 220 cfs	Target: 10% Maximum: 20%
Snowmelt Bench	June 23 – August 10	220 cfs	Maximum Ascending: 20% Maximum Descending: 10% or 10 cfs*
Snowmelt Flood and Snowmelt Peak	Starting between June 23 and July 19 with the 5-day peak between June 29 and July 29	220 cfs ascending to 750 cfs, 750 cfs for 5 days, 750 cfs descending to 220 cfs	Target Ascending: 20% Maximum Ascending: 40% Maximum Descending: 10% or 10 cfs*
Medium Recession (Node)	August 11 – August 25	220 cfs descending to 87 cfs	Target: 6% Maximum: 10% or 10 cfs*
Slow Recession	August 26 – September 30	87 cfs descending to 30 cfs	Target: 3% Maximum: 10% or 10 cfs*
Fall and Winter Baseflow	October 1 – March 31	27 cfs target (25 cfs minimum and 29 cfs maximum)	Maximum: 10% or 10 cfs*
			* whichever is greater



Licenses 10191 and 10192
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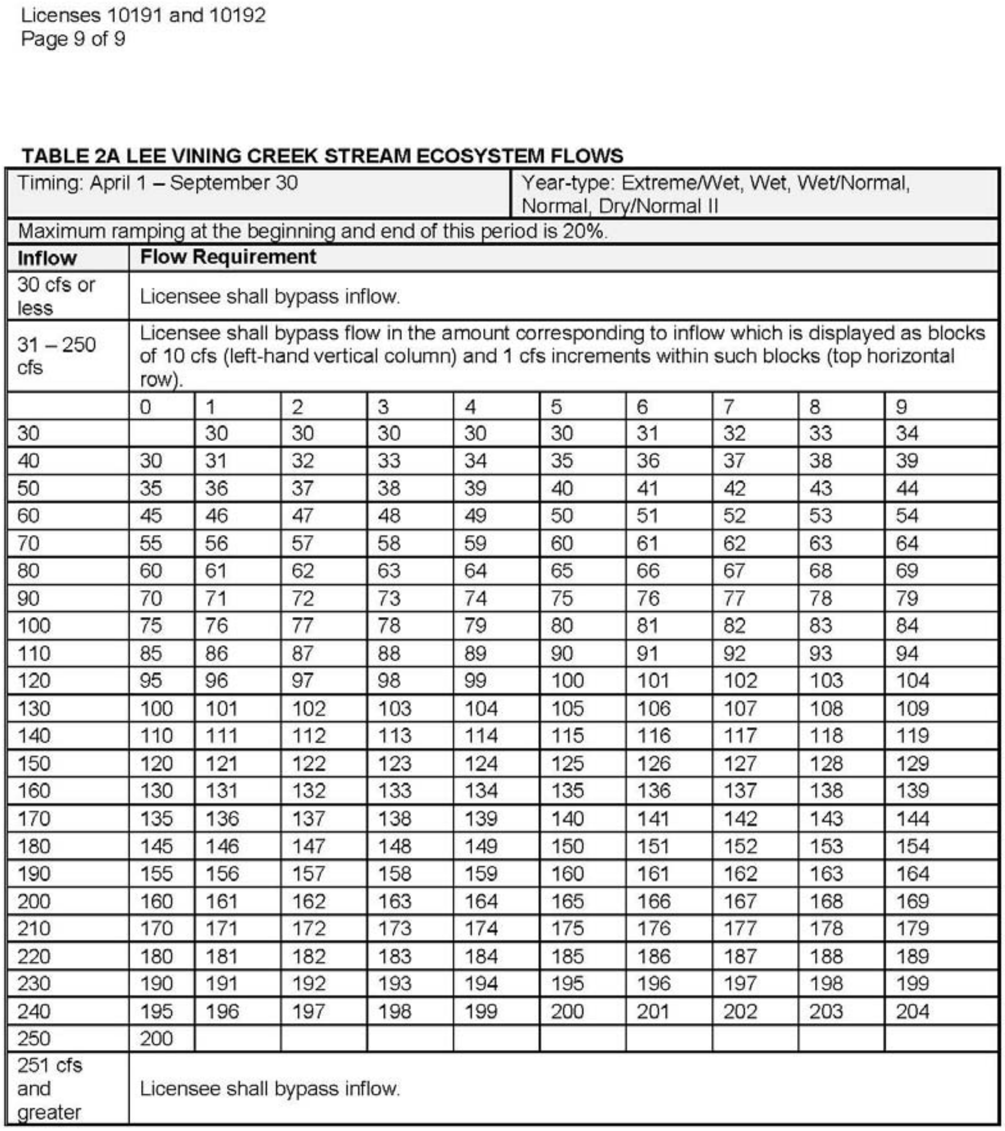
TABLE 1B: RUSH CREEK STREAM ECOSYSTEM FLOWS FOR WET YEARS

Hydrograph Component	Timing	Flow Requirement	Ramping Rate
Spring Baseflow	April 1 – April 30	40 cfs	Maximum: 10% or 10 cfs*
Spring Ascension	May 1 – May 15	40 cfs ascending to 80 cfs	Target: 5% Maximum: 25%
Spring Bench	May 16 – June 11	80 cfs	Maximum: 20%
Snowmelt Ascension	June 12 – June 19	80 cfs ascending to 170 cfs	Target: 10% Maximum: 20%
Snowmelt Bench	June 20 – August 1	170 cfs	Maximum Ascending: 20% Maximum Descending: 10% or 10 cfs*
Snowmelt Flood and Snowmelt Peak	Starting between June 20 and July 8 with the 5-day peak between June 27 and July 19	170 cfs ascending to 650 cfs, 650 cfs for 5 days, 650 cfs descending to 170 cfs	Target Ascending: 20% Maximum Ascending: 40% Maximum Descending: 10% or 10 cfs*
Medium Recession (Node)	August 2 – August 15	170 cfs descending to 71 cfs	Target: 6% Maximum: 10% or 10 cfs*
Slow Recession	August 16 – September 13	71 cfs descending to 30 cfs	Target: 3% Maximum: 10% or 10 cfs*
Summer Baseflow	September 14 – September 30	30 cfs target 28 cfs minimum	Maximum: 10% or 10 cfs*
Fall and Winter Baseflow	October 1 – March 31	27 cfs target 25 cfs minimum and 29 cfs maximum	Maximum: 10% or 10 cfs*
			* whichever is greater

TABLE 1C: RUSH CREEK STREAM ECOSYSTEM FLOWS FOR WET/NORMAL YEARS

Hydrograph Component	Timing	Flow Requirement	Ramping Rate
Spring Baseflow	April 1 – April 30	40 cfs	Maximum: 10% or 10 cfs*
Spring Ascension	May 1 – May 15	40 cfs ascending to 80 cfs	Target: 5% Maximum: 25%
Spring Bench	May 16 – June 11	80 cfs	Maximum: 20%
Snowmelt Ascension	June 12 – June 18	80 cfs ascending to 145 cfs	Target: 10% Maximum: 20%
Snowmelt Bench	June 19 – July 23	145 cfs	Maximum Ascending: 20% Maximum Descending: 10% or 10 cfs*
Snowmelt Flood and Snowmelt Peak	Starting between June 19 and July 1 with the 3-day peak between June 26 and July 10	145 cfs ascending to 550 cfs, 550 cfs for 3 days, 550 cfs descending to 145 cfs	Target Ascending: 20% Maximum Ascending: 40% Maximum Descending: 10% or 10 cfs*
Medium Recession (Node)	July 24 – August 4	145 cfs descending to 69 cfs	Target: 6% Maximum: 10% or 10 cfs*
Slow Recession	August 5 – September 1	69 cfs descending to 30 cfs	Target: 3% Maximum: 10% or 10 cfs*
Summer Baseflow	September 2 – September 30	30 cfs target 28 cfs minimum	Maximum: 10% or 10 cfs*
Fall and Winter Baseflow	October 1 – March 31	27 cfs target 25 cfs minimum and 29 cfs maximum	Maximum: 10% or 10 cfs*
			* whichever is greater

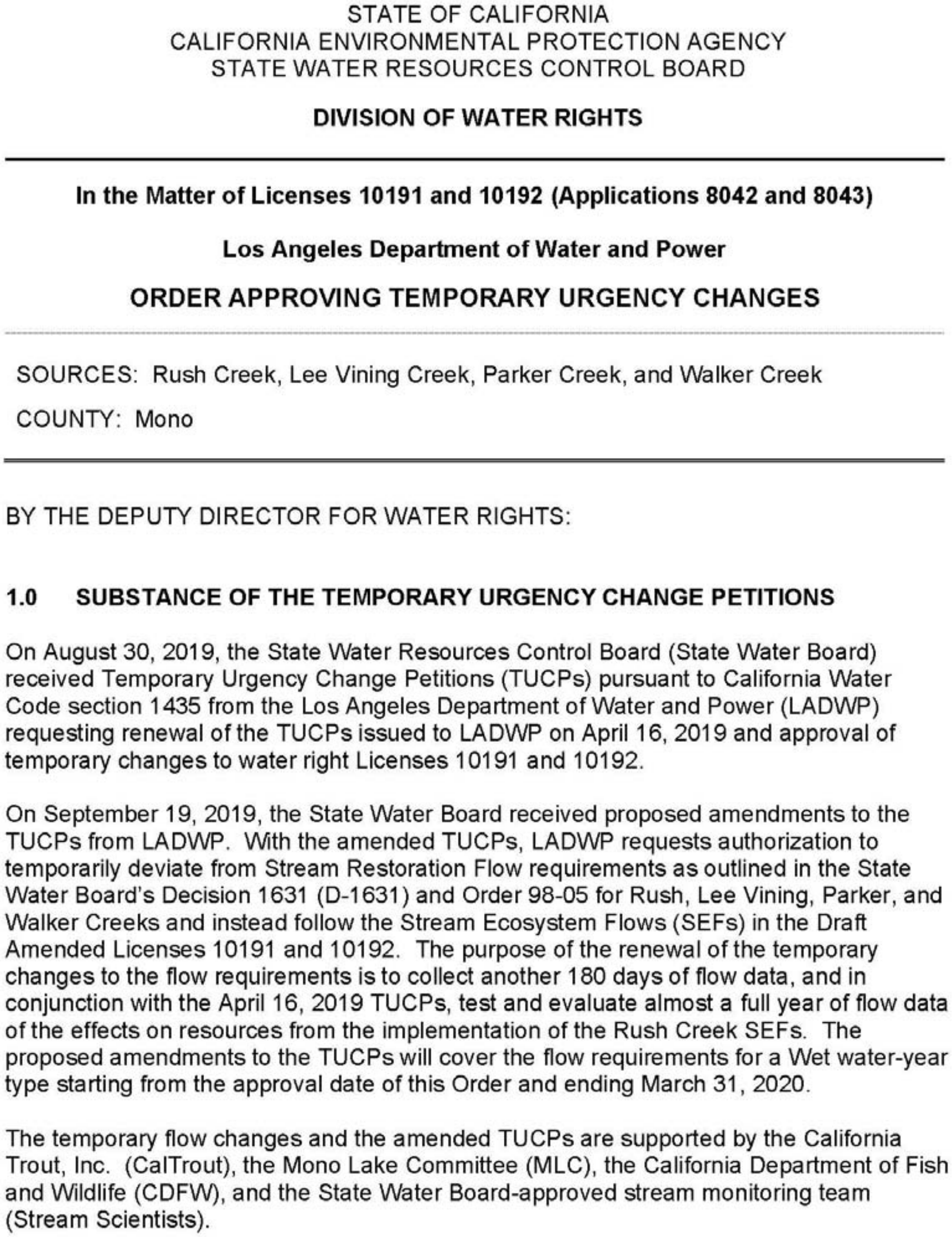


Licenses 10191 and 10192
Page 9 of 9

TABLE 2A LEE VINING CREEK STREAM ECOSYSTEM FLOWS

Timing: April 1 – September 30						Year-type: Extreme/Wet, Wet, Wet/Normal, Normal, Dry/Normal II				
Maximum ramping at the beginning and end of this period is 20%.										
Inflow	**Flow Requirement**									
30 cfs or less	Licensee shall bypass inflow.									
31 – 250 cfs	Licensee shall bypass flow in the amount corresponding to inflow which is displayed as blocks of 10 cfs (left-hand vertical column) and 1 cfs increments within such blocks (top horizontal row).									
	0	1	2	3	4	5	6	7	8	9
30		30	30	30	30	30	31	32	33	34
40	30	31	32	33	34	35	36	37	38	39
50	35	36	37	38	39	40	41	42	43	44
60	45	46	47	48	49	50	51	52	53	54
70	55	56	57	58	59	60	61	62	63	64
80	60	61	62	63	64	65	66	67	68	69
90	70	71	72	73	74	75	76	77	78	79
100	75	76	77	78	79	80	81	82	83	84
110	85	86	87	88	89	90	91	92	93	94
120	95	96	97	98	99	100	101	102	103	104
130	100	101	102	103	104	105	106	107	108	109
140	110	111	112	113	114	115	116	117	118	119
150	120	121	122	123	124	125	126	127	128	129
160	130	131	132	133	134	135	136	137	138	139
170	135	136	137	138	139	140	141	142	143	144
180	145	146	147	148	149	150	151	152	153	154
190	155	156	157	158	159	160	161	162	163	164
200	160	161	162	163	164	165	166	167	168	169
210	170	171	172	173	174	175	176	177	178	179
220	180	181	182	183	184	185	186	187	188	189
230	190	191	192	193	194	195	196	197	198	199
240	195	196	197	198	199	200	201	202	203	204
250	200									
251 cfs and greater	Licensee shall bypass inflow.									

Attachment 2



STATE OF CALIFORNIA
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
STATE WATER RESOURCES CONTROL BOARD

DIVISION OF WATER RIGHTS

In the Matter of Licenses 10191 and 10192 (Applications 8042 and 8043)

Los Angeles Department of Water and Power

ORDER APPROVING TEMPORARY URGENCY CHANGES

SOURCES: Rush Creek, Lee Vining Creek, Parker Creek, and Walker Creek

COUNTY: Mono

BY THE DEPUTY DIRECTOR FOR WATER RIGHTS:

1.0 SUBSTANCE OF THE TEMPORARY URGENCY CHANGE PETITIONS

On August 30, 2019, the State Water Resources Control Board (State Water Board) received Temporary Urgency Change Petitions (TUCPs) pursuant to California Water Code section 1435 from the Los Angeles Department of Water and Power (LADWP) requesting renewal of the TUCPs issued to LADWP on April 16, 2019 and approval of temporary changes to water right Licenses 10191 and 10192.

On September 19, 2019, the State Water Board received proposed amendments to the TUCPs from LADWP. With the amended TUCPs, LADWP requests authorization to temporarily deviate from Stream Restoration Flow requirements as outlined in the State Water Board's Decision 1631 (D-1631) and Order 98-05 for Rush, Lee Vining, Parker, and Walker Creeks and instead follow the Stream Ecosystem Flows (SEFs) in the Draft Amended Licenses 10191 and 10192. The purpose of the renewal of the temporary changes to the flow requirements is to collect another 180 days of flow data, and in conjunction with the April 16, 2019 TUCPs, test and evaluate almost a full year of flow data of the effects on resources from the implementation of the Rush Creek SEFs. The proposed amendments to the TUCPs will cover the flow requirements for a Wet water-year type starting from the approval date of this Order and ending March 31, 2020.

The temporary flow changes and the amended TUCPs are supported by the California Trout, Inc. (CalTrout), the Mono Lake Committee (MLC), the California Department of Fish and Wildlife (CDFW), and the State Water Board-approved stream monitoring team (Stream Scientists).

The temporary flow modifications proposed by LADWP will not increase LADWP's annual export of 16,000 acre-feet[1] as specified in D-1631.

2.0 BACKGROUND

2.1 State Water Board Decision 1631, Orders WR 98-05 and WR 98-07, and Licenses 10191 and 10192

In Decision 1631 (D-1631), the State Water Board modified Licenses, 10191 and 10192 for the purpose of establishing instream flow requirements below LADWP's points of diversion on four affected streams tributary to Mono Lake. The decision also established conditions to protect public trust resources at Mono Lake. State Water Board Orders WR 98-05 and WR 98-07 (Orders) amended D-1631. Pursuant to D-1631 and the subsequent Orders, LADWP is required to conduct fisheries studies and stream monitoring activities until the program (or elements thereof) is terminated by the State Water Board. LADWP has been conducting fisheries studies and stream monitoring for over 20 years. These activities are conducted by the Stream Scientists who: (a) oversee implementation of the stream monitoring and restoration program, and (b) evaluate the results of the monitoring program and recommend modifications as necessary. In the Stream Scientists' April 30, 2010 *Synthesis of Instream Flow Recommendations Report* (Synthesis Report), they recommended modification of the flow regime and other aspects of the Mono Basin stream monitoring and restoration program.

2.2 Description of the Temporary Urgency Changes

The basis of the temporary changes to the flow requirements is to allow LADWP to collect data, and to test and evaluate the effects on resources from the implementation of the SEFs, as identified in the *Mono Basin Operations Plan Under The 2019 TUCP*, dated September 19, 2019. The TUCPs request the following temporary changes:

1. Rush Creek - The Mono Basin's April 1st forecast for Runoff Year (RY) 2019-2020 is classified as a Wet water-year type. The Rush Creek's SEFs will follow a Wet water-year type as follows:

Hydrograph Component:	Fall and Winter Baseflow
Timing:	October 1 – March 31
Flow Requirement:	27 cfs target, 25 cfs minimum, 29 cfs maximum
Ramping Rate:	Maximum: 10% or 10 cfs (whichever is greater)

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[1] 16,000 acre-feet may be exported annually when Mono Lake elevation is at or above 6,380 feet and below 6,391 feet.

2. Lee Vining Creek – The Lee Vining Creek SEFs will follow a Wet water-year type as follows:

Timing (October 1 – March 31)	Flow Requirement (includes all year-types)			
	Extreme/ Wet, **Wet**	Wet/Normal	Normal	Dry/Normal II, Dry/Normal I, Dry
October 1 – October 15	**30 cfs**	28 cfs	20 cfs	16 cfs
October 16 – October 31	**28 cfs**	24 cfs	18 cfs	16 cfs
November 1 – November 15	**24 cfs**	22 cfs	18 cfs	16 cfs
November 16 – March 31	**20 cfs**	20 cfs	18 cfs	16 cfs

Maximum ramping at the beginning and end of this period, and at all times, is 20%.

3. Parker Creek – All flow will be continuously bypassed.
4. Walker Creek - All flow will be continuously bypassed.

LADWP will communicate with Mono Basin parties (MLC, CalTrout, CDFW), the Stream Scientists, and the State Water Board during the TUCPs' authorized period to coordinate and gain input as SEFs proceed. Specifically, a conference call will be scheduled with the Mono Basin parties and the Stream Scientists to discuss 2020 operations in consideration of winter snowpack and the contents of any subsequent TUCPs potentially taking effect April 1, 2020. LADWP will also provide reasonable communication to update parties, answer questions, and address unforeseen challenges as SEFs are delivered according to the April 1 forecast for RY 2019-20.

3.0 COMPLIANCE WITH CALIFORNIA ENVIRONMENTAL QUALITY ACT

LADWP, as Lead Agency pursuant to the California Environmental Quality Act (CEQA), prepared a Notice of Exemption for the *Mono Basin Temporary Operation Petition to State Water Resources Control Board* on August 19, 2019. LADWP found that the change is categorically exempt from CEQA, as the project is for the use of existing facilities with negligible or no expansion of existing use, for the purpose of maintaining fish and wildlife habitat areas, maintaining stream flows, and protecting fish and wildlife resources. (14 Cal. Code Regs. § 15301(i).).

The State Water Board has reviewed the information submitted by LADWP and has determined that the petitions qualify for an exemption under CEQA. The State Water Board will issue a Notice of Exemption for the temporary urgency change petitions.

4.0 PUBLIC NOTICE OF TEMPORARY URGENCY CHANGE PETITIONS

On October 10, 2019, the State Water Board issued a public notice of the temporary urgency changes pursuant to Water Code section 1438, subdivision (a). The comment period expires on November 12, 2019. Pursuant to Water Code section 1438, subdivision (b)(1), LADWP is required to publish the notice in a newspaper having a general circulation and published within the counties where the points of diversion are located. LADWP published the notice on October 10, 2019 in the Mammoth Times. The State Water Board posted the notice of the temporary urgency changes on its website and distributed the notice through its electronic notification system. Pursuant to Water Code section 1438(a), the State Water Board may issue a temporary urgency change order in advance of the required notice period.

5.0 COMMENTS REGARDING THE TEMPORARY URGENCY CHANGE PETITIONS

On August 16, 2019, LADWP emailed the proposed 2019 renewal TUCPs to a limited number of Mono Basin interested parties and no comments were received. On August 27, 2019, LADWP sent the renewal TUCPs to the State Water Board assuming the proposed TUCPs were supported by the interested parties. On September 6, 2019, State Water Board staff was informed by CDFW staff that the proposed renewal TUCPs were not consulted or approved and sent to interested parties from an outdated mailing list. On September 17, 2019, LADWP sent out the proposed renewal TUCPs to a larger Mono Basin distribution list for further review. MLC commented on the proposed renewal TUCPs. MLC recommended that wording be included into the TUCPs and that a conference call be scheduled with the Mono Basin parties and for the Stream Scientists to discuss 2020 operations in consideration of the winter snowpack and the contents of any subsequent TUCPs. On September 19, 2019, the State Water Board received the amended renewal TUCPs.

6.0 CRITERIA FOR APPROVING THE PROPOSED TEMPORARY URGENCY CHANGES

Water Code section 1435 provides that a permittee or licensee who has an urgent need to change the point of diversion, place of use, or purpose of use from that specified in the permit or license, may petition for a conditional temporary change order. The State Water Board's regulations set forth the filing and other procedural requirements applicable to TUCPs (Cal. Code Regs., tit. 23, §§ 805, 806.) The State Water Board's regulations also clarify that requests for changes to permits or licenses other than changes in point of diversion, place of use, or purpose of use may be filed, are subject to the same filing and procedural requirements that apply to changes in point of diversion, place of use, or purpose of use. (*Id.*, § 791, subd. (e))

Before approving a temporary urgency change, the State Water Board must make the following findings:

1. The Petitioner has an urgent need to make the proposed change;
2. The proposed change may be made without injury to any other lawful user of water;
3. The proposed change may be made without unreasonable effect upon fish, wildlife, or other instream beneficial uses; and

4. The proposed change is in the public interest.
(Wat. Code, § 1435, subd. (b)(1-4).)

6.1 Urgency of the Proposed Change

Under Water Code section 1435, subdivision (c), an "urgent need" means "the existence of circumstances from which the State Water Board may in its judgment, conclude that the proposed temporary change is necessary to further the constitutional policy that the water resources of the state be put to beneficial use to the fullest extent of which they are capable and that waste of water be prevented." However, the State Water Board shall not find the need urgent, if it concludes that the petitioner has failed to exercise due diligence in petitioning for a change pursuant to other appropriate provisions of the Water Code. (Ibid.)

In this case, there is an urgent need for the proposed changes in the license conditions regarding fish flows for the purpose of furthering protection of public trust resources.

6.2 No Injury to Any Other Lawful User of Water

There are no known lawful users of water that will be affected by the proposed changes to instream flows. Accordingly, granting these renewal TUCPs will not result in injury to any other lawful users of water

6.3 No Unreasonable Effect upon Fish, Wildlife, or Other Instream Beneficial Uses

As described above, the renewal of the temporary urgency changes will benefit the restoration of Rush, Lee Vining, Walker, and Parker Creeks and help with Grant Lake Reservoir management. No other fish or wildlife resources are implicated by the proposed changes; accordingly, the proposed changes will not have unreasonable effects upon fish and wildlife resources.

6.4 The Proposed Change is in the Public Interest

The proposed changes would assist LADWP in maintaining the fishery resources in good condition. Maintenance of the fishery is in the public's interest.

In light of the above, I find in accordance with Water Code section 1435, subdivision (b)(4), that the proposed changes are in the public's interest, including, findings to support change order conditions imposed to ensure that the changes are in the public interest.

Pursuant to Water Code section 1439, the State Water Board shall supervise diversion and use of water under this temporary change order for the protection of all other lawful users of water and instream beneficial uses.

7.0 STATE WATER BOARD DELEGATION OF AUTHORITY

On June 5, 2012, the State Water Board adopted Resolution 2012-0029, delegating to the Deputy Director for Water Rights, the authority to act on petitions for temporary urgency change. This Order is adopted pursuant to the delegation of authority in section 4.4.1 of Resolution 2012-0029.

8.0 CONCLUSIONS

The State Water Board has adequate information in its files to make the evaluation required by Water Code section 1435.

I conclude that, based on the available evidence:

1. The Petitioner has an urgent need to make the proposed changes;

2. The proposed changes will not operate to the injury of any other lawful user of water;

3. The proposed changes, with conditions set forth in this Order, will not have an unreasonable effect upon fish, wildlife, or other instream beneficial uses; and

4. The proposed changes are in the public's interest.

ORDER

NOW, THEREFORE, IT IS ORDERED THAT: the petitions filed by the Los Angeles Department of Water and Power (LADWP) for renewal of the temporary urgency changes in Licenses 10191 and 10192 are approved, and this approval is effective from the date of this Order to March 31, 2020. All existing terms and conditions in Licenses 10191 and 10192 remain in effect, except as temporarily amended by the following terms.

1. For protection of fish in Rush and Lee Vining Creeks, LADWP shall bypass flow below the point of diversion at the flows specified in Section 2.2 of this Order. The Stream Ecosystem Flows provided under this requirement shall remain in the stream channel and not be diverted for any other use.

2. LADWP shall submit to the Deputy Director for Water Rights on a monthly basis a written report that summarizes all activities conducted to ensure compliance with the requirements of this Order. The first monthly report is due at the end of the first complete month of this Order. LADWP shall submit a final report summarizing overall compliance with this Order no later than May 1, 2020.

3. This Order does not authorize any act that results in the taking of a threatened or endangered species, or any act that is now prohibited, or becomes prohibited in the

future, under either the California Endangered Species Act (Fish and Game Code sections 2050 to 2097) or the federal Endangered Species Act (16 U.S.C.A. sections 1531 to 1544). If a "take" will result from any act authorized under this Order, the water right holder shall obtain authorization for an incidental take permit prior to construction or operation. The water right holder shall be responsible for meeting all requirements of the applicable Endangered Species Act for the temporary urgency change authorized under this Order.

4. The State Water Board shall supervise the diversion and use of water under this Order for the protection of legal users of water and instream beneficial uses and for compliance with the conditions. Petitioner shall allow representatives of the State Water Board reasonable access to the project works to determine compliance with the terms of this Order.

5. The State Water Board reserves jurisdiction to supervise the temporary urgency changes under this Order, and to coordinate or modify terms and conditions, for the protection of vested rights, fish, wildlife, instream beneficial uses and the public interest as future conditions may warrant.

6. The temporary urgency changes authorized under this Order shall not result in creation of a vested right, even of a temporary nature, but shall be subject at all times to modification or revocation in the discretion of the State Water Board. The temporary urgency changes approved in this Order shall automatically expire March 31, 2020, unless earlier revoked.

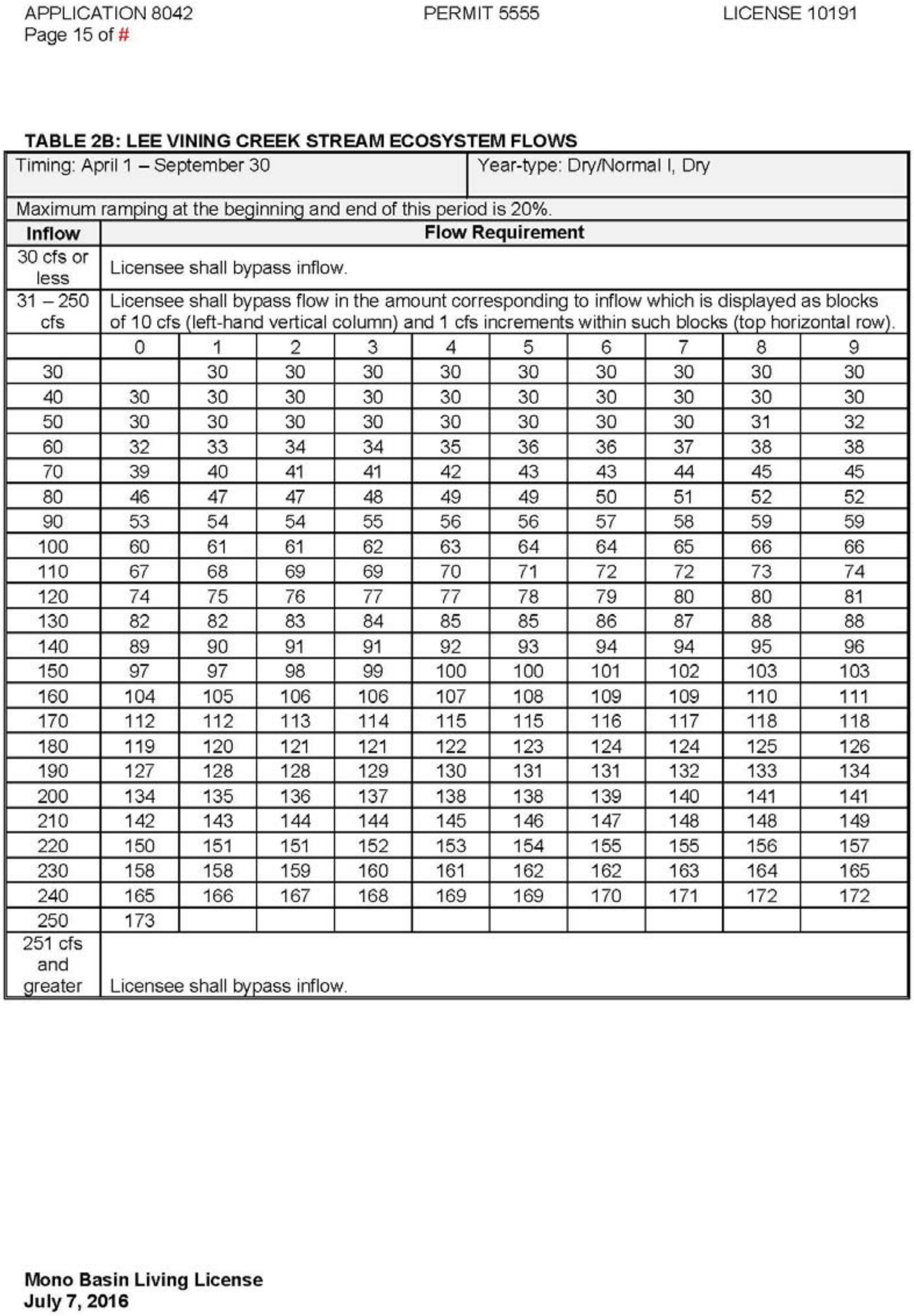
STATE WATER RESOURCES CONTROL BOARD

ORIGINAL SIGNED BY:

Erik Ekdahl, Deputy Director
Division of Water Rights

Dated: OCT 22 2019

Attachment 3



APPLICATION 8042 PERMIT 5555 LICENSE 10191
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TABLE 2B: LEE VINING CREEK STREAM ECOSYSTEM FLOWS

Timing: April 1 – September 30 | Year-type: Dry/Normal I, Dry

Maximum ramping at the beginning and end of this period is 20%.

Inflow	Flow Requirement									
30 cfs or less	Licensee shall bypass inflow.									
31 – 250 cfs	Licensee shall bypass flow in the amount corresponding to inflow which is displayed as blocks of 10 cfs (left-hand vertical column) and 1 cfs increments within such blocks (top horizontal row).									
	0	1	2	3	4	5	6	7	8	9
30		30	30	30	30	30	30	30	30	30
40	30	30	30	30	30	30	30	30	30	30
50	30	30	30	30	30	30	30	30	31	32
60	32	33	34	34	35	36	36	37	38	38
70	39	40	41	41	42	43	43	44	45	45
80	46	47	47	48	49	49	50	51	52	52
90	53	54	54	55	56	56	57	58	59	59
100	60	61	61	62	63	64	64	65	66	66
110	67	68	69	69	70	71	72	72	73	74
120	74	75	76	77	77	78	79	80	80	81
130	82	82	83	84	85	85	86	87	88	88
140	89	90	91	91	92	93	94	94	95	96
150	97	97	98	99	100	100	101	102	103	103
160	104	105	106	106	107	108	109	109	110	111
170	112	112	113	114	115	115	116	117	118	118
180	119	120	121	121	122	123	124	124	125	126
190	127	128	128	129	130	131	131	132	133	134
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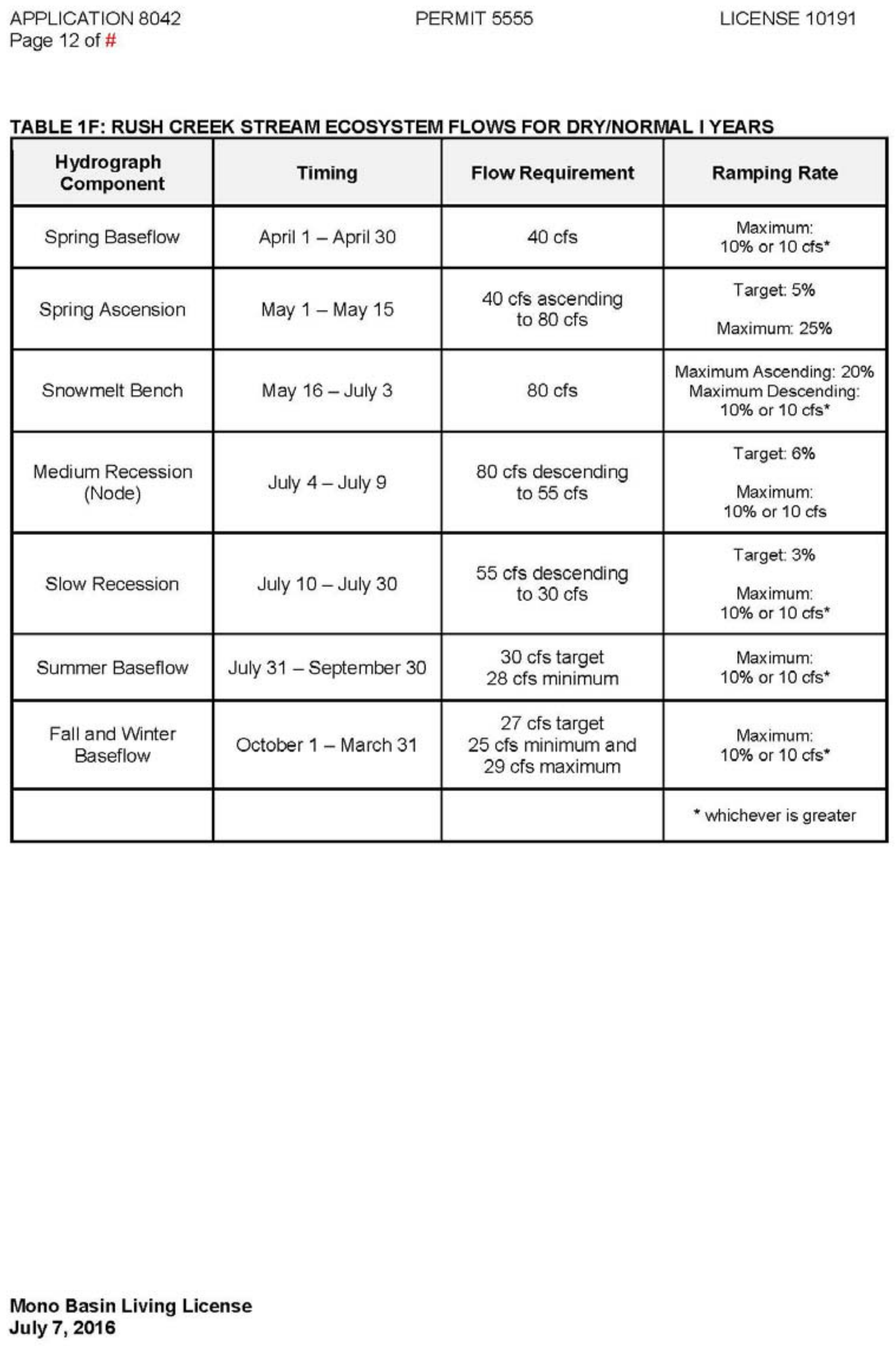
220	150	151	151	152	153	154	155	155	156	157
230	158	158	159	160	161	162	162	163	164	165
240	165	166	167	168	169	169	170	171	172	172
250	173									
251 cfs and greater	Licensee shall bypass inflow.									

Mono Basin Living License
July 7, 2016



APPLICATION 8042 PERMIT 5555 LICENSE 10191
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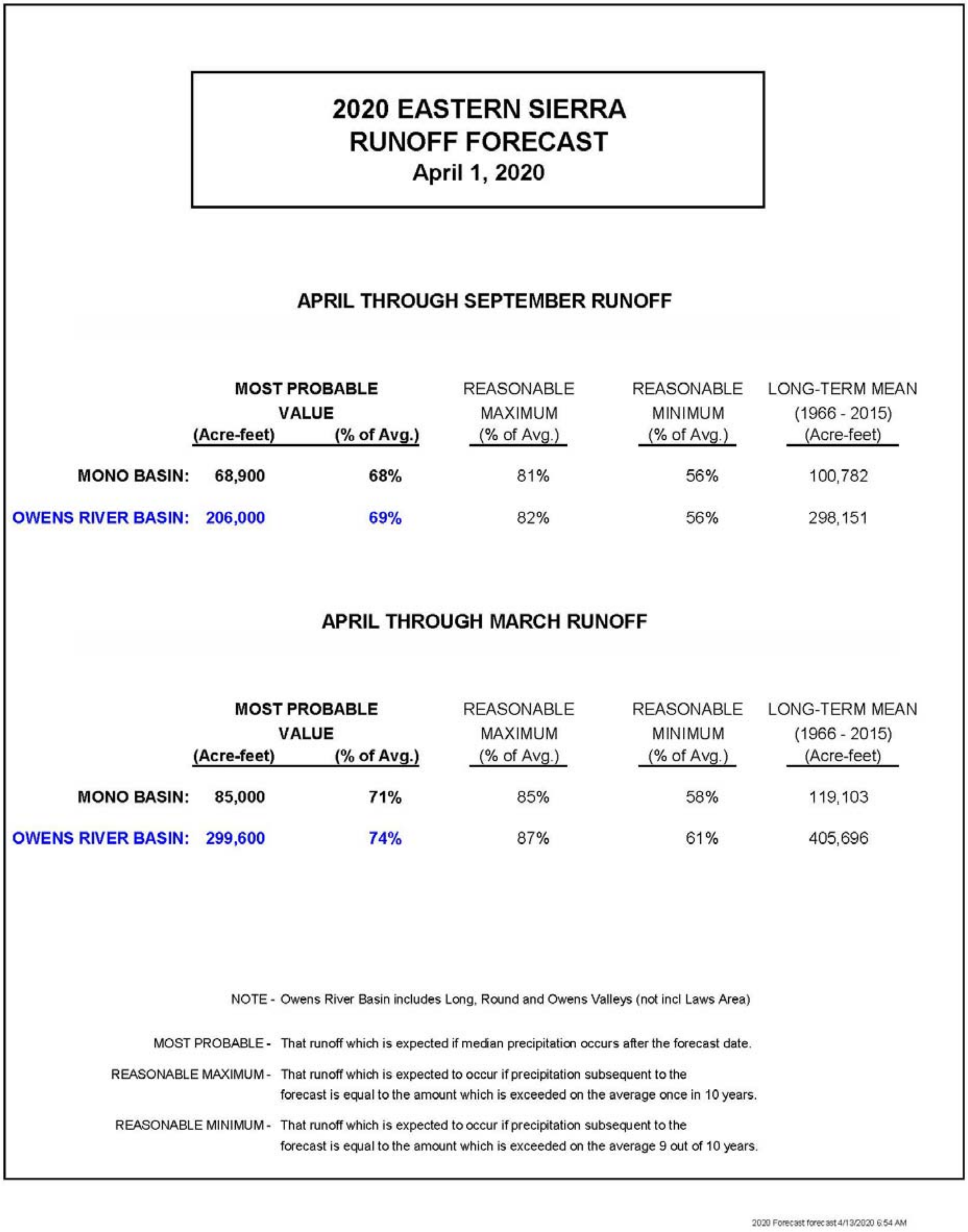
TABLE 1F: RUSH CREEK STREAM ECOSYSTEM FLOWS FOR DRY/NORMAL I YEARS

Hydrograph Component	Timing	Flow Requirement	Ramping Rate
Spring Baseflow	April 1 – April 30	40 cfs	Maximum: 10% or 10 cfs*
Spring Ascension	May 1 – May 15	40 cfs ascending to 80 cfs	Target: 5% Maximum: 25%
Snowmelt Bench	May 16 – July 3	80 cfs	Maximum Ascending: 20% Maximum Descending: 10% or 10 cfs*
Medium Recession (Node)	July 4 – July 9	80 cfs descending to 55 cfs	Target: 6% Maximum: 10% or 10 cfs
Slow Recession	July 10 – July 30	55 cfs descending to 30 cfs	Target: 3% Maximum: 10% or 10 cfs*
Summer Baseflow	July 31 – September 30	30 cfs target 28 cfs minimum	Maximum: 10% or 10 cfs*
Fall and Winter Baseflow	October 1 – March 31	27 cfs target 25 cfs minimum and 29 cfs maximum	Maximum: 10% or 10 cfs*
			* whichever is greater

Mono Basin Living License
July 7, 2016

Attachment 4



2020 EASTERN SIERRA
RUNOFF FORECAST
April 1, 2020

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:	**68,900**	**68%**	81%	56%	100,782
OWENS RIVER BASIN:	**206,000**	**69%**	82%	56%	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:	**85,000**	**71%**	85%	58%	119,103
OWENS RIVER BASIN:	**299,600**	**74%**	87%	61%	405,696

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.

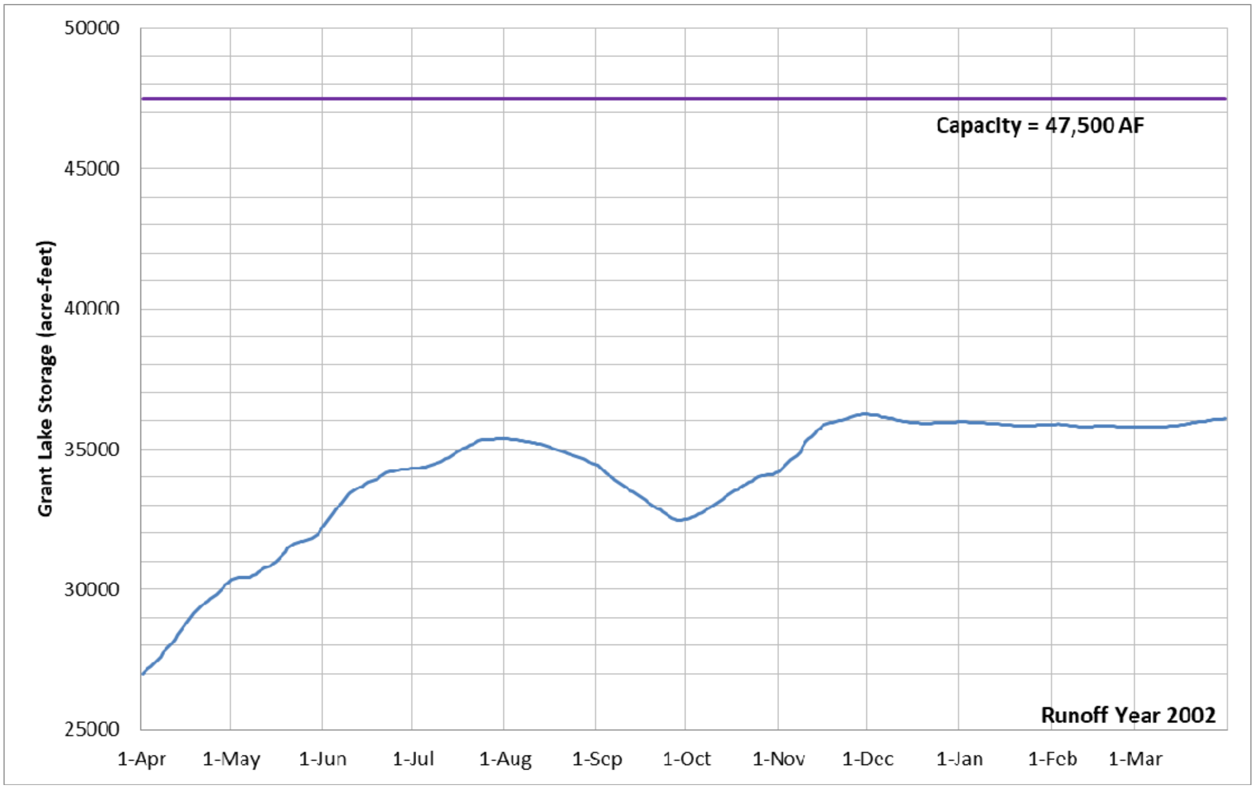
REASONABLE MAXIMUM - That runoff which is expected to occur if precipitation subsequent to the forecast is equal to the amount which is exceeded on the average once in 10 years.

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.

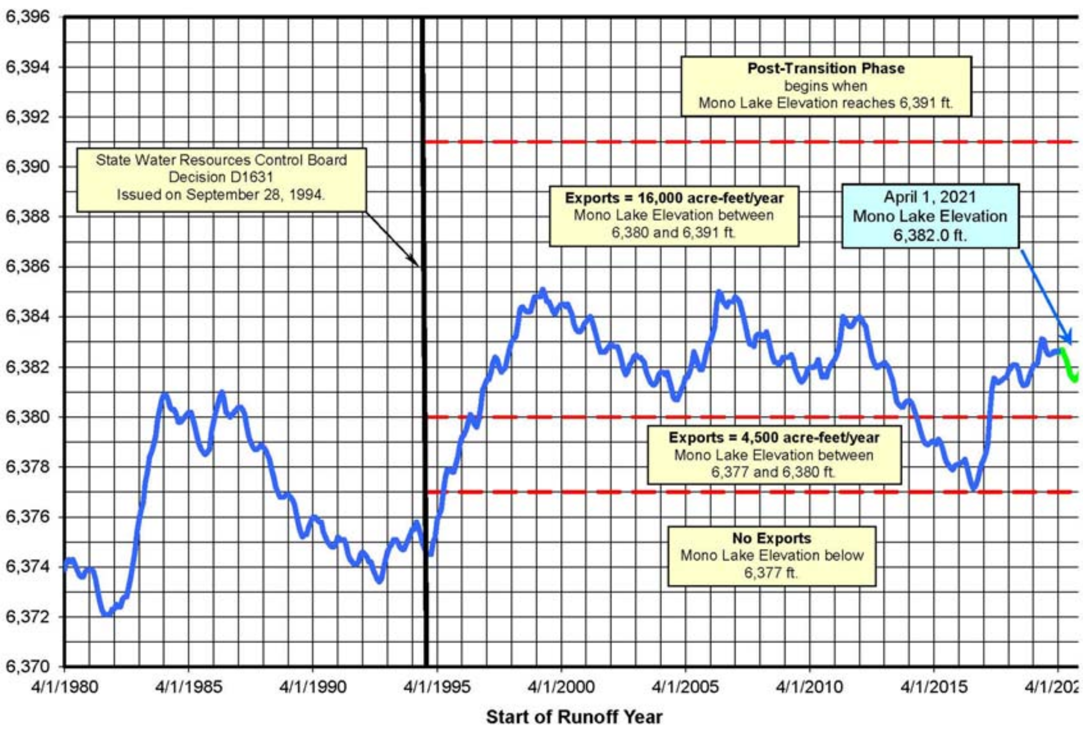
2020 Forecast forecast 4/13/2020 6:54 AM

Attachment 5

RY 2020/21 Grant Lake Reservoir Storage Projection Using 2002 (72.8% Year) Inflow (eSTREAM Release v3.2)



Attachment 6



Mono Lake Elevation

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, 2021 Mono Lake Elevation 6,382.0 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.

Note: The time until the Mono Lake elevation reaches 6,391 ft is called the "Transition Period". Export rules change at the end of that interval.
USGS Datum

4/28/2020 by Paul Scantlin
Mono Lake Elev, data-chart

Section 3

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

2019

Mono Basin Fisheries Monitoring Report
Rush, Lee Vining, and Walker Creeks
2019

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, 2020

Table of Contents

Executive Summary

This report presents results of the 23rd year of trout population monitoring for Rush, Lee Vining, and Walker Creeks pursuant to SWRCB's Water Right Decision 1631 (D1631) and the 21st 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 and demographic data collected in 2019 as mandated by the Orders and the Settlement Agreement.

The 2019 runoff year (RY) was 144% of normal and classified a "Wet" runoff year (RY) type, as measured on April 1st. The range of runoff that defines a Wet year is >136.5% (0-20% exceedence). The preceding seven years included a Normal runoff of 85% in 2018, record runoff of 206% in RY 2017 and five consecutive below "Normal" runoff years (RY 2016 was 74% of normal, 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 the Lee Vining Creek main channel section and in two sections of Rush Creek – Upper Rush and the Bottomlands. Multiple-pass depletion electrofishing was conducted in the Lee Vining Creek side channel and in Walker Creek. A single electrofishing pass was made through the MGORD section of Rush Creek to collect data to generate condition factors, relative stock densities, and growth rates and apparent survival rates from PIT tag recaptures. 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 2,647 age-0 Brown Trout in 2019 compared to 1,572 age-0 fish in 2018. This section supported an estimated 616 Brown Trout 125-199 mm in length in 2019 compared to 196 fish in 2018. In 2019, Upper Rush supported an estimated 203 Brown Trout ≥200 mm in length compared to an estimate of 195 fish in 2018. In 2019, sufficient numbers of naturally-produced Rainbow Trout were sampled in the Upper Rush section to generate unbiased estimates for two of the three size classes. This section supported an estimated 418 Rainbow Trout <125 mm in length (319 fish in 2018) and an estimated 145 Rainbow Trout ≥200 mm in length (27 fish in 2018). In 2019, eight Rainbow Trout ≥200 mm were clipped on the mark run and four of these were caught on the recapture run, which generated an estimate of 13 Rainbow Trout ≥200 mm in length.

The Bottomlands section supported an estimated 638 age-0 Brown Trout in 2019 versus 1,808 age-0 fish in 2018. This section supported an estimated 433 Brown Trout 125-199 mm in length in 2019 compared to 100 fish in 2018. The Bottomlands section supported an estimated 64 Brown Trout ≥200 mm in 2019 compared to 106 trout in 2018.

Lee Vining Creek's main channel section supported an estimated 414 age-0 Brown Trout in 2019, compared to an estimated 192 age-0 fish in 2018. This section supported an estimated 118 Brown Trout 125-199 mm in length in 2019 compared to 71 fish in 2018. Lee Vining Creek's main channel supported an estimated 48 Brown Trout ≥200 mm in 2019 versus 14 fish in 2018.

A total of six Rainbow Trout were captured in Lee Vining Creek's main channel in 2019. Two of these fish were in the 125-199 mm size class (probable age-1 fish) and the remaining four fish were ≥200 mm in total length.

The 2019 age-0 Brown Trout estimate for Walker Creek was 179 fish, compared to 44 fish in 2018. The 2019 population estimate for Brown Trout in the 125-199 mm size class equaled 70 fish, compared to 86 fish in 2018. The 2019 population estimate of Brown Trout ≥200 mm in length was 34 fish, compared to 45 fish in 2018.

In the Lee Vining Creek side channel, 21 Brown Trout were captured in two electrofishing passes during the 2019 sampling (10 fish in two passes during the 2018 sampling). The estimates for each size class were: <125 mm = zero fish; 125-199 mm = 17 fish; and ≥200 mm= 4 fish. No Rainbow Trout were captured in the side channel in 2019. This was the 11th consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the ninth consecutive year the no age-1 and older Rainbow Trout were captured.

Densities of Age-0 Brown Trout

In 2019, the Upper Rush section's estimated density of age-0 Brown Trout was 8,794 fish/ha and the Bottomlands section's estimated density of age-0 Brown Trout equaled 1,389 fish/ha. In Walker Creek, the 2019 density estimate of age-0 Brown Trout was 3,825 fish/ha.

The 2019 age-0 Brown Trout density estimate in the main channel of Lee Vining Creek was 3,247 fish/ha. In 2019, no age-0 Brown Trout were caught in the Lee Vining Creek side channel.

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

In 2019, the Upper Rush section's estimated density of age-1+ Brown Trout was 2,721 fish/ha and the Bottomlands section's estimated density of age-1+ Brown Trout equaled 1,558 fish/ha. In Walker Creek, the 2019 density estimate of age-1+ Brown Trout was 2,222 fish/ha.

The 2019 age-1+ Brown Trout density estimate in the main channel of Lee Vining Creek was 1,302 fish/ha. In 2019, the Lee Vining Creek side channel's density estimate of age-1 and older Brown Trout was 468 fish/ha.

Standing Crop Estimates

In 2019, the estimated standing crop for Brown Trout in the Upper Rush section was 254.3 kg/ha and the estimated standing crop for Rainbow Trout was 36.5 kg/ha. The total standing crop of 290.8 kg/ha for Upper Rush in 2019 was the highest value for this section for the 21 years of available data. The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 91 kg/ha in 2019. The estimated standing crop for Brown Trout in Walker Creek was 179 kg/ha in 2019.

In 2019, the Lee Vining Creek main channel estimated standing crop for Brown Trout equaled 188.7 kg/ha and the estimated standing crop of Rainbow Trout equaled 4.6 kg/ha, for a total standing crop of 192 kg/ha. The 2019 estimated standing crop was the second highest recorded for this section for the 20 years of available data. The Lee Vining Creek side channel total Brown Trout standing crop estimate was 25 kg/ha in 2019.

Condition Factors

Condition factors of Brown Trout 150 to 250 mm in length in 2019 equaled 1.01 in the MGORD section of Rush Creek, 0.99 in the Upper Rush section, 0.95 in the Bottomlands section and 0.98 in Walker Creek. In 2019, the condition factors of Brown Trout 150 to 250 mm in length were 0.99 in the Lee Vining Creek main channel and 1.02 in the side channel. For Rainbow Trout, the condition factor was 1.06 in the Upper Rush section and 1.08 in the Lee Vining Creek main channel.

Relative Stock Densities (RSD)

In the Upper Rush section, the RSD-225 equaled 19 for 2019, the second consecutive large drop from the record RSD-255 value of 78 for 2017. This decrease was most likely influenced by greater numbers of fish smaller than 225 mm. The RSD-300 value was 2 in 2019. This low RSD-300 value in 2019 was influenced by the higher numbers of fish ≤225 mm caught and also a drop in the numbers of Brown Trout ≥300 mm.

In the Bottomlands section of Rush Creek, the RSD-225 for 2019 equaled 8, the second consecutive large drop from the record value of 65 for 2017. As in the Upper Rush section, the Bottomlands 2019 RSD-225 value was influenced by greater numbers of fish smaller than 225 mm. The RSD-300 value was 0 in 2019. In 2019, only one Brown Trout ≥300 mm was captured in the Bottomlands section.

In the MGORD, the RSD-225 value in 2019 was 47, the lowest since the value of 42 in 2013. In 2019, the RSD-300 value was 10, the lowest since the value of 7 in 2014. The RSD-375 value in 2019 was 1, the lowest RSD-375 value for the 17 years of available data. In 2019, a total of 28 Brown Trout ≥300 mm in length were caught, including only four fish ≥375 mm in length.

In 2019, RSD values in Lee Vining Creek were generated for the main channel only. The RSD-225 value equaled 18 for 2019. In 2019, two Brown Trout greater than 300 mm in length were captured in the Lee Vining Creek main channel, which resulted in a RSD-300 value of 2.

Introduction

Study Area

Between September 16th and 25th 2019, Los Angeles Department of Water and Power (LADWP) staff and Ross Taylor (the SWRCB fisheries scientist) 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 2018 (Figure 1). Aerial photographs of the sampling reaches are provided in Appendix A.

Hydrology

The 2019 runoff year (RY) was 144% of normal and classified a “Wet” runoff year (RY) type, as measured on April 1st. The range of runoff that defines a Wet year is >136.5% (0-20% exceedence). The preceding seven years included a Normal runoff of 85% in 2018, record runoff of 206% in RY 2017 and five consecutive below “Normal” runoff years (RY 2016 was 74% of normal, 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 and the Stream Restoration Flows (SRF), a Wet RY prescribes a Rush Creek summer baseflow of 47 cfs from April 1st to September 30th, a two-stage peak release of 400 cfs for five days, followed by 350 cfs for 10 days, followed by baseflows of 44 cfs from October 1 through March 31. Rush Creek flows and storage levels in Grant Lake Reservoir (GLR) during the summer of 2019 were also managed to accommodate appropriate flows for the September fisheries sampling. After achieving the prescribed Rush Creek peak flows from mid-June through early July, LADWP maintained higher flows throughout July and August with a long down-ramping into early September to lower GLR so that Rush Creek flows could be lowered for the fisheries sampling in late September without a spill occurring (Figure 2). In Lee Vining Creek, the existing SWRCB orders require that the primary peak flow is passed downstream. The SRF summer baseflow in Lee Vining Creek below LADWP’s point of diversion was 54 cfs or to pass all the flow if less than 54 cfs.

The peak discharges in Rush Creek at the MGORD exceeded 300 cfs for 36 days from June 18th to July 23rd (red line on Figure 2). GLR spilled for 33 days, from June 14th to July 16th and the spill exceeded 100 cfs for 19 days from June 18th to July 6th. Accretions from Parker and Walker creeks, combined with the GLR spill, resulted in flow fluctuations through the spring and summer, and contributed to the peak of 582 cfs in Rush Creek below the Narrows on June 21st and a total of 19 days where flows exceeded 500 cfs (green line on Figure 2).

In 2019, multiple peaks occurred in Lee Vining Creek, with a peak of 430 cfs passed downstream on June 19th (Figure 3). After two smaller peaks in July, flow-through conditions occurred to assist in lowering GLR for upcoming September fisheries sampling. However, flows in Lee Vining Creek were approximately 48 cfs on 9/11/19, too high for safe wading and electrofishing, thus flows were subsequently lowered to approximately 25 cfs for the duration of the fisheries sampling (Figure 3).

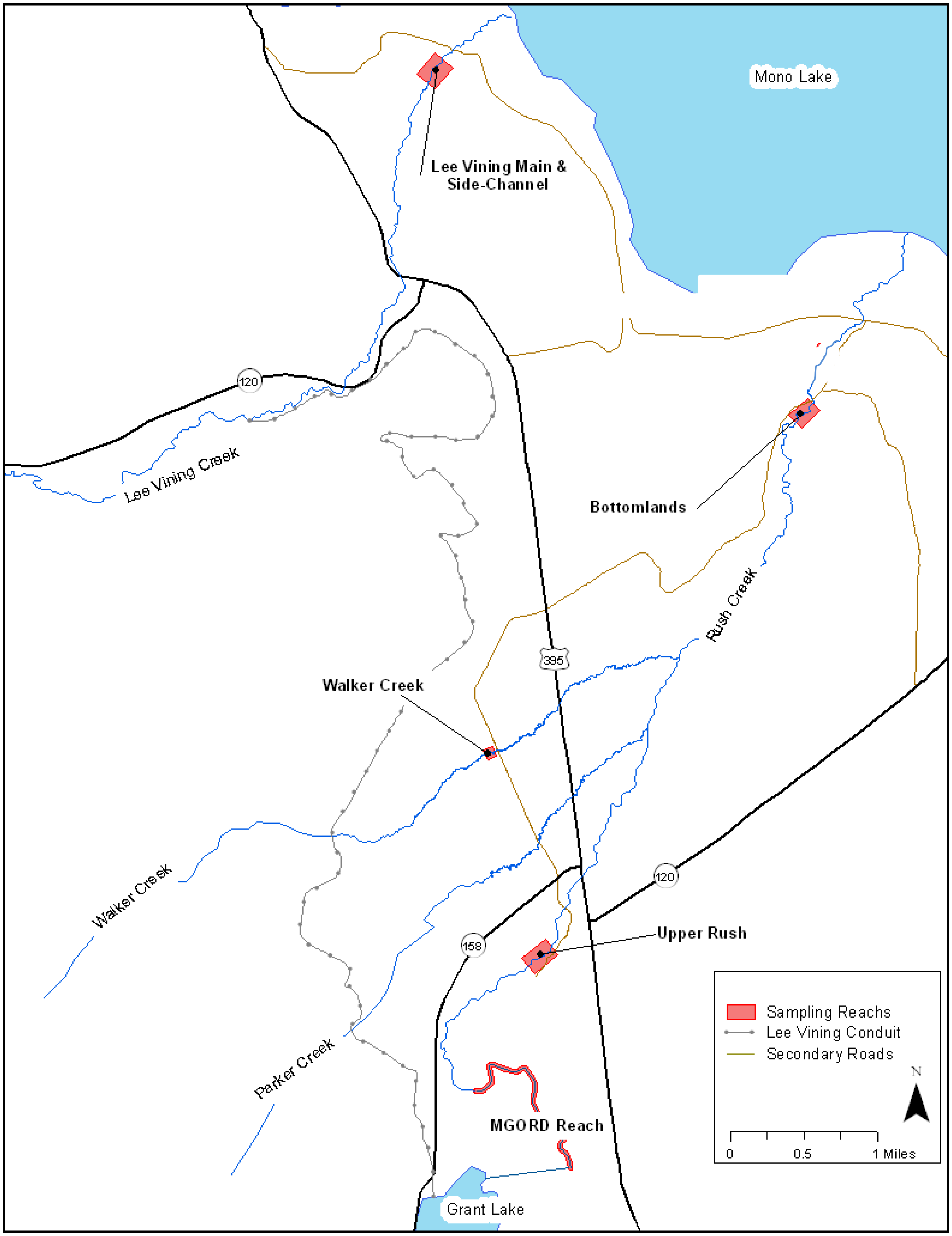


Figure 1. Annual fisheries sampling sites within Mono Basin study area, September 2019.

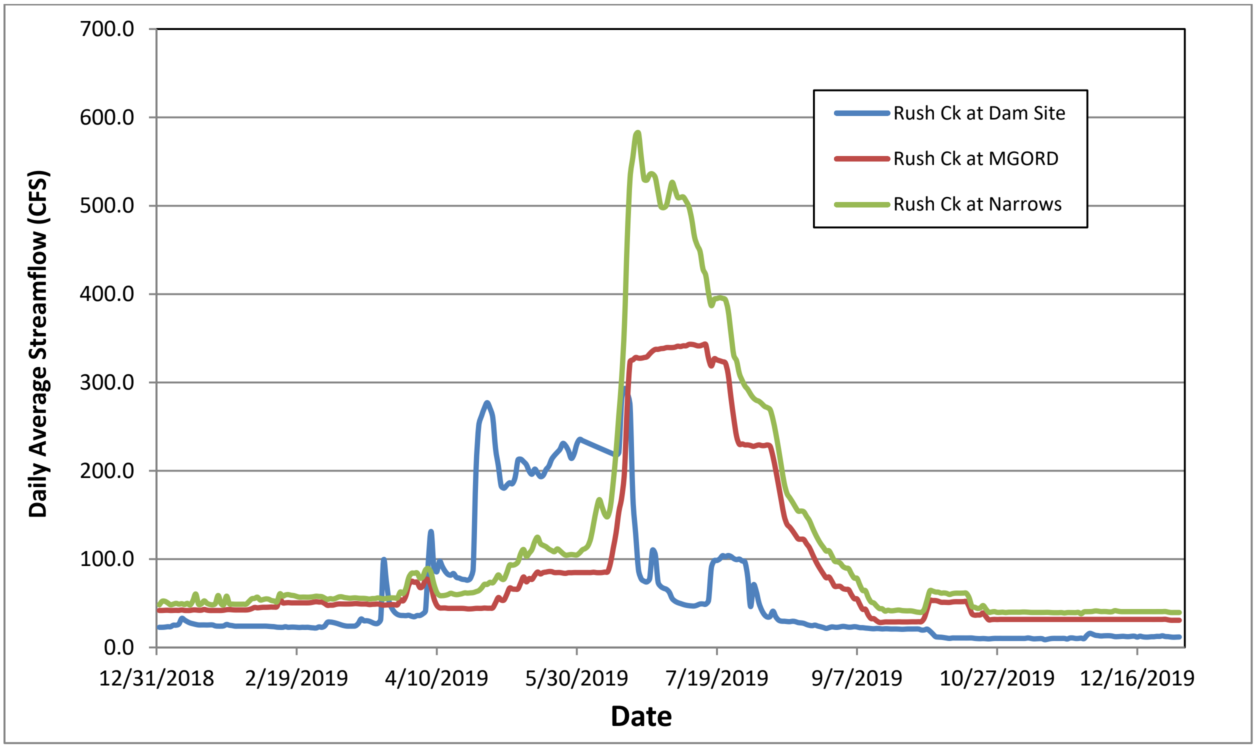


Figure 2. Rush Creek hydrographs between January 1st and December 31 of 2019.

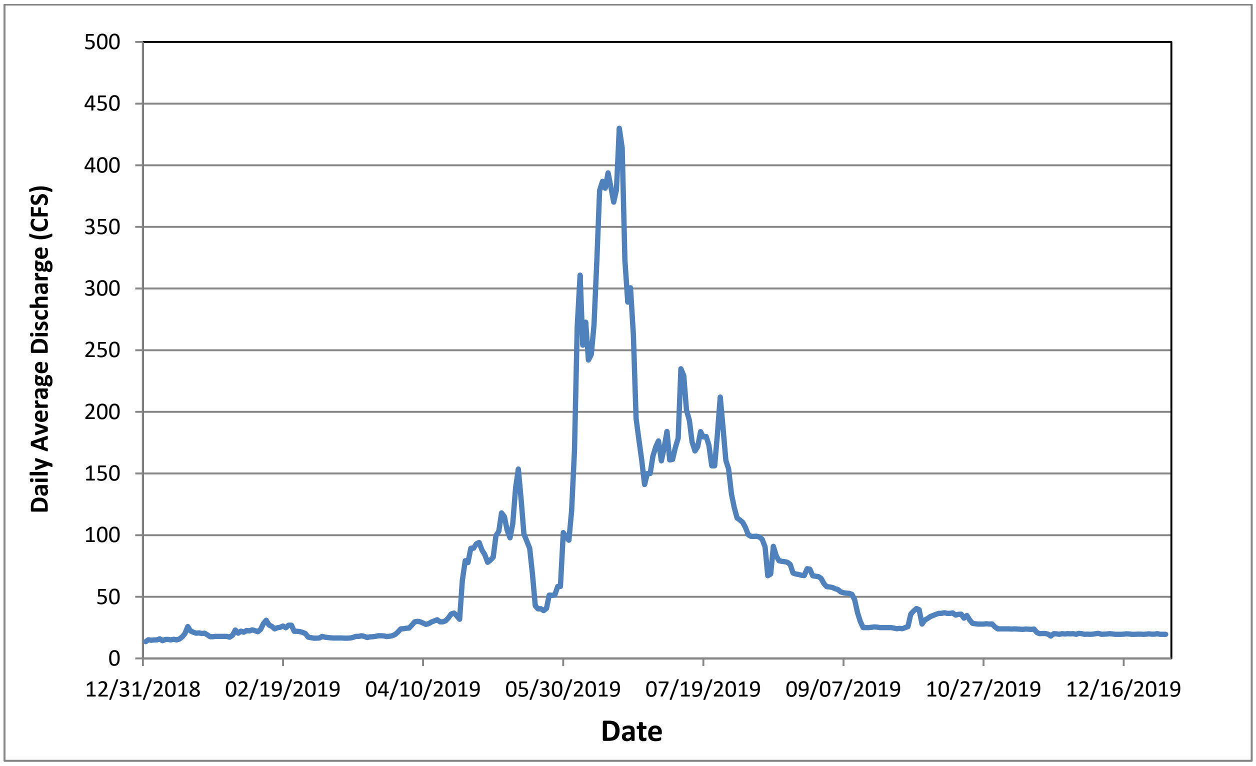


Figure 3. Lee Vining Creek hydrograph between January 1st and December 31st of 2019.

Grant Lake Reservoir

In 2019, storage elevation levels in GLR fluctuated from a low of 7,108.6 ft to a high of 7,130.9 ft, which occurred during the peak of the 33 day spill (Figure 4). In 2019, GLR continued to fill throughout June and July due to the wet year snowmelt and reached its peak storage level during the last week of June.

During RY2019, GLR's elevation was well 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) (green horizontal line in Figure 4). The 2019 summer water temperature monitoring documented cool water temperatures, suitable for fair to good growth of Brown Trout, at all Rush Creek locations downstream of GLR for most of the summer period of July through September.

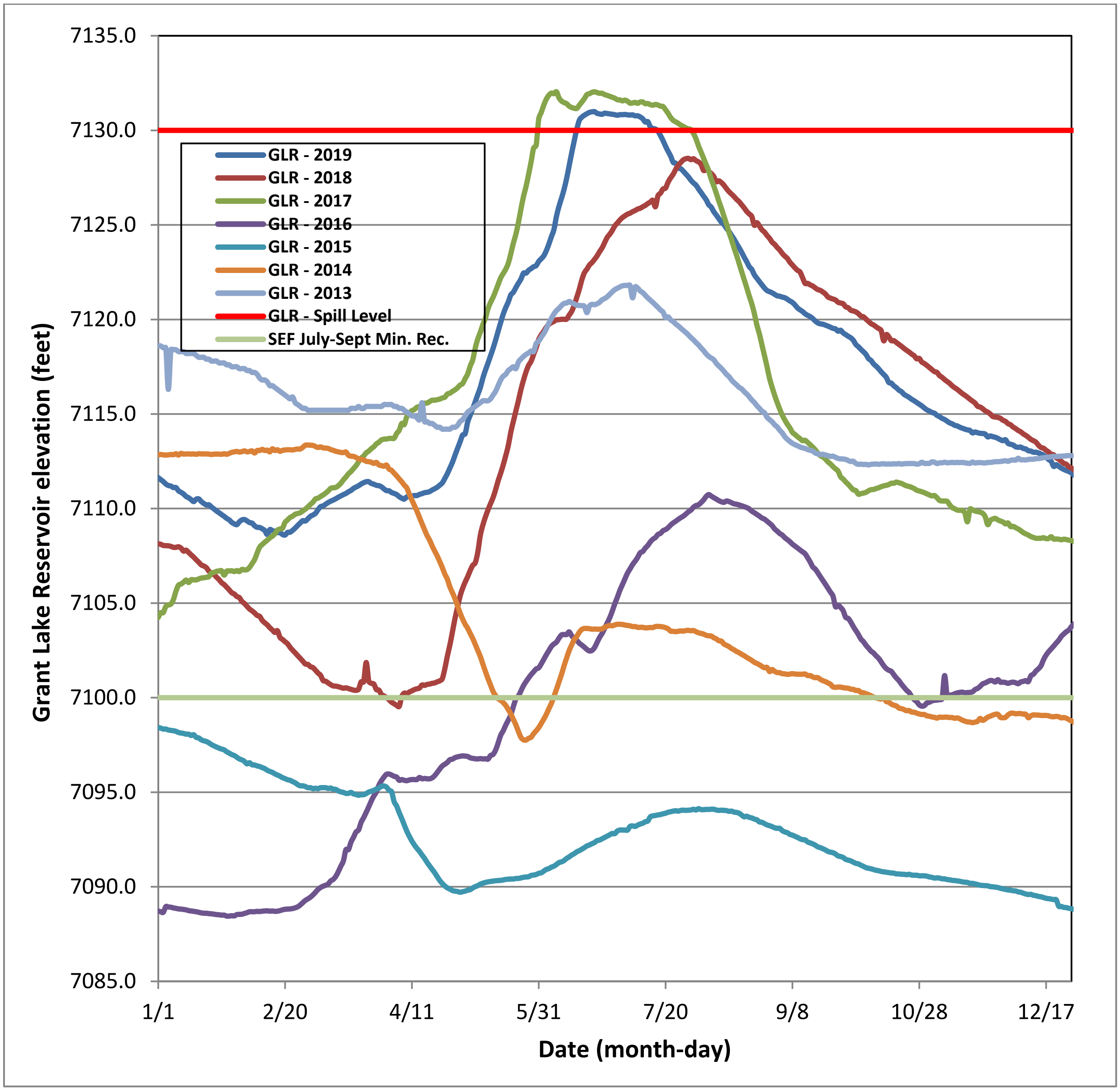


Figure 4. Grant Lake Reservoir's elevation between January 1st and December 31st 2013 - 2019.

Methods

The annual fisheries monitoring was conducted between September 16th and 25th of 2019. Closed population mark-recapture and depletion methods were utilized to estimate trout abundance. The mark-recapture method was used on the Upper and Bottomlands sections of Rush Creek and on the Lee Vining Creek main channel section. The multiple-pass depletion method was used on the Lee Vining Creek side channel and Walker Creek sections. A single pass was made in the MGORD section of Rush Creek, as is typically done in an odd year.

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. 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 upstream (lower) edge of the fence 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 a temporary blockage to prevent fish movement in and out of the study area while conducting the survey. Temporary blockage of the sections was achieved with 3/16 inch-mesh nylon seine nets installed across the channel at the upper and lower ends of the study areas. 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.

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 2019, the field crew consisted of a barge operator, two anode operators, and four netters, two for each anode. A safety officer was also used during the 2019 sampling and this person walked the streambank and observed the in-stream operations. 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.

The mark-recapture runs on the Lee Vining Creek main channel consisted of an upstream pass starting at the lower block fence to the upper block fence, a short 15-20 minute break, and then a downstream pass back down to the lower fence. The electrofishing crew consisted of two crew members operating Smith-Root© LR-24 backpack electrofishers, four netters, and one bucket carrier who transported the captured trout. Again, a safety officer walked the streambank and observed the in-stream operations.

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. A second safety officer walked the streambank and observed the in-stream operations. 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 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 a LR-24 electrofisher; another member was the primary netter and a third member was the backup netter/bucket carrier. Again, a safety officer walked the streambank and observed the in-stream operations. The other crew members processed the trout captured during the first pass while the electrofishing crew was conducting the second pass. Processed first-pass fish were temporarily held in a live car until the second pass was completed. If it was determined that only two passes were required to generate a suitable estimate all fish were then released. If additional passes were needed, fish from each pass were held in live cars until we determined that no additional electrofishing passes were required to generate reasonable 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 received anal fin clips and trout captured in the Upper Rush section received lower caudal fin clips. 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 2014 - 2019 field seasons. Starting in 2017, PIT tags implanted in trout caught in the MGORD were focused primarily on fish up to 250 mm in length, with the intent being to tag age-0 and age-1 trout.

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 and reach lengths were used to generate sample section areas (in hectares), 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 that died during the sampling process was important. Depending on when the fish died (i.e., whether, or not, they were sampled during the mark-run), dictated how these fish were treated within the estimation process.

All fish that died during the mark-run, and were consequently unavailable for sampling during the recapture-run, were considered as "morts" in the mark-run for the purposes of mark-recapture estimates. These fish 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 dead fish, primarily on the lower fences, inside the bounded study sections. 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 that died 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 (dead fish in the block fences that had not been 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 2012) 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; Gabelhouse 1984). 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

For the 2019 Mono Basin fisheries monitoring report, the SWRCB fisheries stream scientist decided to exclude the termination criteria analyses. The reasons for excluding the termination criteria analyses include: (1) the TC metrics used in past annual reports from 2007 through 2018 were never adopted or rejected by the SWRCB, LADWP, CDFW, MLC and CalTrout, (2) the stream scientists recommended dropping the TC in the Synthesis Report, (3) TC were excluded from the 2013 terms of settlement which forms the basis for the amended license and (4) the post-settlement adaptive monitoring program will provide the mechanism to modify flows based, in part, on the status of the trout fisheries in Rush and Lee Vining creeks.

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 by LADWP personnel from the Bishop Office in January and recorded 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 2019:

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 the 2019 summer water temperature regimes (July – September) in 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^{o}F.
5. Number of hours with temperatures exceeding 66.2^{o}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. Lengths, widths, and areas from 2018 were provided for comparisons (Table 1). In 2019, the Upper Rush sample section was shortened so the upper block fence could be set in a favorable location to accomodate changes in channel depth and velocity (Table 1). Between 2018 and 2019, a channel split occurred in Walker Creek, resulting in a wider average channel width and a larger wetted area (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 16-25, 2019. Values from 2018 provided for comparisons.

Sample Section	Length (m) 2018	Width (m) 2018	Area (m^2) 2018	Length (m) 2019	Width (m) 2019	Area (m^2) 2019	Area (ha) 2019
Rush – Upper	406	8.6	3,491.6	381	7.9	3,009.9	0.3010
Rush - Bottomlands	437	7.6	3,321.1	437	7.3	3,190.1	0.3190
Rush – MGORD	2,230	8.4	18,732.0	2,230	7.9	17,617.0	1.7617
Lee Vining – Main	255	5.4	1,377.0	255	5.0	1,275.0	0.1275
Lee Vining - Side	195	2.6	507.0	195	2.3	448.5	0.0449
Walker Creek	193	2.1	405.3	195	2.4	468.0	0.0468

Trout Population Abundance

In 2019, a total of 1,448 Brown Trout ranging in size from 59 mm to 410 mm were captured in the Upper Rush section (Figure 5). For comparison, in 2018 a total of 776 Brown Trout were captured, in 2017 a total of 373 Brown Trout were captured and in 2016 a total of 182 Brown Trout were captured in this section. In 2019, age-0 Brown Trout comprised 62% of the total catch (compared to 67% in 2018 and 58% in 2017). The Upper Rush section supported an estimated 2,647 age-0 Brown Trout in 2019 (including morts) compared to 1,572 age-0 Brown Trout in 2018 (a 68% increase). Compared to 2016 (final year of the five-year drought), the age-0 Brown Trout estimate in the Upper Rush section has increased 17-fold from 146 fish to 2,647 fish. The estimated standard error of the population estimate for age-0 Brown Trout in 2019 was 9% (Table 2).

In 2019, the 403 Brown Trout captured in the 125-199 mm size class comprised 28% of the total catch in the Upper Rush section (compared to 14% in 2018 and 8% in 2017). The Upper Rush section supported an estimated 616 Brown Trout in the 125-199 mm size class in 2019, compared to 196 fish in 2018 (a 214% increase). The estimated standard error of the population estimate for 125-199 mm Brown Trout in 2019 was 6% (Table 2).

Brown Trout ≥200 mm in length comprised 10% of the Upper Rush total catch in 2019 (compared to 18% in 2018 and 34% in 2017). In 2019, Upper Rush supported an estimated 203 Brown Trout ≥200 mm in length compared to an estimate of 195 fish in 2018 and 158 fish in 2017. Standard error of the estimate for this size class was 8% in 2019. In 2019, 12 Brown Trout ≥300 mm in length were captured in the Upper Rush section and these fish comprised 0.8% of the total catch (Figure 5).

A total of 255 Rainbow Trout were captured in the Upper Rush section comprising 15% of the section's total catch in 2019 (compared to 168 Rainbow Trout in 2018). The 255 Rainbow Trout ranged in length from 55 mm to 292 mm and 168 of these were age-0 fish (Figure 6). Most of the Rainbow Trout appeared to be of naturally produced origin and sufficient numbers in two size classes (<125 mm and 125-199 mm) were marked and recaptured to produce unbiased estimates. In 2019, the Upper Rush section supported an estimated 418 Rainbow Trout <125 mm in length (319 in 2018) and an estimated 145 Rainbow Trout 125-199 mm in length (Table 2). The total catch of Rainbow Trout in the ≥200 mm size class was 11 fish (Table 2).

Within the Bottomlands section of Rush Creek, a total of 495 Brown Trout were captured in 2019 (Table 2), which ranged in size from 64 mm to 310 mm (Figure 7). For comparison, 699 Brown Trout were caught in 2018 and 164 Brown Trout were captured in 2017. Age-0 Brown Trout comprised 40% of the total catch in 2019 versus 80% of the total catch in 2018. The Bottomlands section supported an estimated 638 age-0 Brown Trout in 2019 versus 1,808 age-0 fish in 2018 (a 65% decrease). Standard error of the estimate for this size class was 8% in 2019.

Brown Trout 125-199 mm in length comprised 52% of the total catch in the Bottomlands section in 2019 versus 10% of the total catch in 2018. This section supported an estimated 433 Brown Trout 125-199 mm in length in 2019 compared to 100 fish in 2018 (a 333% increase). Estimated standard error for the population estimate of this size class was 8% in 2019 (Table 2).

Brown Trout ≥200 mm in length comprised of 8% of the total catch in 2019 (10% in 2018) with the largest trout 310 mm in length. The Bottomlands section supported an estimated 64 Brown Trout ≥200 mm in 2019 compared to 106 trout in 2018 (a 40% decrease). Standard error for the estimate of this size class was 22% in 2019 (Table 2). In 2019, one Brown Trout ≥300 mm was captured in the Bottomlands section (Figure 7).

Table 2. Rush Creek mark-recapture estimates for 2019 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. * = estimate biased due to four recaptures. BNT = Brown Trout. RBT = Rainbow Trout.

Stream		Mark - recapture estimate					
Section Species Date	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
Rush Creek							
Upper Rush - BNT							
9/16/2019 & 9/23/2019							
	0 - 124 mm	562	395	84	25	**2,647**	231
	125 - 199 mm	280	219	100	5	**616**	36
	≥200 mm	114	73	41	1	**203**	16
Upper Rush - **RBT**							
9/16/2019 & 9/23/2019							
	0 - 124 mm	101	80	19	6	**418**	70
	125 - 199 mm	54	33	12	2	**145**	26
	≥200 mm	8	7	4	0	**13***	2
Bottomlands – BNT							
9/17/2019 & 9/24/2019							
	0 – 124 mm	110	102	17	4	**638**	121
	125 – 199 mm	163	152	57	1	**433**	36
	≥200 mm	25	19	7	0	**64**	14
Lee Vining Creek							
Main Channel – BNT							
9/18/2019 & 9/25/2019							
	0 - 124 mm	128	134	41	0	**414**	43
	125 - 199 mm	67	62	35	0	**118**	77
	≥200 mm	26	26	14	0	**48**	29

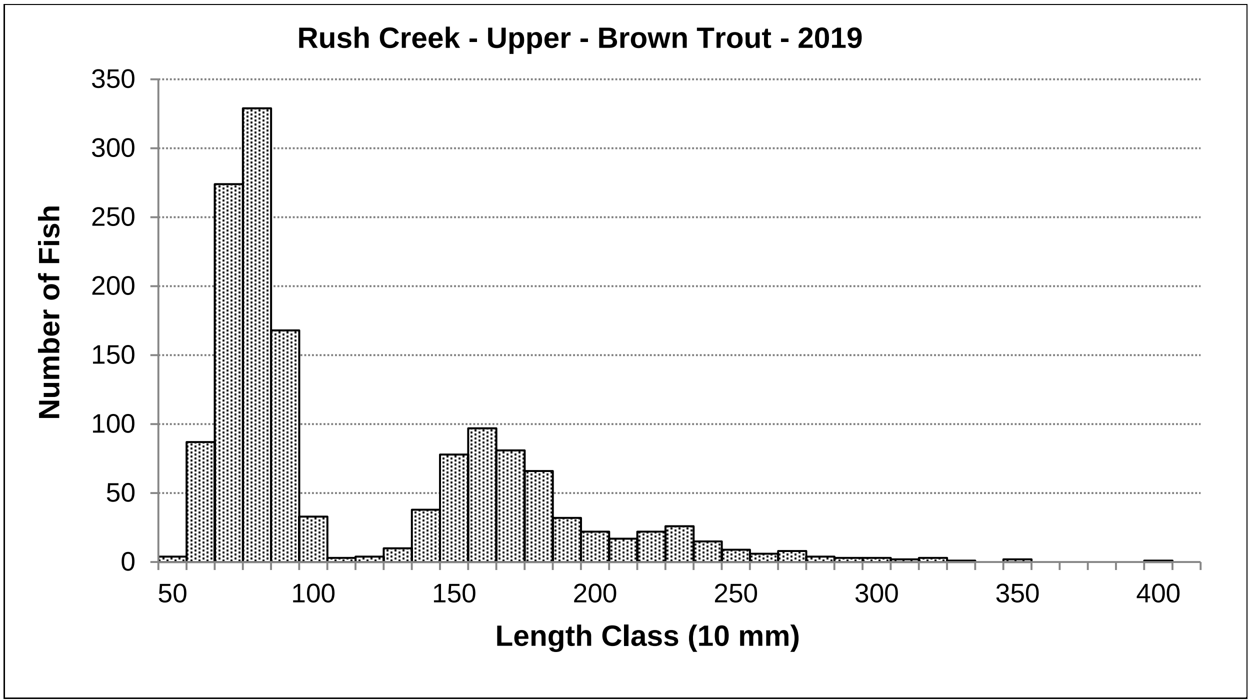

Figure 5. Length-frequency histogram of Brown Trout captured in Upper Rush, September 16th and 23rd, 2019.

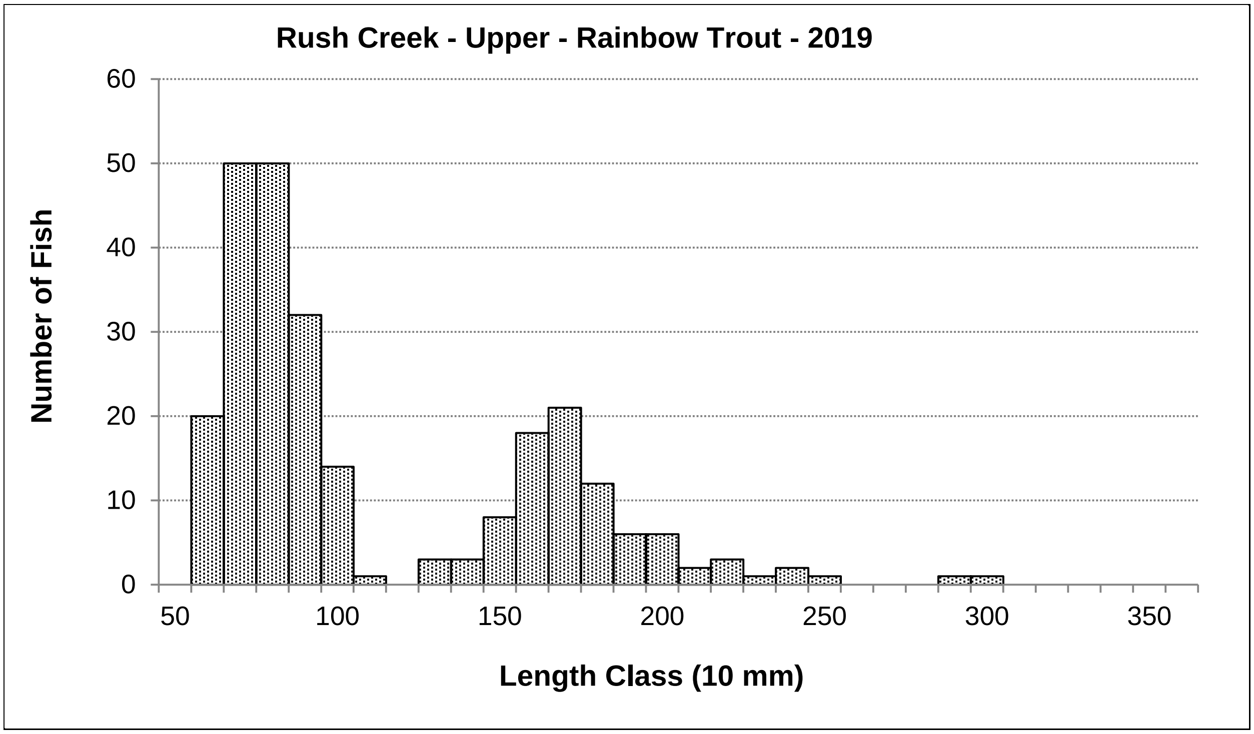

Figure 6. Length-frequency histogram of Rainbow Trout captured in Upper Rush, September 16th and 23rd, 2019.

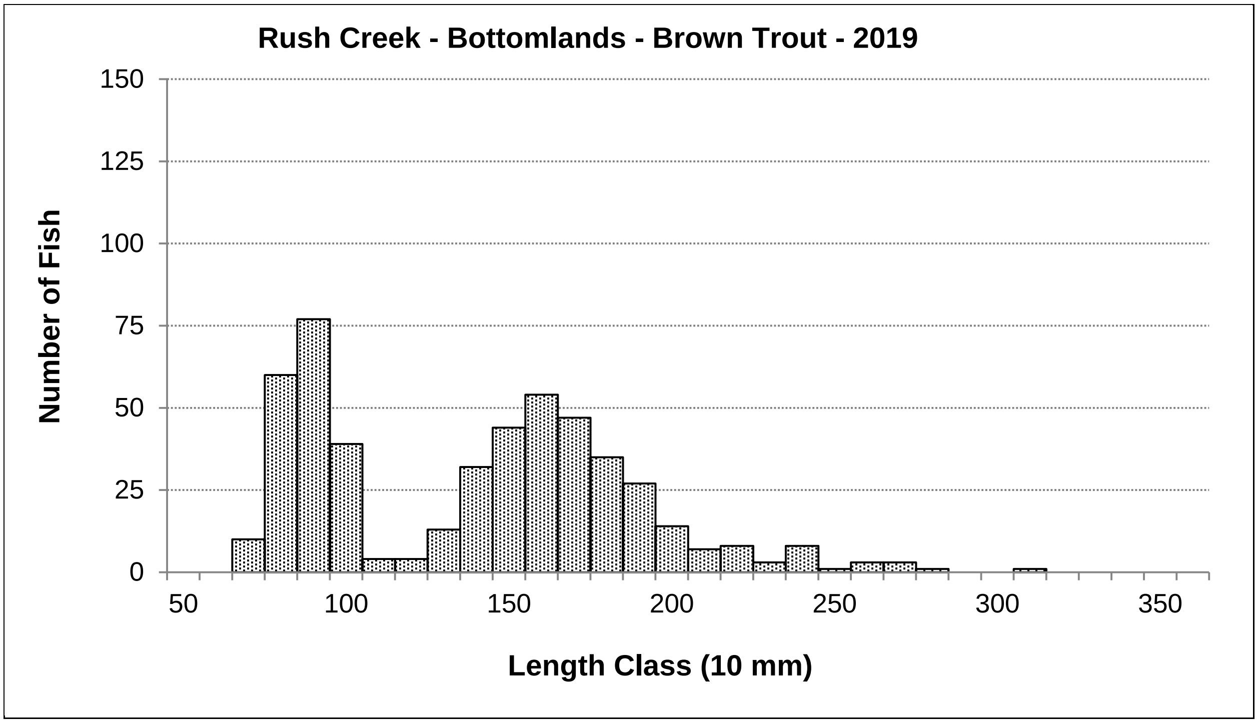

Figure 7. Length-frequency histogram of Brown Trout captured in the Bottomlands section of Rush Creek, September 17th and 24th, 2019.

Within the MGORD section of Rush Creek a total of 343 Brown Trout were captured during the single electrofishing pass made in 2019. These Brown Trout ranged in size from 86 mm to 574 mm (Figure 8). Sixty-seven age-0 Brown Trout were captured in 2019 which comprised 20% of the total catch of Brown Trout (Figure 8).

A total of 103 Brown Trout 125-199 mm in length were caught during the single electrofishing pass and comprised 30% of the total Brown Trout catch in the MGORD section in 2019.

Brown Trout ≥200 mm in length comprised of 50% of the total catch in the MGORD section during 2019. In 2019, 28 Brown Trout ≥300 mm were captured in the MGORD (28 fish ≥300 mm were captured during the single pass made in 2017). Only four Brown Trout ≥375 mm in length were captured in 2019 (compared to 15 fish in 2018, 11 fish in 2017 and 20 fish in 2016), three of these fish were >400 mm in length and one fish was >500 mm in length (Figure 8).

Based on growth rates determined by PIT tag recaptures and annual length-frequency histograms, the cutoff for age-1 Brown Trout residing in the MGORD is approximately 250 mm. Based on this length, 237 of the 343 Brown Trout caught in the MGORD in 2019 were age-0 and age-1 fish. These two age classes comprised nearly 70% of the 2019 catch (Figure 8).

In 2019, 18 Rainbow Trout were captured in the MGORD section (Figure 9). In the previous six years, the Rainbow Trout catch in the MGORD has ranged from zero to 40 fish. Some of the Rainbow Trout captured in 2019 appeared to be of hatchery origin and we suspect they spilled out of GLR during the extended 2019 runoff; as has occurred during previous wet runoff years when GLR spills.

For the past 14 sampling years, electrofishing passes through the MGORD have produced the following total catch values (all size classes of Brown and Rainbow Trout):

- 2019 – Single pass = 361 trout.
- 2018 – Mark run = 233 trout. Recapture run = 188 trout. Two-pass average = 210.5 fish.
- 2017 – Single pass = 203 trout.
- 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.

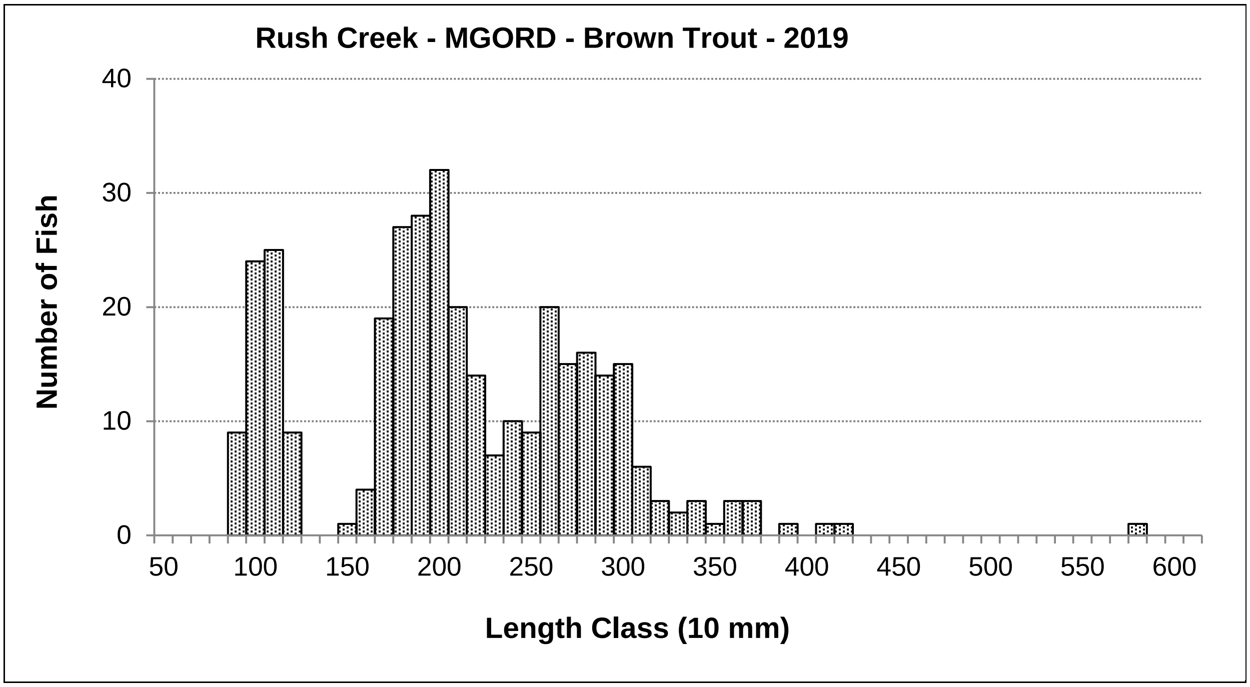

Figure 8. Length-frequency histogram of Brown Trout captured in the MGORD section of Rush Creek, September 19th, 2019.

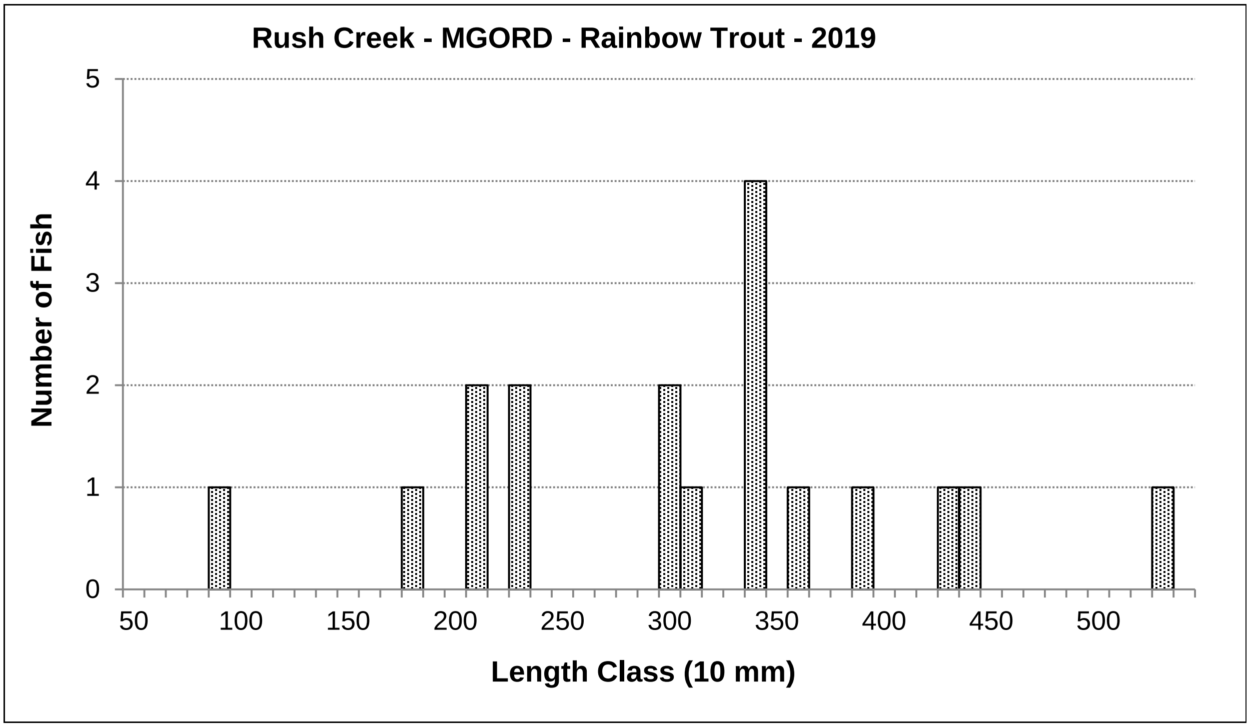

Figure 9. Length-frequency histogram of Rainbow Trout captured in the MGORD section of Rush Creek, September 19th, 2019.

Lee Vining Creek

In 2019, a total of 359 trout were captured in the Lee Vining Creek main channel section versus 147 trout in 2018, 55 trout trout in 2017, 246 fish in 2016, and 422 fish in 2015 (Table 3). Most (353 fish) of the trout captured in 2019 were Brown Trout and the six Rainbow Trout were all age-1 and older fish (165-239 mm in length). In 2019, Brown Trout ranged in size from 65 mm to 354 mm in length (Figure 10). Age-0 fish comprised 63% of the total Brown Trout catch in 2019, compared to 62% in 2018, 58% in 2017 and 28% in 2016. Lee Vining Creek's main channel section supported an estimated 414 age-0 Brown Trout in 2019, compared to an estimated 192 age-0 Brown Trout in 2018, a 116% increase (Table 2). However, the 2019 estimate of 414 age-0 Brown Trout estimate was still 39% lower than the pre-drought estimate of 677 age-0 fish.

In 2019, Brown Trout 125-199 mm in length comprised 27% of the total Brown Trout catch in Lee Vining Creek's main channel section (versus 28% in 2018). This section supported an estimated 118 Brown Trout 125-199 mm in length in 2019 (Table 2) compared to 71 fish in 2018 (a 53% increase). Compared to the 13 fish estimate in 2017, the 2019 estimate of Brown Trout 125-199 mm in length was an eight-fold increase (809%).

In 2019, the population estimate of Brown Trout ≥200 mm in Lee Vining Creek's main channel was 48 fish (versus 14 fish in 2018 and 10 fish in 2017) (Table 2). Two of the Brown Trout captured in 2019 were >300 mm in length (338 and 354 mm) (Figure 10).

No population estimate was generated for age-0 Rainbow Trout due to insufficient numbers of clipped fish (four fish) and recaptures (two fish). No Rainbow Trout in the age-0 size class (<125-mm) were captured in the Lee Vining Creek main channel section in 2019.

In 2019, a single Brook Trout was captured in the main channel section of Lee Vining Creek. This fish was 225 mm in length and was a mature (ready to spawn) male (Figure 11).

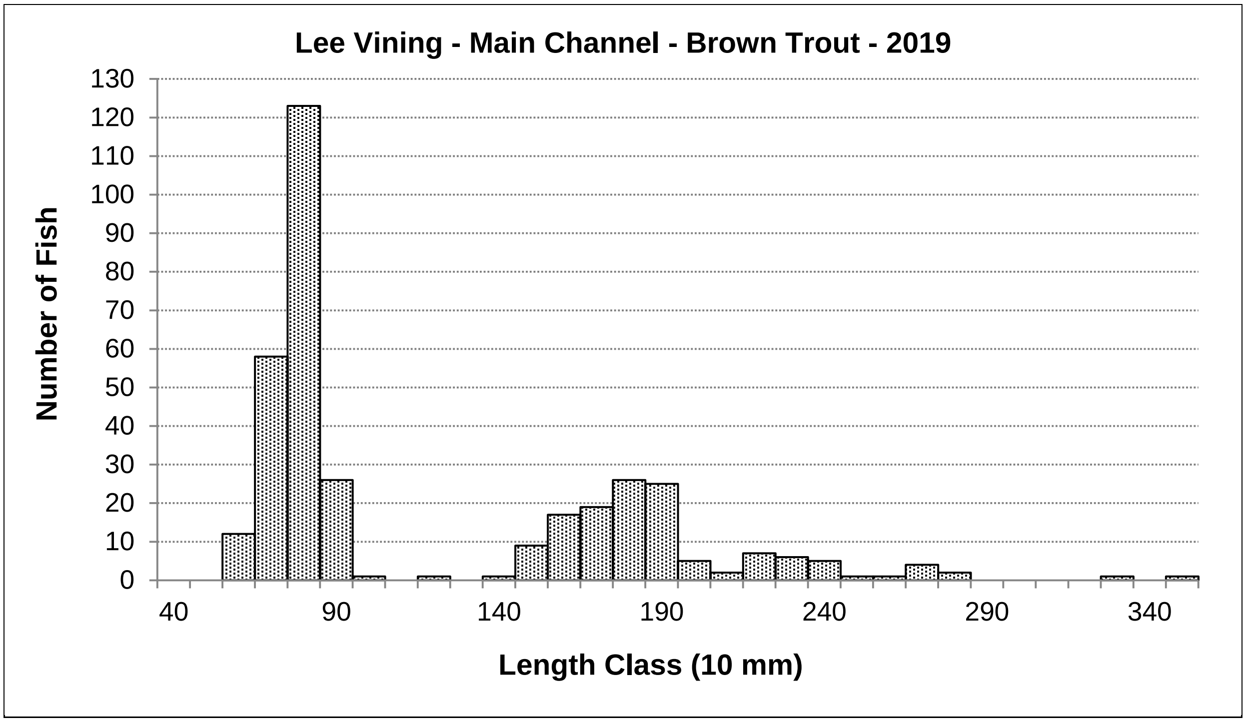

Figure 10. Length-frequency histogram of Brown Trout captured in the main channel section of Lee Vining Creek, September 18th and 25th, 2019.

Figure 11. Brook Trout captured in the main channel section of Lee Vining Creek on 9/25/19.

In the Lee Vining Creek side channel, 21 Brown Trout were captured in two electrofishing passes made during the 2019 sampling (Table 3). No age-0 fish were captured (<125 mm) in 2019 (Figure 12). The estimates for the three size classes equaled the catch numbers (Table 3). No Rainbow Trout were captured in the side channel in 2019. This was the 11th consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the ninth consecutive year that no age-1 and older Rainbow Trout were captured in the side channel.

Walker Creek

In 2019, 278 Brown Trout were captured in two electrofishing passes in the Walker Creek section (175 caught in 2018 and 115 caught in 2017) (Table 3). One hundred seventy-four of these captured fish, or 63%, were age-0 fish ranging in size from 64 mm to 113 mm in length (Figure 13). The 2019 estimated population of age-0 Brown Trout for the Walker Creek section was 179 fish, a 307% increase from the 2018 estimate of 44 fish. For trout <125 mm in length, the estimated probability of capture during 2019 was 83% (Table 3).

Brown Trout in the 125-199 mm size class (70 fish) accounted for 25% of the total catch in 2019. The 2019 population estimate for Brown Trout in the 125-199 mm size class was 70 trout (a 19% decrease from the 2018 estimate of 86) with an estimated probability of capture of 96% (Table 3).

Brown Trout ≥200 mm in length (34 fish caught) accounted for 12% of the total catch in 2019 (was 26% in 2018). The 2019 population estimate for this size class was 34 Brown Trout with a probability of capture of 100% because all 34 fish were caught on the first pass (Table 3). The largest Brown Trout captured in Walker Creek in 2019 was 261 mm in length (Figure 13).

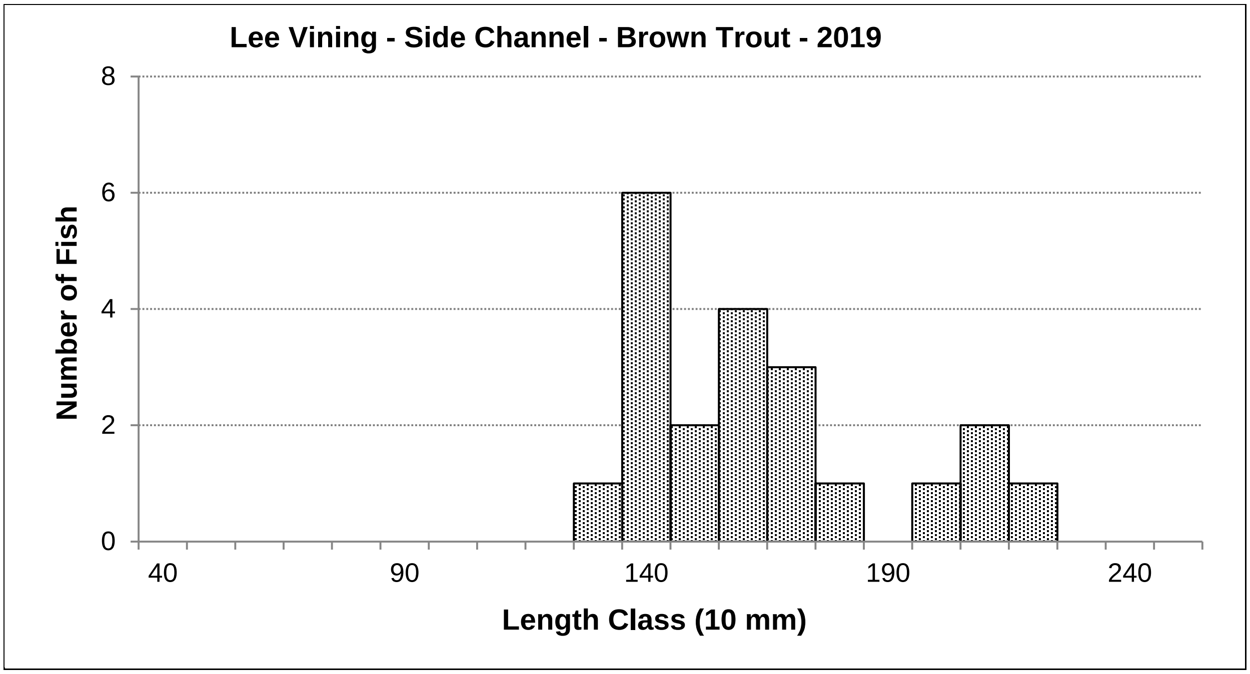

Figure 12. Length-frequency histogram of Brown Trout captured in the side channel section of Lee Vining Creek, September 18th, 2019.

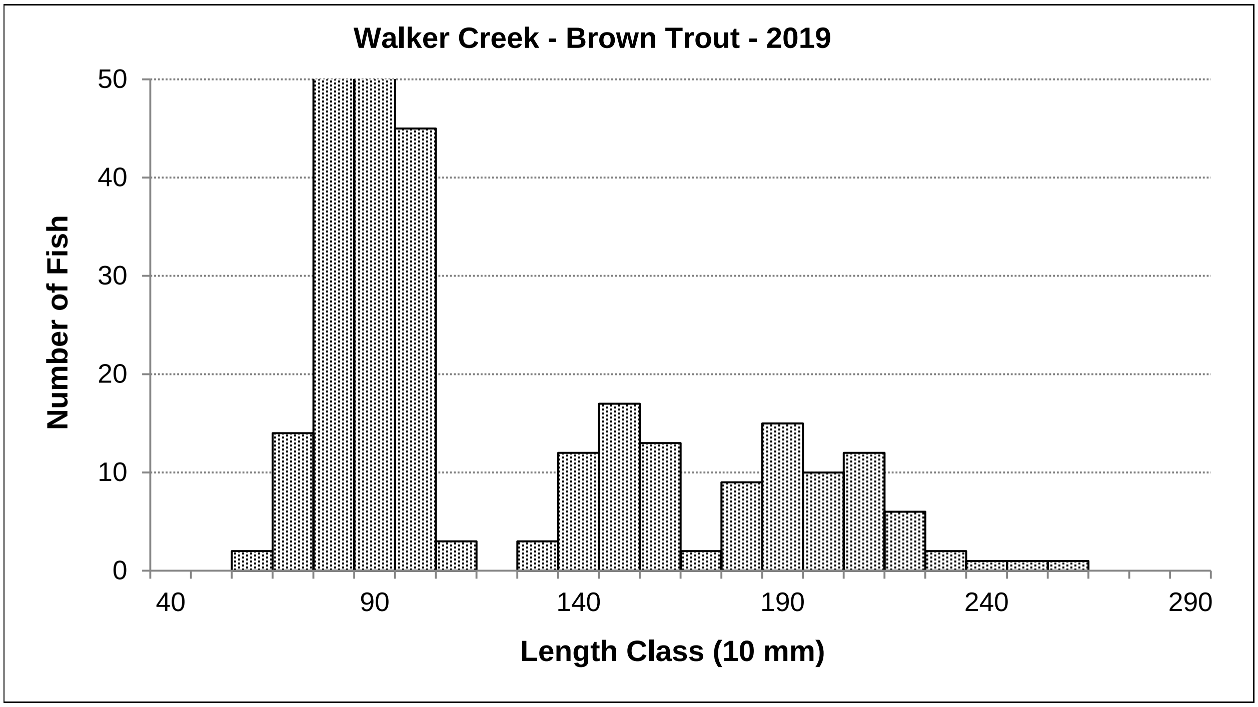

Figure 13. Length-frequency histogram of Brown Trout captured in Walker Creek, September 20th, 2019.

Table 3. Depletion estimates made in the side channel section of Lee Vining Creek and Walker Creek during September 2019 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 - 9/18/2019					
Brown Trout					
	0 - 124 mm	2	0 0	**0**	N/A
	125 - 199 mm	2	14 3	**17**	0.85
	200 + mm	2	4 0	**4**	1.00
Walker Creek - above old Hwy 395 - 9/20/2019					
Brown Trout					
	0 - 124 mm	2	147 27	**179**	0.83
	125 - 199 mm	2	67 3	**70**	0.96
	200 + mm	2	34 0	**34**	1.00

Catch of Rainbow Trout in Rush and Lee Vining Creeks

Beginning with the 2008 annual report, we have only reported catch summaries for Rainbow Trout in Rush Creek and did not attempt to estimate their populations. This decision was made because Rainbow Trout usually accounted for less than 5% of Rush Creek's total catch. In 2011, when GLR spilled significant amounts of water, hatchery-origin Rainbow Trout also spilled out of the reservoir. These spills resulted in Rainbow Trout accounting for 8% of the total catch in 2011, the highest we recorded in Rush Creek until 2017. For the sampling years since 2011; Rainbow Trout accounted for 5% of the total Rush Creek catch in 2012, 2% in 2013, 0.75% in 2014, 1.9% in 2015, and 2.5% in 2016. During the large snowmelt event of 2017, GLR spilled for 60 days and it appeared that fish originating from GLR came over the dam during these spills, as they likely did in 2011. For the 2017 sampling, Rainbow Trout comprised 10.9% of the total catch in Rush Creek (86 Rainbow Trout/787 total trout).

For the 2018 sampling, Rainbow Trout comprised 17.8% of the total catch in the Upper Rush section (168 Rainbow Trout/944 total trout). Nearly 85% of these Rainbow Trout were age-0 fish and most of the larger fish appeared to be naturally-produced, thus for 2018, Rainbow Trout were included in generating biomass estimates for the Upper Rush section. This substantial increase in age-0 Rainbow Trout may have occurred due to the recent, record low numbers of Brown Trout. For a second consecutive year, numerous Rainbow Trout were captured in the Upper Rush section in 2019 and comprised 15% of the total catch (255 Rainbow Trout/1,703 total trout). Age-0 fish comprised 66% of the Rainbow Trout caught and age-1 fish comprised another 30% of the Rainbow Trout caught in 2019 and sufficient numbers were caught on both the mark and recapture runs to generate unbiased population estimates (Table 2).

Between 1999 and 2012 Rainbow Trout numbers in Lee Vining Creek were variable, generally increasing during drier RY types and decreasing 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), seven rainbows in 2016 (no age-0 fish) and no rainbows in 2017. This large drop in Rainbow Trout numbers has occurred during the time period when CDFW shifted to stocking sterile catchable Rainbow Trout. We suggest that in years prior to 2012, supplementation of the Rainbow Trout population with reproductively viable hatchery Rainbow Trout originating from CDFW stocking (upstream of LADWP's point of diversion), and their successful spawning, probably, to a large degree, supported the Lee Vining Creek Rainbow Trout population.

Due to Rainbow Trout historically encompassing a large portion (10-40%) of the Lee Vining Creek trout population, an effort has been made to generate density and biomass values using the available data. In years when adequate numbers of Rainbow Trout 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. Previous fisheries reports have discussed that while catch numbers were not statistically valid they were consistently lower than statistically valid estimates and allowed for comparison between all sampling years (Taylor 2019). An unbiased estimate of age-0 Rainbow Trout in Lee Vining Creek was last made in 2013 and 2015 was the last year that sufficient numbers of age-1+ Rainbow Trout were caught to generate an estimate.

Relative Condition of Brown Trout

Linear regressions of log-length to log-weight for captured Brown Trout ≥ 100 mm indicated strong correlations between length and weight (r^2 values 0.98 and greater; Table 4). Slopes of these relationships were near 3.0 indicating isometric growth, which was assumed to compute fish condition factors, was reasonable.

Table 4. Regression statistics for $\log_{10}$ transformed length (L) to weight (WT) for Brown Trout 100 mm and longer captured in Rush Creek by sample section and year. The 2019 regression equations are in ***bold*** type.

Section	Year	N	Equation	r^2	P
Bottomlands	***2019***	***310***	***$Log_{10}(WT) = 2.9631*Log_{10}(L) – 4.9409$***	***0.99***	***<0.01***
	2018	226	$Log_{10}(WT) = 2.9019*Log_{10}(L) – 4.8059$	0.99	<0.01
	2017	160	$Log_{10}(WT) = 3.0398*Log_{10}(L) – 5.0998$	0.99	<0.01
	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
Upper Rush	***2019***	***686***	***$Log_{10}(WT) = 2.9667*Log_{10}(L) – 4.9298$***	***0.99***	***<0.01***
	2018	391	$Log_{10}(WT) = 2.9173*Log_{10}(L) – 4.8237$	0.99	<0.01
	2017	309	$Log_{10}(WT) = 3.0592*Log_{10}(L) – 5.1198$	0.99	<0.01
	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

Table 4 (continued).

Section	Year	N	Equation	r^2	P
Upper Rush	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	***2019***	***314***	***$Log_{10}(WT) = 2.9774*Log_{10}(L) – 4.9282$***	***0.98***	***<0.01***
	2018	350	$Log_{10}(WT) = 3.0023*Log_{10}(L) – 5.0046$	0.98	<0.01
	2017	159	$Log_{10}(WT) = 3.0052*Log_{10}(L) – 5.0205$	0.99	<0.01
	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 2019 decreased from 2018 values in three sections, remained the same in one section and increased slightly in two other sections (Figures 14 and 15). In 2019, two sections (MGORD and Lee Vining side channel) had Brown Trout condition factors ≥1.00 (Figures 14 and 15).

Brown Trout in the Upper Rush section had a condition factor of 0.99 in 2019, an increase from 0.96 in 2018 (Figure 14). The Upper Rush section has had Brown Trout condition factors ≥1.00 in 10 of 20 sampling seasons (Figure 14).

Brown Trout in the Bottomlands section of Rush Creek had a condition factor of 0.95 in 2019, an increase from the value of 0.92 in 2018 (Figure 14). In 12 years of sampling, the Bottomlands section has failed to generate a Brown Trout condition factor ≥1.00 (Figure 14).

The MGORD's 2019 Brown Trout condition factor was 1.01, the same value as in 2018 (Figure 14). In 2019, condition factors for larger Brown Trout in the MGORD were also computed: fish ≥300 mm had a condition factor of 0.98 (1.00 in 2018) and fish ≥375 mm had a condition factor of 1.04 (1.01 in 2018).

In 2019, the condition factor for Brown Trout in Lee Vining Creek's main channel was 0.99 and in the side channel the condition factor was 1.02 (Figure 15). The 2019 values were decreases from 2018 values (Figure 15). For the ninth year in a row, no age-1+ Rainbow Trout were captured in the Lee Vining Creek side channel. In 2019, Rainbow Trout in Lee Vining Creek's main channel had a condition factor of 1.08 (Figure 15).

In Walker Creek, Brown Trout had a condition factor of 0.98 in 2019, a decrease from 1.02 in 2018 (Figure 14). Brown Trout condition factors in Walker Creek have been ≥1.00 in 12 of the 20 sampling years (Figure 14).

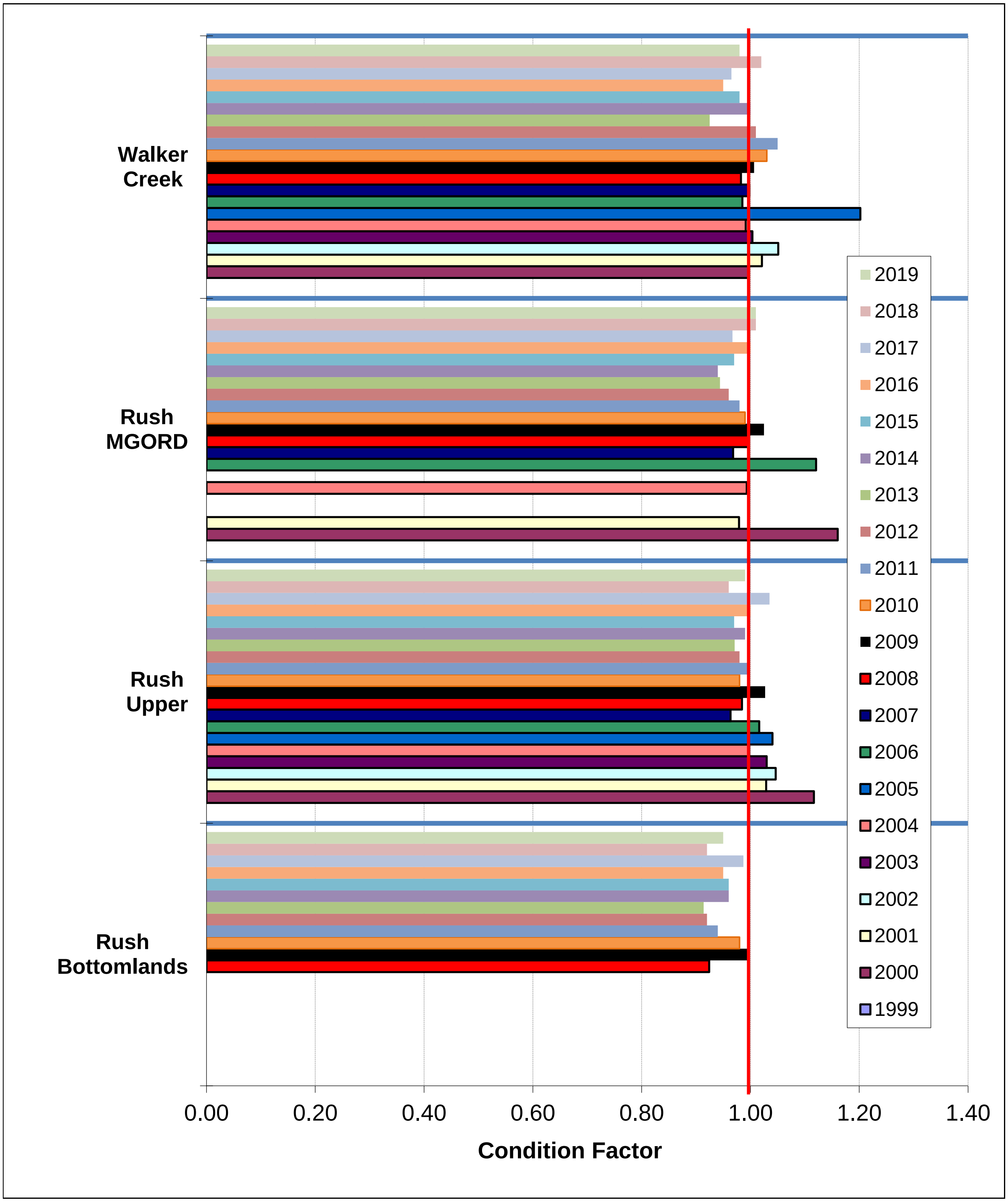

Figure 14. Condition factors for Brown Trout 150 mm to 250 mm in length from sample sections of Rush Creek and Walker Creeks from 1999 to 2019.

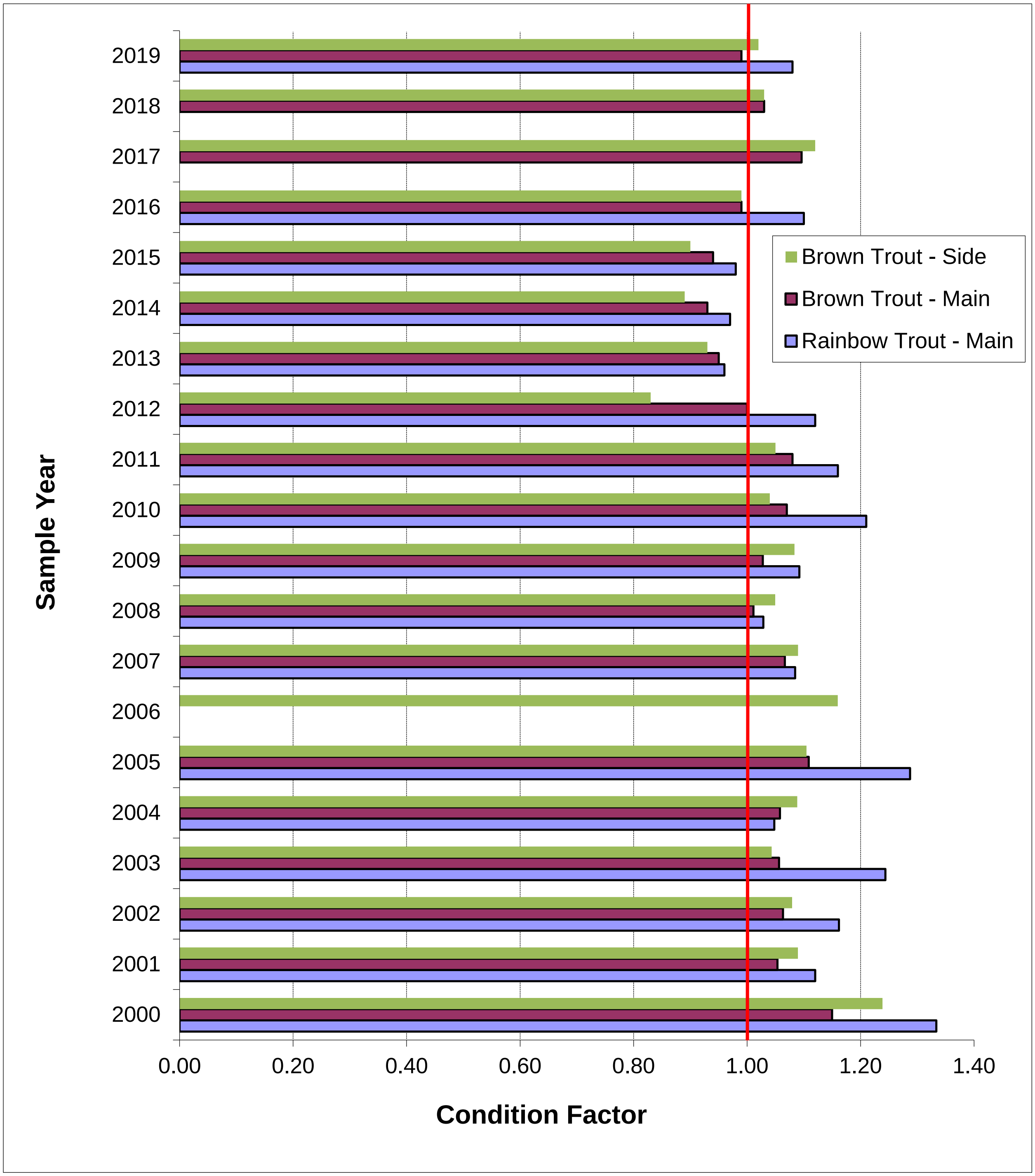

Figure 15. Comparison of condition factors for Rainbow Trout and Brown Trout 150 to 250 mm in length from the main channel and side channel sections of Lee Vining Creek from 2000 to 2019. Main channel was not sampled in 2006 due to high flows. No Rainbow Trout 150 to 250 mm in length were captured in 2017 and 2018.

Estimated Trout Densities Expressed in Numbers per Hectare

Age-0 Brown Trout

The Upper Rush section had an estimated density of 8,794 age-0 Brown Trout/ha in 2019, an increase of 93% from 2018's estimate of 4,502 age-0 Brown Trout/ha and a 357% increase from 2017's estimate of 1,923 age-0 Brown Trout/ha (Figure 16). After a 95% decrease during the five consecutive dry/below average RYs (2012-2016), age-0 Brown Trout density estimates have increased from the 2016 low of 439 fish/ha to 8,794 fish/ha (a 19-fold increase). The 2019 density estimate in the Upper Rush section was 51% higher than the 20-year average of 5,814 age-0 Brown Trout/ha.

The Bottomlands section of Rush Creek had a density estimate of 2,000 age-0 Brown Trout/ha in 2019, a 62% decrease from 2018's estimate of 5,444 age-0 trout/ha (Figure 16). This drop in age-0 estimated densities followed a ten-fold increase between the 2017 and 2018 sampling seasons. When compared to the 12-year average of 2,093 age-0 Brown Trout/ha, the 2019 estimate was 4% lower.

In Walker Creek, the 2019 density estimate of 3,825 age-0 Brown Trout/ha was a 252% increase from the 2018 estimate of 1,086 age-0 trout/ha (Figure 16). The 2019 density estimate was 10% higher than the 21-year average of 3,486 age-0 trout/ha (Figure 16).

In 2019, the estimated density of age-0 Brown Trout in the main channel section of Lee Vining Creek was 3,247 age-0 trout/ha, which was a 133% increase from the 2018 density estimate of 1,394 age-0 trout/ha (Figure 17). After a 96% decrease during the five consecutive dry/below average RYs, the age-0 Brown Trout density estimates increased 13-fold. The 20-year average density estimate for the main channel section of Lee Vining Creeks equaled 1,695 age-0 Brown Trout/ha (Figure 17).

In 2019, no age-0 Brown Trout were caught in the side channel section of Lee Vining Creek (Figure 17). Since 2014, no age-0 Brown Trout were caught in the side channel section in three out of six sampling years (Figure 17).

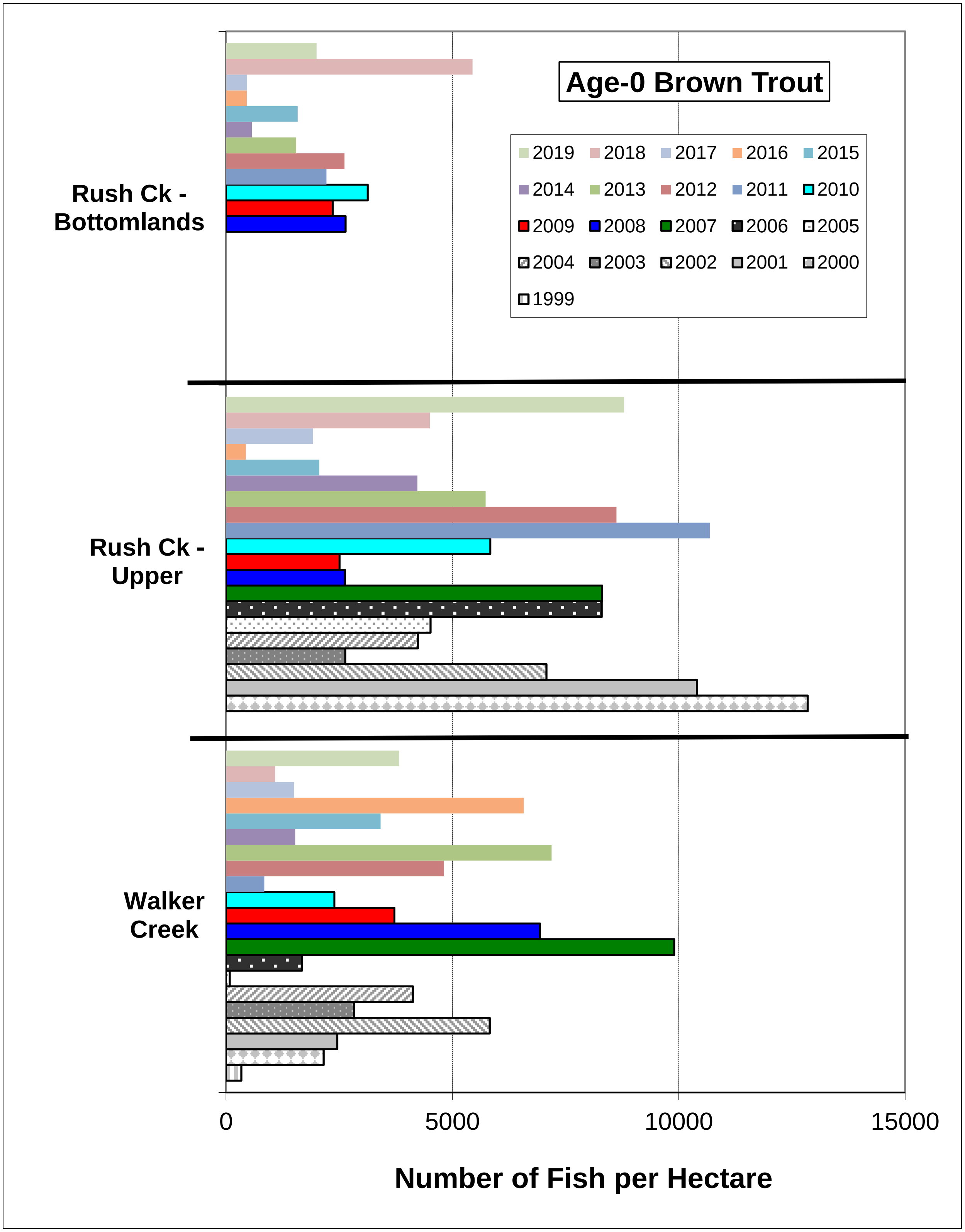

Figure 16. Estimated number of age-0 Brown Trout per hectare in Rush Creek and Walker Creek from 1999 to 2019.

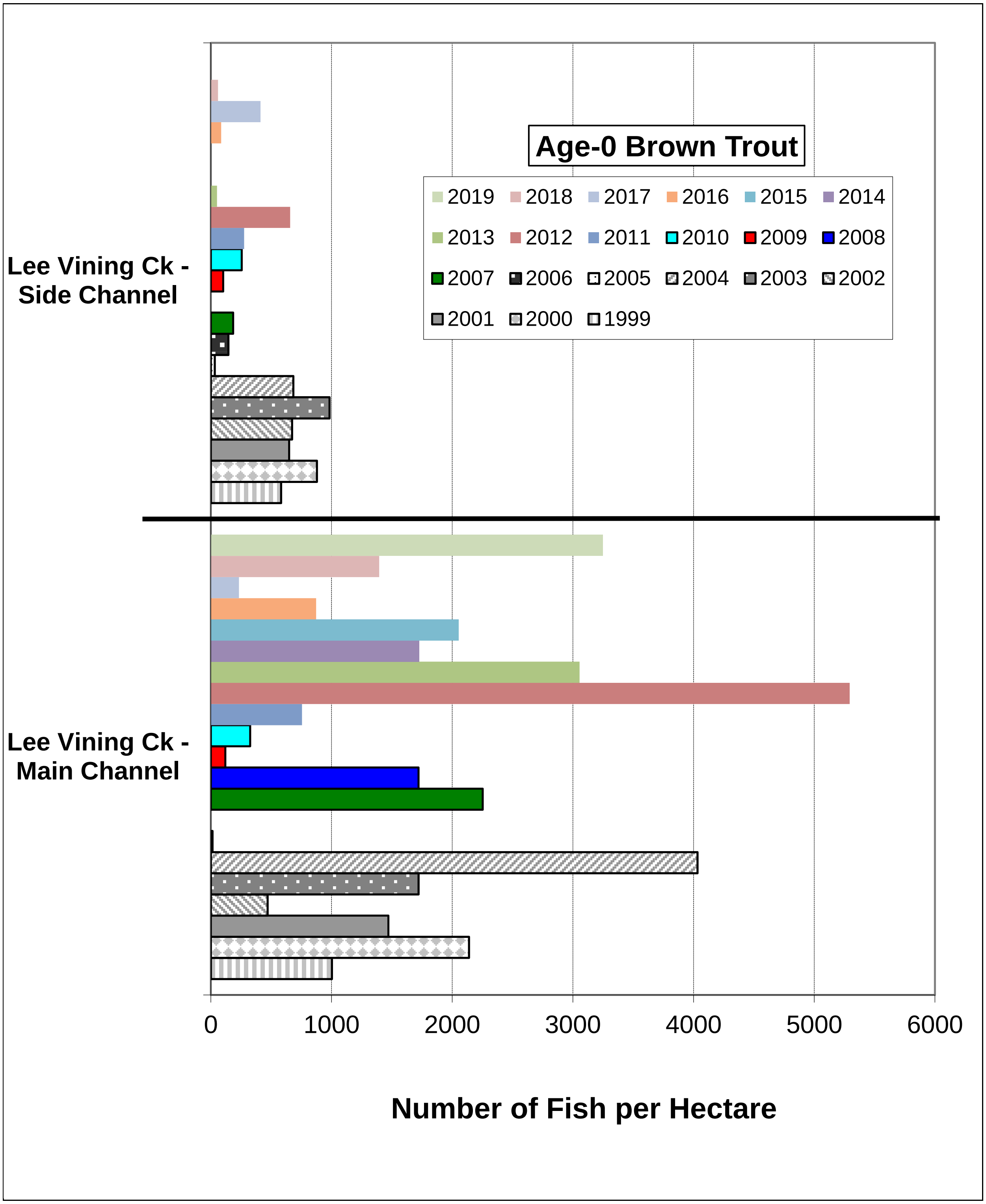

Figure 17. Estimated number of age-0 Brown Trout per hectare in Lee Vining Creek from 1999 to 2019.

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

The Upper Rush section had an estimated density of 2,721 age-1+ Brown Trout/ha in 2019, an increase of 143% from the 2018 estimate of 1,120 trout/ha (Figure 18). After a 75% decrease during the five consecutive dry/below average RYs, the age-1+ Brown Trout density estimates have increased by 449% between the 2016 and 2019 sampling seasons. The 2019 estimate was nearly twice as large as the 21-year average of 1,420 age-1+ Brown Trout/ha.

The estimated density of age-1+ Brown Trout in the Bottomlands section of Rush Creek in 2019 was 1,558 fish/ha, a 151% increase from the 2018 estimate of 620 age-1+trout/ha (Figure 18). After an 86% decrease during the five consecutive dry/below average RYs, the age-1+ Brown Trout density estimates have increased by 536% between the 2016 and 2019 sampling seasons. The 2019 density estimate of age-1+ Brown Trout/ha was 30% higher than the 12-year average of 1,078 age-1+ Brown Trout/ha.

The 2019 density estimate for age-1+ Brown Trout for the Walker Creek section was 2,222 age-1+trout/ha which was a 31% decrease from the 2018 estimate of 3,235 age-1+ trout/ha (Figure 18). The 2019 density estimate of age-1+ Brown Trout was 17% higher than the 21-year average of 1,841 age-1+ Brown Trout/ha.

The 2019 density estimate for age-1+ Brown Trout in the Lee Vining main channel section was 1,302 trout/ha, a 111% increase from the 2018 estimate of 617 age-1+ trout/ha(Figure 19). Since 2017, the density estimate of age-1+ Brown Trout has increased more than six-fold in the Lee Vining Creek main channel section (Figure 19).

In 2019, the side channel of Lee Vining Creek supported an estimated density of 468 age-1+ Brown Trout/ha, an increase of 239% from the 2018 estimate of 138 age-1+ Brown Trout/ha (Figure 19). As discussed in the previous two annual reports, this side channel has experienced variations in the amount of flow that enters the channel due to changes in the geomorphology of the channel’s inlet over time. These variable flows have resulted in highly variable annual wetted areas, which has been a major factor driving density and standing crop estimates for this section. Consequently, the lowest catch of fish (seven in 2015) resulted in the largest density estimate because so little water flowed down the side channel this particular year (Table 5). In September of 2018, more flow continued to enter the top of the side channel, which increased the wetted area within the sampling section to the highest amount since the 2010 and 2011 sampling seasons (Table 5). In September of 2019, the wetted area decreased by 12% compared to 2018, but the total number of Brown Trout caught in 2019 was 21 fish and all of these fish were age-1+ (Table 5).

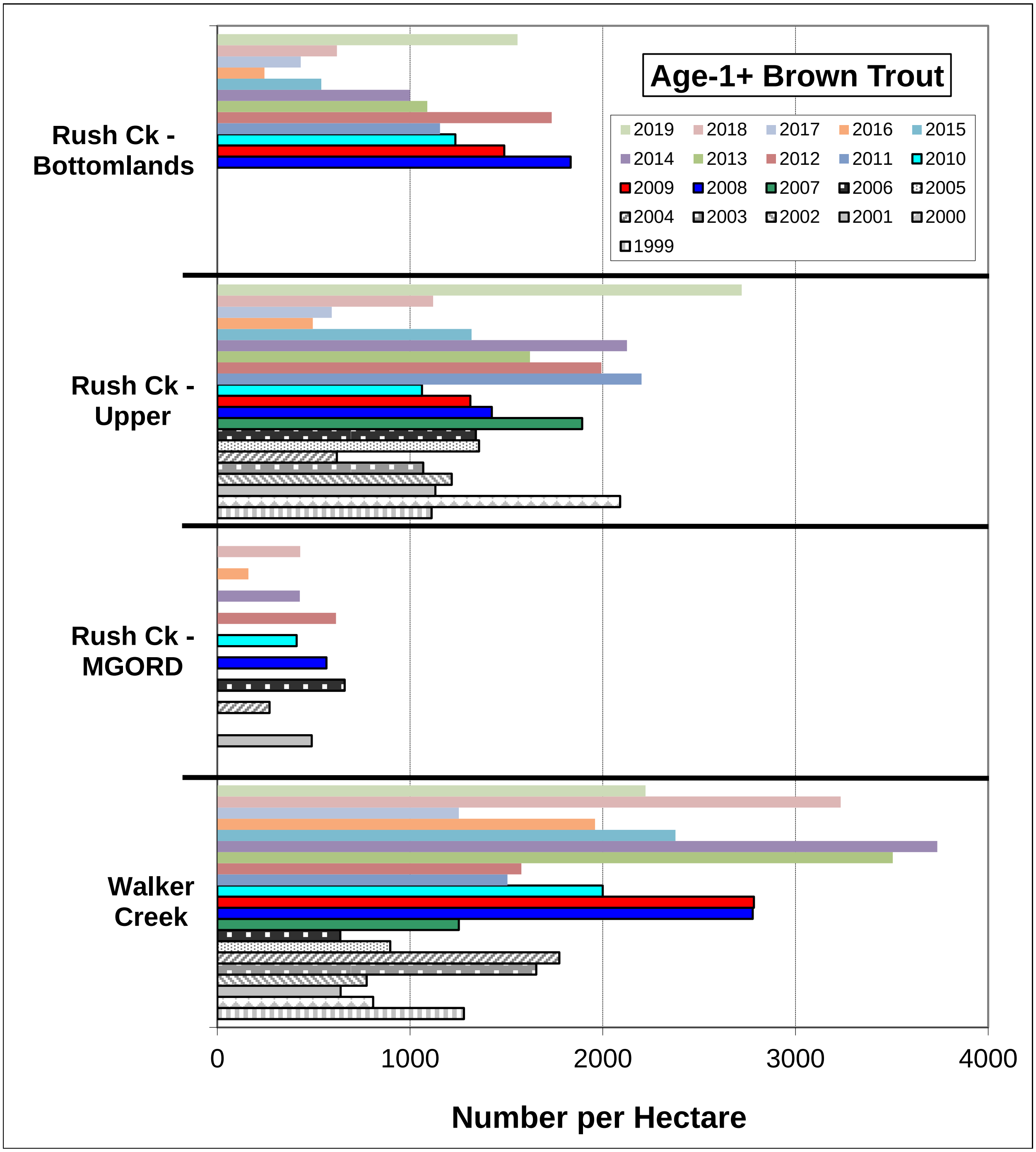

Figure 18. Estimated number of age-1 and older Brown Trout per hectare in sections of Rush and Walker Creeks from 1999 to 2019.

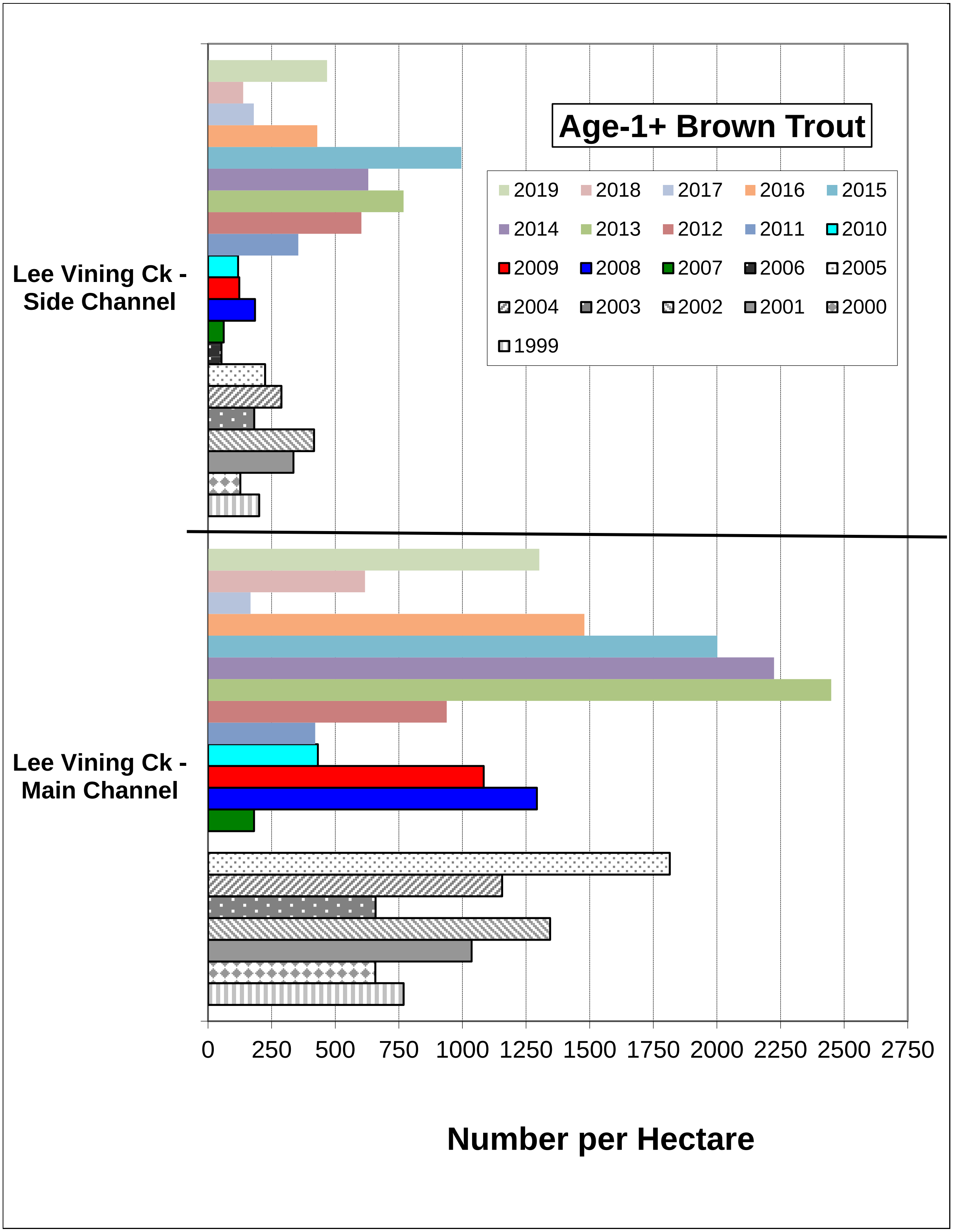

Figure 19. Estimated number of age-1 and older Brown Trout per hectare in sections of Lee Vining Creek from 1999 to 2019.

Table 5. Wetted surface area and total numbers of trout captured in the Lee Vining Creek side channel, from 2007 to 2019.

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
2017	389.4	23
2018	507.0	10
2019	**448.5**	**21**

Age-0 Rainbow Trout

In 2019, for the 11th consecutive year no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel. In the Lee Vining Creek main channel, no age-0 Rainbow Trout were captured during the 2019 sampling.

The Upper Rush section supported an estimated density of 1,389 age-0 Rainbow Trout/ha in 2019.

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

No age-1 and older Rainbow Trout were captured in the Lee Vining Creek side channel during 2019, making it the ninth consecutive year when none were captured. In 2019, a total of six age-1 and older Rainbow Trout were captured in the Lee Vining Creek main channel.

The Upper Rush section supported an estimated density of 525 age-1+ Rainbow Trout/ha in 2019.

Estimated Numbers of Trout per Kilometer

The Upper Rush section contained an estimated 8,910 Brown Trout/km (all size classes combined) in 2019, which was an 84% increase from the 2018 estimate of 4,835 Brown Trout/km (Table 6). The 2019 estimate was the third straight increase of the estimated numbers of Brown Trout/km since five years of declines during the drought (Table 6). The estimated density of age-1+ Brown Trout in 2019 was 2,105 fish/km; a 119% increase from the 2018 estimate of 963 age-1+ fish/km (Table 6).

The Upper Rush section also contained an estimated 1,481 Rainbow Trout/km (all size classes combined) in 2019. This density estimate included 406 age-1+ Rainbow Trout.

The Bottomlands section contained an estimated of 2,094 Brown Trout/km (all size classes combined) in 2019, which was a 55% decrease from the 2018 estimate of 4,608 fish/km (Table 6). This decrease was based soley on the lower numbers of age-0 present during the 2019 sampling. In 2019, the estimate of 1,137 age-1+ Brown Trout/km represented a 141% increase from the 2018 estimate of 471 age-1+ Brown Trout/km (Table 6).

The Lee Vining Creek main channel contained an estimated 2,299 Brown Trout/km and 47 Rainbow Trout/km (all size classes combined) in 2019, which was a 97% increase from the 2018 estimate of 1,189 fish/km (Table 7). In 2019, the estimate of 722 age-1+ Brown and Rainbow Trout/km represented a 66% increase from the 2018 estimate of 436 age-1+ trout/km (Table 7).

The catch of six Rainbow Trout in the Lee Vining Creek main channel section resulted in an estimated density of 47 fish/km. All of these Rainbow Trout were age-1+ fish.

The Lee Vining side channel contained an estimated 108 Brown Trout/km in (all size classes combined) 2019, a 112% increase from the 2018 estimate of 51 fish/km (Table 7). For age-1+ Brown Trout, the 2019 density estimate was 108 Brown Trout/km which was a 200% increase from the 2018 density estimate 36 fish/km (Table 7).

Table 6. Estimated total numbers (number of age-1 and older in parentheses) of Brown Trout per kilometer of stream channel for Rush Creek sample sections from 2008 to 2019.

Collection Location	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Rush Creek, Upper Rush	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)	1,863 (440)	4,835 (963)	**8,910** **(2,105)**
Rush Creek, Bottom-lands	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)	637 (308)	4,608 (471)	**2,094** **(1,137)**

Table 7. Estimated total numbers of Brown and Rainbow Trout (number of age-1 and older in parentheses) per kilometer of stream channel for Lee Vining Creek sample sections from 2008 to 2019.

Collection Location	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lee Vining, Main Channel	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)	216 (90)	1,189 (436)	**2,346** **(722)**
Lee Vining, Side Channel	103 (67)	133 (108)	103 (36)	159 (87)	257 (123)	131 (123)	95 (95)	100 (100)	97 (97)	130 (40)	51 (36)	**108** **(108)**

Estimated Trout Standing Crops (kg/ha)

The total (Brown and Rainbow Trout) estimated standing crop in the Upper Rush section was 291 kg/ha in 2019, a 55% increase from the 188 kg/ha in 2018 and a 137% increase from the 2017 estimate of 123 kg/ha (Table 8 and Figure 20). The total estimated standing crop of 291 kg/ha was the highest value estimated for the Upper Rush section in 21 sampling years (Figure 20). Rainbow Trout comprised 36.5 kg/ha of the 2019 standing crop estimate and was the highest biomass of Rainbow Trout estimated in Upper Rush in the past 21 years. When compared to the 21-year average of 155 kg/ha, the 2019 standing crop estimate was approximately 87% greater (Figure 20).

The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 91 kg/ha in 2019, a 12% decrease from 103 kg/ha in 2018 (Table 8 and Figure 20). When compared to the 12-year average of 82 kg/ha, the 2019 standing crop estimate was approximately 10% greater (Figure 19).

The estimated standing crop for Brown Trout in Walker Creek was 179 kg/ha in 2019, a 27% decrease from the 2018 estimate of 245 kg/ha (Table 8 and Figure 20). The 2019 standing crop estimate was the sixth greatest value recorded in Walker Creek over the 21-year sampling period and the long-term average for this period is 139 kg/ha.

The estimated total standing crop for Brown Trout in the Lee Vining Creek main channel in 2019 was 192 kg/ha; an increase of 174% from the 2018 estimate of 70 kg/ha (Table 9 and Figure 21). The 2019 estimated standing crop of 192 kg/ha was the second highest estimate for the 20-year sampling period and the long-term average for this period is 125 kg/ha.

The estimated standing crop of Brown Trout in the Lee Vining Creek side channel was 25 kg/ha in 2019, which represented a 257% increase from the 2018 estimate of 7 kg/ha (Table 9 and Figure 21). No Rainbow Trout were captured in the Lee Vining Creek side channel in 2019 and none have been sampled in the side channel section for nine consecutive years (2011-2019).

Table 8. Comparison of Brown Trout standing crop (kg/ha) estimates between 2014 and 2019 for Rush Creek sections. These six years cover three drier years of 2014-2016, followed by the extremely wet RY 2017, the normal RY 2018 and the wet RY 2019.

Collection Location	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	2017 Total Standing Crop (kg/ha)	2018 Total Standing Crop (kg/ha)	2019 Total Standing Crop (kg/ha)	Percent Change Between 2018 and 2019
Rush Creek – Upper	167	123	62	123	188*	291**	+55%
Rush Creek - Bottomlands	52	59	34	50	103	91	-12%
Walker Creek	189	183	172	85	245	179	-27%

*includes 18.7 kg/ha of Rainbow Trout **includes 36.5 kg/ha of Rainbow Trout

Table 9. Comparison of total (Brown and Rainbow Trout) standing crop (kg/ha) estimates between 2014 and 2019 for the Lee Vining Creek sections. These six years cover three drier years of 2014-2016, followed by the extremely wet RY 2017, the normal RY 2018 and the wet RY 2019. The Rainbow Trout portion of the main channel's total estimated biomass is provided within the parentheses.

Collection Location	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	2017 Total Standing Crop (kg/ha)	2018 Total Standing Crop (kg/ha)	2019 Total Standing Crop (kg/ha)	Percent Change Between 2018 and 2019
Lee Vining Creek - Main Channel	140 (26.8)	150 (12.5)	113 (8.2)	21 (0)	70 (0)	192 (4.6)	+174%
Lee Vining Creek – Side Channel	30	45	31	20	7	25	+257%

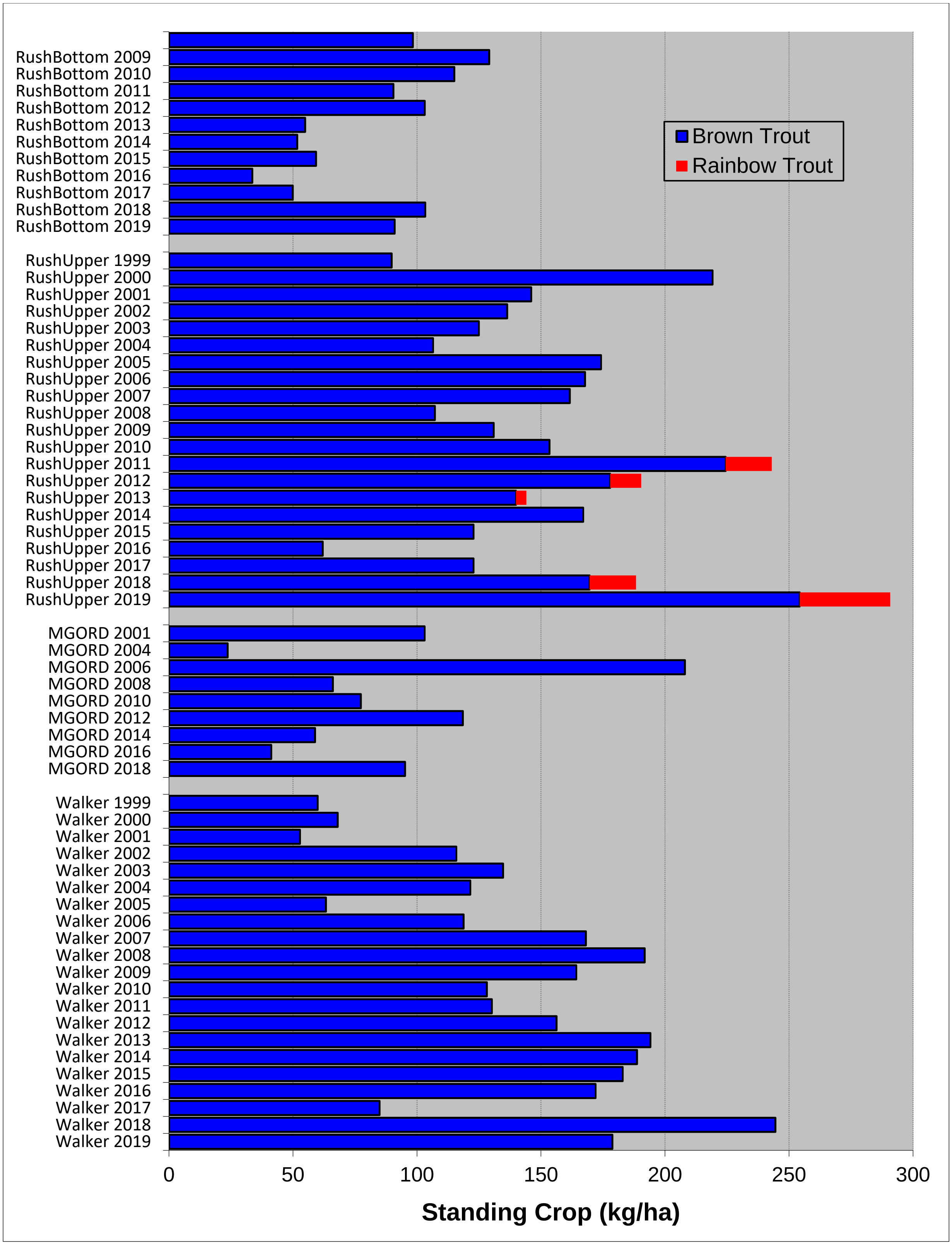

Figure 20. Estimated total standing crop (kilograms per hectare) of Brown Trout in Rush Creek sample sections from 1999 to 2019. NOTE: After 2001, MGORD estimates only made during even years.

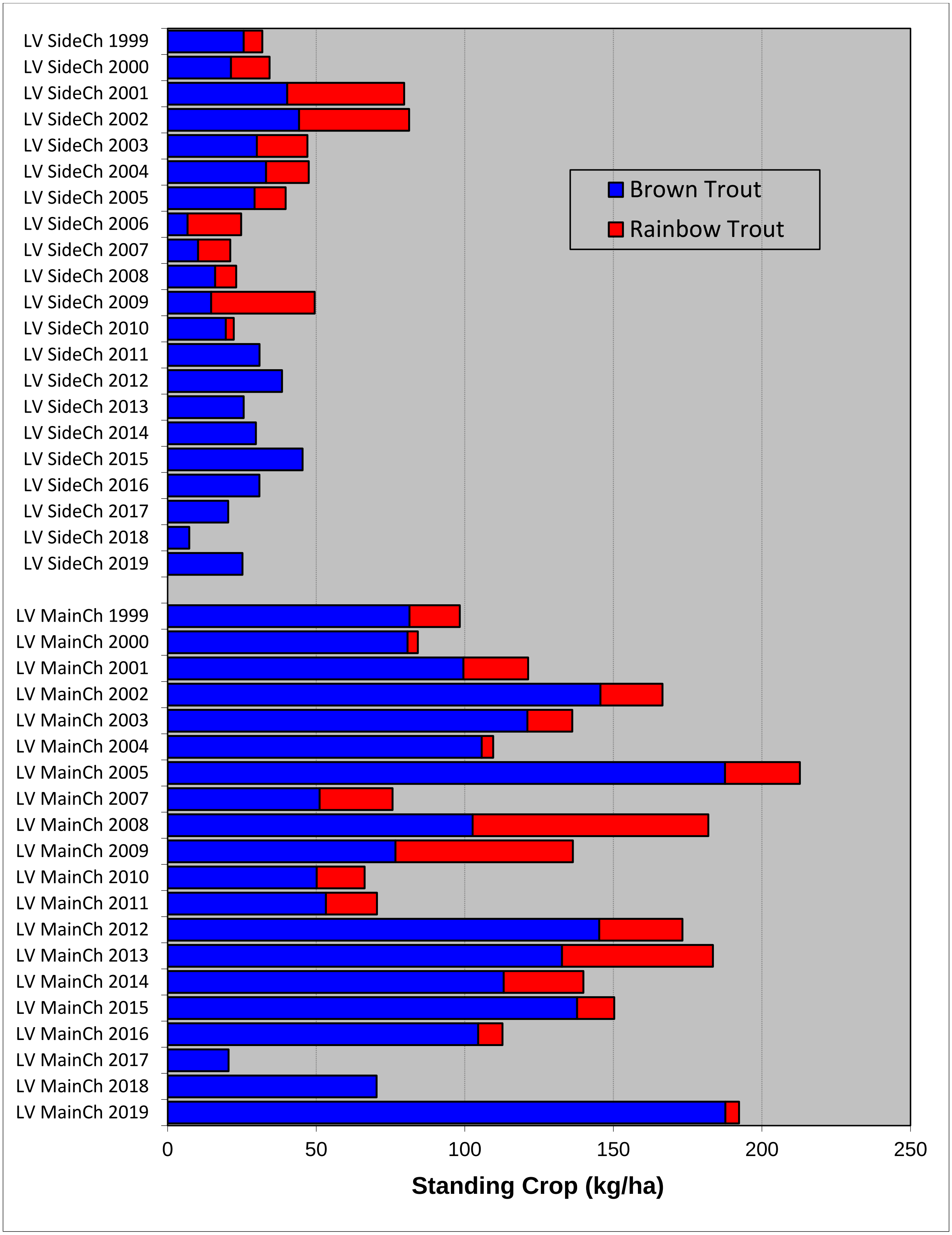

Figure 21. Estimated total standing crop (kilograms per hectare) of Brown Trout and Rainbow Trout (red) in Lee Vining Creek sample sections from 1999 to 2019.

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

In the Upper Rush section, the RSD-225 equaled 19 for 2019, the second straight year of large drops from the record RSD-255 value of 78 for 2017 (Table 10). The 2019 RSD-225 value was most likely influenced by greater numbers of fish, especially the numbers of fish smaller than 225 mm which comprised 81% of the trout ≥150 mm, a result of the increases in age-0 recruitment during the two previous post-drought years (Table 10). The RSD-300 value was 2 in 2019, compared to 9 in 2018 and 15 in 2017 (Table 10). This continued drop in RSD-300 value was influenced by the higher numbers of fish 150-224 mm caught in 2019 and a decrease in the numbers of Brown Trout >300 mm captured in 2019 (Table 10). Over 20 sampling years, a total of 148 Brown Trout ≥300 mm were captured in the Upper Rush Creek section, an average of 7.4 fish ≥300 mm per year (Table 10).

In the Bottomlands section of Rush Creek, the RSD-225 for 2019 equaled 8, the second straight year of large drops from 36 in 2018 and the record value of 65 in 2017 (Table 10). As in the Upper Rush section, the Bottomlands 2019 RSD-225 value was most likely influenced by greater numbers of fish, especially the numbers of fish smaller than 225 mm which comprised 92% of the trout ≥150 mm. The RSD-300 value was 0 in 2019 and only one Brown Trout ≥300 mm was captured in the Bottomlands section (Table 10). Over the 12 sampling years, a total of 26 Brown Trout ≥300 mm were captured in the Bottomlands section, an average of 2.2 fish ≥300 mm per year (Table 10).

In the MGORD, the RSD-225 value decreased from 88 in 2017 to 70 in 2018 to 47 in 2019; most likely due to larger numbers of trout <225 mm in length that were captured; which comprised 53% of the fish ≥150 mm (Table 10). In 2019, the RSD-300 value was 10, the second lowest RSD-300 value recorded in the MGORD for the 16 years of available data (Table 10). The RSD-375 value decreased from 11 in 2017 to 5 in 2018 to 1 in 2019; the lowest RSD-375 value recorded in the MGORD (Table 10). The single-pass catch of Brown Trout ≥150 mm in the MGORD during the 2019 season was 275 fish, which included: 28 fish ≥300 mm in length and four fish ≥375 mm in length (Table 10). For sampling conducted between 2001 and 2012, the annual average catch of Brown Trout ≥300 mm equaled 180 fish/year; then for the past seven sampling years the annual average catch of Brown Trout ≥300 mm equaled 39 fish/year (Table 10). This 78% decline in larger Brown Trout coincided with the five years of drier water-years and poor summer thermal regimes within the MGORD in 2012-2016; however numbers of larger (≥300 mm) Brown Trout caught in 2019 were comparable to the two previous one-pass seasons of 2017 and 2015 where drought effects likely impacted the survival of larger, older fish (Table 10).

RSD values in Lee Vining Creek were generated for the main channel only (Table 11). The RSD-225 value for main channel decreased from 24 in 2018 to 18 in 2019, most likely influenced by larger numbers of trout <225 mm in length that were captured; which comprised 81% of the fish ≥150 mm (Table 11). In 2019, two Brown Trout greater than 300 mm in length were captured in Lee Vining Creek main channel, which generated a RSD-300 value of 2 (Table 11).

Table 10. RSD values for Brown Trout in Rush Creek sections from 2000 to 2019.

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	**2019**	**503**	**406**	**85**	**11**	**1**	**19**	**2**	**0**
Upper Rush	2018	254	155	75	24	0	39	9	0
Upper Rush	2017	130	28	82	19	1	78	15	1
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	**2019**	**220**	**202**	**17**	**1**	**0**	**8**	**0**	**0**
Bottomlands	2018	140	90	41	9	0	36	6	0
Bottomlands	2017	82	29	49	4	0	65	5	0
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	**2019**	**275**	**145**	**102**	**24**	**4**	**47**	**10**	**1**
MGORD	2018	326	98	162	51	15	70	20	5
MGORD	2017	104	12	64	17	11	88	27	11
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

Table 10 (continued).

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
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 11. RSD values for Brown Trout in the Lee Vining Creek main channel section from 2000-2019.

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 Channel	**2019**	**131**	**107**	**22**	**2**	**0**	**18**	**2**
Main Channel	2018	51	39	10	2	0	24	4
Main Channel	2017	23	17	5	1	0	26	4
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	Not sampled in 2006 due to unsafe high flows						
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

PIT Tag Recaptures

PIT Tags Implanted between 2009 and 2019

Between 2009 and 2019, a total of 9,052 PIT tags were implanted in Brown Trout and Rainbow Trout within the annually sampled sections of Rush, Lee Vining and Walker Creeks (Appendix B). All PIT tagged fish received adipose fin clips. The numbers of PIT tags implanted each year varied according to fish availability and inventory of PIT tags, with year-specific information tabulated in the Appendix B.

In 2019, a total of 985 trout received PIT tags and adipose fin clips in Rush and Lee Vining creeks (Table 12). In addition, 15 recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 1,000 PIT tags were implanted during the 2019 fisheries sampling (Table 12). Of the 1,000 trout tagged, 784 were age-0 Brown Trout and 182 were age-1 and older Brown Trout (Table 12). For Rainbow Trout, 29 age-0 fish and five older fish were tagged (Table 12). One hundred sixty-seven of the age-1+ Brown Trout tagged in the MGORD section were ≤250 mm in total length and were presumed to be age-1 fish (Table 12). The 64 age-0 Brown Trout tagged in the MGORD were the most age-0 fish tagged in a single season within this section (Table 12). Tagged and recaptured fish provided empirical information to estimate fish growth, tag retention, fish movements, and survivals.

Table 12. Total numbers of trout implanted with PIT tags during the 2019 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	257	3*	28	0	**288 Trout**
	Bottomlands	152	3*	0	0	**155 Trout**
	MGORD	64	167** 8*	1	5	**245 Trout**
Lee Vining Creek	Main Channel	174	0	0	0	**174 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	137	1*	0	0	**138 Trout**
Age Class Sub-totals:		**784**	**182**	**29**	**5**	**Total Trout: 1,000**

*shed tag/new tag implanted **≤250 mm in total length

In September of 2019, a total of 92 previously tagged trout (that retained their tags) were recaptured in Rush Creek (Appendix C). Fifty-one of the recaptures occurred in the Upper Rush section (46 Brown Trout and five Rainbow Trout), followed by 16 recaptures in the Bottomlands section, 15 recaptures in Walker Creek and 10 recaptures in the MGORD (Appendix C). In

September of 2019, a total of 23 previously tagged Brown Trout (that retained their tags) were recaptured in the Lee Vining Creek main channel section (Appendix C).

In the following text, growth between 2018 and 2019 will be referred to as 2019 growth rates. A 2019 trout refers to a fish recaptured in September of 2019. An age of a PIT tagged trout reflects the age during the sampling year. For instance, an age-1 trout in 2019 indicates that a trout was tagged in September 2018 at age-0 and its length and weight were measured in September 2019 when it was recaptured.

Growth of Age-1 Brown Trout between 2018 and 2019

In 2019, a total of 74 known age-1 Brown Trout were recaptured that were tagged as age-0 fish in 2018, for an overall recapture rate of 9.8% (74/757 age-0 fish tagged in 2018). Of the 74 age-1 recaptures; 54 of these fish were from Rush Creek sections and 20 fish were from the Lee Vining Creek main channel section. Thus, by creek, the age-1 recapture rates for 2019 were 23% in Lee Vining Creek (29% in 2018 and 2.2% in 2017), 7.3% in Rush Creek (14.1 % in 2018, 19% in 2017 and 5% in 2016), and 18.6% in Walker Creek. These recapture rates suggest survival between age-0 and age-1 in Rush Creek decreased in 2019 and that survival rates in Lee Vining Creek in 2019 remained somewhat comparable to the previous year.

In the Upper Rush section, 25 age-1 Brown Trout were recaptured in 2019 and the average growth rates of these trout were 77 mm and 43 g (Table 13). Compared to 2018 rates, the average growth rates of the 25 age-1 Brown Trout were lower by 6 mm and 13 g (Table 13). Growth rates of age-1 Brown Trout in the Upper Rush section had generally declined annually from 2010 to 2014, but the 2015-2017 growth rates increased each year, with the 2017 growth rates the largest recorded for this section (Table 13). The 2019 average growth rates for age-1 Brown Trout were the lowest recorded for the past five years and the second consecutive decrease since the 2017 sampling (Table 13).

In the Bottomlands section of Rush Creek, 13 age-1 Brown Trout were recaptured in 2019 and the average growth rates of these trout were 74 mm and 38 g (Table 13). Compared to 2018 rates, the growth rates of the 13 age-1 Brown Trout were greater by 2 mm and lower by 4 g (Table 13). Growth rates of age-1 Brown Trout in the Bottomlands section had generally declined annually from 2010 to 2014, but the 2015-2017 growth rates increased each year, with the 2017 growth rates the largest recorded for this section (Table 13).

In Walker Creek, eight age-1 Brown Trout were captured in 2019 and the average growth rates of these eight trout were 55 mm and 28 g (Table 13). The growth rates of age-1 Brown Trout in Walker Creek have typically been lower than the rates documented in Rush and Lee Vining creeks (Table 13).

In Lee Vining Creek, 19 age-1 Brown Trout was recaptured in 2019 and the average growth rates of these trout were 71 mm and 41 g (Table 13). Compared to 2018 rates, the growth rates of the 19 age-1 Brown Trout were lower by 32 mm and 36 g (Table 13). Growth rates of age-1 Brown Trout in Lee Vining Creek have decreased for two straight years (Table 13).

Growth of Age-1 Rainbow Trout between 2018 and 2019

In 2019, a total of six known age-1 Rainbow Trout were recaptured that were tagged as age-0 fish in 2018, for an overall recapture rate of 7.4% (6/81 age-0 RBT tagged in 2018). Of the six age-1 recaptures; five of these fish were from the Upper Rush Creek section and one fish was from the Lee Vining Creek main channel. In Upper Rush Creek, the five age-1 Rainbow Trout captured in 2019 had average growth rates of 80 mm and 39 g. In Lee Vining Creek, the one age-1 Rainbow Trout had growth rates of 80 mm and 43 g (Table 13).

Growth of Age-2 Brown Trout between 2018 and 2019

In 2019, a total of 10 known age-2 Brown Trout were recaptured that were tagged as age-0 fish in 2017, for a recapture rate of 3.8% (10/262 age-0 fish tagged in 2017). Nine of these fish were recaptured in Rush Creek and one fish was captured in Lee Vining Creek. In addition, within the MGORD section of Rush Creek, seven Brown Trout were captured in 2019 that were tagged as presumed age-1 fish in 2018 and these presumed age-2 fish had a recapture rate of 4.7% (7/148 age-1 fish tagged in 2018).

Within the Upper section of Rush Creek, eight age-2 fish were recaptured in 2019 that had been tagged as age-0 fish in 2017 (Table 13). Between age-1 and age-2, the average growth rates of these eight Brown Trout were 48 mm and 71 g (Table 13). Compared to 2018 rates, the growth rates of the eight age-2 Brown Trout were greater by 9 mm and by 5 g (Table 13). The 2019 average growth rates were the second lowest recorded for the past five years (Table 13).

In the Bottomlands section of Rush Creek, one age-2 Brown Trout was recaptured in 2019 that had been tagged as age-0 fish in 2017. Between age-1 and age-2, the growth rates of this one Brown Trout were 36 mm and 44 g, 3 mm lower and 11 g lower than the average growth rates of the age-2 fish recaptured in 2018 (Table 13).

In Walker Creek, no age-0 Brown Trout were tagged during the 2017 sampling, thus no tagged age-2 fish were available for recapture during the 2019 sampling.

In the Vining Creek main channel section, one age-2 Brown Trout was recaptured in 2019 that had been tagged as age-0 fish in 2017. Between age-1 and age-2, the growth rates of this one Brown Trout were 80 mm and 43 g (Table 13).

Growth of Age-3 Brown Trout between 2018 and 2019

In 2019, one known age-3 Brown Trout was recaptured in the Upper Rush Creek section that was tagged as age-1 fish in 2017 (shed tag, new tag implanted). Between 2018 and 2019, this age-3 Brown Trout grew by 15 mm and 27 g (Table 13).

Table 13. Average growth (length and weight) of all Brown Trout recaptured from 2009 through 2019 by age. <u>Note:</u> *denotes only one PIT tagged fish recaptured. ✸denotes one fish that moved from Upper Rush to the MGORD.

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	2016 - 2017	2017 - 2018	2018 - 2019
Upper Rush Creek	Age 1	89/51	81/50	83/48	72/33	67/35		90/55	105/77	132/129	83/56	77/43
	Age 2		58/70	54/73	43/42	41/42		64/69	99/176✸	108/239	39/66	48/71
	Age 3				14/29		24/41				11/40*	15/27*
	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	118/96	72/42	74/38
	Age 2		50/54	35/32	30/28	27/22	32/29*	62/62			39/55	36/44*
	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	110/92*	103/77	71/41
	Age 2		66/95		77/110	33/34	35/29	47/40	47/49	77/128*		60/91*
	Age 3			34/92		23/48*	16/20*	27/32	42/75			
	Age 4				21/41*				25/47*			
	Age-5											
LV Main Channel RB Trout	Age 1					78/47		80/35				80/43*
	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	66/33		55/28
	Age 2		31/26	60/56	40/33	27/21	39/35		47/44	37/37	42/52	
	Age 3			28/44	18/12	9/2	20/36	27/29		42/59*	25/37	25/37
	Age 4				7/2	2/-16*		28/45*			27/37*	
	Age-5						0/-10*					

Growth of Age-4 Brown Trout between 2018 and 2019

In 2019, no known age-4 Brown Trout were recaptured in Upper Rush, the Bottomlands section of Rush Creek, Walker Creek or Lee Vining Creek. Only three known age-4 fish have been recaptured during the past five sampling years (Table 13).

Growth of MGORD Brown Trout between 2018 and 2019

Starting in September of 2017, PIT tagging of Brown Trout in the MGORD section of Rush Creek has been focused on age-0 and age-1 fish. Based on past years' length-frequency histograms and growth rates of know age-1 fish (from recaptures of previously tagged age-0 fish), a cut-off of 250 mm total length was made to define the likely upper limit for age-1 Brown Trout in the MGORD. Thus moving forward, most recaptures of previously tagged fish within the MGORD will allow us to compute annual growth rates of known age fish.

In 2019, one age-1 Brown Trout was captured in the MGORD that was tagged at age-0 in 2018 in the MGORD. Between 2018 and 2019, this fish grew by 124 mm and 106 g and at age-1 had a total length of 232 mm.

In 2019, a seven PIT tagged Brown Trout were recaptured in the MGORD that were PIT tagged in the MGORD as presumed age-1 fish in 2018. Between age-1 and age-2, the average growth rates of these seven Brown Trout were 56 mm and 98 g. These seven age-2 fish ranged from 256 mm to 308 mm in FL. The weight gain of 98 g for these age-2 Brown Trout from the MGORD is greater than any age-2 weight gain previously documented in any of the other annually sampled sections in Rush and Lee Vining creeks (Table 17).

One Brown Trout (Tag #98-9001006111290) was tagged in 2016 as a probable age-1 fish with a FL of 258 mm. This fish was recaptured each of the next three sampling seasons, 2017-2019. Between age-1 and age-2, this fish grew by 94 mm and 221 g. Between age-2 and age-3, this fish grew by 35 mm and 157 g. Between age-3 and age-4, this fish's growth slowed down considerably, with gains of only 14 mm and 3 g.

Growth of MGORD Brown Trout from non-consecutive years

Two additional age-2 Brown Trout were captured in the MGORD in 2019 that were tagged as age-0 fish in 2017; one of these fish was tagged at age-0 in the MGORD and the other was tagged at age-0 in the Upper Rush section. The fish residing within the MGORD grew by 175 mm and 197 between age-0 and age-2. The fish tagged in Upper Rush at age-0 and recaptured in the MGORD in 2019, grew by 145 mm and 167 g between age-0 and age-2.

The other non-consecutive year recapture within the MGORD in 2019 was of a Brown Trout tagged in 2014 at a total length of 286 mm (likely at age-3). This fish was initially recaptured in 2016 and grew by 167 mm and 845 g during this two-year time span. This fish was then recaptured in 2017 and grew by 43 mm and 336 g between 2016 and 2017. Its third recapture occurred in 2019 and the two-year growth between 2017 and 2019 was 78 mm and 1,112 g. This likely age-8 Brown Trout was 574 mm in total length and weighed 2,493 g with a condition factor of 1.32 when recaptured on 9/19/19.

Movement of PIT Tagged Trout between Sections

From 2009 to 2019 just over 9,000 PIT tags were surgically implanted in Brown Trout and Rainbow Trout in the following annually sampled sections: Upper Rush, County Road, Bottomlands, MGORD, and Walker Creek. Most recaptures have occurred in the same sections where fish were originally tagged. Between 2010 and 2019, 39 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 also documented some limited movement between the Bottomlands and County Road sections. From 2009 to 2013, no movement between other sections was documented. However in 2014, a large Brown Trout initially tagged in the MGORD was recaptured in the Bottomlands section.

In 2019, one Brown Trout recaptured in the MGORD had been tagged in the Upper Rush section in 2017. Because there was a two year gap between intial tagging at age-0 in Upper Rush and its recapture in the MGORD at age-2, it is unknown if the movement upstream to the MGORD occurred at age-1 or age-2. Also, without an antenna array at the lower end of the MGORD, we have no knowledge of timing or magnitude of movement of Brown Trout between the Upper Rush and MGORD sections.

PIT Tag Shed Rate of Trout Recaptured in 2019

In 2019, a total of 115 trout with adipose fin clips were recaptured and 23 of these fish failed to produce a PIT tag number when scanned with the tag reader (12 shed tags were from the MGORD, seven from Upper Rush, three were from the Bottomlands and one was from Walker Creek recaptures). Assuming that all these fish were previously PIT tagged, the 2019 calculated shed rate was 20% (23 shed tags/115 clipped fish recaptured). This rate was the highest shed we’ve experienced during the 11 years of PIT tagging fish in Rush and Lee Vining creeks. Retention rates tend to be higher in juvenile fish because adult salmonids are known to shed tags during spawning (Bateman et al. 2009). Also, tag retention rates have also been linked tagger’s experience and crew turnover rates, with less experienced taggers resulting in higher shed rates (Dare 2003). However, our crew members implanting tags has remained relatively stable.

Comparison of Length-at Age amongst Sample Sections

During the September 2019 sampling, three age-classes of PIT tagged Brown Trout were recaptured within four fisheries monitoring sections in Rush, Walker and Lee Vining creeks (Tables 14 and 15). 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 2013-2019 (Tables 14 and 15).

In Upper Rush, the average length-at-age-1 in 2019 was 173 mm, 20 mm lower than the average length-at-age-1 in 2018 and 70 mm lower than in 2017 (Table 14). Similar to the four previous years, in 2019, age-1 Brown Trout in Upper Rush were larger than age-1 fish in the Bottomlands section (Table 14). In the Bottomlands section, the average length-at-age-1 in 2018 was 168 mm, 13 mm less than the 2018 average length-at-age-1 and 43 mm less than in 2017 (Table 14).

In Upper Rush, the average length-at-age-2 in 2019 of eight age-2 Brown Trout was 237 mm, 37 mm less than the average length-at-age-2 in 2018 and 76 mm lower than in 2017 (Table 14). In the Bottomlands section, a single age-2 Brown Trout in 2019 had a length-at-age-2 of 212 mm, 55 mm lower than the average length-at-age-2 in 2018 (Table 14).

In 2019, a single PIT tagged age-3 Brown Trout was recaptured in the Upper Rush sampling section and at 251 mm in length this fish was 44 mm shorter than the length-at-age-3 of the one age-3 Brown Trout recaptured in 2018 (Table 14).

In 2019, no age-4 or age-5 fish with PIT tags were captured in the Upper or Bottomlands sections of Rush Creek. The 2014 sampling season was the last time PIT tagged age-4 Brown Trout were recaptured in Upper Rush or the Bottomlands section (Table 14).

For Walker Creek in 2019, eight age-1 Brown Trout were recaptured and the average length-at-age-1 was 159 mm, 7 mm less than the average length-at-age-1 in 2017 (no age-1 fish were available for recapture in 2018) (Table 14). In 2019, no age-2 Brown Trout were available for recapture in Walker Creek. In 2019, seven age-3 Brown Trout in Walker Creek were recaptured and the average length-at-age-3 was 220 mm, 7 mm less than in 2018 (Table 14). In 2019, no age-4 Brown Trout were recaptured in Walker Creek

In the Lee Vining Creek main channel, 19 age-1 Brown Trout were recaptured and the average length-at-age-1 for these Brown Trout caught in 2019 was 174 mm, 9 mm less than in 2018 (Table 15). In 2019, two previously tagged age-2 Brown Trout were recaptured and the average length-at-age-2 equalled 247 mm (Table 15). In 2019, no age-3 or age-4 Brown Trout were recaptured. In 2019, a single age-1 Rainbow Trout was recaptured and this fish was 165 mm in total length (Table 15).

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. However, the growth rates that Brown Trout exhibited in 2017 and 2018 confirmed that some age-2 and age-3 fish were near or just above lengths of 300 mm, the size class approaching the metrics of the pre-1941 fishery. These growth rates appear to be a function of relatively low fish densities and mostly favorable summer water temperature conditions in 2017 and 2018. However, increasing densities of trout during the past three years

(2017 through 2019) may have influenced the decline in growth rates observed between these three years. Summer water temperatures remained mostly favorable in 2019, yet growth rates dropped as fish densities continued to increase.

Table 14. Size range of PIT tagged fish recaptured in 2013-2019 by age class for Brown Trout at three electrofishing sections on Rush and Walker Creeks. NOTE: years omitted if no fish were caught.

Section	Cohort	Size Range (mm)	Average Length (mm)
Upper Rush	Age-1	**2019** = 128-202 **2018** = 158-232 **2017** = 224-264 **2016** = 192-237 **2015** = 169-203	**2019** = 173 **2018** = 193 **2017** = 243 **2016** = 208 **2015** = 187
	Age-2	**2019** =203-251 **2018** = 236-305 **2017** = 284-337 **2016** = 289* **2015** = 205-242	**2019** = 237 **2018** = 274 **2017** = 313 **2016** = 289* **2015** = 217
	Age-3	**2019** = 251 **2018** = 295 **2014** = 226-236 **2013** = 227-263	**2019** = 251 **2018** = 295 **2014** = 231 **2013** = 245
	Age-4	**2014** = 288 **2013** = 252-255	**2014** = 288 **2013** = 254
	Age-5	**2014** = 298	**2014** = 298
Bottomlands	Age-1	**2019** = 133-196 **2018** = 166-199 **2017** = 189-246 **2016** = 172-217 **2015** = 150-181	**2019** = 168 **2018** = 181 **2017** = 221 **2016** = 197 **2015** = 169
	Age-2	**2019** = 219 **2018** = 251-287 **2015** = 197-239 **2014** = 192 **2013** = 156-196	**2019** = 212 **2018** = 267 **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	**2019** = 141-168 **2017** = 151-179 **2016** = 145-187 **2015** = 133-177	**2019** = 159 **2017** = 166 **2016** = 167 **2015** = 154
	Age-2	**2018** = 191-221 **2017** = 180-224 **2016** = 180-226 **2014** = 168-200 **2013** = 181-208	**2018** = 210 **2017** = 202 **2016** = 201 **2014** = 186 **2013** = 197
	Age-3	**2019** = 215-235 **2018** = 204-245 **2017** = 238 **2015** = 211-231 **2014** = 207-222 **2013** = 219-221	**2019** = 220 **2018** = 228 **2017** = 238 **2015** = 219 **2014** = 217 **2013** = 220
	Age-4	**2018** = 265 **2015** = 249 **2014** = 211 **2013** = 219	**2018** = 265 **2015** = 249 **2014** = 211 **2013** = 219
	Age-5	**2014** = 220	**2014** = 220

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

Table 15. Size range of PIT tagged fish recaptured in 2013-2019 by age class 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)
Brown Trout in Lee Vining Main Channel	Age-1	**2019** = 142-209 **2018** = 170 -194 **2017** = 210 **2016** = 147-186 **2015** = 149-190	**2019** = 174 **2018** = 183 **2017** = 210 **2016** = 171 **2015** = 166
	Age-2	**2019** = 222-274 **2017** = 247 **2016** = 205-217 **2015** = 176-214 **2014** = 174-195 **2013** = 206-225	**2019** = 247 **2017** = 247 **2016** = 211 **2015** = 197 **2014** = 188 **2013** = 215
	Age-3	**2017** = 280-305 **2016** = 210-256 **2015** = 188-228 **2014** = 234-241 **2013** = 238-271	**2017** = 293 **2016** = 240 **2015** = 215 **2014** = 238 **2013** = 253
	Age-4	**2016** = 237	**2016** = 237
	Age-5	None captured in past seven years	
Rainbow Trout in Lee Vining Main Channel	Age-1	**2019** = 165 **2015** = 140-177	**2019** = 165 **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 seven years	
	Age-5	None captured in past seven years	

Summer Water Temperature

Compared to the drought years of 2013-2016, the 2017 summer water temperatures in all sections of Rush Creek were lower than during the four previous summers, providing trout a reprieve from previous stressful thermal conditions (Tables 16-19). Although RY 2018 was a normal year, GLR remained close to full due to rainfall and SCE's upstream maintenance operations, and this led to a second consecutive summer of mostly favorable water temperatures for Brown Trout growth and survival (Table 16). In 2019, the wet-year runoff and 33 day spill out of GLR also resulted in mostly favorable summer thermal condictions, with no peak temperatures above 70°F at any of the Rush Creek monitoring locations (Table 16). Daily mean temperatures, average daily minimum temperatures and average daily maximum temperatures were lower at all Rush Creek temperature monitoring locations in 2019 than in 2018 (Table 16).

Similar to the 2013-2018 annual reports, 2019 Rush Creek summer average daily water temperature data were classified based on its predicted influence on growth of Brown Trout 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 17). Development of these growth criteria were fully described in previous annual reports (Taylor 2013 and 2014). Using these growth prediction metrics, good potential growth days in 2019 varied from 62 to 76 days in Rush Creek out of the 92-day period from July 1 to

September 30 (Table 17). The range of the number of good thermal days in 2019 was more than the 23 to 58 good thermal days recorded in 2018 (Table 17). For all Rush Creek monitoring locations, most of the remaining days in 2019 were classified as “fair” potential growth days; with only four days at Top of MGORD and two days at Bottom of MGORD classified as poor growth days (Table 17).

As was done with the 2013 - 2018 data, the diurnal temperature fluctuations for July–September 2019 were characterized by the one-day maximum fluctuation that occurred each month and by monthly averages (Table 18). Also, for each temperature monitoring location, the highest average diurnal fluctuations over consecutive 21-day durations were determined (Table 18). The diurnal fluctuations throughout the summer of 2019 were relatively low at the Top of MGORD and Bottom of MGORD temperature monitoring locations, but diurnal fluctuations increased at the downstream monitoring locations, most likely due to effects of daily warming and nightly cooling of air temperatures (Table 18). Over the 21-day durations, these larger diurnal fluctuations were still below thresholds considered detrimental to trout growth during the summer of 2019 (Bell 2006). In September 2019, the diurnal fluctuations were greater than in September 2018, and it appears this was due to cooler minimum temperatures in 2019 (Table 18).

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 2013 through 2019. 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 19). The values from 2013 - 2018 were also included to better illustrate the variability that occurred at all the temperature monitoring locations (Table 19). The 2019 data show that all the temperature monitoring locations downstream of GLR experienced low numbers of hours bounded by the 66.2-71.6°F thermal window (Table 19). In the MGORD, hourly water temperatures exceeded 66.2°F less than 1% of the time and at the three downstream monitoring locations, hourly water temperatures of 66.2°F were exceeded less than 10% of the time (Table 19). In 2019, the Rush Creek County Road location had the most hours (86 hours) within the thermal window bounded by 66.2-71.6°F (Table 19).

In 2019, the water temperature monitoring locations Above Parker and Below Narrows continued to document cooler water accretions from Parker and Walker Creeks having a slight, yet positive, effect on Rush Creek’s summer thermal regime, including 7% more good growth thermal days downstream of the tributaries’ accretions (Tables 16-19). Conversely, the At Damsite water temperature monitoring location continued to provide data documenting the thermal loading in Rush Creek as flow passes through GLR and the MGORD, although during a wet-year runoff this thermal loading was less pronounced (Tables 16-19).

Summer water temperatures in Lee Vining Creek were all within the range of good growth potential during 2019. Regardless of water-year type, excessively warm water has not been an issue in Lee Vining Creek, thus detailed analyses were not performed with the 2019 data.

Table 16. Summary of water temperature data during the summer of RY 2019 (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 2013-2018 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
	2017 = 58.1	2017 = 57.5	2017 = 58.7	2017 = 0	2017 = 2.1	9/07/17
	2018 = 59.7	2018 = 58.9	2018 = 60.4	2018 = 0	2018 = 2.4	8/22/18
	2019 = 57.8	**2019 = 57.4**	**2019 = 58.5**	**2019 = 0**	**2019 = 2.3**	**8/21/19**
Rush Ck. – Top of MGORD	2013 = 63.1	2013 = 62.7	2013 = 63.7	2013 = 0	2013 = 3.4	7/09/13
	2014 = 64.8	2014 = 64.6	2014 = 65.0	2014 = 0	2014 = 3.9	8/13/14
	2015 = 64.4	2015 = 64.1	2015 = 64.8	2015 = 0	2015 = 2.1	7/03/15
	2016 = 63.8	2016 = 63.0	2016 = 64.7	2016 = 0	2016 = 6.5	7/07/16
	2017 = 57.0	2017 = 56.5	2017 = 58.1	2017 = 0	2017 = 5.4	9/07/17
	2018 = 60.7	2018 = 59.6	2018 = 61.9	2018 = 0	2018 = 6.7	8/20/18
	2019 = 58.5	**2019 = 57.2**	**2019 = 59.9**	**2019 = 0**	**2019 = 8.2**	**8/10/19**
Rush Ck. – Bottom MGORD	2013 = 63.2	2013 = 60.9	2013 = 67.1	2013 = 1	2013 = 9.0	7/09/13
	2014 = 64.8	2014 = 62.9	2014 = 68.5	2014 = 20	2014 = 8.3	7/13/14
	2015 = 64.4	2015 = 62.3	2015 = 68.0	2015 = 20	2015 = 8.4	7/06/15
	2016 = 63.8	2016 = 61.8	2016 = 66.9	2016 = 1	2016 = 8.0	7/04/16
	2017 = 57.1	2017 = 56.5	2017 = 58.5	2017 = 0	2017 = 6.4	9/07/17
	2018 = 61.0	2018 =58.9	2018 = 63.9	2018 = 0	2018 = 8.7	7/05/18
	2019 = 58.7	**2019 = 56.6**	**2019 = 61.3**	**2019 = 0**	**2019 = 8.1**	**8/10/19**
Rush Ck. – Old Highway 395 Bridge	2013 = 62.6	2013 = 58.8	2013 = 68.7	2013 = 40	2013 = 13.5	7/09/13
	2014 = 64.0	2014 = 60.5	2014 = 69.8	2014 = 51	2014 = 13.3	7/13/14
	2015 = N/A	2015 = N/A	2015 = N/A	2015 = N/A	2015 = N/A	N/A
	2016 = 63.5	2016 = 60.1	2016 = 68.8	2016 = 47	2016 = 12.5	7/11/16
	2017 = 59.0	2017 = 57.5	2017 = 61.0	2017 = 0	2017 = 7.6	9/07/17
	2018 = 60.9	2018 = 58.0	2018 = 65.3	2018 = 0	2018 = 10.9	7/10/18
	2019 = 58.7	**2019 = 56.1**	**2019 = 62.3**	**2019 = 0**	**2019 = 10.7**	**9/14/19**
Rush Ck. – Above Parker	2016 = 63.2	2016 = 58.8	2016 = 69.4	2016 = 55	2016 = 13.7	7/11/16
	2017 = 59.0	2017 = 57.2	2017 = 61.9	2017 = 0	2017 = 8.6	9/08/17
	2018 = 60.9	2018 = 57.2	2018 = 66.3	2018 = 0	2018 = 13.4	7/10/18
	2019 = 58.4	**2019 = 55.5**	**2019 = 62.3**	**2019 = 0**	**2019 = 11.8**	**9/14/19**
Rush Ck. – below Narrows	2013 = 61.2	2013 = 56.2	2013 = 67.6	2013 = 24	2013 = 16.3	7/19/13
	2014 = 63.2	2014 = 57.1	2014 = 69.4	2014 = 46	2014 = 17.3	7/26/14
	2015 = 62.3	2015 = 58.8	2015 = 66.1	2015 = 0	2015 = 11.5	9/23/15
	2016 = 61.7	2016 = 56.9	2016 = 68.3	2016 = 34	2016 = 14.3	7/13/16
	2017 = 58.4	2017 = 56.3	2017 = 61.3	2017 = 0	2017 = 8.2	9/07/17
	2018 = 60.0	2018 = 56.0	2018 = 65.4	2018 =0	2018 = 12.4	7/10/18
	2019 = 57.8	**2019 = 54.4**	**2019 = 62.2**	**2019 = 0**	**2019 = 12.7**	**9/22/19**
Rush Ck. – County Road	2013 = 61.4	2013 = 56.5	2013 = 66.6	2013 = 7	2013 = 14.7	8/02/13
	2014 = 62.0	2014 = 56.7	2014 = 67.8	2014 = 24	2014 = 17.6	7/26/14
	2015 = 62.1	2015 = 59.1	2015 = 65.5	2015 = 2	2015 = 9.2	7/28/15
	2016 = 61.6	2016 = 56.0	2016 = 68.3	2016 = 32	2016 = 16.1	7/11/16
	2017 = N/A	2017 = N/A	2017 = N/A	2017 = N/A	2017 = N/A	N/A
	2018 = N/A	2018 = N/A	2018 = N/A	2018 = N/A	2018 = N/A	N/A
	2019 = 58.2	**2019 = 54.0**	**2019 = 63.6**	**2019 = 0**	**2019 = 13.5**	**9/13/19**

Table 17. Classification of 2013-2019 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. ≤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%) 2017 = 88 (96%) 2018 = 53 (58%) **2019 = 76 (83%)**	2016 = 23 (25%) 2017 = 4 (4%) 2018 = 39 (42%) **2019 = 16 (17%)**	2016 = 0 2017 = 0 2018 = 0 **2019 = 0**	2016 = 0 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – Top of MGORD	2013 = 14 (15%) 2014 = 5 (6%) 2015 = 7 (8%) 2016 = 10 (11%) 2017 = 66 (71%) 2018 = 47 (51%) **2019 = 65 (71%)**	2013 = 43 (47%) 2014 = 14 (15%) 2015 = 20 (22%) 2016 = 32 (35%) 2017 = 26 (29%) 2018 = 42 (46%) **2019 = 23 (25%)**	2013 = 17 (18%) 2014 = 25 (27%) 2015 = 5 (5%) 2016 = 17 (18%) 2017 = 0 2018 = 3 (3%) **2019 = 4 (4%)**	2013 = 18 (20%) 2014 = 48 (52%) 2015 = 60 (65%) 2016 = 33 (36%) 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – Bottom MGORD	2013 = 11 (12%) 2014 = 6 (6%) 2015 = 8 (9%) 2016 = 9 (10%) 2017 = 67 (73%) 2018 = 48 (52%) **2019 = 62 (68%)**	2013 = 38 (41%) 2014 = 11 (12%) 2015 = 20 (22%) 2016 = 31 (34%) 2017 = 25 (27%) 2018 = 42 (46%) **2019 = 28 (30%)**	2013 = 20 (22%) 2014 = 21 (23%) 2015 = 5 (6%) 2016 = 16 (17%) 2017 = 0 2018 = 2 (2%) **2019 = 2 (2%)**	2013 = 23 (25%) 2014 = 54 (59%) 2015 = 59 (64%) 2016 = 36 (39%) 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – Old Highway 395 Bridge	2013 = 14 (15%) 2014 = 7 (8%) 2015 = N/A 2016 = 16 (17%) 2017 = 75 (82%) 2018 = 36 (39%) **2019 = 64 (70%)**	2013 = 41 (45%) 2014 = 25 (27%) 2015 = N/A 2016 = 24 (26%) 2017 = 17 (18%) 2018 = 56 (61%) **2019 = 28 (30%)**	2013 = 33 (36%) 2014 = 27 (29%) 2015 = N/A 2016 = 19 (21%) 2017 = 0 2018 = 0 **2019 = 0**	2013 = 4 (4%) 2014 = 33 (36%) 2015 = N/A 2016 = 33 (36%) 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – Above Parker Ck.	2016 = 17 (18%) 2017 = 65 (71%) 2018 = 28 (30%) **2019 = 67 (73%)**	2016 = 26 (28%) 2017 = 27 (29%) 2018 = 64 (70%) **2019 = 25 (27%)**	2016 = 24 (26%) 2017 = 0 2018 = 0 **2019 = 0**	2016 = 25 (27%) 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – Below Narrows	2013 = 17 (18%) 2014 = 13 (14%) 2015 = 24 (26%) 2016 = 22 (24%) 2017 = 75 (82%) 2018 = 46 (50%) **2019 = 74 (80%)**	2013 = 69 (75%) 2014 = 58 (63%) 2015 = 44 (48%) 2016 = 52 (57%) 2017 = 17 (18%) 2018 = 46 (50%) **2019 = 18 (20%)**	2013 = 6 (7%) 2014 = 18 (20%) 2015 = 22 (24%) 2016 = 16 (17%) 2017 = 0 2018 = 0 **2019 = 0**	2013 = 0 2014 = 3 (3%) 2015 =2 (2%) 2016 = 2 (2%) 2017 = 0 2018 = 0 **2019 = 0**
Rush Ck. – County Road	2013 = 17 (18%) 2014 = 17 (18%) 2015 = 25 (27%) 2016 = 24 (26%) 2017 = N/A 2018 = N/A **2019 = 71 (77%)**	2013 = 64 (70%) 2014 = 59 (65%) 2015 = 39 (42%) 2016 = 50 (54%) 2017 = N/A 2018 = N/A **2019 = 21 (23%)**	2013 = 8 (9%) 2014 = 14 (15%) 2015 =23 (25%) 2016 = 13 (14%) 2017 = N/A 2018 = N/A **2019 = 0**	2013 = 3 (3%) 2014 = 2 (2%) 2015 = 5 (6%) 2016 = 5 (6%) 2017 = N/A 2018 = N/A **2019 = 0**

Table 18. Diurnal temperature fluctuations in Rush Creek for 2019: 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: 2018 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 = 1.1°F (2.0) Ave = 0.3°F (1.0)	Max = 2.3°F (2.4) Ave = 1.6°F (1.5)	Max = 1.9°F (2.4) Ave = 1.3°F (1.6)	1.9 °F (1.9) Aug-12 – Sept 1
Rush Ck. – Top of MGORD	Max = 5.5°F (4.0) Ave = 2.3°F (2.6)	Max = 8.2°F (6.7) Ave = 3.8°F (3.0)	Max = 6.2°F (1.8) Ave = 2.1°F (1.0)	4.1°F (3.4) July 30 – Aug 19
Rush Ck. – Bottom MGORD	Max = 6.4°F (8.7) Ave = 3.4°F (6.1)	Max = 8.1°F (7.2) Ave = 5.0°F (4.7)	Max = 7.9°F (5.3) Ave = 6.3°F (4.0)	6.1°F (6.5) Sept 1 – 21
Rush Ck. – Old Highway 395 Bridge	Max = 6.7°F (10.9) Ave = 4.0°F (8.4)	Max = 8.2°F (8.6) Ave = 6.3°F (6.7)	Max = 10.7°F (8.6) Ave = 8.4°F (6.6)	8.7°F (8.8) Sept 6 - 28
Rush Ck. – Above Parker Ck.	Max = 7.0°F (13.4) Ave = 4.4°F (10.3)	Max = 9.7°F (10.6) Ave = 7.0°F (8.4)	Max = 11.8°F (10.9) Ave = 9.1°F (8.6)	9.7°F (10.8) Sept 6 - 26
Rush Ck. – below Narrows	Max = 7.6°F (12.4) Ave = 5.2°F (9.6)	Max = 10.4°F (11.0) Ave = 7.9°F (9.0)	Max = 12.7°F (12.1) Ave = 10.2°F (9.7)	10.8°F (10.2) Sept 6 -28
Rush Ck. – County Road	Max = 9.3°F Ave = 7.4°F	Max = 13.2°F Ave = 10.3°F	Max = 13.5°F Ave = 11.0°F	11.7°F Sept 7 - 27

Table 19. Number of hours (percent of hours in parentheses) that temperature exceeded 66.2°F in Rush Creek: by month and for 92-day period from July 1 to September 30, 2013 - 2019. The total number of hours within each month is shown in parentheses in the column headings.

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 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**	2016 = 0 hrs 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**	2016 = 0 hrs 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**	2016 = 0 hrs 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**
Rush Ck. – Top of MGORD	2013 = 4 hrs (0.5%) 2014 = 315 hrs (42%) 2015 = 140 hrs (19%) 2016 = 42 hrs (6%) 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**	2013 = 4 hrs (0.5%) 2014 = 96 hrs (13%) 2015 = 205 hrs (28%) 2016 = 127 hrs (17%) 2017 = 0 hrs 2018 = 6 hrs **2019 = 0 hrs**	2013 = 0 hrs 2014 = 0 hrs 2015 = 0 hrs 2016 = 0 hrs 2017 = 0 hrs 2018 = 0 hrs **2019 = 13 hrs**	2013 = 8 hrs (0.4%) 2014 = 411 hrs (19%) 2015 = 345 hrs (16%) 2016 = 169 hrs (8%) 2017 = 0 hrs 2018 = 6 hrs (0.3%) **2019 = 13 hrs (0.6%)**
Rush Ck. – Bottom MGORD	2013 = 121 hrs (16%) 2014 = 282 hrs (38%) 2015 = 305 hrs (41%) 2016 = 142 hrs (19%) 2017 = 0 hrs 2018 = 0 hrs **2019 = 0 hrs**	2013 = 229 hrs (31%) 2014 = 248 hrs (33%) 2015 =282 hrs (38%) 2016 = 268 hrs (36%) 2017 = 0 hrs 2018 = 1 hr (0.01%) **2019 = 0 hrs**	2013 = 61 hrs (9%) 2014 = 115 hrs (16%) 2015 = 17 hrs (2%) 2016 = 38 hrs (5%) 2017 = 2 hrs (0.3%) 2018 = 1 hr (0.01%) **2019 = 46 hrs (6%)**	2013 = 411 hrs (19%) 2014 = 645 hrs (29%) 2015 = 604 hrs (27%) 2016 = 448 hrs (20%) 2017 = 2 hrs (0.09%) 2018 = 2 hrs (0.09%) **2019 = 46 hrs (2.1%)**
Rush Ck. – Old 395 Bridge	2013 = 181 hrs (24%) 2014 = 287 hrs (39%) 2016 = 216 hrs (29%) 2017 = 0 hrs 2018 = 17 hrs (2%) **2019 = 0 hrs**	2013 = 228 hrs (31%) 2014 = 248 hrs (33%) 2016 = 263 hrs (35%) 2017 = 0 hrs 2018 = 32 hrs (4%) **2019 = 4 hrs (0.5%)**	2013 = 73 hrs (10%) 2014 = 117 hrs (16%) 2016 = 53 hrs (7%) 2017 = 3 hrs (0.4%) 2018 = 33 hrs (5%) **2019 = 41 hrs (6%)**	2013 = 482 hrs (22%) 2014 = 639 hrs (29%) 2016 = 532 hrs (24%) 2017 = 3 hrs = (0.1%) 2018 = 82 hrs (4%) **2019 = 45 hrs (2%)**
Rush Ck. – Above Parker Creek	2016 = 240 hrs (32%) 2017 = 0 hrs 2018 = 70 hrs (9%) **2019 = 0 hrs**	2016 = 269 hrs (36%) 2017 = 0 hrs 2018 = 68 hrs (9%) **2019 = 11 hrs (2%)**	2016 = 65 hrs (9%) 2017 = 14 hrs (2%) 2018 = 44 hrs (6%) **2019 = 27 hrs (4%)**	2016 = 574 hrs (26%) 2017 = 14 hrs (0.6%) 2018 = 182 hrs (8%) **2019 = 38 hrs (2%)**
Rush Ck. – below Narrows	2013 = 158 hrs (21%) 2014 = 244 hrs (33%) 2015 = 129 hrs (17%) 2016 = 167 hrs (22%) 2017 = 0 hrs 2018 = 36 hrs (5%) **2019 = 0 hrs**	2013 = 192 hrs (26%) 2014 = 193 hrs (26%) 2015 = 189 hrs (25%) 2016 = 222 hrs (30%) 2017 = 0 hrs 2018 = 42 hrs (6%) **2019 = 13 hrs (2%)**	2013 = 55 hrs (7%) 2014 = 105 hrs (15%) 2015 = 0 hrs (0%) 2016 = 49 hrs (7%) 2017 = 0 hrs 2018 = 36 hrs (5%) **2019 = 8 hrs (1%)**	2013 = 405 hrs (18%) 2014 = 542 hrs (25%) 2015 = 318 hrs (14%) 2016 = 438 hrs (20%) 2017 = 0 hrs 2018 = 114 hrs (5%) **2019 = 21 hrs (1%)**
Rush Ck. – County Road	2013 = 197 hrs (27%) 2014 = 222 hrs (30%) 2015 = 174 hrs (23%) 2016 = 212 hrs (28%) 2017 = N/A 2018 = N/A **2019 = 0 hrs**	2013 = 172 hrs (23%) 2014 = 195 hrs (26%) 2015 = 119 hrs (16%) 2016 = 233 hrs (31%) 2017 = N/A 2018 = N/A **2019 = 76 hrs (10%)**	2013 = 42 hrs (6%) 2014 = 79 hrs (11%) 2015 = 0 hrs (0%) 2016 = 42 hrs (6%) 2017 = N/A 2018 = N/A **2019 = 10 hrs (1%)**	2013 = 411 hrs (19%) 2014 = 496 hrs (23%) 2015 = 293 hrs (13%) 2016 = 487 hrs (22%) 2017 = N/A 2018 = N/A **2019 = 86 hrs (4%)**

Discussion

The 2019 sampling year documented fish populations responding favorably in Rush Creek to better water conditions related to a third continuous year of high storage levels in GLR. Wet-year peak flows (including 33 day spill) in conjunction with cooler summer water temperatures in 2019 appeared to facilitate a continued recovery of the trout populations from the previous five years of drought. Population estimates of age-0 and age-1 and older trout increased for a third consecutive year; however apparent survival rates dropped from the previous year. Thus, this report's Discussion is focused on the trout populations' response to the Wet RY2019, mostly favorable summer water temperatures and the resulting increases in densities of fish.

2019 Summer Water Temperature, Fish Densities and Trout Growth Rates

The 2019 Brown Trout growth, as measured by weight gains of PIT tagged fish, between age-0 and age-1 in the Upper Rush and Bottomlands sampling sections was less than the long-term averages (Table 20). In the Upper Rush section, the weight gain of age-1 fish was 39 g in 2019, nearly 16 g less than the long-term average (Table 20). Similarly, in the Bottomlands section, the 2019 weight gain of age-1 Brown Trout was 38 g, almost 7 g lower than the long-term average (Table 20).

The Upper Rush section's age-2 recaptures gained an average of 71 g between 2018 and 2019; a growth rate 23 g lower than the average growth rate (94.2 g) for the nine years of available tag return data (Table 20). The below average growth rates documented in 2018 and 2019 suggest that a combination of increasing densities of fish was an important factor, even with mostly favorable summer water temperatures. In the Upper Rush section, as densities of all age classes of Brown Trout have increased since 2017, growth rates of age-1 fish decreased by 70% and growth rates of age-2 fish decreased by 60% (Table 20).

Studies have determined that trout growth in streams is a complex interaction of population density, water temperature and food availability (Baerum et al. 2013). Conditions in Rush Creek during 2017 were favorable for the record growth we documented with respect to multiple variables, especially low fish densities and cool summer water temperatures. Then in 2018 growth rates dropped with mostly favorable summer water temperatures, but Brown Trout densities increased in all monitoring sections. In 2019, the wet-year runoff resulted in more favorable summer water temperatures than 2018, yet growth rates continued to drop as fish densities increased. 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, 14 years (2006-2019) 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 22). Trend lines through each of the population estimates strongly suggest that density-dependent growth of age-0 fish does occur in the Upper Rush section (Figure 22). In the past three years, average weights of age-0 Brown Trout sampled from the Upper Rush section dropped from 12.3 g in 2017 to 8.6 g in 2018 to 6.3 g in 2019. Similarly, in the Bottomlands section average weights of age-0 Brown Trout dropped from 13.7 g in 2017 to 6.8 g in 2018; a 50% decrease in average weights when densities of age-0 fish increased tenfold. In 2019, the average weight of age-0 Brown Trout in the Bottomlands section equaled 6.4 g.

Table 20. Annual growth rate (g) for PIT tagged or fin-clipped age-0 to age-1 and age-1 to age-2 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
	2016-2017	129	96	PIT Tag
	2017-2018	56	42	PIT Tag
	2018-2019	**39**	**38**	PIT Tag
	Long-term Ave.	*54.8*	*44.8*	
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
	2016-2017	239	N/A	PIT Tag
	2017-2018	66	55	PIT Tag
	2018-2019	**71**	**44**	PIT Tag
	Long-term Ave.	*94.2*	*40.8*	

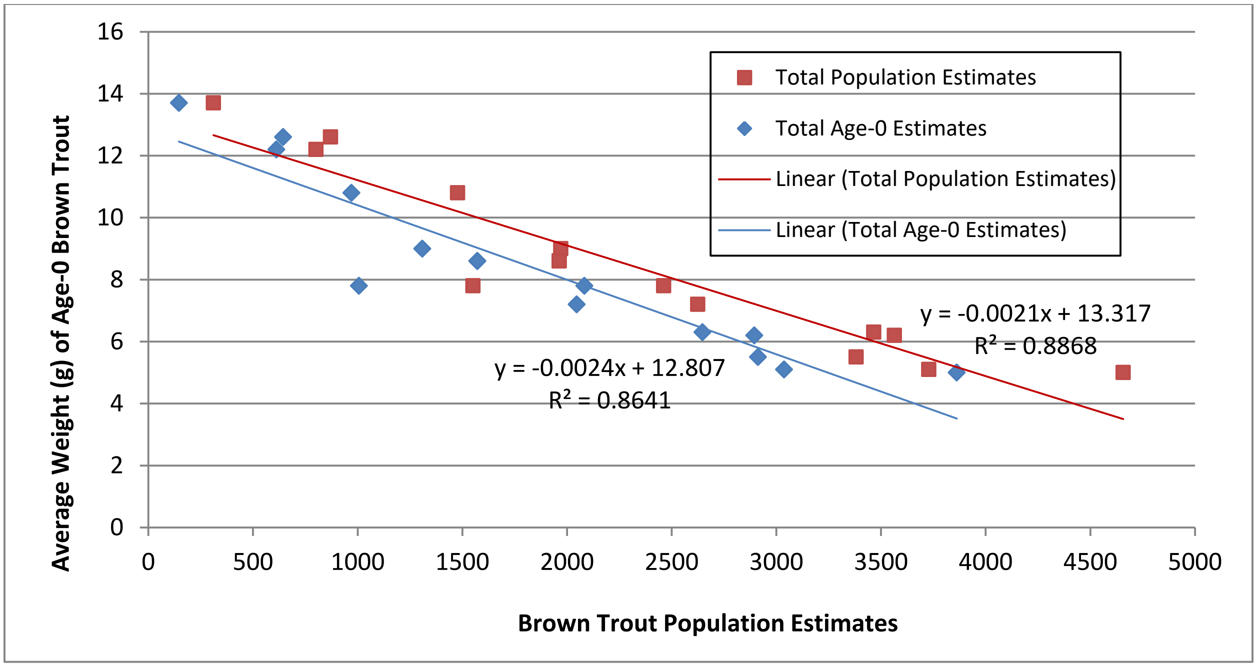

Figure 22. Relationship between average weights of age-0 brown trout and population estimates (age-0 and all trout) in the Upper Rush sampling section, 2006-2019.

Apparent Survival Rates

Apparent survival rates of age-1 Brown Trout were calculated with the following equation: [# age-1 recaps in 2019/capture probability of age-1 fish] ÷ [# age-0 tagged in 2018 - # shed tags]. For mark-recapture sections, capture probabilities were derived from the recapture run data: # of recaptures/# of captures. Compared to the 2018 survival rates, the 2019 apparent survival rates decreased by 33% in Upper Rush Creek and by 55% in the Bottomlands section of Rush Creek (Table 25). In Lee Vining Creek, the age-1 Brown Trout apparent survival rates decreased by 30% from 2018 to 2019 (Table 25).

Table 25. Apparent survival rates of age-1 Brown Trout in Rush, Walker and Lee Vining creeks in 2018. The 2016 values are in parentheses for comparisons.

Creek and Section	Capture Probability	No. Age-1 Recaps in 2019	No. Age-0 Tagged in 2018	No. Shed Tags	Apparent Survival Rate
Rush – Upper	0.46	25	314	2	2016 = 22.7% 2017 = 106% 2018 = 50.2% **2019 = 17.4%**
Rush - Bottomlands	0.38	13	288	3	2016 = 9.7% 2017 = 72.3% 2018 = 66.8% **2019 = 12.0%**

Walker Creek	0.96	8	43	1	2016 = 37.8% 2017 = 7.0% 2018 = N/A **2019 = 19.8%**
Lee Vining Creek	0.56	19	87	0	2016 = 46.3% 2017 = 4.8% 2018 = 70.6% **2019 = 40.0%**

Associations between Brown Trout Metrics and Rush Creek Flows, Water Temperatures and Grant Lake Reservoir Storage

Given the large rebound of Brown Trout population and density estimates in Rush Creek in the three years (2017-2019) since the five-year drought period, further analyses were conducted to examine the associations between fish metrics and flow, water temperatures and storage levels in GLR. These analyses utilized the same methods as the effort conducted by the fisheries consulting team prior to development of the Synthesis Report (Shepard et al. 2009). This current effort used additional data collected from 2009 to 2019 (Table 26).

Methods – Sample Sites

Fish, water temperature and stream flow data were collected at standard sample sites according to methods described by Shepard et al. (2009). LADWP monitored daily flows at several locations throughout the Mono Basin. Flows in the MGORD, Grant Dam spill, and 5-siphon outflow were added together to compute flows for the Upper Rush fish sampling site. The 5-siphon outflow only had flows for short periods of time during 2005, 2006, and 2008, when flow tests were conducted. Flows for these three sites were added to flows from Walker (Station 5003) and Parker (Station 5002) creeks to estimate flows in Rush Creek at the lower fish sampling sites. Water temperature data were collected by McBain and Trush, LADWP and/or the MLC. We assumed that fish metrics in the County Road fish sampling section (sampled from 1999 through 2013) and fish metrics from the Bottomlands fish sampling section (sampled from 2008 through 2019) represented the same conditions for fish in lower Rush Creek. The six years of overlapping data from these two sampling locations had similar trends in population and density estimates.

Methods – Rush Creek Flows

Summer flows in Rush Creek were summarized for the period June 1 through September 30. The highest summer flows for the years 1999 through 2019 occurred during 2017 and the lowest occurred during 2007 (Figure 2). Flow metrics used in these analyses were minimum annual flow (cfs), maximum annual flow, mean summer flow, number of days summer flows were less than 50 cfs, number of days summer flows were greater than 150 cfs, mean flow in June, mean flow in July, mean flow in August, and mean flow in September. We used flows summed for the MGORD, GLR spill, and 5-siphon outflows to estimate flows at the Upper Rush fish sampling site (Figure 23). We used the above estimated flows plus flows contributed from Walker and Parker creeks to estimate flows below the Narrows area for the fish sampling sites at County Road and Bottomlands in Rush Creek.

Table 26. Parameters estimated for assessing associations between Brown Trout metrics and flow, water temperature and GLR storage variables in Rush Creek from 1999 to 2019.

Parameter estimated	Units	Abbreviation
Fulton-type condition factor (K)	None	K
Biomass of all brown trout (age-0 and older)	kg/ha	Biom
Density of age-0 brown trout	#/ha	Dens0
Density of age-1 and older brown trout	#/ha	Dens1
Minimum annual flow	cfs	MinAnnFlow
Maximum annual flow	cfs	MaxAnnFlow
Mean summer flow	cfs	Mean6_9Flow
Days summer flows < 50 cfs	days	SumDays.50
Days summer flows >150 cfs	days	SumDays.150
Mean flow in June	cfs	June_Flow
Mean flow in July	cfs	July_Flow
Mean flow in August	cfs	Aug_Flow
Mean flow in September	cfs	Sept_Flow
Grant mean summer storage	acre-ft	GrantMean
Grant maximum summer storage	acre-ft	GrantMax
Grant minimum summer storage	acre-ft	GrantMin
Average summer water temperature	^{o}F	Avg_Sum_Temp
Average max daily summer water temp	^{o}F	Avg_Max_Daily.Sum_Temp
Days water temperature > 70 F	days	DaysGT70F
Days water temperature ≥ 67 F	days	Days.GT67F
Days water temperature 52 to 66 F	days	Days_Ideal_Temp
Average length of fish < 125 mm	mm	AvgL.0

Methods – Grant Lake Reservoir Storage

Data for daily reservoir elevations (feet MSL) and reservoir volumes (acre-feet) of GLR from 1996 through January 21, 2009 were obtained from LADWP. GLR daily storage estimates, but not water surface elevations, for the period January 22, 2009 to December 31, 2012 were obtained from the Mono Lake Committee. Daily reservoir elevations for GLR from January 1, 2013 to December 31, 2019 were obtained from LADWP. We used mean summer (May 1 through September 30), maximum summer, and minimum summer water surface elevations (MSL; ft) for the years 2013 to 2019 to derive annual summer mean, maximum, and minimum water volumes (acre-feet) from 2013 through 2019 (Figure 24).

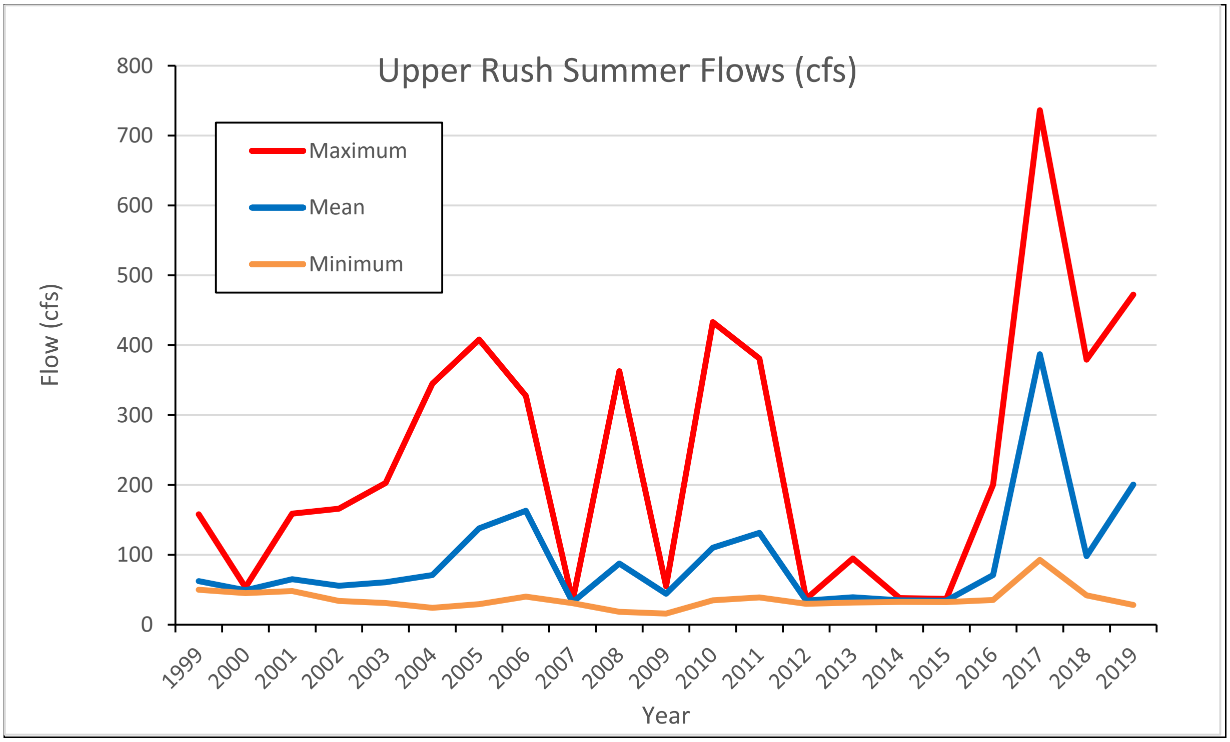

Figure 23. Mean, minimum and maximum summer flows (June 1 to September 30) by year in upper Rush Creek.

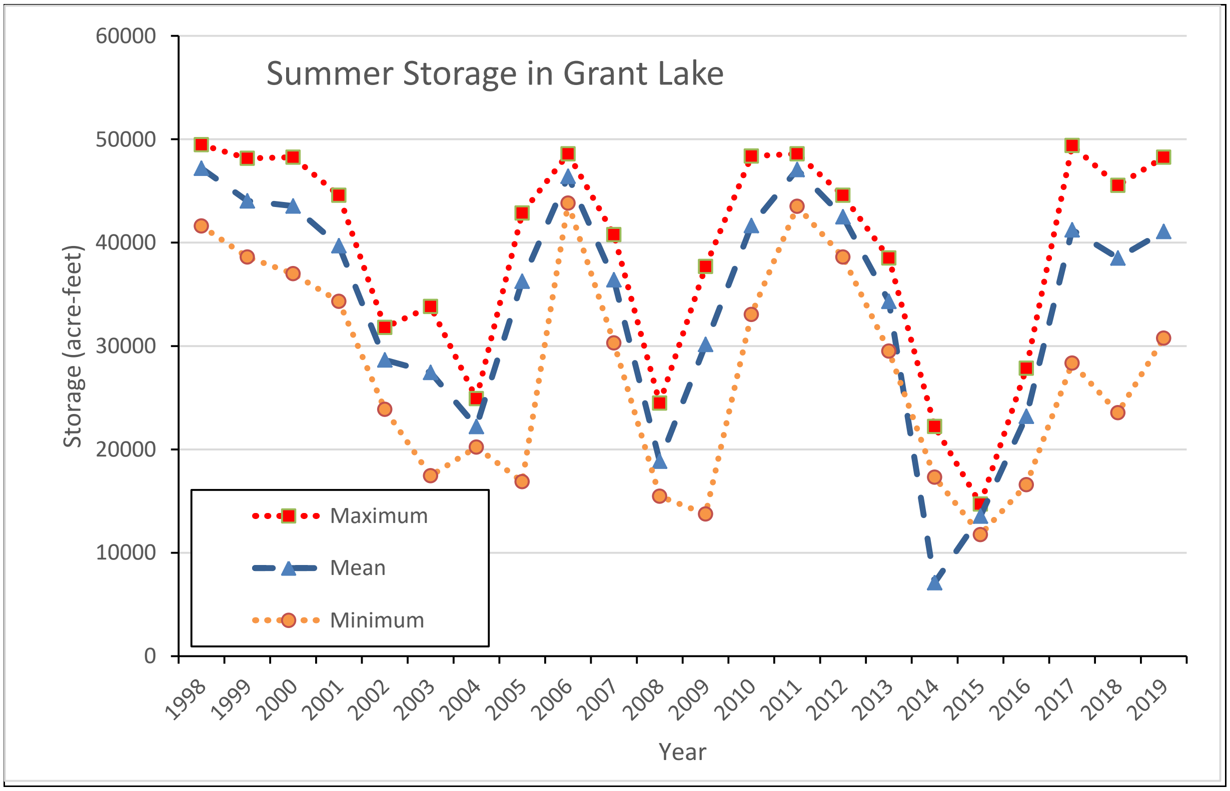

Figure 24 Mean, minimum and maximum summer storage (June 1 to September 30; acre-feet) by year in Grant Lake Reservoir.

Methods – Rush Creek Water Temperatures

Average summer temperature (June 1 to September 30) was computed as the average of all average daily temperatures during the summer, the average maximum summer temperature as the average of all the daily maximum temperatures, the number of days maximum daily temperatures exceeded or were equal to 67^{o}F and 70^{o}F, and the number of days all measured water temperatures fell within an ideal temperature range (52^{o}F to 66^{o}F) for growth of Brown Trout (Elliott and Hurley 1999). For 2013, minimum and maximum daily water temperatures at the Narrows and County Road sites in Rush Creek were only available from July 1 to August 31 and then only had hourly temperatures from September 1 to December 20. For the bottom of the MGORD during 2013, hourly temperatures were available for all days from January 1 to December 20.

Methods – Rush Creek Brown Trout Metrics

The same metrics as Shepard et al. (2009) were evaluated for Brown Trout from all Rush Creek sampling sections. For age-0 fish we used average total length (TL) of age-0 (<125 mm) and density of age-0 fish (number/ha). For age-1 and older fish we evaluated condition factor (K) of Brown Trout 150 to 250 mm in TL and total biomass (kg/ha) of age-1 and older fish.

Results – Brown Trout Conditions Factors

Average condition factors (K) of fish 150 to 250 mm ranged from 0.95 to 1.01 in the five fish sampling sections from 1999 to 2019 (Figure 25). Spearman rank correlations indicated that neither flow nor GLR summer storage variables were significantly ($p=0.05$) correlated to estimates of fish condition with correlation coefficients for all these variables less than 0.25. Water temperature variables were more highly correlated than flow and GLR storage variables (coefficients ranging from 0.42 to 0.51; $p<0.01$). Water temperature variables with negative correlations to condition factors were average summer temperature, average maximum daily summer temperatures and number of days that water temperatures exceeded 67^{o}F or 70^{o}F. The number of days that water temperatures fell within the ideal range of 52^{o}F to 66^{o}F was positively correlated to condition factor. Since only water temperature variables were significantly correlated to condition factor, a simple regression analysis was conducted comparing condition factor to number of days with ideal water temperatures (Figure 26).

Shepard et al. (2009) found that mean summer storage of GLR was the best model that explained variation in condition of Brown Trout 150 to 250 mm (adjusted-r^2 = 0.16; $p<0.05$). The current analyses with all data from 1999 to 2019 indicated that the number of days with ideal water temperatures was the best and simplest model related to fish condition (adjusted-r^2 = 0.24; $p<0.01$). This current model performed better than the older model with higher statistical significance and adjusted-r^2 values. It makes biological sense that more days of ideal water temperatures for Brown Trout growth would result in better fish condition. Shepard et al. (2009) found that flow and GLR elevations were often correlated to water temperatures. Shepard et al. (2009) also found that a model with multiple independent covariates including minimum annual flow, mean summer flow, and days of ideal water temperatures best explained variation in fish condition (adjusted-R^2 = 0.638; *P<0.01*). For this current analysis, we re-tested this multiple-regression model using the current data and found that the three-way interaction of the three independent variables were significant (p<0.05), a finding not exposed during the earlier (Shepard et al. 2009) analyses. Measuring water temperatures will probably provide the best indicator for fish growth and we recommend continuing to measure hourly water temperatures throughout Rush Creek.

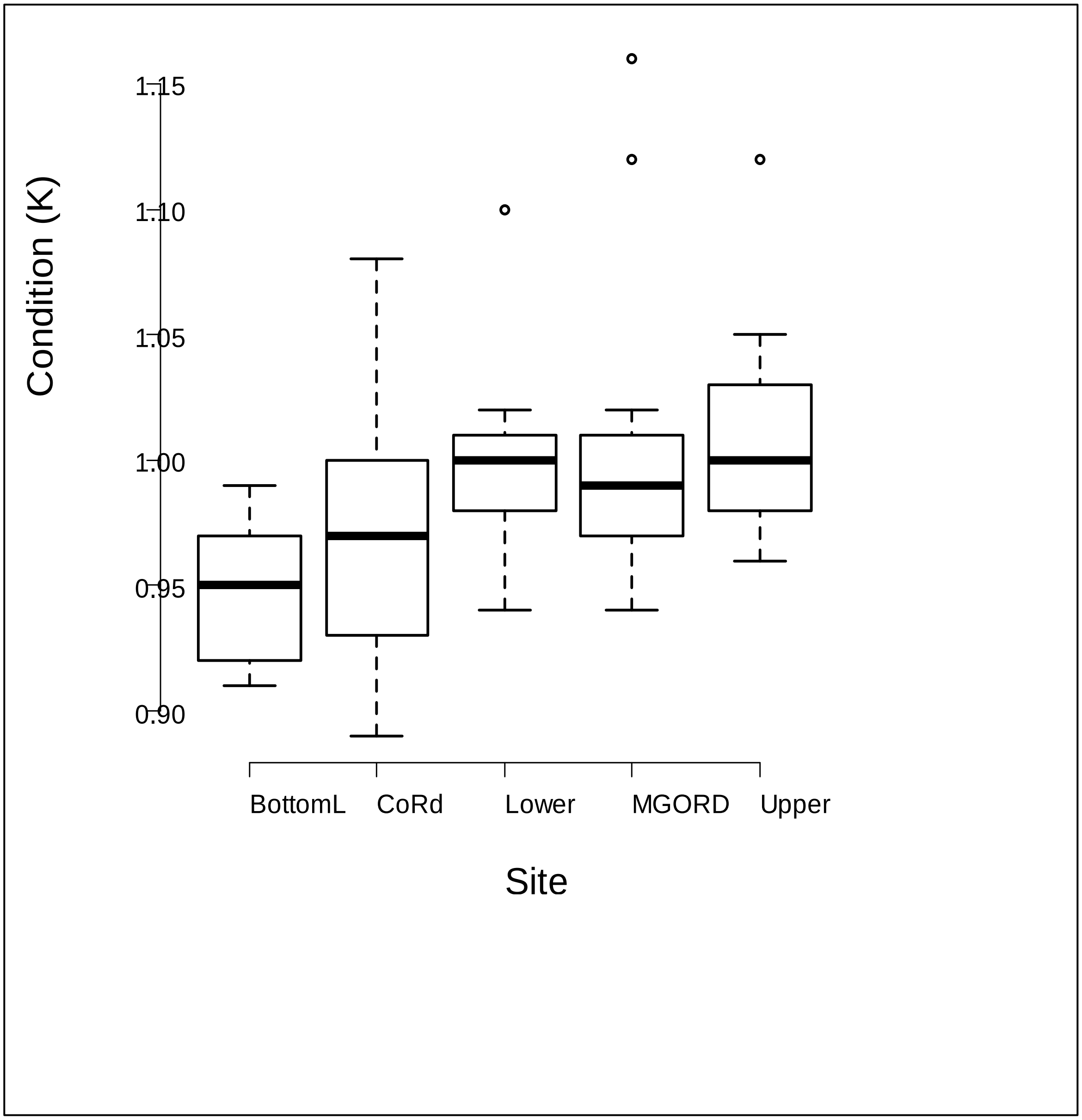

Figure 25. Box plots of conditions factors of Brown Trout 150 to 250 mm in total length, by Rush Creek sampling sections from 1999 to 2019.

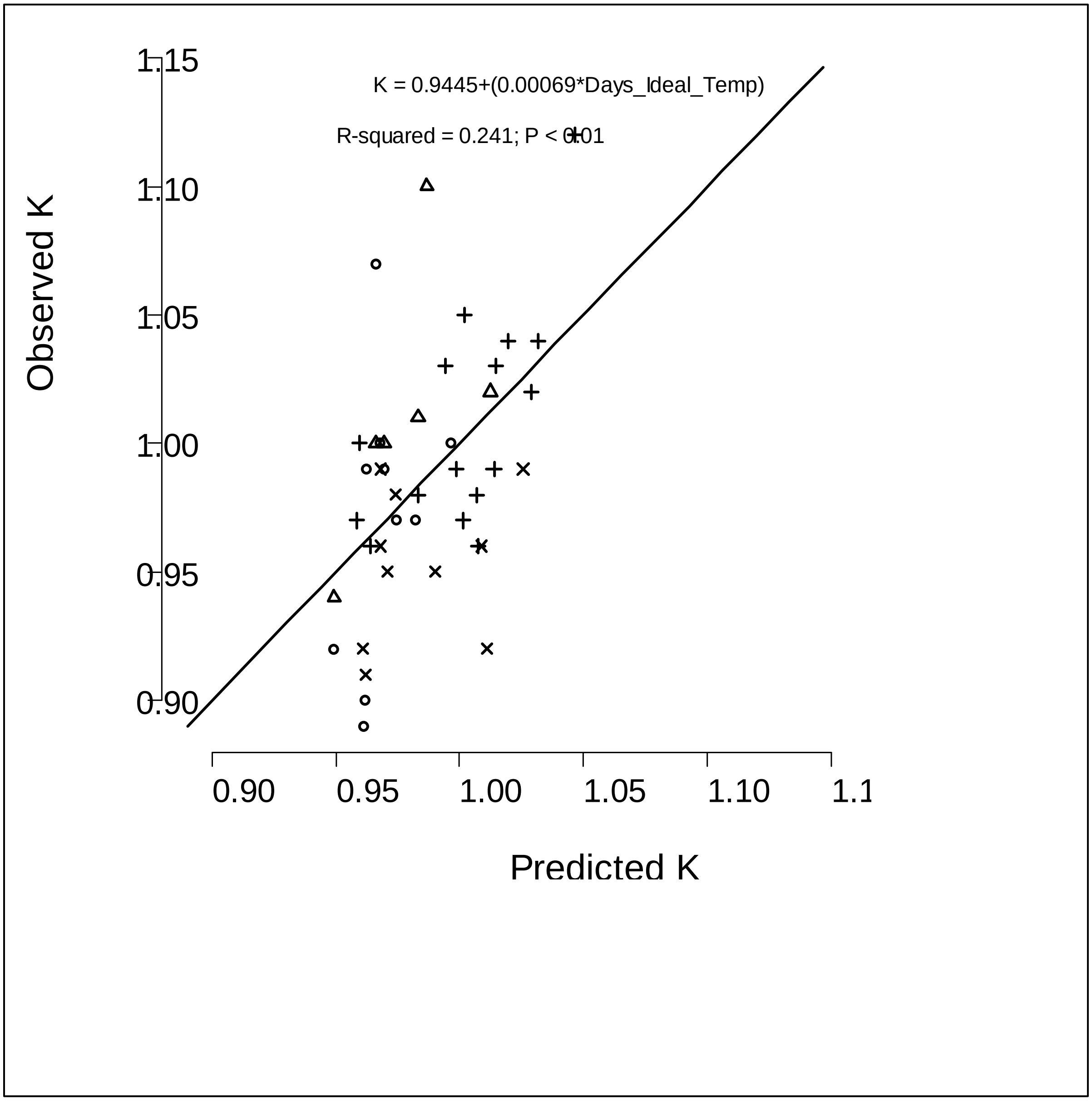

Figure 26. Results of simple regression between estimated fish condition (K) of Brown Trout 150 to 250 mm in total length and number of days with ideal water temperatures for growth (52°F to 66°F) showing predicted versus measured K with different fish sampling sections shown as different point characters. The regression model and regression statistics are also shown within upper-left corner of the graph. The line represents where predicted and estimated values were the same.

Results – Brown Trout Biomass Estimates

Biomass estimates of age-1 and older Brown Trout averaged from 81 to 102 kg/ha for all sampling sections except the Upper Rush section, which averaged 150 kg/ha (Figure 27). Estimated biomasses of Brown Trout were highly correlated to estimated densities of age-0 and age-1 and older Brown Trout, but this result was expected since these two variables were used to compute fish biomass. Biomass was also significantly correlated to water temperature variables (range: -0.31 to -0.25 and 0.33) and variables related to summer water storage in GLR (range: 0.33 to 0.42), but not to flow variables (range: -0.16 to 0.04). Since storage in GLR and water temperatures in Rush Creek were correlated, a simple regression using only mean storage of GLR during the summer was assessed (Figure 6). This regression was highly significant ($p<0.01$), but the adjusted-r^2 value was relatively low (0.18). There were some relatively high estimated values of biomass that were not well predicted by the model. A simple regression testing the number of days when water temperatures were ideal for growth of Brown Trout (52°F to 67°F) and estimated biomass of age-1 and older Brown Trout was also highly significant with a higher r^2-value ($p<0.01$; adjusted-r^2=.022; Figure 7).

These current regression results were less statistically precise than modeling that occurred earlier (Shepard et al. 2009), indicating that sampling from 1999 to 2008 had not adequately captured the full range of variability in potential estimates of biomass in Rush Creek. Utilizing curvilinear modeling might be warranted because high biomass estimates observed in several sampling sections were not well predicted by the linear model (Figures 28 and 29). Multiple-regression models that included flow variables of number of days in the summer when flows were less than 50 cfs and mean summer storage of GLR and a different model that included minimum and maximum annual flows (and interactions of these two variables) and number of days of ideal water temperatures were relatively precise (adjusted-R^2 = 0.47 and 0.84, respectively) and highly significant ($P<0.01$ and <0.001, respectively) using data from 1999 to 2008 (Shepard et al. 2009). However, re-testing of these models with additional data from 2009 to 2019 resulted in much lower precision (adjusted-R2 = 0.29 and 0.31), but high statistical significance ($P<0.001$) and the interaction between minimum and maximum annual flows was not significant. When only ideal temperature and minimum annual flow were analyzed, ideal temperature was highly significant, but minimum annual flow was marginally significant (p<0.10) and the model was not very precise (adjusted-R^2 = 0.26), but highly significant ($P<0.001$).

Again, the results of these current analyses strongly suggest that summer water temperatures is an important metric in supporting a Brown Trout population in the Rush Creek that exhibits traits of a fishery in good condition (as defined in D-1631 and subsequent SWRCB Orders). Summer water temperatures were also associated with RY type and subsequent storage levels in GLR. The past three RY's (2017-2019) has also shown that the Brown Trout population in Rush Creek has the capacity to rebound quickly from extended periods of drought conditions.

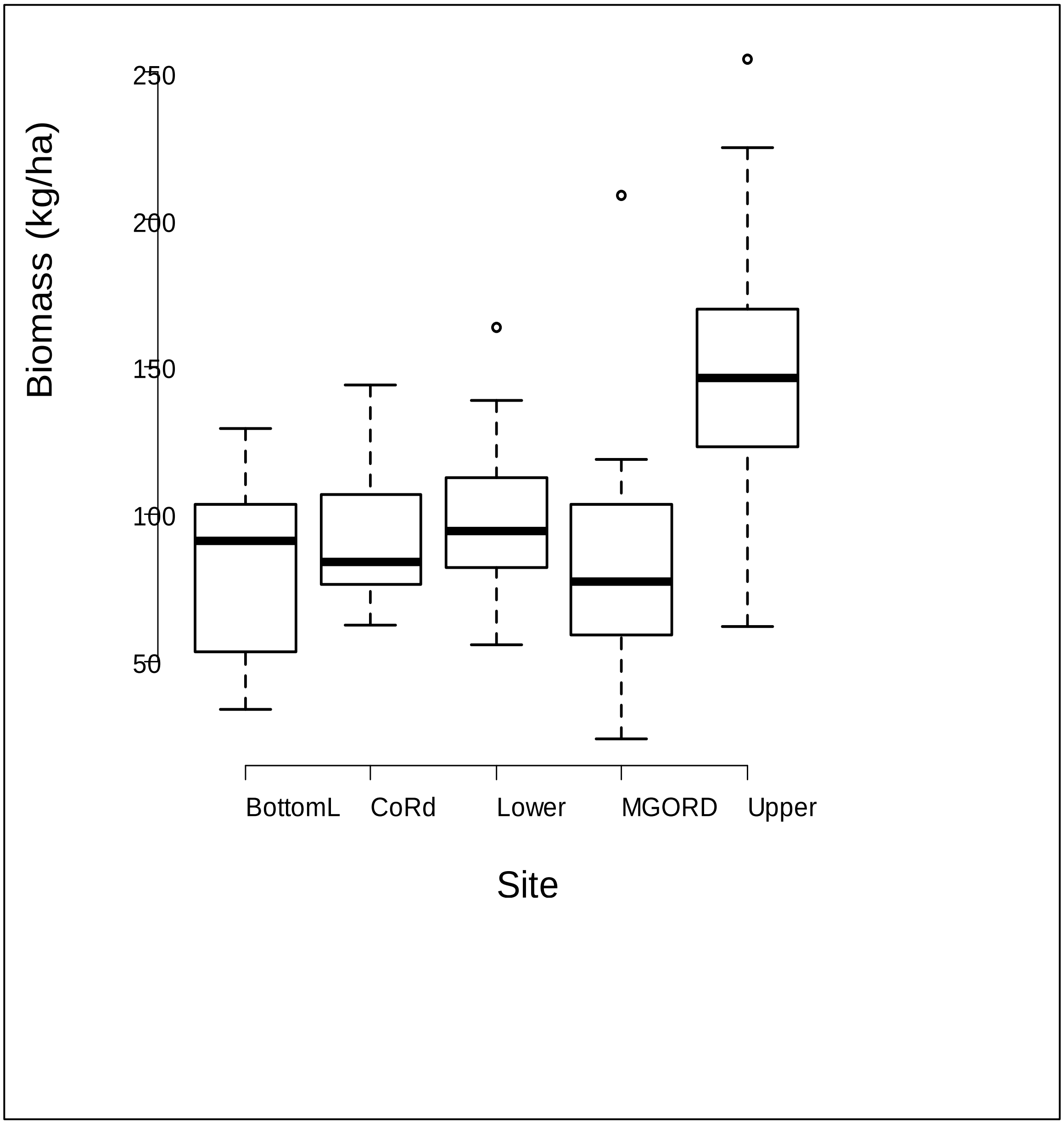

Figure 27. Box plots of biomass (kg/ha) of age-1 and older Brown Trout by fish sampling section of Rush Creek from 1999 to 2019.

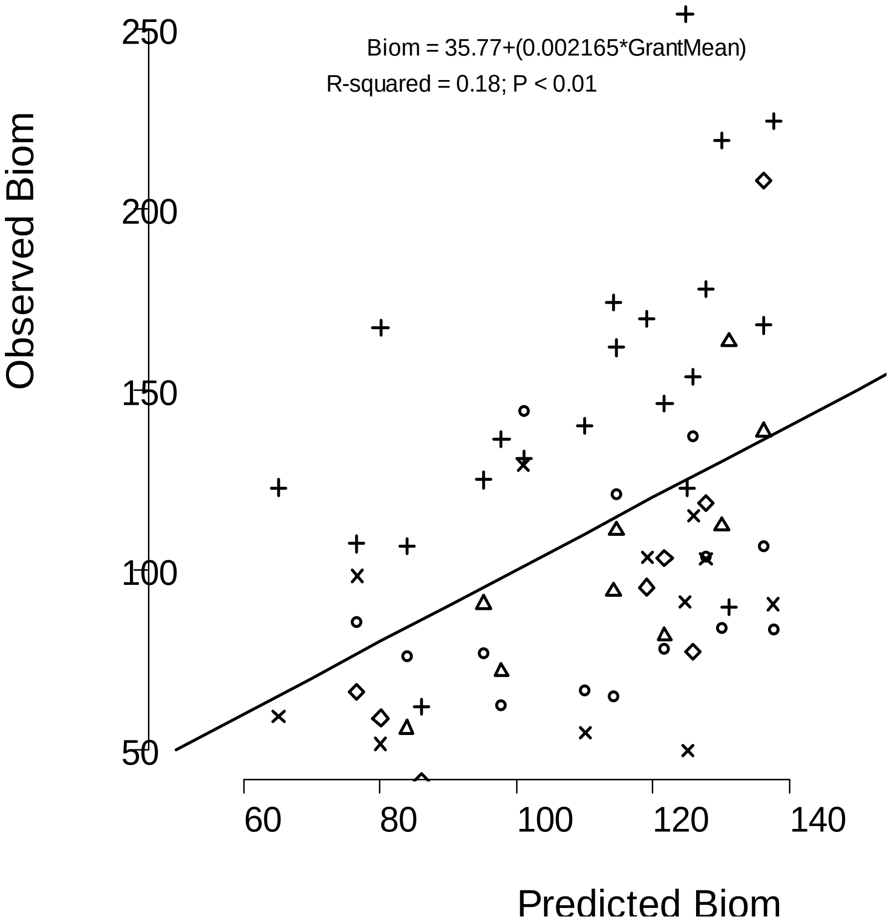

Figure 28. Results of simple regression between biomass of age-1 and older Brown Trout and mean summer storage of Grant Reservoir (acre-feet) showing predicted versus measured biomass with different fish sampling sections shown as different point characters. The regression model and regression statistics are also shown within upper-left corner of the graph. The line represents where predicted and estimated values were the same.

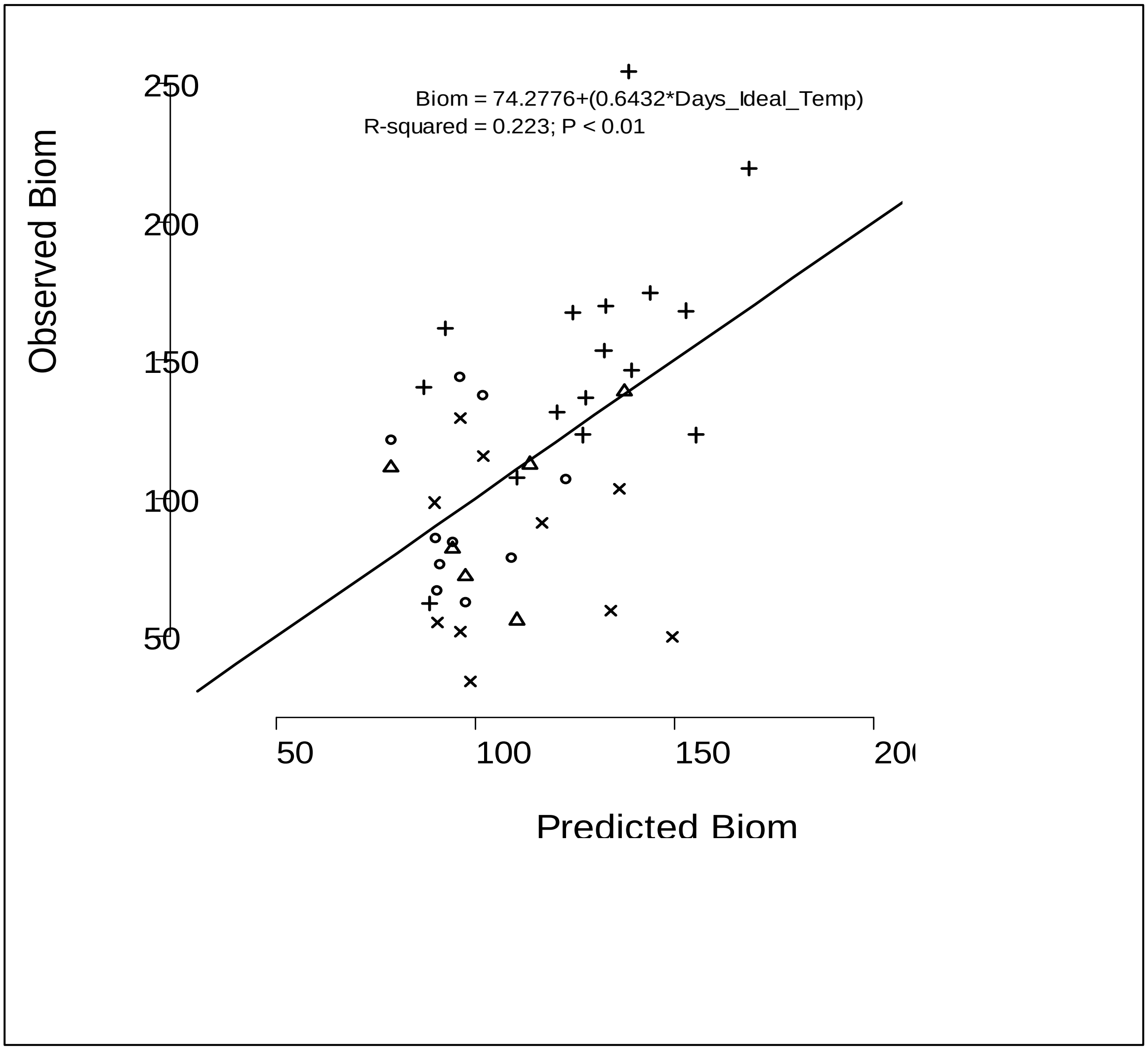

Figure 29. Results of simple regression between biomass of age-1 and older Brown Trout and days of ideal water temperatures (52°F to 66°F) showing predicted versus measured biomass with different fish sampling sections shown as different point characters. The regression model and regression statistics are also shown within upper-left corner of the graph. The line represents where predicted and estimated values were the same.

Results – Average Lengths of Age-0 Brown Trout

Average lengths of age-0 Brown Trout were from 88 to 92.5 mm in the four fish sampling sections where age-0 Brown Trout were abundant (Figure 8). Spearman rank correlations indicated that densities of age-0 and densities of age-1 Brown Trout were highly and negatively correlated (*rho = -0.565* and *-0.506*, respectively) to average lengths of age-0 Brown trout, indicating that growth of age-0 fish was slower in the presence of higher fish densities. Neither flow nor water temperature variables were correlated (*rho < 0.15*) for almost all variables, except June flow (*rho = 0.239*). All three GLR storage variables were also highly and negatively correlated (*rho* of *-0.565* to *-0.3318*). A multiple regression model that included both estimated densities of age-0 Brown Trout and minimum summer storage of GLR was highly significant (*P<0.001*) and moderately precise (adjusted-R^2 = 0.46). The intercept term and independent covariates of age-0 densities and minimum summer storage in GLR were all highly significant (p<0.001) and the interaction term between density of age-0 Brown Trout and minimum summer storage in GLR was only slightly significant *(p = 0.074*).

It appears that average lengths of age-0 Brown Trout were highly influenced by the abundance of both age-0 and age-1 and older Brown Trout, and these abundances were likely influenced by summer storage volumes of GLR (probably due to their influence on more ideal summer water temperatures). These findings were similar to our earlier findings (Shepard et al. 2009).

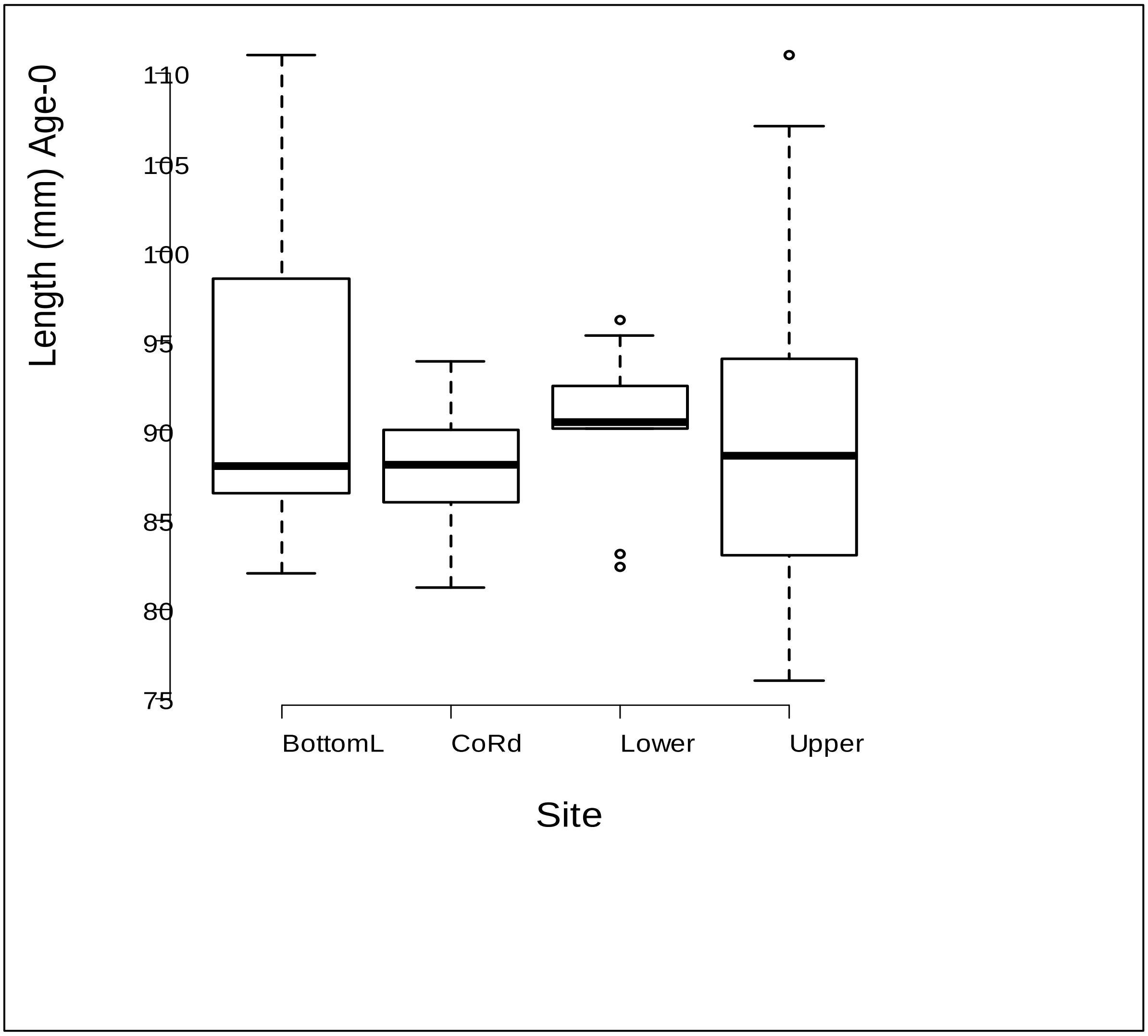

Figure 30. Box plots for average lengths (mm; TL) of age-0 Brown Trout in Rush Creek sampling sections where age-0 fish were abundant.

Methods Evaluation

In 2019, 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. 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. Fence failure has become more prevelant over the past eight or nine sampling years and for future sampling, it's recommended that LADWP dedicate a person whose primary job is to clean fences. A dedicated fence cleaner would be valuable in keeping the fences up for the seven-day duration between mark and recapture electrofishing runs.

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 Upper Rush's upper block fence due to changes in channel depths and increased velocities. The Walker Creek sampling section also experienced a change in channel length and average width after the Wet RY2019. Thus, it is recommended that channel lengths and widths are re-measured annually.

The PIT tagging program was continued during the September 2019 sampling and tags were implanted primarily in age-0 fish and presumed age-1 fish in the MGORD. The PIT tagging program allowed us to continue to document annual growth rates of trout, calculate apparent survival rates, and assess the ability of fish to reach or exceed lengths of 300 mm (or 12 inches). Continuation of the PIT tagging program is recommended 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 for calculations of population estimates (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, flow in Rush Creek should not exceed **40 cfs** and flow in Lee Vining Creek should not exceed **30 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.

As of late-February 2020, the eastern Sierras had experienced a below normal winter and the snow pack near Mammoth was approximately 45% to 60% of normal. LADWP's 2020 Eastern Sierra forecast made on March 1st for the Mono Basin was 51% of normal. If RY 2020 remains below average (by April 1st) then Rush Creek below GLR may experience less than favorable summer water temperature conditions, which could translate into an interruption of the recent trend of increasing population numbers, high recruitment of age-0 fish, and relatively high survival rates.

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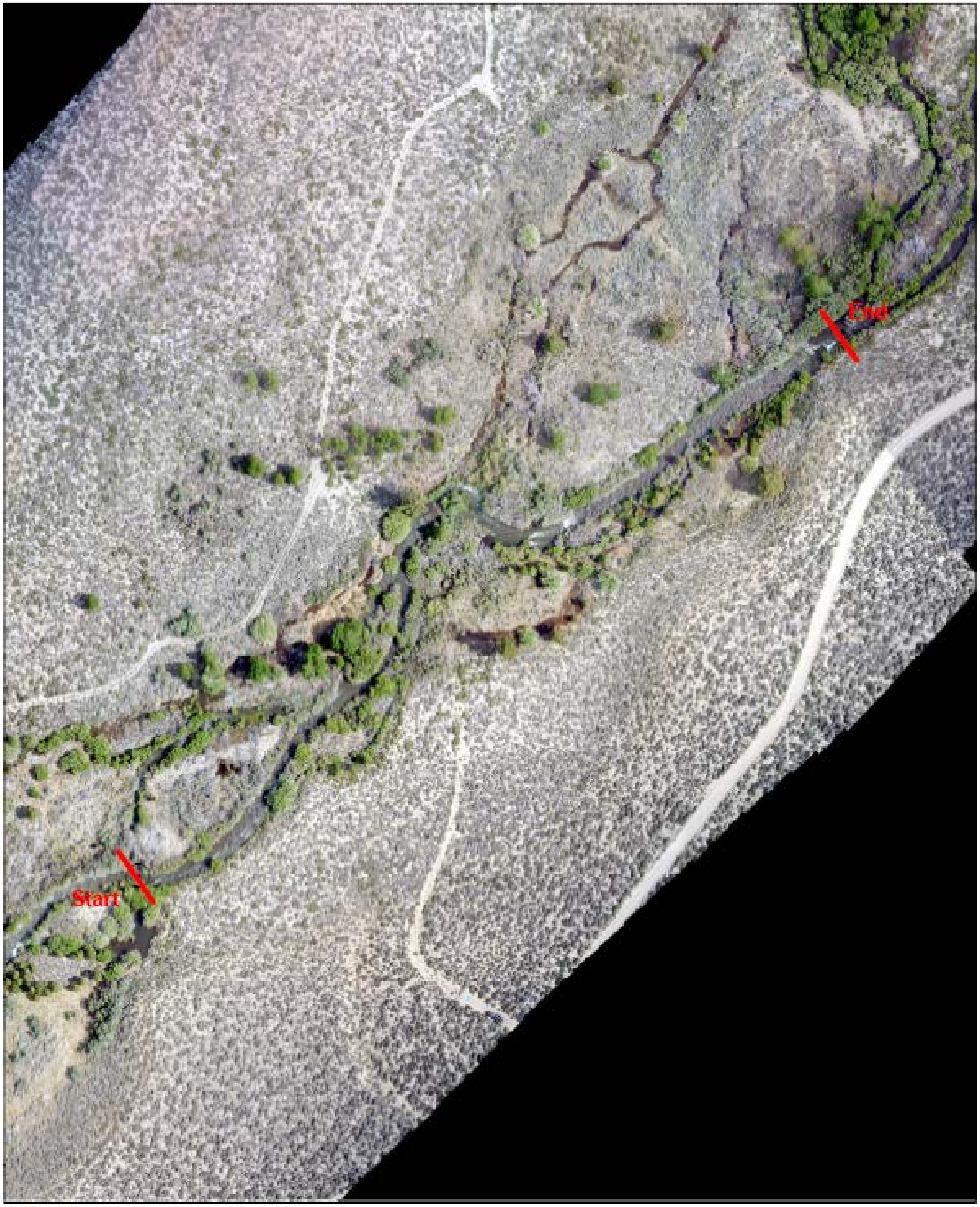
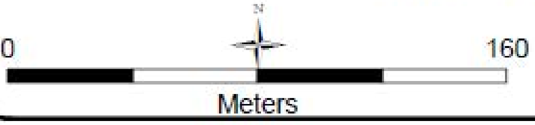
Appendices for the 2019 Mono Basin Annual Fisheries Report

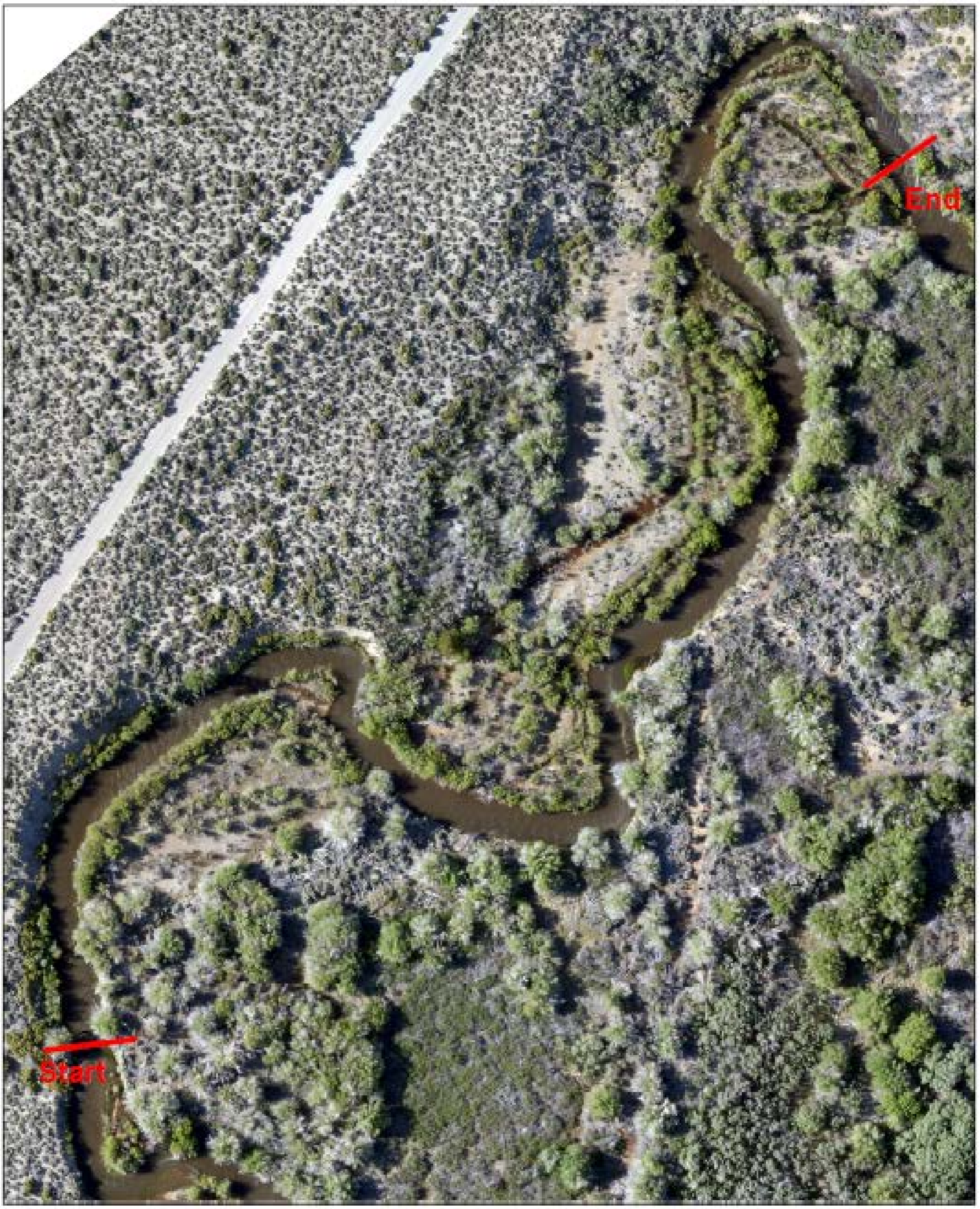
Appendix A: Aerial Photographs of Annual Sample Sites on Rush, Walker and Lee Vining Creeks



Upper Rush Creek

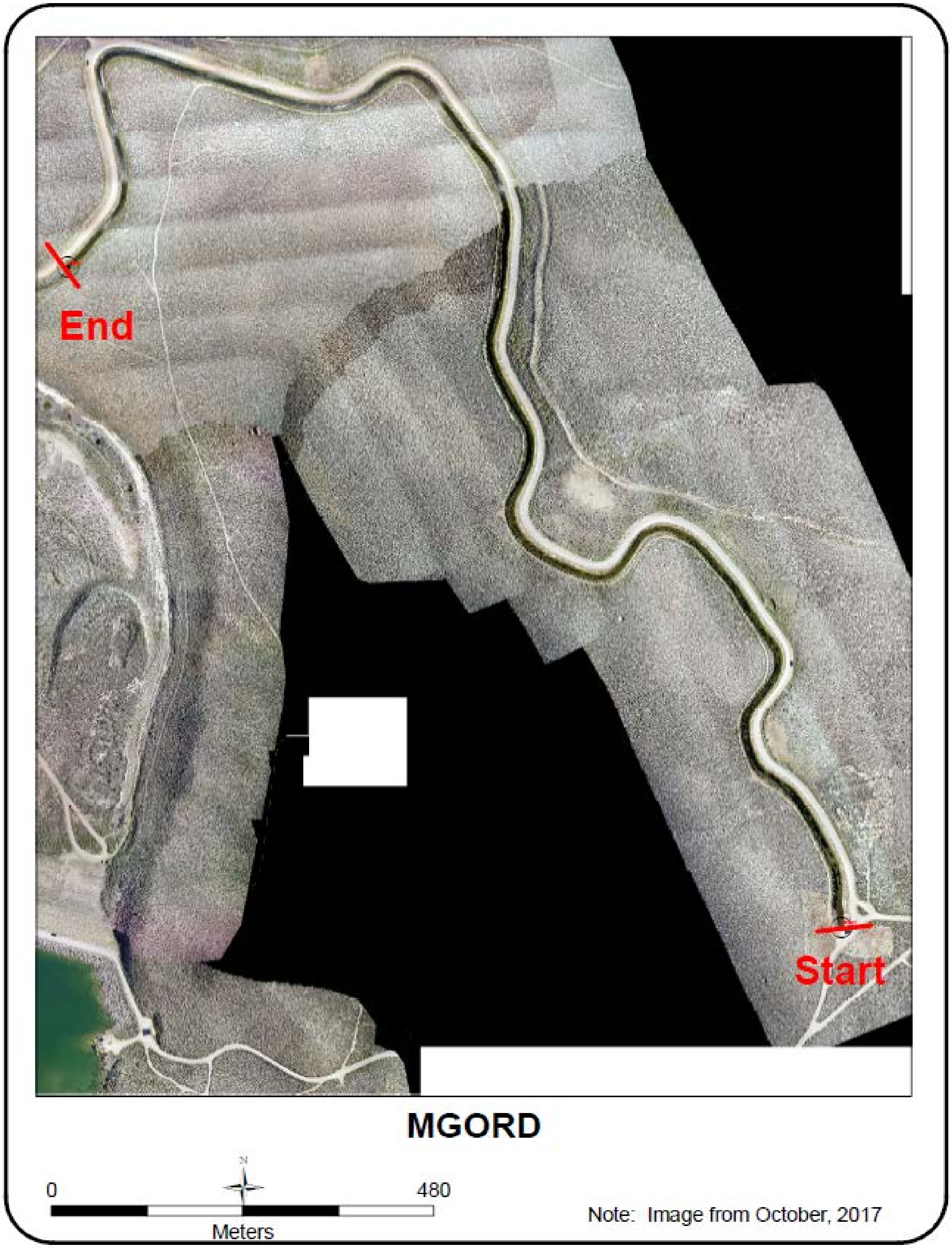


Note: Image from October, 2017



Rush Bottomlands

Note: Image from October, 2017



Note: Image from October, 2017


End
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Walker Creek
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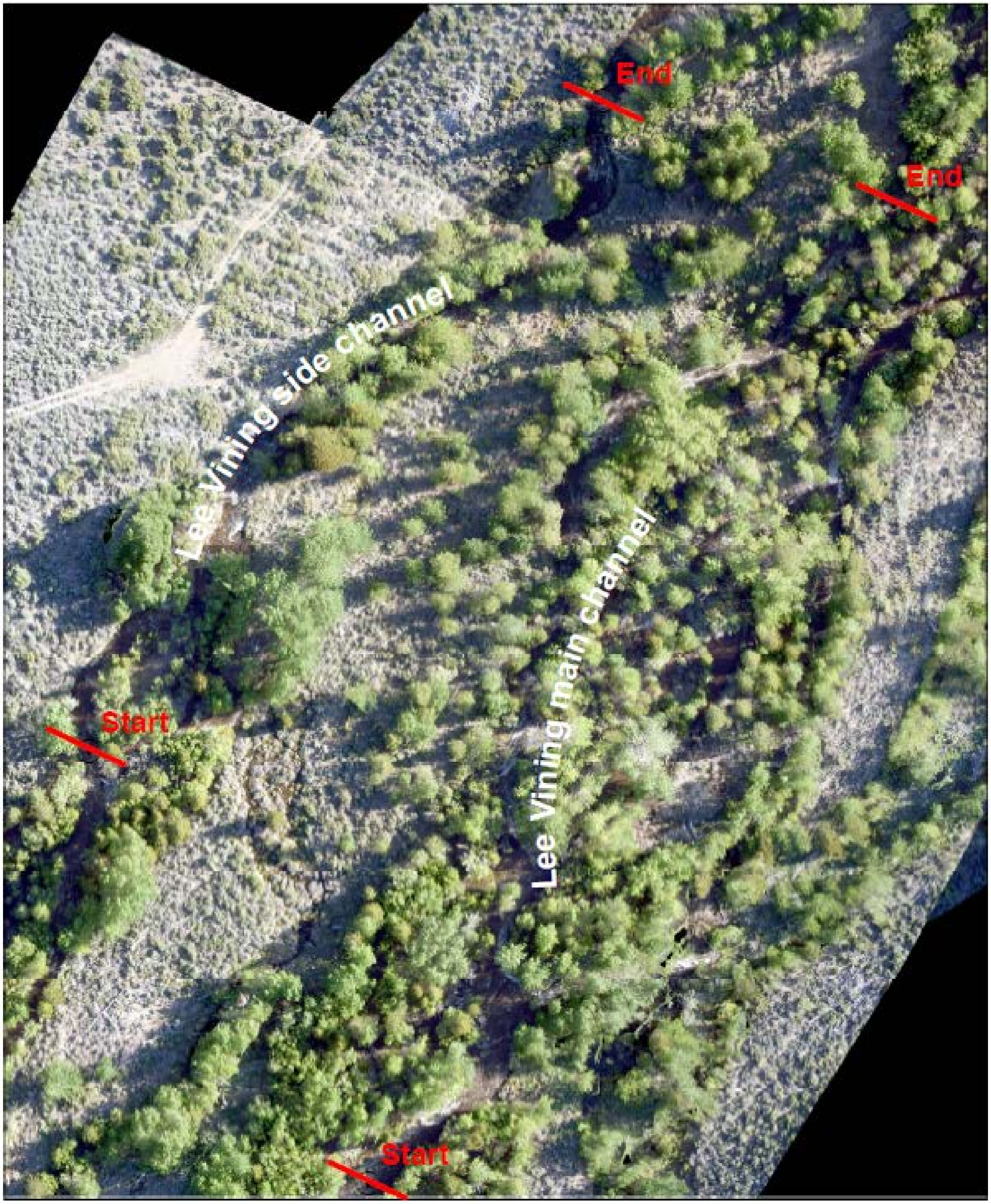
Note: Image from October, 2017



Lee Vining Creek Main and B-1 Side Channels

Note: Image from October, 2017

Appendix B: Tables of Numbers of Brown Trout and Rainbow Trout Implanted with PIT Tags (by sampling section) between 2009 and 2018

Table B-1. 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 B-2. 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 B-3. 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 B-4. 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 B-5 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 B-6. 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

Table B-7. Total numbers of trout implanted with PIT tags during the 2016 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	36	0	1	0	**37 Trout**
	Bottomlands	79	1*	0	0	**80 Trout**
	MGORD	4 BNT 1 RBT	125-199 mm = 9 BNT ≥200 mm = 154** BNT and 7 RBT			**175 Trout**
Lee Vining Creek	Main Channel	46	1*	0	0	**47 Trout**
	Side Channel	1	0	0	0	**1 Trout**
Walker Creek	Above old 395	228	1*	0	0	**229 Trout**
Age Class Sub-totals:		**394**	**166**	**2**	**7**	**Total Trout: 569**

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

Table B-8. Total numbers of trout implanted with PIT tags during the 2017 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	192	2*	14	0	**208 Trout**
	Bottomlands	34	0	0	0	**34 Trout**
	MGORD	38	0	2	0	**40 Trout**
Lee Vining Creek	Main Channel	31	0	0	0	**31 Trout**
	Side Channel	5	0	0	0	**5 Trout**
Walker Creek	Above old 395	0	0	0	0	**0 Trout**
Age Class Sub-totals:		**300**	**2**	**16**	**0**	**Total Trout: 318**

*shed tag/new tag implanted

Table B-9. Total numbers of trout implanted with PIT tags during the 2018 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	314	3*	72	1*	**390 Trout**
	Bottomlands	288	0	0	0	**288 Trout**
	MGORD	25	148**	1	7	**181 Trout**
Lee Vining Creek	Main Channel	87	0	8	0	**95 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	43	2*	0	0	**45 Trout**
Age Class Sub-totals:		**757**	**153**	**81**	**8**	**Total Trout: 999**

*shed tag/new tag implanted **≤250 mm in total length

Appendix C: Table of PIT-tagged Fish Recaptured during September 2019 Sampling

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creeks, September 2019.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2019 Recapture	Location of Initial Capture and Tagging
9/16/2019	BNT	245	156	989001006111470	Upper Rush	Upper Rush
9/16/2019	BNT	234	137	989001006111497	Upper Rush	Upper Rush
9/16/2019	BNT	251	155	989001006111512	Upper Rush	Upper Rush
9/16/2019	BNT	245	148	989001006111516	Upper Rush	Upper Rush
9/16/2019	BNT	230	121	989001006111542	Upper Rush	Upper Rush
9/16/2019	BNT	203	81	989001006111549	Upper Rush	Upper Rush
9/16/2019	BNT	251	158	989001006111553	Upper Rush	Upper Rush
9/16/2019	BNT	217	97	989001006111558	Upper Rush	Upper Rush
9/16/2019	BNT	223	117	989001006111561	Upper Rush	Upper Rush
9/16/2019	BNT	230	122	989001006111562	Upper Rush	Upper Rush
9/16/2019	BNT	229	125	989001006111568	Upper Rush	Upper Rush
9/16/2019	BNT	246	145	989001006111571	Upper Rush	Upper Rush
9/16/2019	BNT	247	137	989001006111578	Upper Rush	Upper Rush
9/16/2019	BNT	260	150	989001006111580	Upper Rush	Upper Rush
9/16/2019	BNT	250	181	989001006111642	Upper Rush	Upper Rush
9/16/2019	BNT	243	151	989001006111661	Upper Rush	Upper Rush
9/16/2019	BNT	165	43	989001028113827	Upper Rush	Upper Rush
9/16/2019	BNT	189	63	989001028113863	Upper Rush	Upper Rush
9/16/2019	BNT	163	40	989001028113878	Upper Rush	Upper Rush
9/16/2019	BNT	179	55	989001028113963	Upper Rush	Upper Rush
9/16/2019	BNT	243	141	989001028113986	Upper Rush	Upper Rush
9/16/2019	BNT	173	49	989001028114004	Upper Rush	Upper Rush
9/16/2019	BNT	161	42	989001028114024	Upper Rush	Upper Rush
9/16/2019	BNT	184	57	989001028114496	Upper Rush	Upper Rush
9/16/2019	BNT	172	50	989001028114542	Upper Rush	Upper Rush
9/16/2019	BNT	171	44	989001028114544	Upper Rush	Upper Rush
9/16/2019	BNT	202	78	989001028114558	Upper Rush	Upper Rush
9/16/2019	BNT	182	65	989001028114559	Upper Rush	Upper Rush
9/16/2019	BNT	184	66	989001028114564	Upper Rush	Upper Rush
9/16/2019	BNT	178	53	989001028114616	Upper Rush	Upper Rush
9/16/2019	BNT	160	43	989001028114628	Upper Rush	Upper Rush
9/16/2019	BNT	186	65	989001028114644	Upper Rush	Upper Rush
9/16/2019	BNT	156	35	989001028114667	Upper Rush	Upper Rush
9/16/2019	BNT	179	56	989001028114669	Upper Rush	Upper Rush
9/16/2019	BNT	184	62	989001028114681	Upper Rush	Upper Rush
9/16/2019	BNT	164	42	989001028114685	Upper Rush	Upper Rush
9/16/2019	BNT	174	55	989001028114688	Upper Rush	Upper Rush
9/16/2019	BNT	192	70	989001028114700	Upper Rush	Upper Rush

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creeks, September 2019.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2019 Recapture	Location of Initial Capture and Tagging
9/16/2019	BNT	128	23	989001028114713	Upper Rush	Upper Rush
9/16/2019	BNT	188	74	989001028114723	Upper Rush	Upper Rush
9/23/2019	BNT	235	127	989001006111510	Upper Rush	Upper Rush
9/23/2019	BNT	236	135	989001006111530	Upper Rush	Upper Rush
9/23/2019	BNT	153	36	989001028114566	Upper Rush	Upper Rush
9/23/2019	BNT	170	54	989001028114712	Upper Rush	Upper Rush
9/23/2019	BNT	228	126	989001006111687	Upper Rush	Upper Rush
9/16/2019	**RBT**	152	35	989001028114013	Upper Rush	Upper Rush
9/16/2019	**RBT**	155	48	989001028114131	Upper Rush	Upper Rush
9/16/2019	**RBT**	167	52	989001028114610	Upper Rush	Upper Rush
9/23/2019	**RBT**	173	49	989001028113834	Upper Rush	Upper Rush
9/23/2019	**RBT**	160	42	989001028114002	Upper Rush	Upper Rush
9/17/2019	BNT	235	116	989001006111411	Bottomlands	Bottomlands
9/17/2019	BNT	219	109	989001006111449	Bottomlands	Bottomlands
9/17/2019	BNT	212	90	989001006111465	Bottomlands	Bottomlands
9/17/2019	BNT	175	47	989001028114044	Bottomlands	Bottomlands
9/17/2019	BNT	143	23	989001028114066	Bottomlands	Bottomlands
9/17/2019	BNT	190	63	989001028114281	Bottomlands	Bottomlands
9/17/2019	BNT	192	61	989001028114297	Bottomlands	Bottomlands
9/17/2019	BNT	155	37	989001028114472	Bottomlands	Bottomlands
9/17/2019	BNT	155	41	989001028114497	Bottomlands	Bottomlands
9/17/2019	BNT	146	32	989001028114499	Bottomlands	Bottomlands
9/24/2019	BNT	177	55	989001028114018	Bottomlands	Bottomlands
9/24/2019	BNT	172	46	989001028114032	Bottomlands	Bottomlands
9/24/2019	BNT	169	45	989001028114125	Bottomlands	Bottomlands
9/24/2019	BNT	196	69	989001028114280	Bottomlands	Bottomlands
9/24/2019	BNT	177	50	989001028114448	Bottomlands	Bottomlands
9/24/2019	BNT	133	42	989001028114461	Bottomlands	Bottomlands
9/19/2019	BNT	574	2493	989001001356456	MGORD	MGORD
9/19/2019	BNT	401	543	989001006111290	MGORD	MGORD
9/19/2019	BNT	260	181	989001006111539	MGORD	**Upper Rush**
9/19/2019	BNT	281	209	989001006111619	MGORD	MGORD
9/19/2019	BNT	280	204	989001028114349	MGORD	MGORD
9/19/2019	BNT	232	118	989001028114402	MGORD	MGORD
9/19/2019	BNT	256	161	989001028114425	MGORD	MGORD
9/19/2019	BNT	283	214	989001028114738	MGORD	MGORD
9/19/2019	BNT	308	274	989001028114785	MGORD	MGORD
9/19/2019	BNT	285	237	989001028114788	MGORD	MGORD

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creeks, September 2019.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2019 Recapture	Location of Initial Capture and Tagging
9/19/2019	BNT	282	214	989001028114789	MGORD	MGORD
9/19/2019	BNT	261	200	989001028114800	MGORD	MGORD
9/20/2019	BNT	225	113	989001006111014	Walker Ck	Walker Creek
9/20/2019	BNT	216	105	989001006111045	Walker Ck	Walker Creek
9/20/2019	BNT	221	100	989001006111055	Walker Ck	Walker Creek
9/20/2019	BNT	235	138	989001006111064	Walker Ck	Walker Creek
9/20/2019	BNT	215	98	989001006111072	Walker Ck	Walker Creek
9/20/2019	BNT	215	92	989001006111191	Walker Ck	Walker Creek
9/20/2019	BNT	141	27	989001028114139	Walker Ck	Walker Creek
9/20/2019	BNT	215	100	989001028114159	Walker Ck	Walker Creek
9/20/2019	BNT	167	46	989001028114162	Walker Ck	Walker Creek
9/20/2019	BNT	167	41	989001028114170	Walker Ck	Walker Creek
9/20/2019	BNT	154	35	989001028114179	Walker Ck	Walker Creek
9/20/2019	BNT	168	45	989001028114180	Walker Ck	Walker Creek
9/20/2019	BNT	147	32	989001028114181	Walker Ck	Walker Creek
9/20/2019	BNT	164	45	989001028114182	Walker Ck	Walker Creek
9/20/2019	BNT	162	40	989001028114187	Walker Ck	Walker Creek
9/18/2019	BNT	238	149	989001006111313	LV Main	LV Main
9/18/2019	BNT	274	219	989001006111351	LV Main	LV Main
9/18/2019	BNT	200	73	989001028114347	LV Main	LV Main
9/18/2019	BNT	180	61	989001028114355	LV Main	LV Main
9/18/2019	BNT	185	63	989001028114366	LV Main	LV Main
9/18/2019	BNT	192	68	989001028114386	LV Main	LV Main
9/18/2019	BNT	209	93	989001028114417	LV Main	LV Main
9/18/2019	BNT	165	41	989001028114763	LV Main	LV Main
9/18/2019	BNT	181	52	989001028114766	LV Main	LV Main
9/18/2019	BNT	180	61	989001028114767	LV Main	LV Main
9/18/2019	BNT	160	38	989001028114771	LV Main	LV Main
9/18/2019	BNT	173	45	989001028114774	LV Main	LV Main
9/18/2019	BNT	142	25	989001028114777	LV Main	LV Main
9/18/2019	BNT	166	40	989001028114781	LV Main	LV Main
9/18/2019	BNT	180	59	989001028114784	LV Main	LV Main
9/18/2019	BNT	179	54	989001028114804	LV Main	LV Main
9/18/2019	BNT	180	60	989001028114813	LV Main	LV Main
9/18/2019	**RBT**	165	49	989001028114424	LV Main	LV Main
9/25/2019	BNT	222	120	989001006111392	LV Main	LV Main
9/25/2019	BNT	160	40	989001028114380	LV Main	LV Main
9/25/2019	BNT	154	38	989001028114728	LV Main	LV Main

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creeks, September 2019.

9/25/2019	BNT	165	35	989001028114751	LV Main	LV Main
9/25/2019	BNT	160	42	989001028114799	LV Main	LV Main

Section 4

RY 2019 Mono Basin Stream Monitoring Report

RY2019 Mono Basin Report

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April 27, 2020

In theory there is no difference between theory and practice. In practice, there is. Yogi Berra

Introduction

Yogi Berra's insight really does define an important directive guiding HSU River Institute's monitoring investigations and annual reports beginning RY2015. With development of a future 10-year monitoring program for Rush Creek and Lee Vining Creeks still ongoing, monitoring objectives and their methodologies remain to be finalized. What may seem appropriate theoretically, may be unrealistic or inappropriate when applied 'on the ground' or be too expensive to implement annually. Fieldwork and analyses have provided valuable practical experience in assessing what should - and should not - work in a long-term monitoring program. Nothing remains the same. Yet many monitoring methodologies presume otherwise. For example, a monumented channel cross-section can be re-surveyed annually to document changing channel width. But the channel meander might migrate through the cross section (and odds are that it will), transforming a cross section originally surveyed through a pool into one now crossing a riffle. A log jam might form. Or beavers might occupy the cross-section to completely alter future channel width independent of recovering physical processes attributable (or not) to the Stream Ecosystem Flows (SEF's). In HSU River Institute's Annual Report RY2018, changes in the 'permanent' Beaver Nibble cross section (situated above a migrating knickpoint at the top of the 4-Floodplain) due to the RY2017 peak flood were difficult to establish as a clean cause-effect relationship.

The Mono Basin Stream Monitoring Project for RY2019 had two primary objectives consistent with previous RYs: (1) continue channel morphology and riparian floodplain monitoring beginning RY2015 toward developing baseline conditions for the future monitoring program and (2) recommend monitoring techniques, including remote sensing methodologies, that objectively measure cause-effect outcomes throughout a multi-year monitoring period as unambiguously and efficiently (w/r to effort, cost, and information acquired) as possible. Unfortunately, no field data were collected in RY2019 due to contractual difficulties. However ancillary field data collected late-September to early-October 2018 were not reported in the RY2018 Monitoring Report.

These data were exploratory (to be followed-up in the field RY2019) but in keeping with our second objective of monitoring plan development. Unlike former annual reports, this RY2019 annual report first provides more extensive background information to introduce basic riffle crest concepts. Second, findings from the additional 2018 fieldwork have been analyzed to produce a working demonstration for the concepts presented. Third, hydraulic controls at riffle crests are introduced and quantified. Fourth, long-term monitoring applications targeting the Synthesis Report's desired ecological outcomes are discussed. And fifth, RY2020 fieldwork objectives given uncertainties imposed by the COVID-19 pandemic are briefly listed.

Background

Hydraulic Units and Riffle Crests

A basic geomorphic unit in Lower Rush Creek is the riffle-pool sequence, or 'hydraulic unit.' The dashed line in Figure 1 traces the thalweg pathway through a single meander wavelength comprised of two channel bends. At the riffles, the thalweg 'crosses-over' from one bank to the opposite bank. The hydraulic unit (HU) can therefore be characterized as a riffle-pool sequence between thalweg cross-overs. The riffle crest (RC) is the channel cross-section at the very top of each riffle. Each HU is bounded by riffle crests, sharing them with adjoining upstream and downstream HUs.

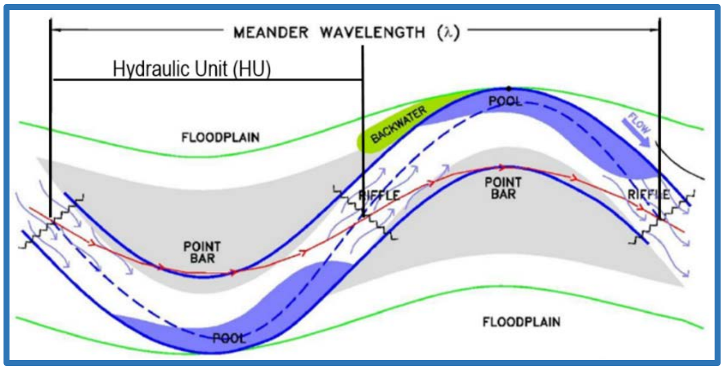


Figure 1. Hydraulic unit and riffle crests. The three squiggly lines are riffle crest cross-sections and the flow lines begin in the pools' tailouts and extend downstream through the riffles.

Riffle Crests as Weirs

Channel shape, particularly at riffle crests, determines the rate of increase in stage height with increasing streamflow (Figure 2). In Lower Rush Creek, riffle crest cross-sections are primarily hybrids of 'V-shaped' and trapezoidal configurations. With power function fits to their respective Stage-Q rating curves, the exponent can be interpreted as a simple descriptor of rate-of-stage change. Ecologically, the hydraulics of channel shape hugely affect key physical variables such as streamflow depth. In Figure 2, the same 10 m^3/sec streamflow generates an approximate depth of 1.5 m in a 'V-shaped' channel but only a 0.75 m depth in a trapezoidal channel. As Lower Rush Creek continues adjusting its grade (in continued response to historic Mono Lake level impacts) and maturing riparian vegetation keeps expanding coverage, the mainstem channel also will adjust its shape, and consequently its hydraulics.

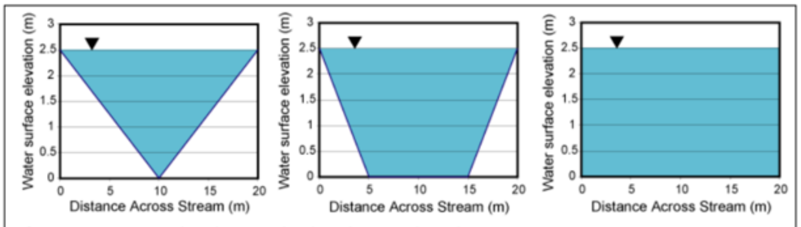


Figure 3.3. V, trapezoid, and rectangular shaped stream channels.

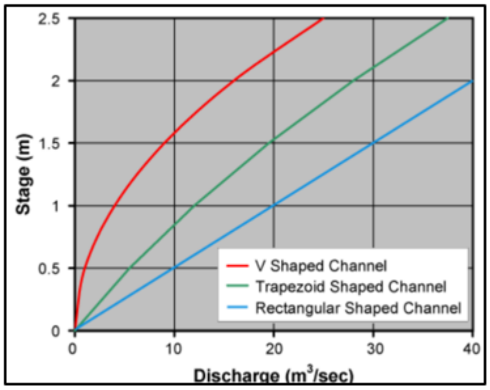


Figure 2. Channel shape and stage change with streamflow for three generalized channel shapes. Figures 3.3 and 3.4 reproduced from Brad Finney's website: http://gallatin.humboldt.edu/~brad/nws/lesson3.html.

Shapes of riffle crest cross-sections bear strong resemblance to engineered weirs (Figure 3). Their similarity in shape extends to their similarity in function, making riffle crest cross sections natural weir prototypes (Figure __). Understanding how weirs function hydraulically does go a long way toward explaining how riffle crests function. From a hydraulic perspective, most stream channel reaches can be evaluated/investigated ecologically as a collection of unique weirs, one at each riffle crest cross section.

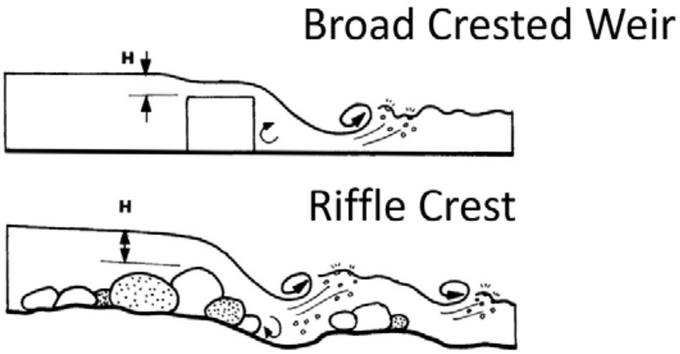


Figure 3. Functional similarity between a broad crested weir and a cobble-bedded, alluvial riffle crest.

Engineered weirs come in two basic shapes: rectangular and triangular (Figure 4) as Brad Finney describes for channel types (Figure 2). Others combining both shapes, generally a rectangular weir stacked on top a triangular weir, are considered 'compound weirs.' Both basic weir shapes behave hydraulically as power functions:

Rectangular or Broad-Crested Weir: $Q = c_d L h^{1.5}$

Triangular or V-Notched Weir: $Q = c_d \tan (O/2) h^{2.5}$

These power functions share two common independent variables, h and c_d. The coefficient, c_d, is the time-honored calibration coefficient that groups many contributing physical factors into a single value that has been derived empirically (i.e., that balances the equation, similar to Mannings 'n'). The other common independent variable, h or 'head,' is similar to what we measure in nature's prototype weirs as the thalweg depth on the riffle crest cross-section.

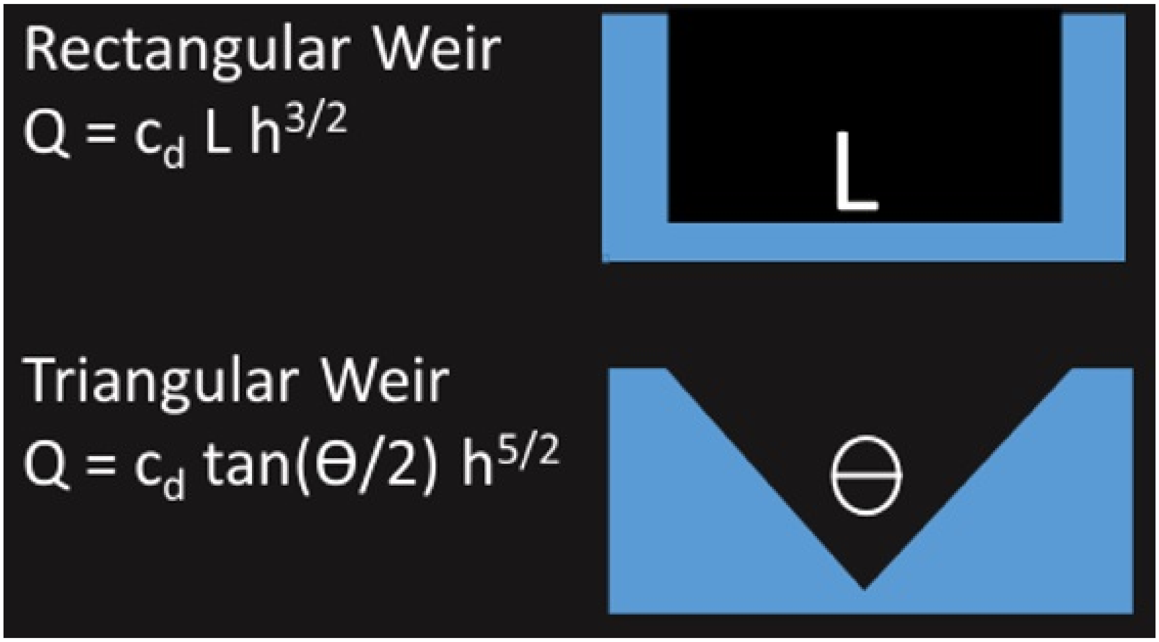


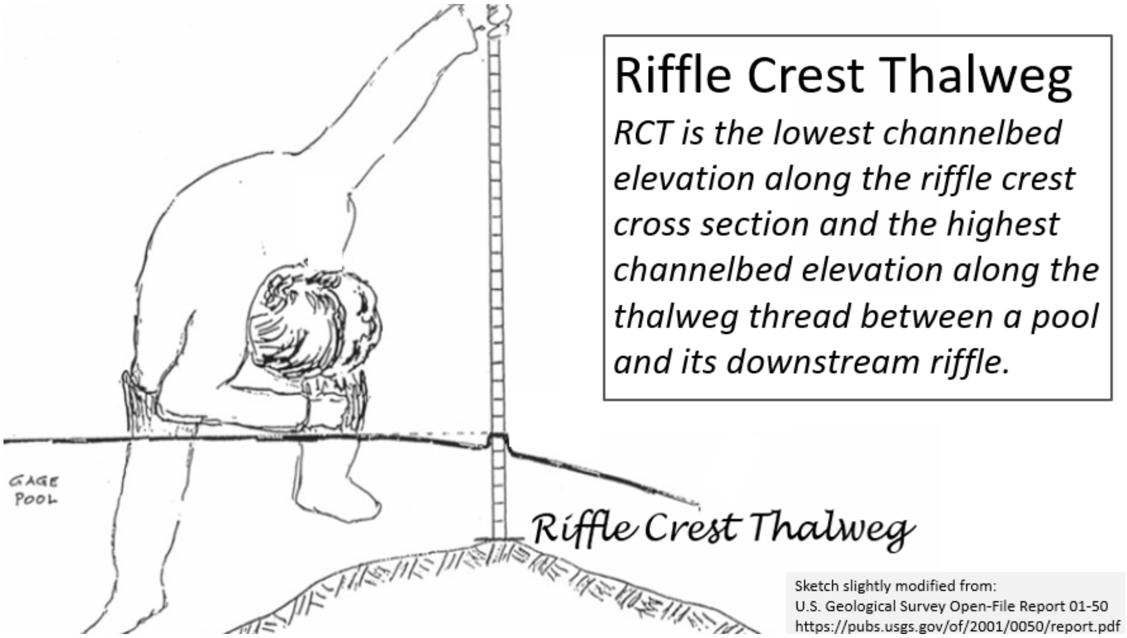
Figure 4. Two basic engineered weir shapes.

Rectangular weirs have an additional independent variable L, the rectangular weir's width. L in a natural-made weir (i.e., most riffle crests) should be a function of drainage area (DA, mi^2). The independent variable 'theta' for triangular weirs is the angle of a V-notch weir. A tighter angle in triangular weirs should be a function of increasing channelbed particle size in the riffle crest cross-section.

Exponents of both weir power functions are of particular interest ecologically. Roughly each is a ratio of the change in streamflow in relation to the change in hydraulic head. Both power functions can be modified to represent the change in streamflow as a function of the change in depth.

Riffle Crest Thalweg (RCT)

The lowest channelbed elevation along a stream's riffle crest cross-section is its Riffle Crest Thalweg (RCT). It typically is located at the channel's thalweg crossover and is the highest channelbed thalweg elevation between a pool and its downstream riffle (Figure 5). RCT is singularly the most identifiable physical channelbed location for measuring a stream's depth, while also serving as the benchmark for measuring residual pool depths.



Riffle Crest Thalweg

RCT is the lowest channelbed elevation along the riffle crest cross section and the highest channelbed elevation along the thalweg thread between a pool and its downstream riffle.

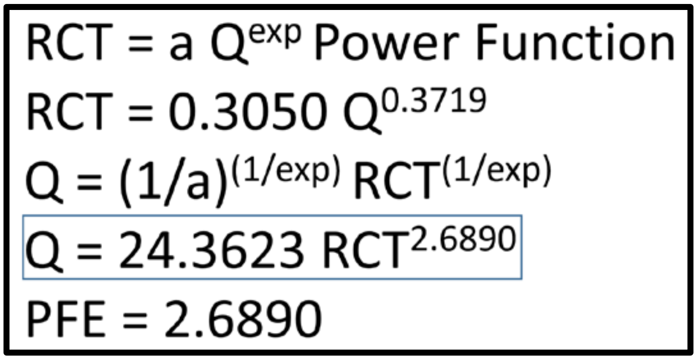
Sketch slightly modified from:
U.S. Geological Survey Open-File Report 01-50
https://pubs.usgs.gov/of/2001/0050/report.pdf

Figure 5. Riffle crest measurement and definition.

RCT-Q Rating Curve

The greatest importance of RCT towards understanding how stream ecosystems work, under past and present environments, is not because of its usefulness as a universal depth measure, but because of its rate of change in depth as streamflow changes, i.e., when we think *verb* rather than *noun*.

RCT-Q rating curves are power function fits to the relationship between RCT depth and streamflow (Q). In the USGS website, Q is the dependent variable (Y-axis) presented as a function of stage height, the independent variable (X-axis). In RCT-Q rating curves, streamflow (Q) also is the dependent variable with RCT depth the independent variable. Switching independent/dependent variables is often necessary, e.g., when estimating RCT depth from a streamflow measurement. Figure 6 goes through the computational steps necessary to switch axes. The exponent of the RCT-Q rating curve, where Q is the dependent variable, is called the Power Function Exponent (PFE).



$$\mathrm{RCT} = a\,Q^{\mathrm{exp}} \text{ Power Function}$$

$$\mathrm{RCT} = 0.3050\,Q^{0.3719}$$

$$Q = (1/a)^{(1/\mathrm{exp})}\,\mathrm{RCT}^{(1/\mathrm{exp})}$$

$$\boxed{Q = 24.3623\,\mathrm{RCT}^{2.6890}}$$

$$\mathrm{PFE} = 2.6890$$

Figure 6. Switching axes in RCT-Q rating curves. Blue rectangle is the RCT-Q rating curve.

RY2018 RCT-Q Rating Curve Findings

Lower Rush Creek RCT-Q Rating Curves

RCT depths from earlier streamflow peaks/baseflows in RY2018 and ambient streamflows in late-September through early-October 2018 were surveyed to generate preliminary RCT-Q rating curves in ten locations on Lower Rush Creek mainstem (Figure 7). These data were collected opportunistically on RY2018 fieldwork days during a single basin visit. RY2020 fieldwork will attempt additional site visits targeting specific streamflows at more HUs.

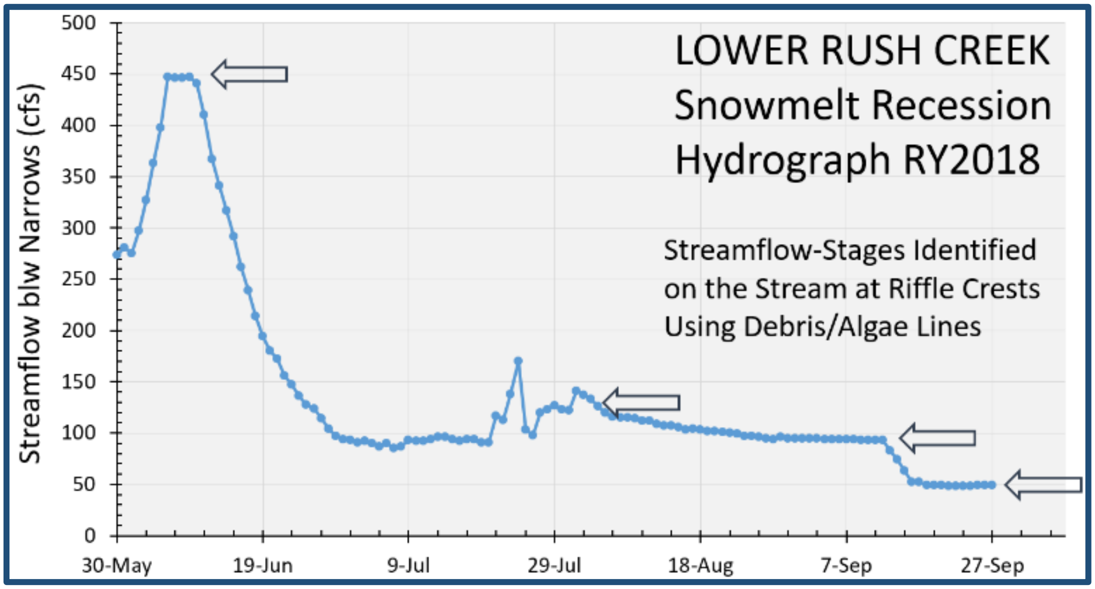
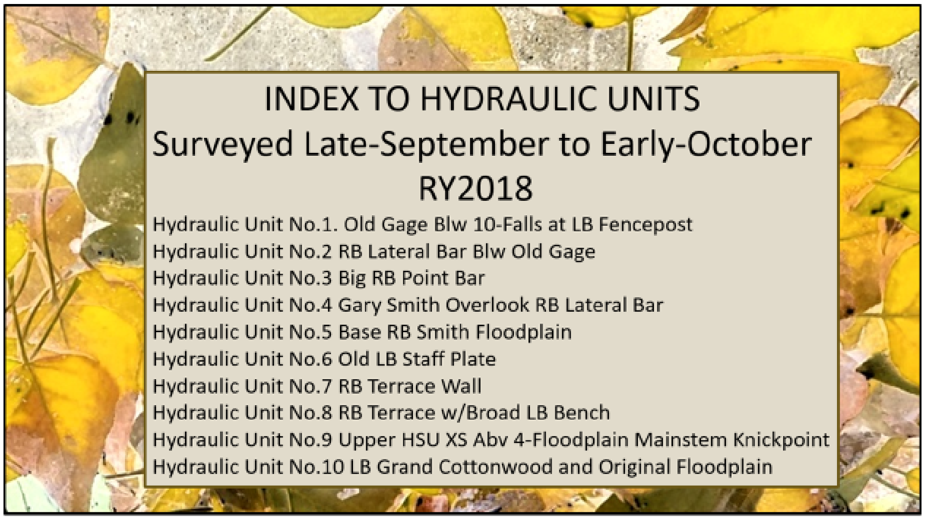


Figure 7. Streamflow thresholds with tangible field evidence in RY2018 to estimate RCT depths for specific streamflows to construct the ten RCT-Q rating curves.

Hydraulic HU's No. 1 through 8 (Figure 8) extend from the Old 10-Falls downstream to the Ford. HU's No.9 and No.10 are located approximately 300 ft and 500 ft upstream of the 4-Flooplain's upper 4-Bii side-channel entrance. HU No.10 is located on one of the least altered channel cross-sections recently found in Lower Rush Creek. A photograph accompanies most RCT-Q rating curves (HU No's 1 and 10 do not) to help visually associate mathematical functions with actual stream channel HUs. Note the range in PFE among the HUs.



INDEX TO HYDRAULIC UNITS
Surveyed Late-September to Early-October
RY2018

Hydraulic Unit No.1. Old Gage Blw 10-Falls at LB Fencepost
Hydraulic Unit No.2 RB Lateral Bar Blw Old Gage
Hydraulic Unit No.3 Big RB Point Bar
Hydraulic Unit No.4 Gary Smith Overlook RB Lateral Bar
Hydraulic Unit No.5 Base RB Smith Floodplain
Hydraulic Unit No.6 Old LB Staff Plate
Hydraulic Unit No.7 RB Terrace Wall
Hydraulic Unit No.8 RB Terrace w/Broad LB Bench
Hydraulic Unit No.9 Upper HSU XS Abv 4-Floodplain Mainstem Knickpoint
Hydraulic Unit No.10 LB Grand Cottonwood and Original Floodplain

Figure 8. Index to hydraulic units with RCT-Q rating curves surveyed late-September to early-October 2018.

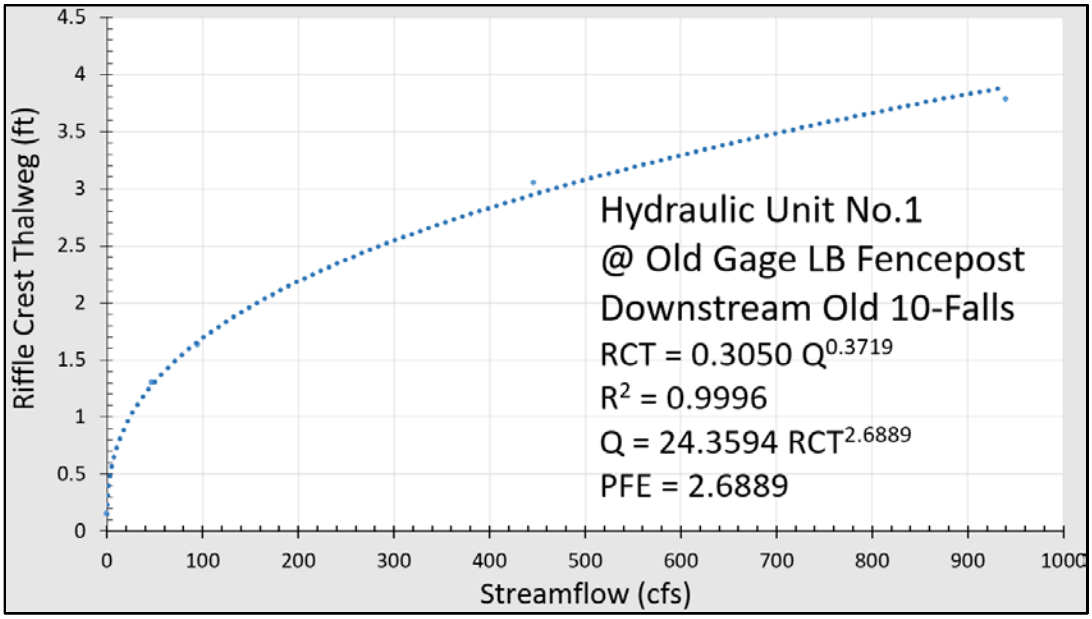


Figure 9. Lower Rush Creek HU No.1. at Old Gage LB Fencepost. PFE = 2.6889.

Figure 10. Lower Rush Creek HU No.2. Downstream of Old LB Gage below 10-Falls. Photo Taken: 27Sept2018.

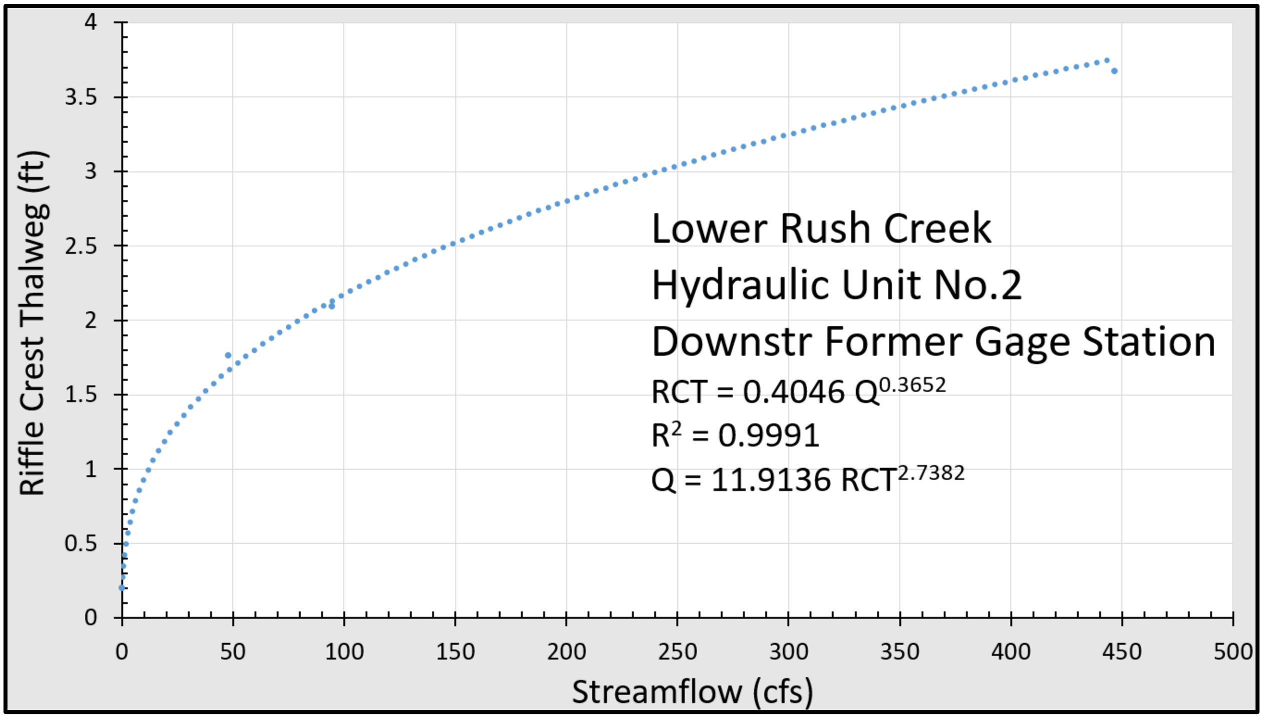


Figure 11. HU No.2. RCT-Q rating curve w/ a PFE = 2.7382.

Figure 12. Lower Rush Creek HU No.3 at Big RB Point Bar. Photo Taken: 25Sept2018 12:01PM.

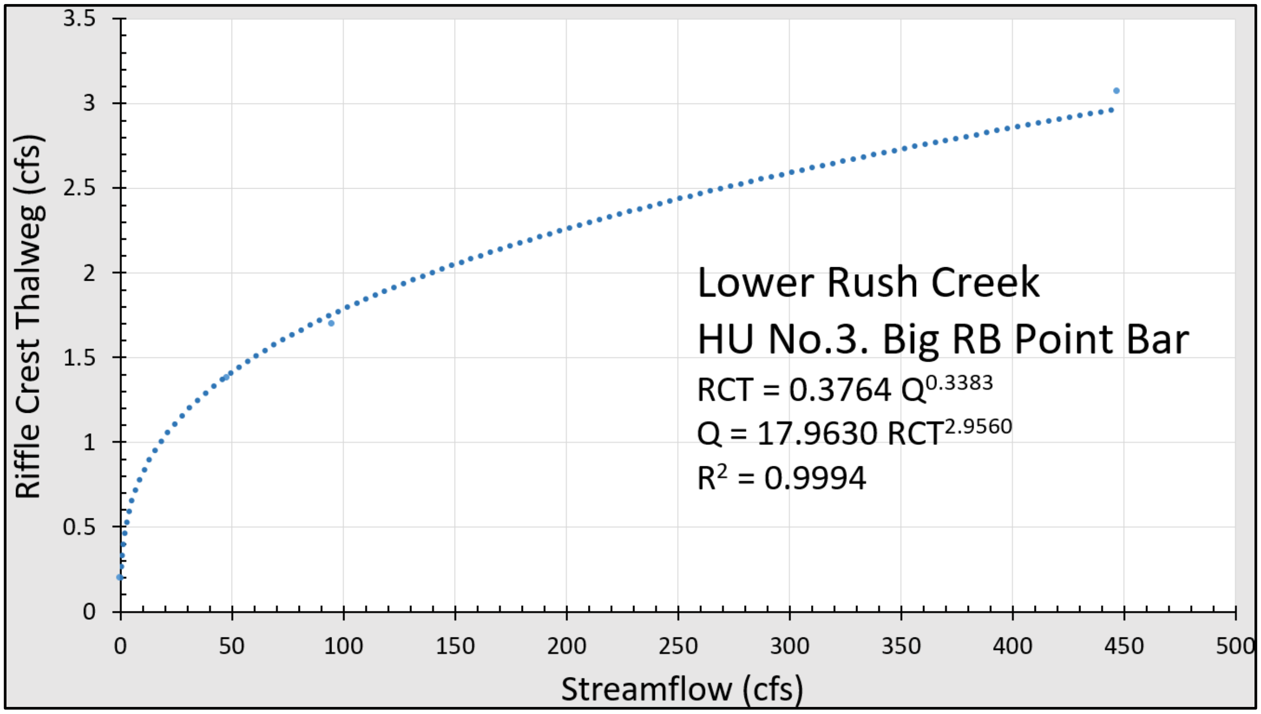


Figure 13. HU No.3 RCT-Q rating curve w/ PFE = 2.9560.

Figure 14. Lower Rush Creek HU No.4 at Gary Smith Overlook. Photo Taken: Thursday 27Sept2018 @ 3:24PM

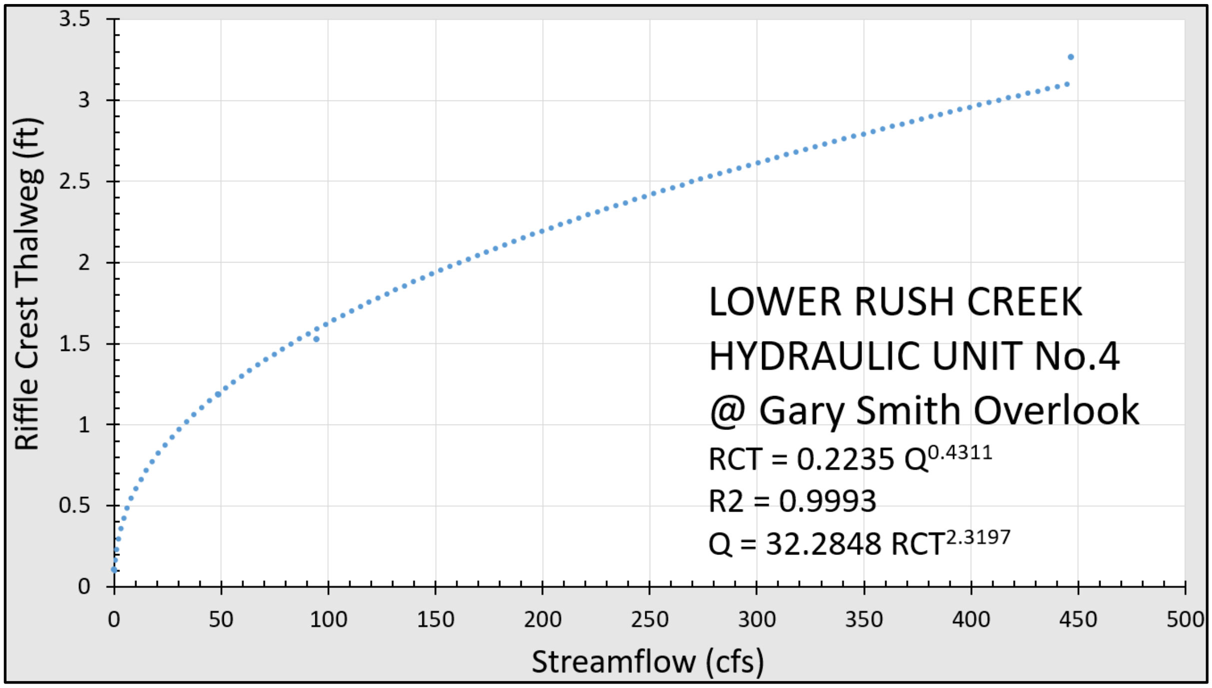


Figure 15. HU No.4 at Gary Smith Overlook w/ PFE = 2.3197.

Figure 16. Lower Rush Creek HU No.5 Downstream RB Point Bar Gary Smith Overlook. PFE = 2.40. Photo Taken: 03October2017 2:11PM.

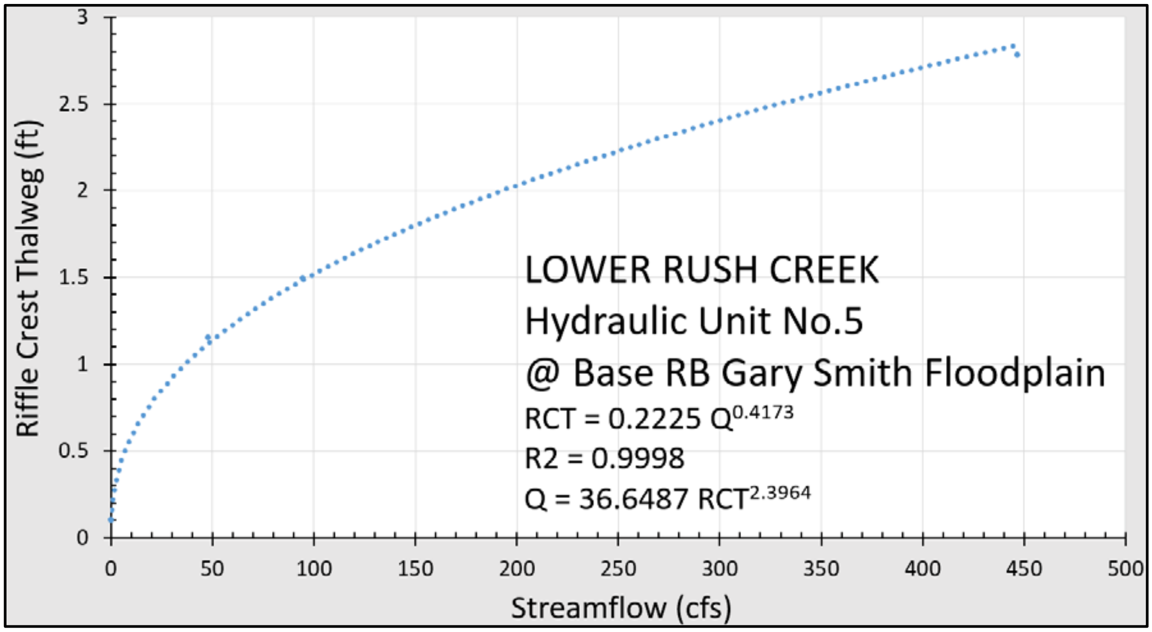


Figure 17. HU No.5 at base RB Gary Smith floodplain. PFE = 2.3964.

Figure 18. Lower Rush Creek HU No.6 at LB Old Gage Plate. Photo Taken: 27Sept2018 3:24 PM.

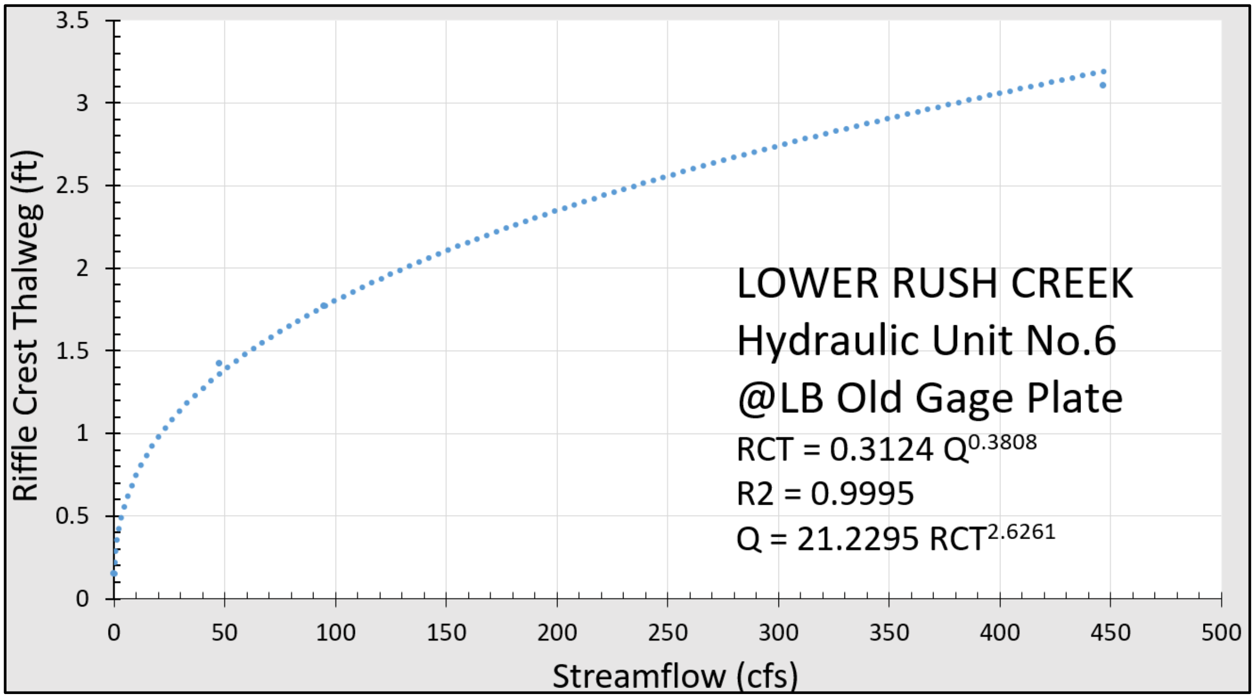


Figure 19. HU No.6 at Old Gage Plate. PFE = 2.6261.

Figure 20. Lower Rush Creek HU No.7 at RB Terrace Wall. Photo Taken: 27Sept2018 4:24PM.

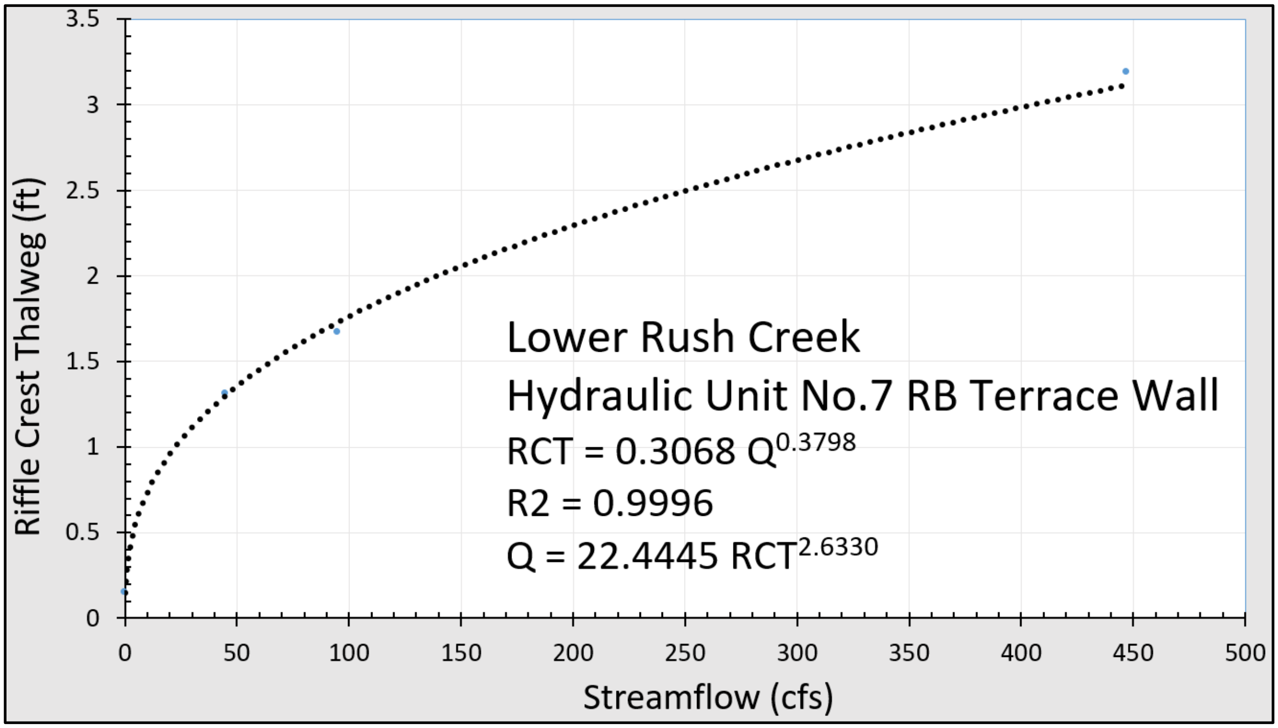


Figure 21. HU No.7 at RB Terrace Wall. PFE = 2.6330.

Figure 22. Lower Rush Creek HU No.8 Approach to Prominent RB Point Bar. Photo Taken: 27Sept2018.

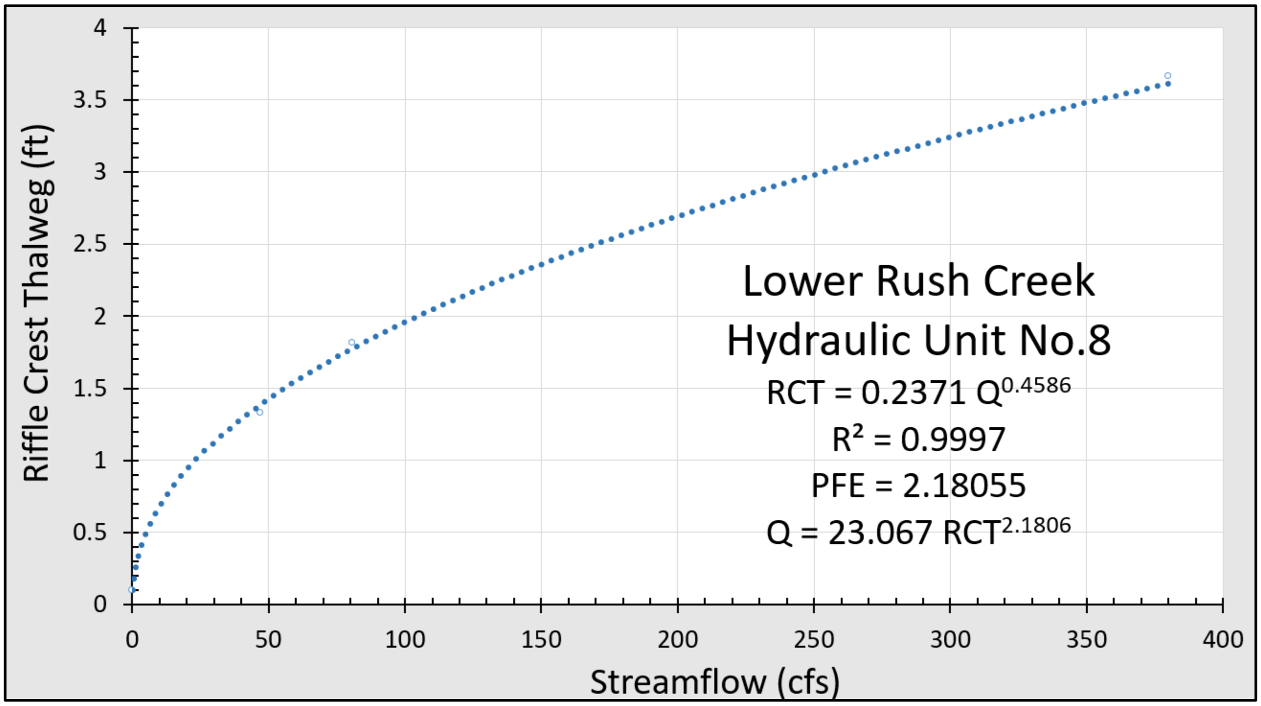


Figure 23. HU No.8 Approach to Prominent RB Point Bar. PFE = 2.1806.

Figure 24. Lower Rush Creek above 4-Floodplain Knickpoint. Photo Taken: 25Sept2018.

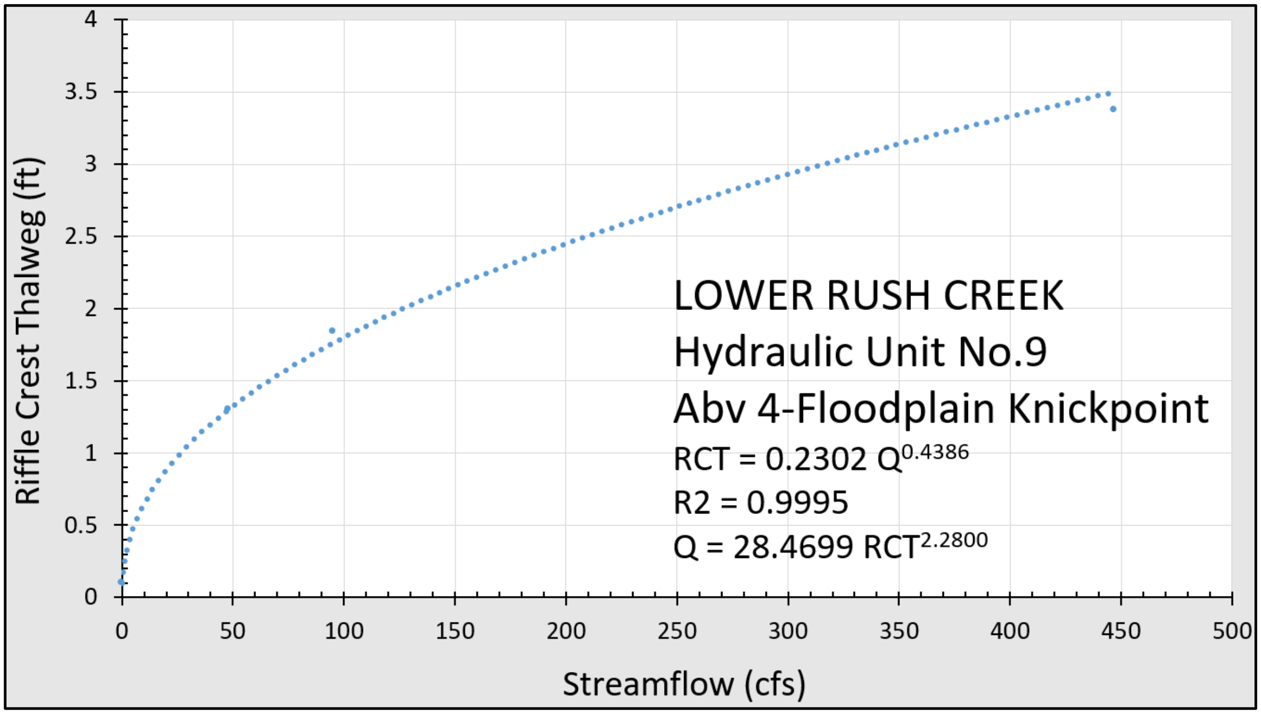


Figure 25. HU No.9 above 4-Floodplain Knickpoint. PFE = 2.2800.

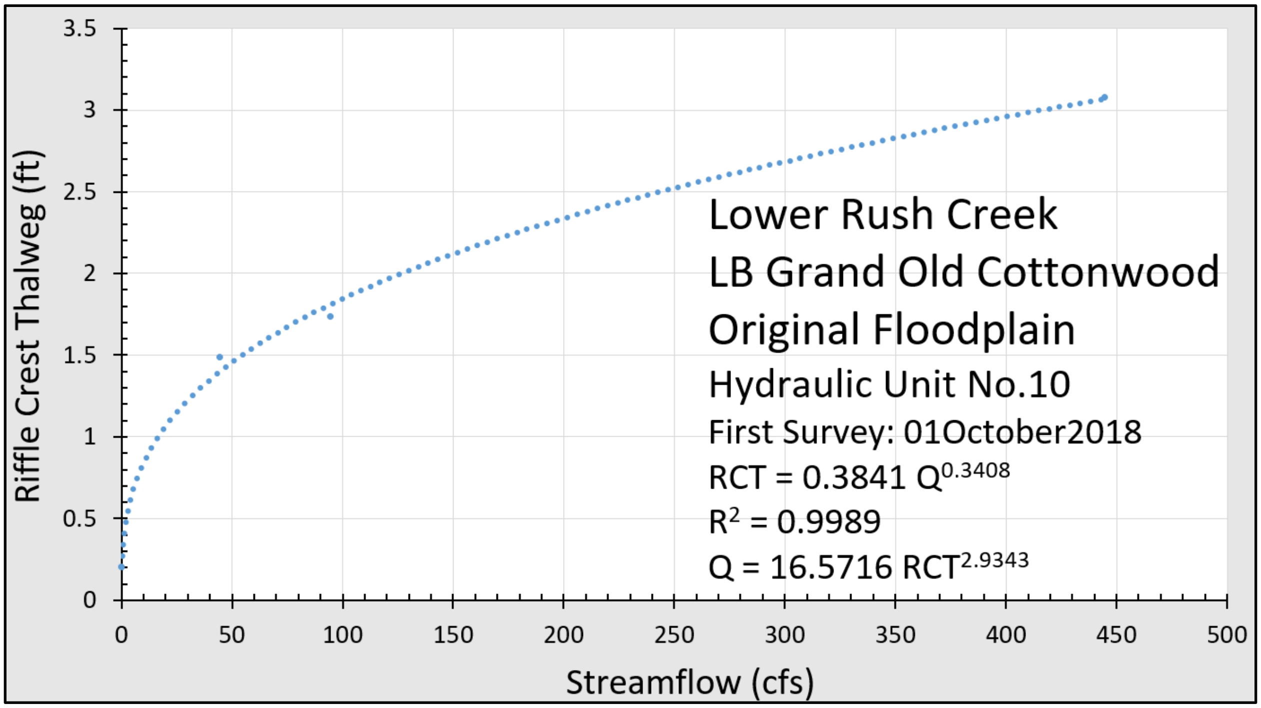


Figure 26. HU No.10 LB Grand Old Cottonwood Original Floodplain. PFE = 2.9343.

Riffle Crest Family

Every stream channel is a collection of riffle crests geomorphically derived and hydraulically characterized by their individual RCT-Q rating curves. This collection is called the RC Family (Figure 27). Selecting any streamflow from Figure 27 produces a wide range in RCT depths. For example at 40 cfs, the Family range in RCT depth is approximately 1.0 ft to 1.6 ft. The RC Family represents, via its collection of RCT-Q rating curves, the spatial hydraulic complexity of that stream channel. Constructing RCT-Q rating curves for 10% to 20% of a channel’s total HUs would be ideal for defining a RC Family, but very challenging.

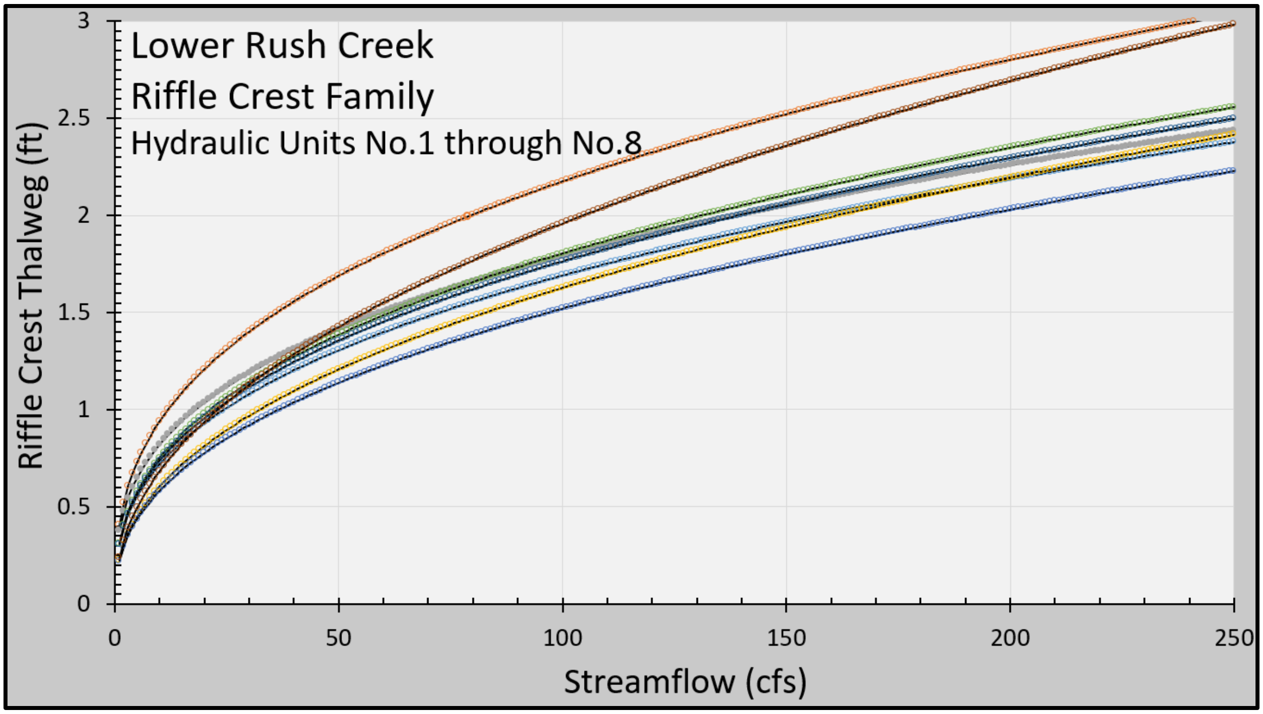


Figure 27. RC Family for Lower Rush Creek between the Old Gage Site (below the 10-Falls) and the Ford.

Another way to characterize hydraulic complexity of the RC Family is by describing the variable distribution of its PFE values among all RCT-Q rating curves. No single PFE is uniquely associated with any one channel type as the RC Family demonstrates. However, the median PFE value, or other descriptor of the PFE distribution, offers quantitative assessment. This is accomplished by creating a cumulative frequency distribution of Family PFE values (Figure 28). Median PFE for the Lower Rush Creek RC Family is 2.63.

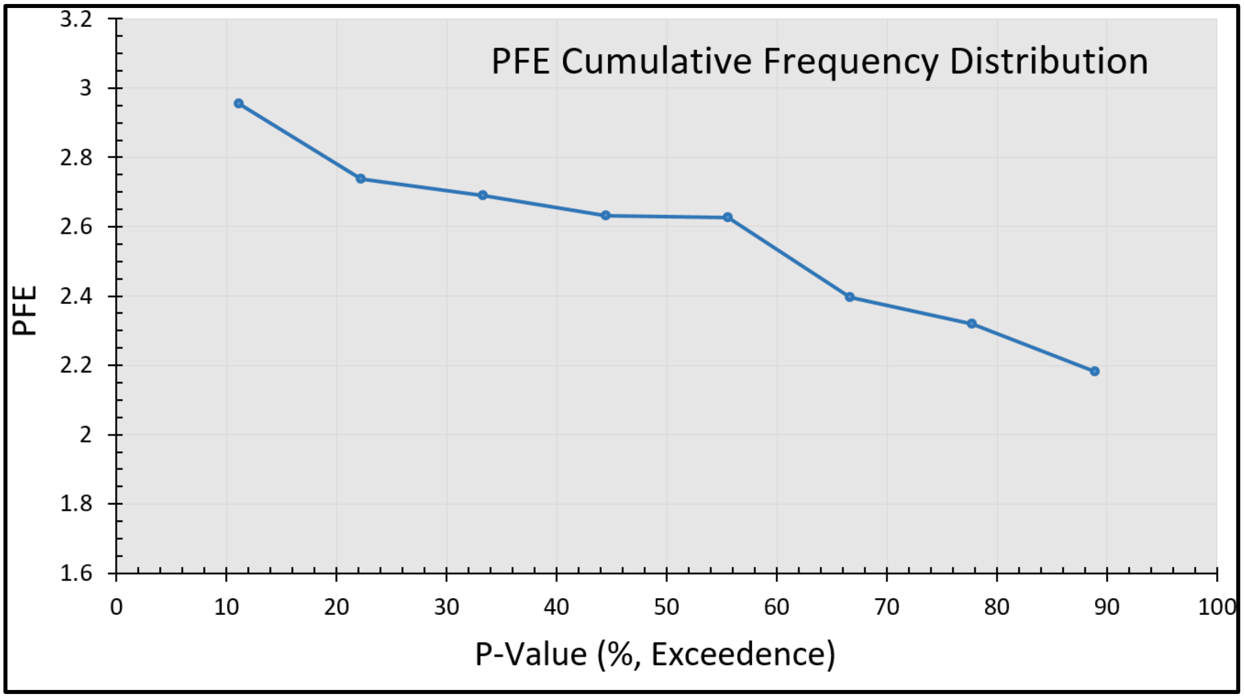


Figure 28. Cumulative frequency distribution of PFEs for RC Family in Lower Rush Creek.

Riffle Crest Hydraulics

Hydraulic Controls

There are several types of hydraulic controls in streams, each nested within another, that ultimately determine the power function coefficient (a) and exponent (PFE) in each hydraulic unit's RCT-Q rating curve. S. E. Rantz (1968, USGS Water Supply Paper No.2175) describes two basic hydraulic controls in stream channels as: *A prerequisite for any discussion of logarithmic rating curves is an understanding of the functioning of stage-discharge controls on streams. Two types of controls are section and channel. Section control exists when the geometry of a single cross section of a stream controls the relation between stage and discharge. Often the cross section that is the control for lower stages is not the control for higher stages. A cross section downstream may become effective at higher stages by causing backwater that submerges the original low-water control, or channel control may become effective at higher stages. Channel control exists when the geometry and roughness of a long reach of channel, downstream from a gage, control the relation between stage and discharge* [pp. 142-143]. Note Rantz does not say there are only two types of hydraulic controls. But he does explicitly distinguish these two by their separate spatial scales: Section Control occurs "*at a single channel cross-section*" whereas Channel Control occurs when "*the geometry and roughness of a long reach of channel"* determines the relation between stage and discharge. Rantz also does not make particular reference to the riffle crest cross-section, but rather to 'a cross-section' capable of controlling stage and discharge upstream. The riffle crest cross-section is ideally positioned to control lower streamflows passing through one hydraulic unit to the next downstream.

Its strategic location can be appreciated by bending a barn door hinge (Figure 29). At low baseflows, keep the pool wing of the hinge flat and sharply bend the riffle wing downward to approximate a steep riffle slope (refer to Figure 30 at low flow). Now, at higher streamflow (somewhere between low and high flow in Figure 30), bend the pool wing slightly upward and the riffle wing slightly downward. There remains a break in slope between the two wings. Last at high flow in Figure 30, continue bending the pool wing sharply upward (steeper) and the riffle wing downward until both wings merge as one common surface slope. The riffle crest, therefore, functions as the hydraulic hinge for changing water surface slopes from 'low' baseflows up to the 'high' flows that eventually drown it out.

Figure 29. The barn door hinge of hydraulic units.

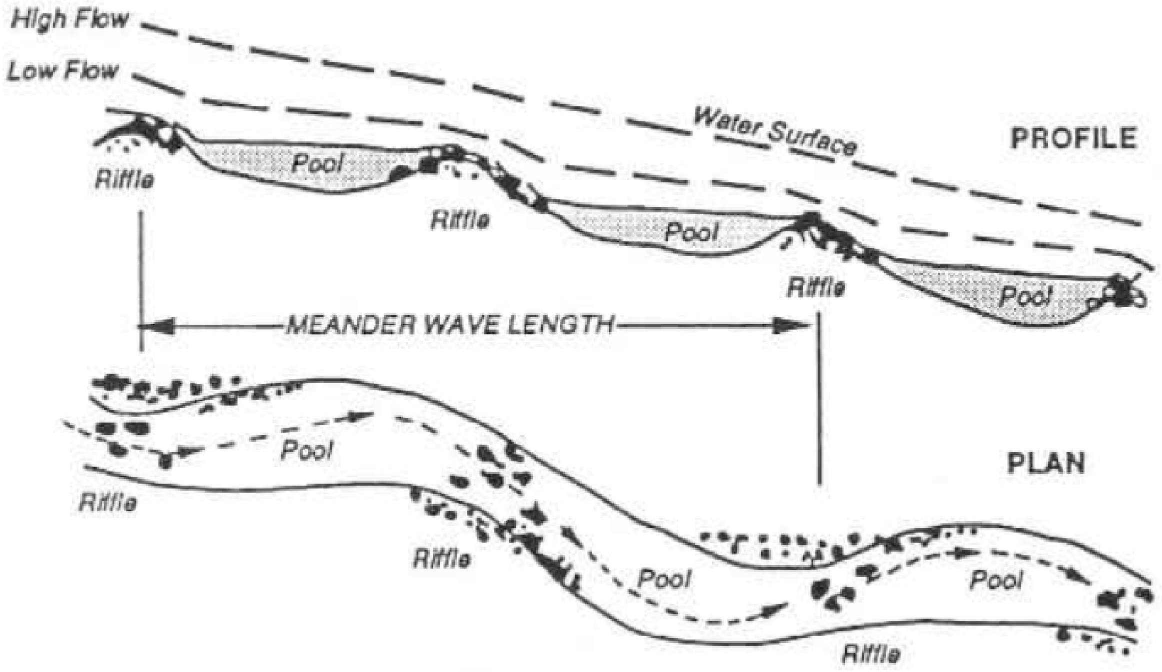


Figure 30. Long profile and plan view of three hydraulic units.

Hydraulic Controls in Lower Rush Creek

A ubiquitous, living geomorphic feature in Lower Rush Creek is the willow benches apparent in many HU No.2 through No.9 photographs taken late-September RY2018. Preliminary estimates of the streamflow threshold just inundating the base of these contemporary willow benches ranged from 220 cfs to 270 cfs. Figure 37 illustrates what a 220 cfs to 250 cfs streamflow looks like on Lower Rush Creek HU No.2 relative to a channel flowing (in the photograph) at approximately 50 cfs. Imagining 250 cfs mostly, and possibly entirely, drowning out the riffle crest is not difficult. Referring back to Figure 11, HU No.2 has an RCT depth of 1.67 ft at 50 cfs, 3.04 ft RCT depth at 250 cfs, and a 3.77 ft RCT depth at 450 cfs. The streamflow threshold beginning to inundate the base of the willow bench is called the Active Channel Streamflow (Q_{ACT}). Bankfull Flood, the 450 cfs, is only 0.70 ft higher in stage than the stage at Q_{ACT} yet inundates far back into the willow benches. And with widespread inundation, comes fine sediment deposition and the construction of a contemporary floodplain. The bankfull flood hydraulically performs as Rantz's Channel Control. At this location, the '*roughness of a long reach of channel*' would comprise an entire meander bend of evolving floodplain.

Figure 37. Active channel (Q_{ACT}) stage height between willow benches in Lower Rush Creek at HU No.2 (looking downstream from RCT). Streamflows exceeding Q_{ACT} trigger the onset of bankfull channel control.

Q_{ACT} is a streamflow threshold (QT) for a third type of channel control that is intermediate to Section and Channel controls, and called Active Channel Control. Willow benches accrete fine and coarse sediment to create bedforms that are 'effective' (as Rantz defines) controlling stage and streamflow. Q_{ACT} gets its name from inundating actively (frequently) scoured alluvial surfaces as in the photograph. But this control could also could be named 'Bedform Control.' Strictly speaking, Q_{ACT} can be defined as the very onset of Bankfull Channel Control. Above the RCT depth at Q_{ACT}, hydraulic roughness changes significantly (Section Control has been entirely drowned-out) and oftentimes requires a separate rating curve.

Three hydraulic controls dominating baseflows (winter and summer) and snowmelt recession streamflows in Lower Rush Creek are: (1) Section Control, (2) Dominant Section Control, and (3) Active Channel Control. Each has a major influence on key physical environmental variables including depth, velocity, turbulence, and side-channel flow. Each hydraulic unit affects these variables differently depending on its unique RCT-Q rating curve.

In addition to the three hydraulic controls, there is one more streamflow threshold of interest. It is not a streamflow threshold for another hydraulic control but rather a hydraulic tipping point. As streamflows rise, riffle crests gradually transition from overall Section Control (including Dominant Section Control) to overall Active Channel Control. A tipping point arrives when section and active controls are co-dominant (i.e., roughly 50:50). This is called the Lower Hydraulic Transition (Q_{LHT}) streamflow threshold. With both controls competing, the stream channel's hydraulic complexity around Q_{LHT} is at its greatest. Most riffles flow deep, fast, and broadly, yet pockets of slower, shallower streamflow (especially along the wetted channel margins and in pools) are abundant as well. The ecological ramifications are subtle and profound.

Quantifying Streamflow Thresholds for Hydraulic Controls

For these streamflow thresholds to be useful in long-term monitoring, they must be quantifiable. The shape of RCT-Q rating curves provides a way, beginning with Q_{LHT}. But there is one condition of the RCT-Q rating curve that must be met. Q_{ACT} is the onset of Bankfull Channel Control. The RCT-Q rating curve must extend from near zero streamflow up to at least the onset of Bankfull Channel Control. From the RY2018 exploratory fieldwork, Q_{ACT} equals 250 cfs.

Finding (quantifying) Q_{LHT}, and then hydraulic control streamflow thresholds as well, requires finding the maximum deviation from the RCT-Q rating curve's trendline (Figure 38). This can be accomplished geometrically. For each 1 cfs streamflow increment, starting at 1 cfs and ending at Q_{ACT} (i.e., the streamflow threshold for willow benches), compute RCT depth from the hydraulic unit's RCT-Q rating curve and from a linear equation defining the power function's trendline (Figure 38). The streamflow with the greatest difference between the two RCT depths at the same streamflow is the point (threshold streamflow) of maximum trendline deviation. Basically, this empirical method locates the asymptote to a RCT-Q rating curve. For HU No.1 in Figure 38, Q_{LHT} is approximately 50 cfs.

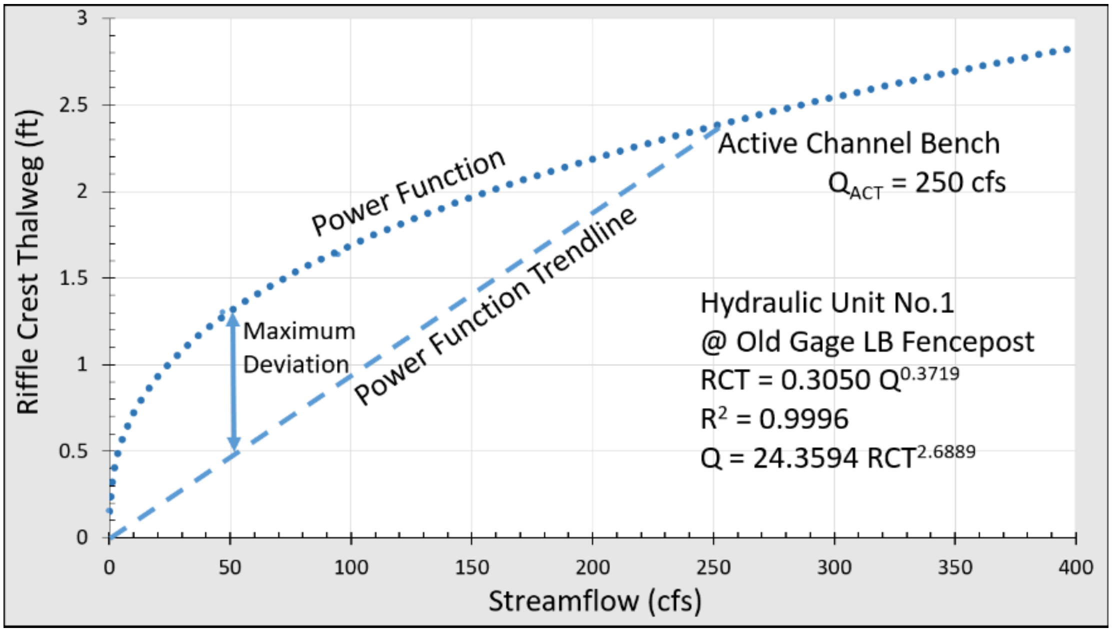


Figure 38. Estimating streamflow at maximum deviation from the power function's trendline geometrically for Lower Rush Creek HU No.1.

Alternatively, a simple equation was developed empirically to accomplish the same task by taking advantage of a power function's constant proportionality labeled the Hydraulic Transition Ratio (HTR) (Figure 39). HTR was used to compute streamflow thresholds for these three hydraulic controls for each RC Family member.

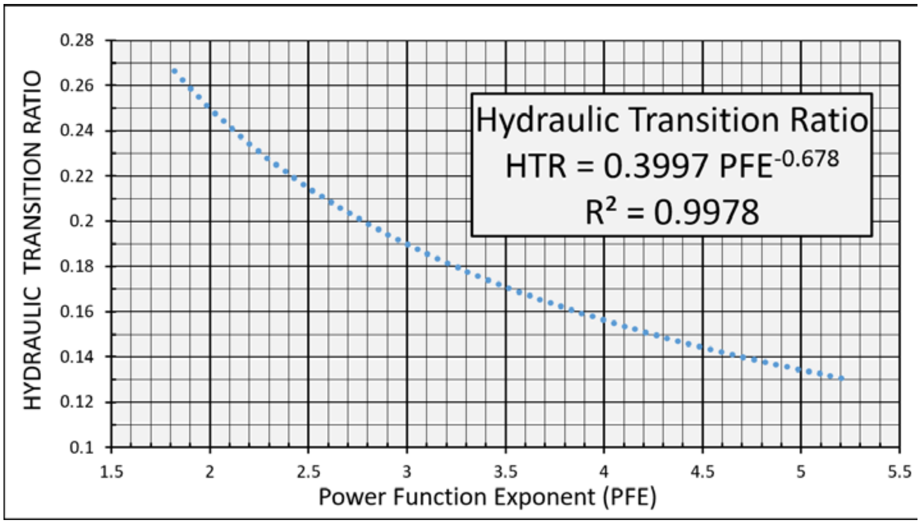


Figure 39. Hydraulic Transition Ratio (HTR) for estimating maximum deviation from a power function trendline as a function of the RCT-Q rating curve's PFE.

As an example, the RCT-Q rating curve for Lower Rush Creek HU No.6 (Figure 19) has a PFE of 2.6261. The maximum deviation between its RCT-Q rating curve and its linear trendline originating at 0 cfs and terminating at Q_{ACT} (Figure 40) equals 250 cfs * (0.3997 * ($2.6261^{-0.678}$)) = 51.9 cfs. This is Q_{LHT}, the streamflow for the Lower Hydraulic Threshold. The streamflow at the maximum deviation from a new trendline now between 0 cfs and Q_{LHT} equals 51.9 cfs * (0.3997 * ($2.6261^{-0.678}$)) = 10.8 cfs. This is Q_{DSECT}, the streamflow threshold for Dominant Section Control. And last, the streamflow at the maximum deviation from a new trendline now between 0 cfs and $Q_{DOMSECT}$ equals 10.8 cfs * (0.3997 * ($2.6261^{-0.678}$)) = 2.24 cfs. This is Q_{SECT}, the streamflow threshold for Section Control. Returning to HU No.1, Q_{LHT} equaled 51.1 cfs using HTR compared to the geometric estimate of 50 cfs in Figure 38.

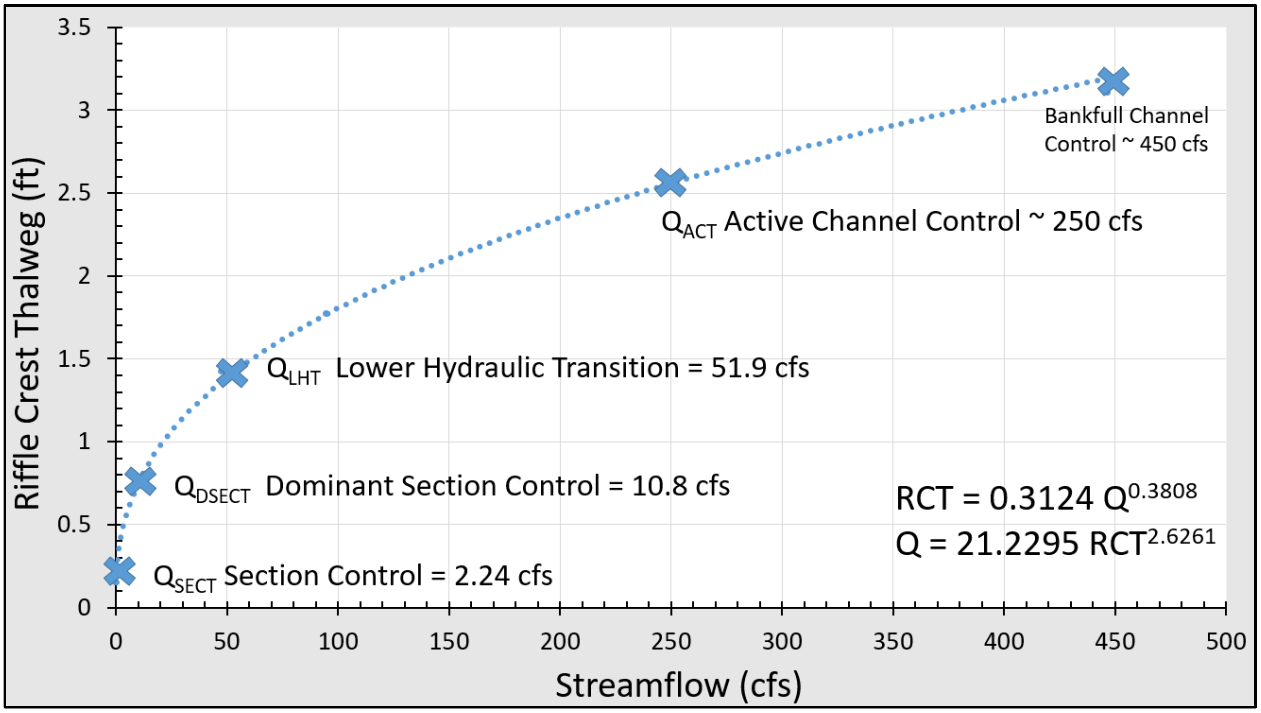


Figure 40. RCT-Q rating curve for Lower Rush Creek HU No.6 with streamflow thresholds for Section Control, Dominant Section Control, Active Channel Control, and Lower Hydraulic Transition.

Each RC Family member will have unique streamflow thresholds for Q_{LHT}, Q_{DSECT}, and Q_{SECT} entirely dependent on their specific PFE (Figure 41). The collective variability of these three hydraulic streamflow thresholds serves as one quantitative measure of stream channel complexity. One that can be objectively measured inter-annually to quantify stream channel restoration/recovery.

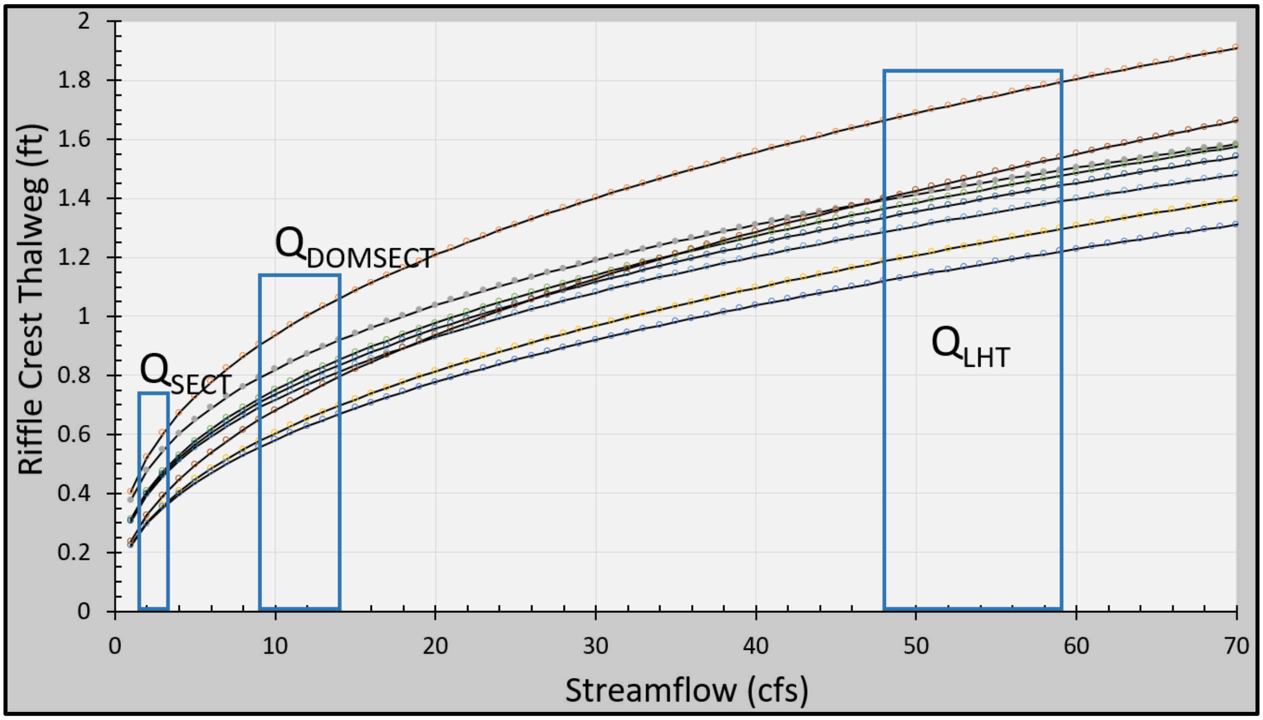


Figure 41. Streamflow threshold ranges for Q_{Sect}, Q_{DSECT}, and Q_{LHT} in Lower Rush Creek Family HU No.1 through No.8.

All eight estimates of thalweg depths at each control were plotted as cumulative frequency distributions (Figure 42). This analytical approach is highly preferable to using the mean and median which mask the complexity we want to achieve and quantify in a long-term monitoring program.

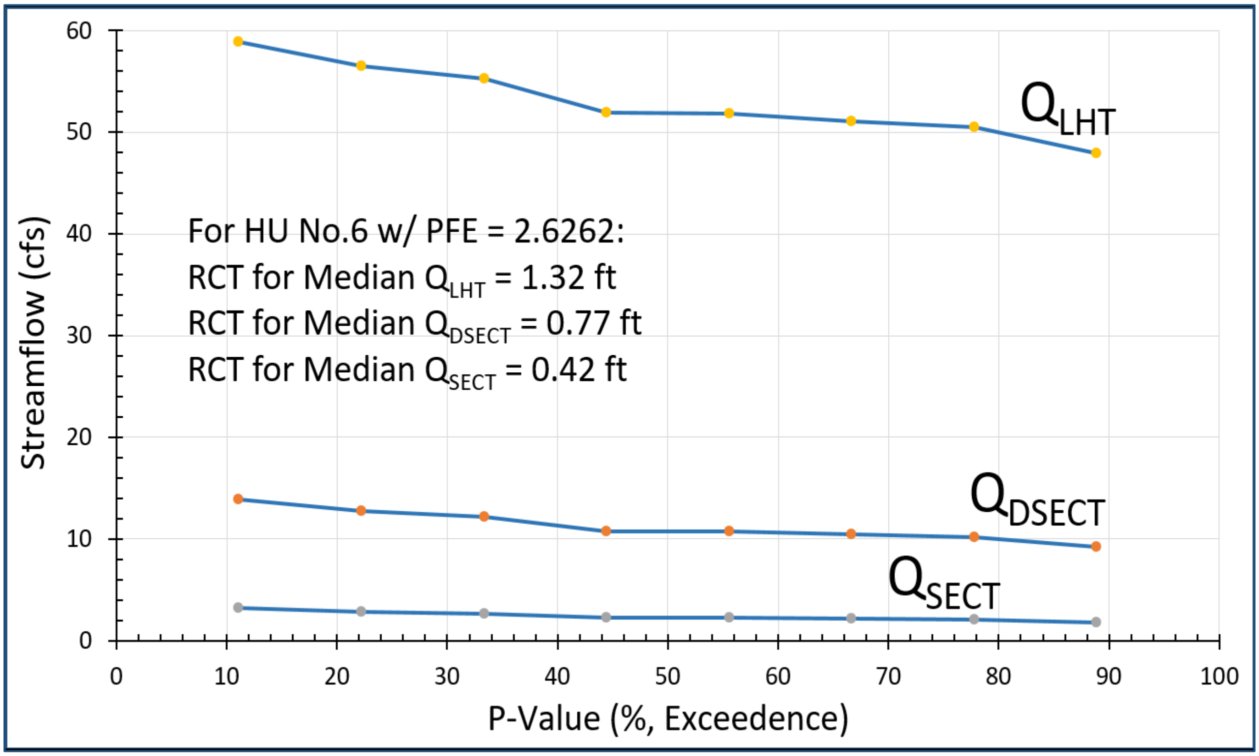
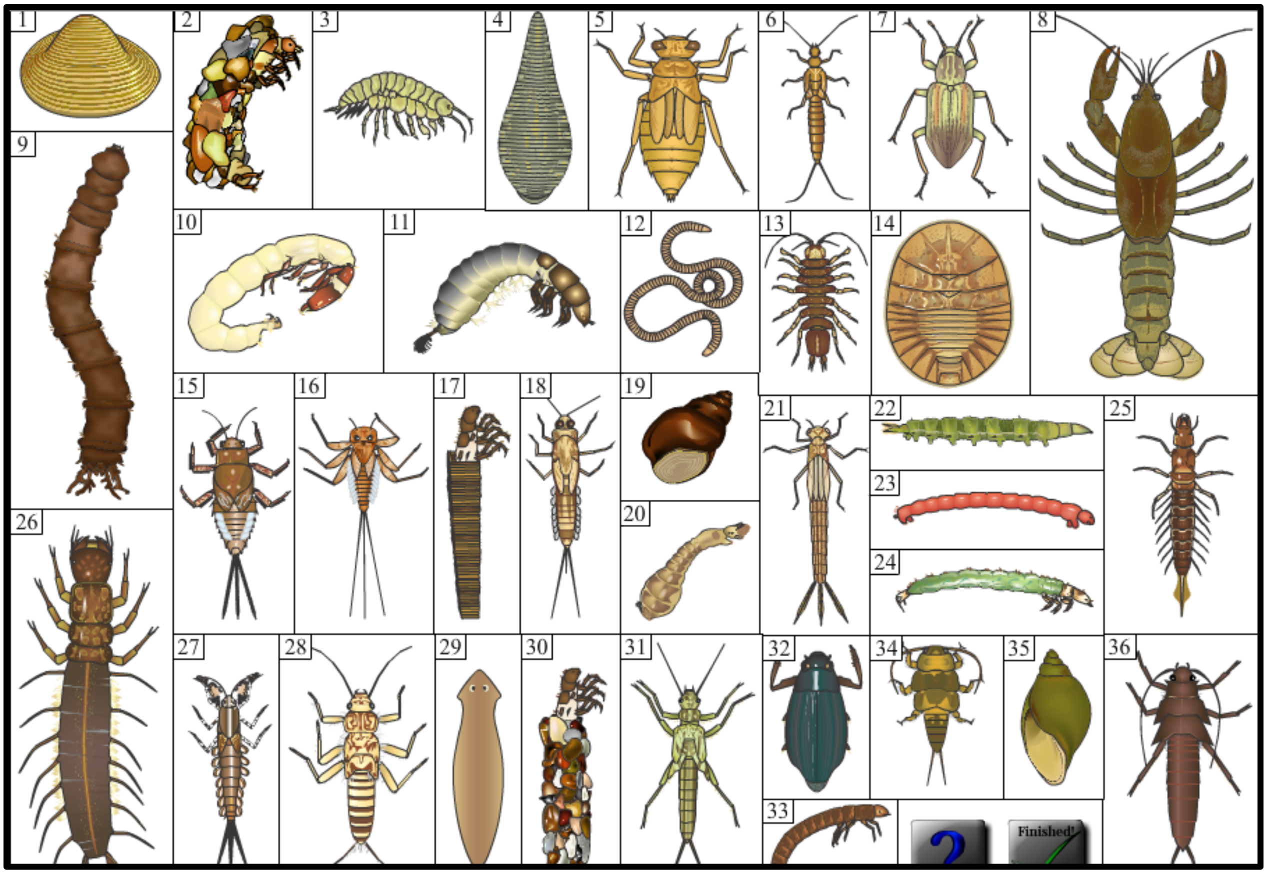


Figure 42. Cumulative frequency distribution of streamflow hydraulic thresholds Q_{LHT}, Q_{DSECT}, and Q_{SECT} for Lower Rush Creek RCT Family (N=8), including (as an example) corresponding RCT depths at HU No.6 with a PFE = 2.6261.



http://www.cacaponinstitute.org/Benthics/BMI%20dich%20key.html

Riffle Crest-Q Rating Curve Applications and Desired Ecological Outcomes

Each hydraulic control, in each hydraulic unit expressed in each annual hydrograph, determines the magnitude, duration, frequency, and timing of key ecological outcomes identified in the Synthesis Report. 'Ecosystem complexity' is created by the hydraulic spatial variability of the RC Family and the temporal variability of annual hydrographs. Two applications of RCT-Q rating curves to ecological outcomes are addressed, with a key goal in RY2020 of improving and expanding both applications and several others identified in the Synthesis Report.

Brown Trout Holding Habitat

Spatial scale dominates everything ecological. The adult brown trout's size in Figure 43 scales the ecological connection to the RC Family. If RCT = 0.60 ft was considered a minimum for favorable fish passage, its streamflow threshold (QT) would range from approximately 3 cfs to 11 cfs (to produce a 0.60 ft RCT) based solely on eight HU's. Therefore there is no single QT providing RCT = 0.60 ft. 'Abundant Winter Brown Trout Holding Habitat,' in Ecological Outcomes Table 3.1 of the Synthesis Report, is assigned a Rush Creek streamflow range of 25 cfs to 40 cfs. From Figure 43, a 25 cfs streamflow can have an RCT depth ranging between 1.3 ft down to 0.8 ft. Undoubtedly a few other HU's at 25 cfs will have RCT depths less than 0.8 ft especially in lower gradient, finer particle-sized riffle crests with PFEs less than 2.2 (i.e., w/ riffle crests strongly rectangular and broad). The desired outcome of the Synthesis Report's 25 cfs to 45 cfs QT was directed towards abundant winter holding habitat not solely fish passage at riffle crests. But the RCT Family can address trout holding habitat quality and abundance outside the spatial scale constraints of inundation depth at any given streamflow.

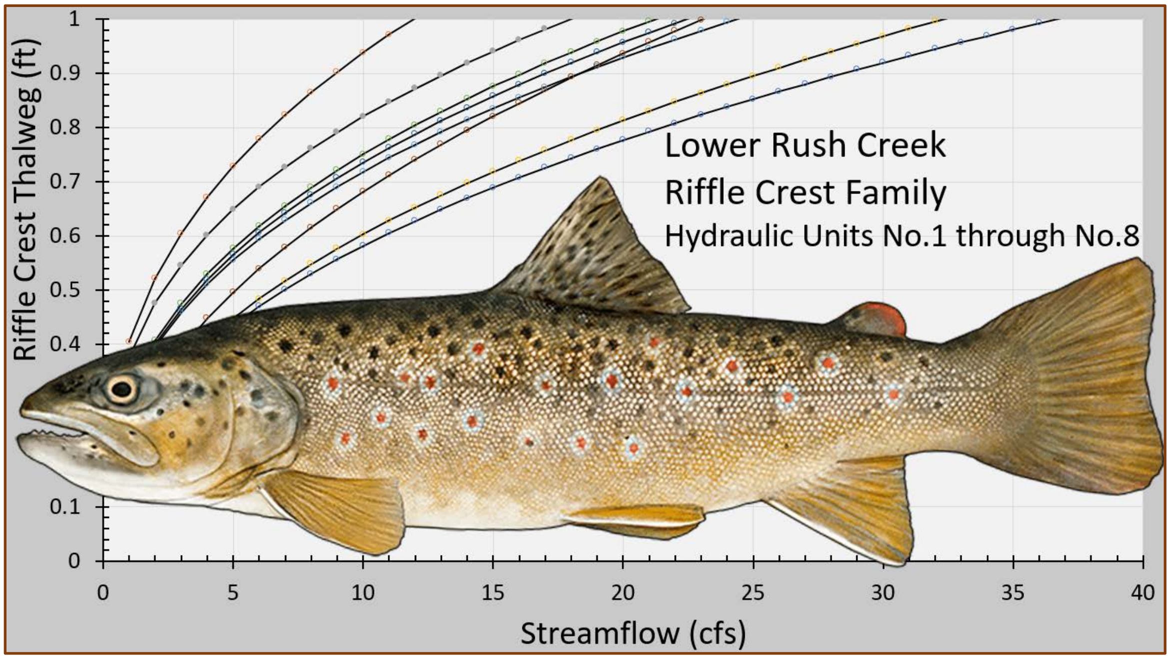


Figure 43. Lower Rush Creek RC Family in comparison to an adult brown trout spanning 1 cfs to 50 cfs streamflows.

Productive Benthic Macroinvertebrate (BMI) Riffles

Channel hydraulics also dominates everything ecological. Benthic Macro-Invertebrate (BMI) riffle productivity is essential to Rush and Lee Vining creek ecosystems including maintaining the brown trout holding habitat. Riffles with turbulent streamflow (Figure 44) provide hydraulically complex eddies promoting high BMI biomass and high productivity. Both contribute to holding habitat quality.

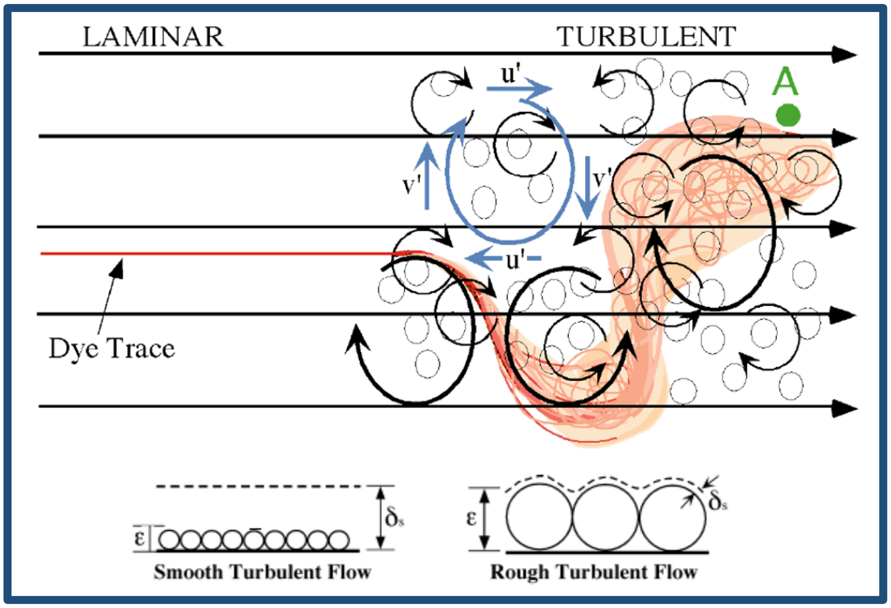


Figure 44. Smooth turbulent streamflow versus rough turbulent streamflow (reproduced from: http://www.mit.edu/course/1/1.061/www/dream).

Using three D_{84} cobbles as the upper depth limit for turbulent streamflow (Figure 45 stacked on the right), an upper and lower QT defines good BMI riffle habitat. The RC Family was then superimposed onto Figure 45 to estimate upper (3 D_{84}s) and lower (1 D_{84}) RCT depths and corresponding streamflow thresholds (QTs).

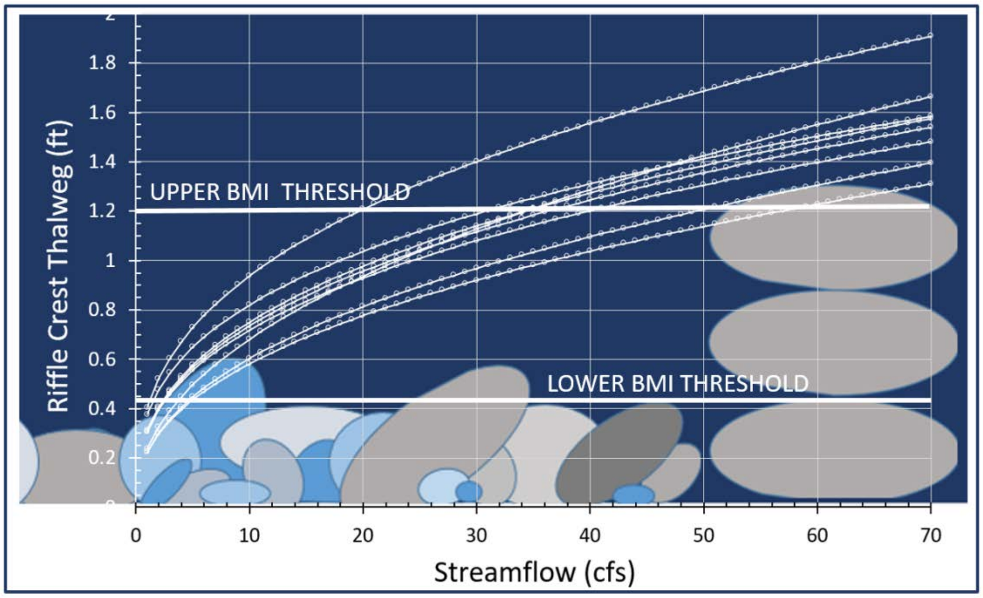


Figure 45. Highly productive BMI riffle habitat streamflow thresholds with superimposed RC Family RCT-Q rating curves.

But more ecological insight can be gained from the Lower Rush Creek RC Family. Q_{DSECT} ranges from 9 cfs to 14 cfs and Q_{LHT} from 47 cfs to 59 cfs (Figures 41 and 42). At Q_{LHT}, sectional and active channel controls co-dominate. This tags a segment of the annual hydrograph … especially mid-April through early-June … when stream temperatures are favorable and BMI productivity is innately high. While Figures 43 and 45 provide inundation depths (as RCT) relative to fish passage and BMI habitat, the hydraulic control QT thresholds also predict complex 3-D hydraulics bank-to-bank. Back to another desired ecological outcome in the Synthesis Report Table 3.1, ‘Abundant Productive BMI Riffle Habitat’ is assigned a streamflow range of 40 cfs to 110 cfs. Most of the RCT-Q rating curves predict approximately 40 cfs streamflows as an upper streamflow limit for rough turbulent flow. The higher recommended baseflows up to 110 cfs encompass more of the entire riffle area as productive BMI streamflows. RCT depth at 40 cfs is approximately 1.2 ft to 1.3 ft and the RCT depth at 100 cfs is approximately 1.8 ft, for an approximate increase of 0.5 ft. The modifier ‘approximate’ is necessary given no single optimal RCT depth exists. And last, BMI riffle habitat, brown trout, and the RC Family were superimposed (Figure 46) to offer a more complete visual perspective on the importance of scale in a stream ecosystem.

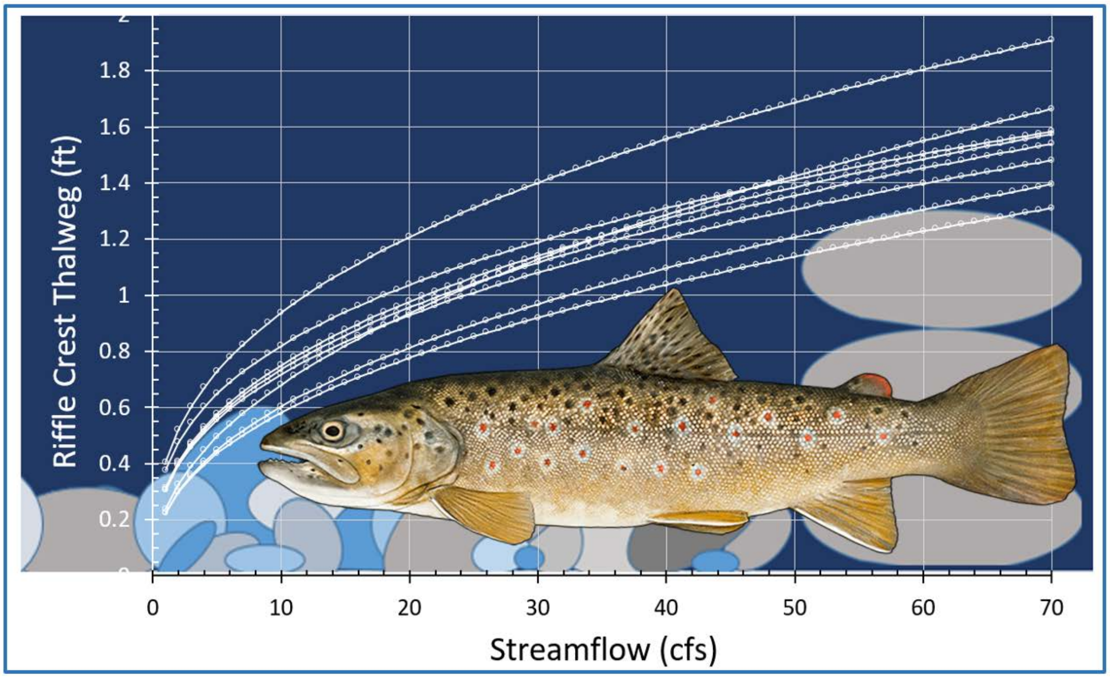


Figure 46. Overlay of RCT-Q Rating curves from RC Family with BMI riffle habitat and adult brown trout.

RC Family and Long-Term Monitoring

As the mainstem channel continues adjusting its grade and shape, Q_{LHT} will also continue adjusting with significant ecological implications. For example, streamflow velocities sharply increase approaching Q_{LHT} which will significantly affect juvenile salmonid rearing habitat quality and availability. Narrower channels with more LWD influence will increase PFE's among the mainstem's hydraulic units. PFE's, therefore, will measure future hydraulic complexity. Increasing PFE will cause the same streamflow to have a greater RCT depth. This will significantly help dictate the future of floodplain connectivity.

The RC Family physically links quantifiable thresholds in stream channel hydraulics to multiple ecological processes temporally and spatially. Annual hydrographs offer the temporal complexity; the RCT-Q rating curves of the RC Family generate the spatial complexity. Together, they largely define top-down stream ecosystem complexity. Healthy, self-renewing Rush Creek and Lee Vining Creek ecosystems will require both.

RY2020 Field Season Objectives

Although the COVID-19 pandemic may alter plans, these are the tasks planned:

Establish additional RCT-Q rating curves, including at all primary side-channel inlets and floodplain scour channels.

Estimate streamflow thresholds for contemporary Active Channel benches.

Sample annual stem increment from subset of cottonwoods and yellow willows sampled in RY2018 and measure stem increment at two other time intervals through the RY2020 summer.

Resurvey residual pool depths and riffle crest widths last sampled in RY2018.

Section 5

Mono Basin Waterfowl Habitat Restoration Program 2019 Monitoring Report with Recommendations by Ms. Debbie House, Interim Mono Basin Waterfowl Monitoring Program Director

Mono Basin Waterfowl Habitat Restoration Program

Statement of Compliance and Summary of 2019 Monitoring

Prepared for the State Water Resources Control Board

The Los Angeles Department of Water and Power (LADWP) conducts monitoring in compliance with the 1996 Mono Basin Waterfowl Habitat Restoration Plan and the 1998 State Water Resources Control Board Order WR 98-05. LADWP completed the following monitoring tasks in 2019:

Hydrology:

- Monthly Mono Lake elevation readings
- Daily stream flows in Rush, Lee Vining, Parker and Walker Creeks
- Spring surveys

Limnology:

- Meteorological, physical/chemical, phytoplankton, and brine shrimp population monitoring

Vegetation Status in Lake-fringing Wetlands:

- Still-image photography of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoir

Waterfowl Populations:

- Summer ground surveys and documentation of habitat use
- Fall aerial surveys at Mono Lake, Bridgeport Reservoir and Crowley Reservoir

The *Mono Basin Waterfowl Habitat Restoration Program 2019 Monitoring Report* included herein provides detailed discussion of monitoring methods, results, and discussion for each component. Below are brief summaries of the results of the 2019 monitoring year.

Hydrology

The 2018-2019 Runoff year was “Wet/Normal” at 151,818 acre-feet, or 124% of the long-term average. Mono Lake experienced an overall increase in lake level as compared to 2018. The peak lake level in 2019 of 6,382.7 feet occurred in August due to delayed seasonal runoff. In December 2019, Mono Lake was at 6382.1 feet, or 1.2 feet higher than in December 2018.

The spring survey recorded flow, water temperature, electrical conductivity and other parameters at a subset of springs on the Mono Lake shoreline. Dense vegetation and high water levels made it difficult to access some spring sources. Most sites were heavily vegetated, however several spring sites along the east shore were denuded due to grazing and trampling by feral horses. Spring flow into Mono Lake showed an increase of 44.17 gpm as compared to the 2014 spring survey results. The largest increase in flow from 2014 to 2019 occurred at springs on the west, northwest, and southeast shores and is likely attributed to high infiltration from runoff over the past two years after four years of drought.

Limnology

This monitoring year marked the beginning of the 3rd year of a meromictic event, and Mono Lake remained stratified in 2019. Epilimnetic nutrients were depleted while hypolimnetic nutrients continued to increase. Epilimnetic salinity continued to decline and hypolimnetic salinity started to decline due to a weakening chemocline. Water temperature was lower than normal throughout the water column, and hypolimnetic DO remained suboxic to anoxic.

Artemia population abundance increased slightly from 2018 even though it remained below the long-time average. Clarity remained above 3 m due to higher *Artemia* abundance and also due to increased Mono Lake input. A lack of holomixis in 2019 ensures further buildup of nutrients in the hypolimnion..

Vegetation Status in Lake-fringing Wetlands

The increase in lake level in 2019 resulted in the presence of ponds in multiple shoreline areas. Increases in lake level also restore the connectivity of existing ponds with the water line and spring outflow areas of Mono Lake. Increased pond acreage and connectivity to shoreline and spring outflow areas resulted in improved habitat quality for waterfowl.

Waterfowl Populations

The breeding waterfowl population at Mono Lake in 2019 was 306, or approximately 153 pairs. The 2019 breeding population was comparable in size to the long-term mean of 304.8 +/- 20.7 SE. Dabbling duck production of 69 broods was well above the long-term average of 46.9 +/- 3.9 SE. Breeding activity was concentrated along the south shoreline, including the South Shore Lagoons and Simon's Spring shoreline areas. In the northwest shore areas of DeChambeau Creek, Mill Creek and Wilson Creek, breeding activity was notably below average.

Fall waterfowl use at Mono Lake in 2019 increased over the extreme low observed in 2018, but was still well below the long-term average. The total fall waterfowl observed at Mono Lake in 2019 was 13,333 as compared to the long-term mean of 24,762. The peak count of 3,195 was also well below the long-term average of 7,678. The population estimator, which is the most conservative estimate of annual fall waterfowl use, indicates that an average of 8,888 waterfowl (range 2,148-18,590) have visited Mono Lake each fall 2002-2019.

Total waterfowl use in 2019 was below the long-term means for Mono Lake, Bridgeport Reservoir, and Crowley Reservoir, however the difference was greatest at Mono Lake. Multiple factors influence migrating populations, including flyway conditions, productivity on breeding grounds, weather, climate and disease. Unlike the breeding waterfowl community, fall waterfowl use of Mono Lake has not been directly correlated with lake elevation.

Recommendations

I recommend that the second year of the waterfowl time budget study, as required by Order 98-05, be completed by the end of 2020. In addition, I recommend interested parties work with the Mono Basin Waterfowl Director in evaluating the feasibility of implementing a seasonal flooding program at the Restoration Ponds to improve the productivity for waterfowl.

Debbie House

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Debbie House

Mono Basin Waterfowl Monitoring Program Director

Mono Basin Waterfowl Habitat Restoration Program 2019 Monitoring Report

Prepared by:
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Prepared for the State Water Resources Control Board
And Los Angeles Department of Water and Power
April 2020

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EXECUTIVE SUMMARY

In 1983, National Audubon Society v. Superior Court resulted in the California State Water Resources Control Board (SWRCB) reevaluating the effect of water diversions by the City of Los Angeles (City) on the public trust values of Mono Lake. SWRCB Decision 1631, signed in 1994, amended the City's water rights, establishing instream flow requirements for the Mono Basin creeks and placing limitations on water exports from the Mono Basin. Order WR 98-05 (SWRCB 1998) directed the Los Angeles Department of Water and Power (LADWP) to implement waterfowl habitat restoration measures and monitoring to mitigate the loss of waterfowl habitat in the Mono Basin from diversions. This report summarizes the results of monitoring conducted in 2019 under the Mono Basin Waterfowl Habitat Restoration Plan (Plan) (LADWP 1996a), as required by Order 98-05.

Mono Lake experienced an overall increase in lake level as compared to 2018. The peak lake level in 2019 of 6,382.7 feet did not occur until August due to delayed seasonal runoff. At the final lake level read in December 2019 (6382.1 feet), Mono Lake was 1.2 feet higher than in December 2018. The 2018-2019 Runoff year was "Wet/Normal" at 151,818 acre-feet, or 124% of the long-term average. Input from the two major tributaries (Rush and Lee Vining Creeks) in 2019 was 138,154 acre-feet, or 141% of the long-term average since re-watering in 1982.

The Spring Survey was completed in 2019 and involved recording flow, water temperature, electrical conductivity and other parameters at a subset of springs on the Mono Lake shoreline. Dense vegetation and high water levels made it difficult to access some spring sources. Most sites were heavily vegetated, however several spring sites along the east shore were denuded due to grazing and trampling by feral horses. Overall, flow from the springs into Mono Lake in 2019 increased by 44.17 gpm compared to that measured in the 2014 Spring Survey. The largest increase in flow from 2014 to 2019 occurred at springs on the west, northwest, and southeast shores and is likely attributed to high infiltration from runoff over the past two years after four years of drought.

The 2019 monitoring year marked the beginning of the 3rd year of a meromictic event that started in 2017 with the second largest Mono Lake input on record and Mono Lake remained stratified in 2019. As a result, epilimnetic nutrients were depleted while hypolimnetic nutrients continued to increase. Epilimnetic salinity continued to decline and hypolimnetic salinity started to decline due to weakening chemocline. Water temperature was lower than normal throughout the water column, and hypolimnetic DO remained suboxic to anoxic while epilimnetic DO was much higher in November and December. *Artemia* population abundance increased slightly from 2018 even though it remained below the long-time average. *Artemia* daily population abundance shows a broader and later peak. Clarity remained above 3 m due to higher *Artemia* abundance compared to the period between 2014 and 2016, and also due to increased Mono Lake input. A lack of holomixis in 2019 ensures further buildup of nutrients in the hypolimnion even though the hypolimnetic ammonium in December is still below the long-term average. The latest meromixis, even though showing signs of weakening, should last throughout 2020 and most likely will result in *Artemia* population peak in 2021 unless snowpack improves considerably in late winter and spring.

Climatic factors may be influencing Mono Lake and its recovery. Seasonal salinity and water temperature show increasing trends. These findings are aligned with the regional climatic trends. Based on our analysis, a lack of sustained high freshwater input will not be able to reverse the trend of increasing salinity.

The increase in lake level in 2019 resulted in somewhat predictable changes to waterfowl habitat. Shoreline ponds were present in multiple shoreline subareas in 2019. Shoreline ponds develop more readily along the south and east shores, and their presence and formation are influenced by lake level, and wind and wave action. Increases in lake level also restore the connectivity of existing ponds with the water line and spring outflow areas of Mono Lake. Increased pond acreage and connectivity to shoreline and spring outflow areas resulted in improved habitat quality for waterfowl.

The breeding waterfowl population at Mono Lake in 2019 was 306, or approximately 153 pairs. The 2019 breeding population was comparable in size to the long-term mean of 304.8 +/- 20.7 SE. At total of 76 waterfowl broods were seen in 2019, including seven broods of Canada Geese and 69 dabbling duck broods. Dabbling duck production in 2019 of 69 broods was well above the long-term average of 46.9 +/- 3.9 SE. In 2019, breeding activity was concentrated along the south shoreline, including the South Shore Lagoons and Simon's Spring shoreline areas. Breeding was particularly concentrated in the South Shore Lagoons subarea where more than half of all waterfowl broods were found in 2019. In the northwest shore areas of DeChambeau Creek, Mill Creek and Wilson Creek, breeding activity was notably below average. No broods were detected in Mill Creek in 2019, an area typically supporting up to 13% of lakewide broods.

Fall waterfowl use at Mono Lake in 2019 increased over the extreme low observed in 2018, but was still well below the long-term average. The total fall waterfowl observed at Mono Lake in 2019 was 13,333 as compared to the long-term mean of 24,762. The peak count of 3,195 was also well below the long-term average of 7,678. The population estimator, which is the most conservative estimate of annual fall waterfowl use, indicates that an average of 8,888 waterfowl (range 2,148-18,590) have visited Mono Lake each fall 2002-2019.

The two key waterfowl species at Mono Lake are the dabbling duck Northern Shoveler and the diver Ruddy Duck, which generally comprise over 80% of total fall waterfowl numbers. In 2019, Northern Shoveler and Ruddy Duck populations were below the long-term mean. Total waterfowl use in 2019 was below the long-term means for all three survey areas, however the difference was greatest at Mono Lake. Multiple factors influence migrating populations, including flyway conditions, productivity on breeding grounds, weather, climate and disease. Unlike the breeding waterfowl community, fall waterfowl use of Mono Lake has not been directly correlated with lake elevation.

With the exception of the Ruddy Duck, most waterfowl use at Mono Lake occurs in lake-fringing ponds, or very near to shore. The near shore areas used by waterfowl are generally shallow, have gentle offshore gradients, and freshwater spring, creek, or brackish water input. Mono Lake is deep, highly saline, with limited shallow shoreline areas. These features limit the habitat quality for waterfowl, and may ultimately limit recovery of waterfowl populations.

We recommend that the second year of the waterfowl time budget study, as required by Order 98-05, be completed by the end of 2020. We also recommend interested parties work with the Mono Basin Waterfowl Director in evaluating the feasibility of implementing a seasonal flooding program at the Restoration Ponds to improve the productivity for waterfowl.

1.0 INTRODUCTION

Mono Lake is a large terminal saline lake at the western edge of the Great Basin in Mono County, California. The largest lake in Mono County, Mono Lake has an east-west dimension of 13 miles, a north-south dimension of over nine miles (Raumann et al. 2002), and a circumference of approximately 40 miles. With an average depth of over 60 feet and a maximum depth of approximately 150 feet (Russell 1889), Mono Lake is a large, moderately deep terminal saline lake (Jellison and Melack 1993, Melack 1983). The deepest portions of the lake are found south and east of Paoha Island in the Johnson and Putnam Basins, respectively (Raumann et al. 2002). Shallower water and a gently sloping shoreline is more typical of the north and east shores (Vorster 1985, Raumann et al. 2002).

Mono Lake is widely known for its value to migratory waterbirds, supporting up to 30% percent of the North American Eared Grebe (*Podiceps nigricollis*) population, the largest nesting population of California Gull (*Larus californicus*) in California (Winkler 1996), and up to 140,000 Wilson's (*Phalaropus tricolor*) and Red-necked Phalaropes (*P. lobatus*) during fall migration (Jehl 1986, Jehl 1988).

Saline lakes are highly productive ecological systems (Jellison et al. 1998), however productivity is influenced by factors such as salinity, water depth, temperature, and water influx and evaporation on a seasonal, annual, and inter-annual basis. Saline lakes often respond rapidly to environmental changes, and alterations to the hydrological budget (Jehl 1988, Williams 2002). Water demands for agriculture, human development and recreation, as well as changes in climate are impacting saline lakes globally (Wurtsbaugh et al. 2017).

In 1941, the City of Los Angeles (City) began diverting water from Lee Vining Creek, Rush Creek, Walker Creek, and Parker Creek for municipal water supply. From 1941-1970, when the City was exporting an annual average of 56,000 acre-feet, the elevation of Mono Lake dropped over 29 feet. In 1970, the completion of the second aqueduct in the Owens Valley expanded the capacity of the Los Angeles Aqueduct system, resulting in increased diversions, and frequent full diversion of flows from Lee Vining, Walker, Parker and Rush Creek (SWRCB 1994). From 1970 to 1989, Mono Lake dropped another 12.6 feet as yearly exports averaged 82,000 acre-feet, with a peak export of 140,756 acre-feet in 1979. The elevation of Mono Lake dropped to a record low of 6,372.0 feet above mean sea level in 1982. In 1979, the National Audubon Society filed suit with the Superior Court of California against the City (National Audubon Society v. Superior Court), arguing that the diversions in the Mono Basin were resulting in environmental damage and were a violation of the Public Trust Doctrine.

After a series of lawsuits and extended court hearings, the State Water Resources Control Board (SWRCB) amended the City's water rights with the Mono Lake Basin Water Right Decision 1631 (Decision 1631) (SWRCB 1994). Decision 1631 established instream flow requirements for the Mono Basin creeks for fishery protection, and placed limitations on water exports from the basin until the surface elevation of Mono Lake reached 6,391 feet. In addition to diversion reductions, Decision 1631 required LADWP to conduct restoration and monitoring of Mono Lake ecological resources.

SWRCB Order 98-05, adopted on September 2, 1998, defined waterfowl restoration measures and elements of a waterfowl habitat monitoring program for Mono Lake. The Mono Basin Waterfowl Habitat Monitoring Plan has been implemented continuously since. In 2017, LADWP conducted a comprehensive analysis of restoration actions taken under Order 98-05 since its inception. The Mono Basin Waterfowl Habitat Restoration Program Periodic Overview Report (LADWP 2018) summarized the results of this analysis and included recommendations to increase effectiveness of various monitoring tasks, and to reduce the cost of the monitoring project while continuing to provide indices to track restoration progress. This report summarizes the results of waterfowl habitat restoration monitoring conducted in 2019.

2.0 WATERFOWL HABITAT RESTORATION MEASURES

The SWRCB issued Order 98-05 in 1998, defining the waterfowl restoration habitat restoration measures and associated monitoring to be conducted in compliance with Decision 1631. The export criteria of Decision 1631 were developed to result in an eventual long-term average lake water elevation of 6,392 feet (SWRCB 1996). In determining the most appropriate water level for the protection of public trust resources at Mono Lake, the SWRCB recognized that there was no single lake elevation that would maximize protection of, and accessibility to, all public trust resources. Decision 1631 stated that maximum restoration of waterfowl habitat would require restoring the lake elevation to 6,405 feet. Raising the lake elevation to 6,405 feet however, would have precluded use of any water from the Mono Basin by the City for municipal needs, and inhibited public access to South Tufa, the most frequently visited tufa site. Furthermore, it was determined that a lower target lake elevation of 6,390 feet would accomplish some waterfowl habitat restoration, and that there were opportunities to restore additional habitat, mitigating the overall loss as a result the target being set below 6,405 feet. A target level of 6,392 feet was ultimately established as this level would restore some waterfowl habitat, allow continued access to South Tufa, and ensure compliance with federal air quality standards.

As noted in Order 98-05, and recognized in the restoration plans, the most important waterfowl habitat restoration measures were maintaining an average lake elevation of 6,392 feet, and restoring perennial flow to streams tributary to Mono Lake . In addition to lake level recovery, and stream restoration, Order 98-05 included the following measures to be undertaken by LADWP:

1. reopen distributaries in the Rush Creek bottomlands,
2. provide financial assistance for the restoration of waterfowl habitat at the County Ponds and Black Point or other lake-fringing wetland area,
3. participate in a prescribed burn program subject to applicable permitting and environmental review requirements;
4. participate in exotic species control efforts if an interagency program is established in the Mono Basin; and
5. develop a comprehensive waterfowl and waterfowl habitat monitoring program.

Table 2-1 describes each restoration measure required under Order 98-05, providing a brief discussion on LADWP's progress to date and the current status. Some of these projects have been completed, some are ongoing, and other have been determined by the stakeholders to be unfeasible. More details regarding these restoration measures can be found in the *Periodic Overview Report* (LADWP 2018).

Table 2-1. Mono Basin Waterfowl Habitat Restoration Activities

Mono Basin Waterfowl Habitat Restoration Activities *(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)*				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Rewatering Distributary Channels to Rush Creek (below the Narrows)	To restore waterfowl and riparian habitat in the Rush Creek bottomlands.	Rewater the Channel 4bii complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, rewatering of the 4bii channel was deferred because natural revegetation of riparian and wetland species was occurring. The area was reevaluated in 2007 and rewatering was completed in March 2007.	Complete
		Rewater the Channel 8 complex, unplugged lower section	In 2002, the sediment plug was removed and the 8 channel was widened at the upstream end. In contrast to rewatering for constant flow, the final design called for flows overtopping the bank and flowing into the 8 channel at approximately 250 cfs and above. Woody debris was spread and willows were transplanted along new banks following excavation. Further rewatering of Rush Creek side channel complex 8 was deferred by the Stream Scientists. Final review was conducted by McBain and Trush (2010). After presentation of the final review, LADWP followed the recommendations of the Stream Scientists and SWRCB approved the plan. Side channel 8 was rewatered in March 2007.	Complete
		Rewater the Channel 10 complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. This evaluation concluded that rewatering the 10 channel complex would result in detrimental impacts to reestablished fishery and riparian habitats. Therefore, there have been no further actions taken to rewater this channel. Project considered complete.	Complete

Mono Basin Waterfowl Habitat Restoration Activities, cont.

(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)

Activity	Goal	Description	Progress to Date	Status
Rewatering Distributary Channels to Rush Creek (below the Narrows)	To restore waterfowl and riparian habitat in the Rush Creek bottomlands.	Rewater Channel 11, unplugged lower portion	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, it was determined that there would be little benefit to unplugging the 11 channel compared to the impacts to reestablished riparian vegetation from mechanical intrusion. Further evaluation was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to rewater the channel. This item is now approved by SWRCB and was therefore considered complete in 2008.	Complete
		Rewater the Channel 13 complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, it was determined that the 13 channel would not be stable or persist in the long term and riparian vegetation was already rapidly regenerating in this reach. Therefore, there have been no further actions taken to rewater the 13 channel. Project is considered complete.	Complete

Mono Basin Waterfowl Habitat Restoration Activities, cont.

(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)

Activity	Goal	Description	Progress to Date	Status
Financial Assistance to United States Forest Service(USFS) for Waterfowl Habitat Improvement Projects at County Ponds and Black Point areas	To support repairs and improvement of infrastructure on USFS land in the County Ponds area.	Upon request of the USFS, Licensee (LADWP) shall provide financial assistance in an amount up to $250,000 for repairs and improvements to surface water diversion and distribution facilities and related work to restore or improve waterfowl habitat on USFS land in the County Ponds area.	LADWP was to make available a total of $275,000 for waterfowl restoration activities in the Mono Basin per Order 98-05. 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. These funds will continue to be budgeted by LADWP until such a time that they have been utilized. Currently, this money has tentatively been included in the 2013 Settlement Agreement as part of Administrative Monitoring Accounts to be administered by a Monitoring Administration Team (MAT).	In Progress
	To support waterfowl habitat improvement projects on USFS land in the Black Point area.	Upon request of the USFS, Licensee (LADWP) shall provide financial assistance in an amount up to $25,000 for waterfowl habitat improvements on USFS land in the Black Point area.		

Mono Basin Waterfowl Habitat Restoration Activities, cont. *(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)*				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Prescribed Burn Program	To enhance lake-fringing marsh and seasonal wet meadow habitats for waterfowl	The licensee shall proceed with obtaining the necessary permits and approval for the prescribed burning program described in the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996 and provide the SWRCB a copy of any environmental documentation for the program. Following review of the environmental documentation, the SWRCB may direct Los Angeles to proceed with implementation of the prescribed burning program pursuant to D1631 and Order 98-05, or modify the program.	LADWP began a prescribed burn program with limited success. LADWP requested to remove this item from the requirements in 2002 and the SWRCB instead ruled that the prescribed burn program will be deferred until Mono Lake reaches the target elevation. Once Mono Lake reaches the target elevation, LADWP will reassess the prescribed burn program. Based on results from the assessment, LADWP will either reinstate the program or request relief from the SWRCB from this requirement.	Deferred
Saltcedar Eradication Program	To control non-native vegetation in the Mono Basin	In the event that an interagency program is established for the control or elimination of saltcedar or other non-native vegetation deemed harmful to waterfowl habitat in the Mono Basin, Licensee (LADWP) shall participate in that program and report any work it undertakes to control saltcedar or other non-native vegetation.	LADWP continues treatment of saltcedar as needed. Progress of the salt cedar eradication efforts is reported in the annual reports following the vegetation monitoring efforts. This item will continue until notice from SWRCB is received that LADWP's obligation for this in the Mono Basin is complete.	Ongoing

3.0 WATERFOWL HABITAT RESTORATION MONITORING PROGRAM

The Plan and SWRCB Order WR 98-05 directed LADWP to conduct monitoring to assess the success of waterfowl habitat restoration efforts, evaluate the effects of changes in the Mono Lake area, and plan for future restoration activities. Components of the Mono Basin Waterfowl Habitat Monitoring Program (Program) include hydrology, limnology, the vegetation status of riparian and lake-fringing wetlands, and waterfowl population surveys. Table 3-1 provides a brief description of the monitoring components, their required frequency under the Plan and Order 98-05, and the dates that each monitoring task has been performed.

In 2019, monitoring conducted under the Program included lake elevation, stream flows, spring surveys, lake limnology and secondary producers, and waterfowl population surveys. The remainder of this report provides a summary and discussion on the 2019 data collected under the Program.

Table 3-1. Mono Basin Habitat Restoration Monitoring Program

Mono Basin Habitat Restoration Monitoring Program
(as described in SWRCB Order 98-05 and the Waterfowl Habitat Restoration Plan dated February 29, 1996)

Monitoring Component	Description	Required Frequency	Dates Monitoring Performed
Hydrology	Lake Elevation	Weekly through one complete wet/dry cycle after the lake level has stabilized.	Monthly data collected 1936-present; ongoing
	Stream Flows	Daily through one complete wet/dry cycle after the lake level has stabilized.	Daily data collected 1935-present; ongoing
	Spring Surveys	Five year intervals (August) through one complete wet/dry cycle after the lake level has stabilized.	1999, 2004, 2009, 2014, 2019; ongoing
Lake Limnology and Secondary Producers	Meteorological data, data on physical and chemical environment of the lake, phytoplankton, and brine shrimp population levels.	Annually (monthly February-December) until the lake reaches a relatively stable level. LADWP will evaluate monitoring at that time and make a recommendation to the SWRCB whether or not to continue.	1987-present; ongoing
Vegetation Status in Riparian and Lake Fringing Wetland Habitats	Establishment and monitoring of vegetation transects and permanent photopoints in lake fringing wetlands	Five year intervals or after extremely wet year events (whichever comes first) until 2014. LADWP will evaluate the need to continue this program in 2014 and present findings to SWRCB.	2000, 2005, 2010, 2015; ongoing
	Aerial photographs of lake fringing wetlands and Mono Lake tributaries	Five year intervals until target lake elevation of 6,392 feet is achieved.	1999, 2005, 2009, 2014; ongoing

Mono Basin Habitat Restoration Monitoring Program *(as described in SWRCB Order 98-05 and the Waterfowl Habitat Restoration Plan dated February 29, 1996)*			
Monitoring Component	**Description**	**Required Frequency**	**Dates Monitoring Performed**
Waterfowl Population Surveys and Studies	Fall aerial counts	Two counts conducted every other year October 15- November 15. All waterfowl population survey work will continue until 2014, through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. Since 2002, six fall counts have been conducted annually at Mono Lake, Bridgeport Reservoir and Crowley Reservoir.	Annually; ongoing
	Aerial photography of waterfowl habitats	Conducted during or following one fall aerial count.	Annually; ongoing
	Ground counts	Total of eight ground counts annually (two in summer, six in fall). All waterfowl population survey work will continue until 2014, or through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. Since 2002, three summer ground counts have been conducted. Fall ground counts were replaced with six aerial counts.	Annually; ongoing
	Waterfowl time activity budget study	To be conducted during each of the first two fall migration periods after restoration plans are approved, and then again when the lake is at or near the target elevation.	Conducted one of two fall migration periods in 2000; completion of second study is recommended

3.1 Hydrology

Lake Level

Mono Lake is hydrographically closed and as such, all surface and groundwater drains towards Mono Lake. Lake elevation, salinity, and water chemistry are influenced by inputs via surface water, springs, precipitation, and subsequent evaporative losses (Vorster 1985). The Mono Basin receives drainage and runoff from several nearby mountains and ranges including the Sierra Nevada, Cowtrack Mountain, the Excelsior Mountains, and others.

Climate has influenced the Mono Lake environment over geologic and historic time. During the late Pleistocene and Holocene periods, climatic variation resulted in an extreme high stand of 7,200 feet, and an extreme low of an approximately 6,368 foot lake elevation (Scholl et al. 1967 in Vorster). Since 1941, lake level and salinity have also been influenced by water exports by the City.

In April of 1941, the City began exporting water from the Mono Basin by diverting Lee Vining Creek, Rush Creek, Walker Creek, and Parker Creek. The prediversion elevation of Mono Lake in April of 1941 was 6,416.9 feet. From 1941-1970, annual exports averaged 56,000 acre-feet, and the surface elevation of Mono Lake dropped over 29 feet during this same time period. In 1970, the completion of the second aqueduct in the Owens Valley expanded the capacity of the system, resulting in an increase in diversions and frequent full diversion of flows from Lee Vining, Walker, Parker and Rush Creek (SWRCB 1994). From 1970 to 1989, Mono Lake dropped another 12.6 feet as yearly exports averaged 82,000 acre-feet, with a peak export of 140,756 acre-feet in 1979. The lake level dropped to a record low of 6,371.0 feet in 1982, representing a cumulative 45-foot vertical drop in lake elevation as compared to the prediversion level. Decision 1631 amended the City's water rights license in order to support reaching a long-term average lake elevation of 6,392 feet.

Stream Flow

There are seven perennial creeks tributary to Mono Lake, all of which originate on the east slope of the Sierra Nevada. The perennial creeks are primarily snow-melt fed systems, with peak flows typically occurring in June or July, especially in normal-to-wet years. Peak flows may occur in April or May in dry years or on the smaller creeks (Beschta 1994). Rush Creek is the largest tributary, accounting for approximately 50% of stream-flow contributions to Mono Lake. Parker and Walker Creeks are small creeks tributary to Rush Creek. Rush Creek was permanently re-watered in 1982, however Parker Creek and Walker Creek, were not re-watered until 1990. Mono Lake's second largest tributary, Lee Vining Creek, was re-watered in 1986. Along the west shore is Log Cabin Creek, a small tributary monitored as part of the spring monitoring program. Flows in DeChambeau Creek along the northwest shore are intermittent, and do not consistently reach the lakeshore. Mill and Wilson Creeks are along the northwest shore of Mono Lake. Mill Creek is the third largest tributary to Mono Lake.

Springs

Almost 200 springs have been identified in the Mono Basin (LADWP 1987, LADWP 2018). Springs in the Mono Basin seep groundwater to the surface when the pressure on groundwater in the underlying aquifer overcomes gravitational force. Pressure builds up in the aquifer via two mechanisms: *elevation gradient flow* and *hydrothermal flow*. *Elevation gradient flow* exists where runoff infiltrates into the aquifer from nearby higher elevations such as the Sierra Nevada range. *Hydrothermal flow* is the convection of groundwater due to volcanic activity, forcing groundwater up to the cooler surface. Increased runoff from local mountains or increased volcanic activity can contribute to increased spring flow and the potential manifestation of new springs.

3.1.1 Hydrologic Monitoring Methodologies

Mono Lake Elevation

LADWP hydrographers record the elevation of Mono Lake monthly using a staff gauge installed at the boat dock on the west shore. The staff gauge is demarcated in tenths and hundredths of a foot. The Mono Lake Committee (MLC) also measures lake level, and since 1979, lake level data reported by the MLC has averaged 0.3 feet higher than LADWP data. Lake elevation is used to evaluate progress in meeting the target lake level, and for determining the annual allowable export. Lake elevation data is also used to evaluate the response of biological indicators including secondary producers, vegetation, and waterfowl.

Stream Flow

LADWP is required to monitor stream flow in the four Mono Lake tributaries from which the City diverts water for export- Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. Decision 1631 and Order 98-05 dictate the instream flows (base flows) and channel maintenance flows (peak flows) for these four tributaries. Instream and channel maintenance flows for other Mono Lake tributaries were not specified by the Order.

LADWP hydrographers collect flow data using continuous instream data recorders that measure flow at 15-minute intervals. The measuring stations used to determine Rush Creek flows are Mono Gate One Return Ditch (STAID 5007) and Grant Lake Spill (STAID5078). Lee Vining Creek flows are measured at Lee Vining Creek below Conduit (STAID5009). The stations for Parker

(Parker Creek below Conduit -STAID5003) and Walker Creek (Walker Creek below Conduit - STAID5002) are located just downstream of the diversion point into the Mono Crater Tunnel. Stream flow data are used to determine compliance with the Mono Basin Stream and Stream Channel Restoration Plan (LADWP 1996b), and to provide environmental data to evaluate the response of biological indicators under the Mono Basin Waterfowl Habitat Restoration Plan (LADWP 1996a).

In order to provide a more complete record of annual stream flow contributions to Mono Lake, we also report on flows for DeChambeau Creek, and the estimated inputs of Mill Creek and Wilson Creek. LADWP maintains a continuous instream data recorder station on DeChambeau Creek west of Highway 395 (Dechambeau Creek above Diversion -STAID5049). LADWP does not maintain flow measuring stations on Mill or Wilson Creeks, however flow data was obtained from USGS National Water Information System (waterdata.usgs.gov) for Mill Creek below Lundy Lake (10287069) and Lundy Power Plant Tailrace (10287195). Mill Creek below Lundy Lake measures flow in Mill Creek below the diversion to the Lundy Powerhouse. The Lundy Power Plant Tailrace measures flows downstream of the Lundy Powerhouse. Water downstream of the Lundy Powerhouse is split between return flows to Mill Creek, a diversion to Conway Ranch, and a diversion to Wilson Creek. Further downstream on Wilson Creek, water is diverted off of Wilson Creek for use in the Restoration Ponds.

Springs

The Spring Survey program was initiated in 2004, and since then, a subset of thirty-six of Mono Lake's shoreline springs has been monitored every five years. The spring monitoring sites at Mono Lake have been assigned to one of seven geographic shoreline subareas: north, northwest, west, southwest, south, southeast, or east (LADWP 1987). Springs are essentially absent along the northeast shore, likely due to a low elevation gradient and low hydrothermal flow.

In 2019, 38 spring sites were surveyed (Figure 3-1, Table 3-2), including three potentially new springs (County Park No. 4.5, Babylon 2.0, Charlie's 2.0). The three new springs are along the west and northwest shore, just east of the eastern escarpment of the Sierra Nevada. Each new spring is located within 30 feet of the spring that bears the same name (e.g. *County Park No. 4.5* is within 30 feet of County Park No. 4). *County Park 4.5* is located on the northwest shore, while *Babylon 2.0* and *Charlie's 2.0* are located on the southwest shore.

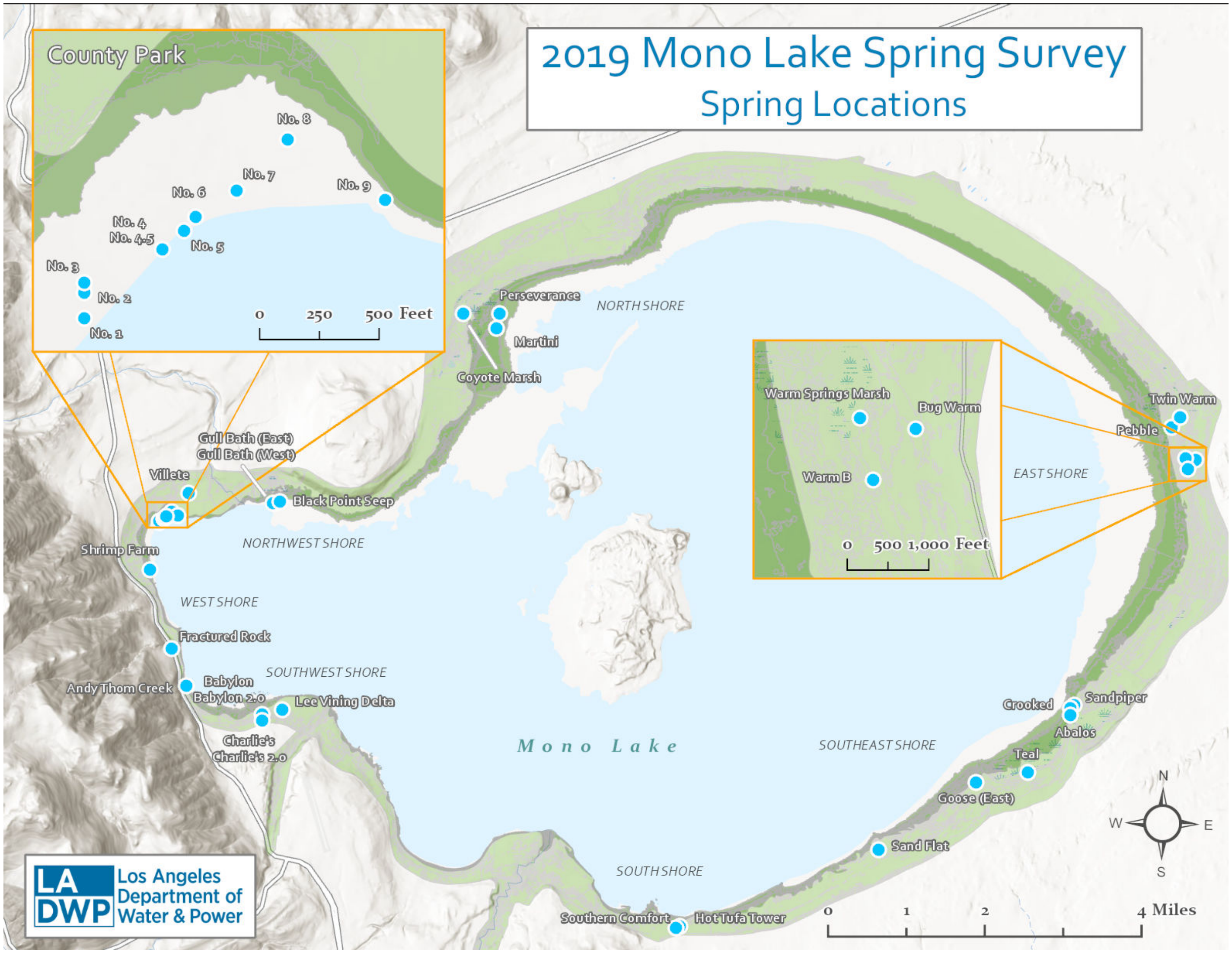


Figure 3-1. 2019 Mono Lake spring monitoring locations

Table 3-2. Springs surveyed in 2019

2019 ID	Spring	WGS Coordinates	
		Latitude	Longitude
South Shore			
M01	Hot Tufa Tower	N 37° 56.481'	W 119° 01.321'
M02	Southern Comfort	N 37° 56.465'	W 119° 01.375'
Southeast Shore			
M03	Sand Flat	N 37° 57.376'	W 118° 58.555'
M04	Sandpiper	N37 59.024”	W118 55.861”
M05	Goose (East)	N 37° 58.145'	W 118° 57.214'
M06	Teal	N 37° 58.273'	W 118° 56.491'
M07	Crooked	N 37° 58.996'	W 118° 55.887'
M08	Abalos	N 37° 58.912'	W 118° 55.905'
East Shore			
M09	Warm B	N 38° 01.772'	W 118° 54.224'
M10	Warm Springs Marsh	N 38° 01.792'	W 118° 54.366'
M11	Twin Warm	N 38° 02.131'	W 118° 54.568'
M12	Pebble	N 38° 02.249'	W 118° 54.457'
M13	Bug Warm	N 38° 01.668	W 118° 54.328'
North Shore			
M14	Perseverance	N 38° 03.232'	W 119° 04.034'
M15	Coyote Marsh	N 38° 03.222'	W 119° 04.550'
M16	Martini	N 38° 03.069'	W 119° 04.072'
Northwest Shore			
M17	Gull Bath (East)	N 38° 01.075'	W 119° 07.131'
M18	Gull Bath (West)	N 38° 01.073'	W 119° 07.160'
M19	Villette	N 38° 01.164'	W 119° 08.346'
M20	County Park No. 1	N 38° 00.827'	W 119° 08.748'
M21	County Park No. 2	N 38° 00.846'	W 119° 08.708'
M22	County Park No. 3	N 38° 00.852'	W 119° 08.707'
M23	County Park No. 4	N 38° 00.875'	W 119° 08.681'
M23.5	County Park No. 4.5	New Spring Beside M23	
M24	County Park No. 5	N 38° 00.889'	W 119° 08.663'
M25	County Park No. 6	N 38° 00.899'	W 119° 08.652'
M26	County Park No. 7	N 38° 00.917'	W 119° 08.618'
M27	County Park No. 8	N 38° 00.953'	W 119° 08.574'
M28	County Park No. 9	N 38° 00.914'	W 119° 08.487'
M29	Black Point Seep	N 38° 01.093'	W 119° 07.062'
West Shore			
M30	Shrimp Farm	N 38° 00.304'	W 119° 08.859'
M31	Fractured Rock	N 37° 59.031'	W 119° 08.314'
M32	Andy Thom Creek	N 37° 59.432'	W 119° 08.535'
Southwest Shore			
M33	Lee Vining Delta	N 37° 58.783'	W 119° 06.962'
M34	Babylon	N 37° 58.727'	W 119° 07.245'
M34.5	Babylon 2.0	New Spring Beside M34	
M35	Charlie’s	N 37° 58.661'	W 119° 07.241'
M35.5	Charlie’s 2.0	New Spring Beside M35	

The parameters recorded during Spring Surveys included flow (gallons per minute - gpm), water temperature (°F), electrical conductivity (uS/cm), and the presence of sulfur strands, hydrogen sulfide gas, and tufa towers. Representative photos were also taken at each spring. Temperature and conductivity help indicate the flow mechanisms by which water seeps to the surface and the presence of salt intrusion deep saline zones in the aquifer. The presence of sulfur strands, hydrogen sulfide gas, and tufa towers at each spring were recorded as these features indicate the presence of volcanic activity and calcium saturation at or near the springs.

The points of measurement at each spring site varied by accessibility due to vegetation density. Generally, the flow rate (as well as temperature and conductivity) of spring water was measured as soon as the water channelized on the surface. Hydrographers measured the flow at spring sites via one of three methods: current meter, v-notch weir, and estimation. A current meter equipped with a positive displacement sensor was used to measure the flow rate by measuring the water velocities at subsections within spring flow channels. A v-notch weir was used when the depths of the spring flow channels were too low to measure flow rate accurately with the current meter. When the flow or depth of the spring flow channels was too low to measure flow rate using a current meter or v-notch weir, hydrographers visually estimated the flow.

Temperature was measured by inserting an electronic temperature probe into the spring flow channels or ponding areas near the eye of springs so long as the probe was kept suspended in water.

Conductivity is a measure of the ability of water to conduct electrical current. Conductivity is directly related to the presence of salts and other conductive ions including carbonates, sulfates, and chlorides, all of which are present in Mono Lake waters. Conductivity was measured by collecting spring water in a bottle and subsequently pouring it into an analog conductivity meter. The operational ranges of the meter are 0 to 10, 100, 1000, and 10,000 µS/cm. The resolution between 0 and 10 µS/cm is 0.1 µS/cm. The resolution decreases ten-fold for every magnitude-increase in range (i.e. that of 10 to 100 µS/cm is 1 µS/cm, etc.).

LADWP staff conducted the 2019 Mono Lake Spring Survey October 21 through October 24. Civil Engineering Associates Dustin Fischer and Gabriel Gaspar Jr. surveyed on the first and second days. Civil Engineering Associates Mark Ching and Amir Hotak surveyed on the third and fourth days. Hydrographers Stephen Tordoff and Clayton Boyd surveyed all four days. Mono Basin Waterfowl Program Coordinator Deborah House surveyed on the first and second days.

3.1.2 Hydrology Data Summary and Analysis

Lake Elevation

Monthly Mono Lake elevation data were summarized for 2019, and for the time period 1990-2019. This time series represents the period during which a preliminary injunction was in place that halted exports until the lake level recovered to 6,377 feet, and the implementation of Decision 1631, beginning in September 1994. Patterns of lake elevation change were evaluated on a yearly and long-term basis.

Water years were further categorized as to runoff year type as described in Order 98-05 (

Table **3-3**). Runoff year is defined as the time period from April 1 to March 31. Runoff year type is based on a comparison of the total acre-feet of predicted runoff to the 1941-1990 average runoff of 122,124 acre-feet. Runoff predictions are based on the results of snow course surveys conducted along drainages contributing to Mono Basin runoff. The runoff year type assigned to any one year is based on the LADWP April 1 Mono Basin runoff forecast, although adjustments may be made on May 1. Runoff year type is used to determine the required annual restoration flows for Rush and Lee Vining Creeks.

Table 3-3. Runoff Year Types per SWRCB Order 98-05

Runoff Year Type	April 1 Runoff Forecast
Dry	<68.5% of average runoff*
Dry/Normal	between 68.5% and 82.5% of average runoff
Normal	between 82.5% and 107% of average runoff
Wet/Normal	between 107% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme Wet	> 160% of average runoff

*average runoff based on 1941-1990 average runoff of 122,124 acre-feet

Stream Flow

The real-time station flow data were converted into daily flow, which was used to calculate monthly and annual inflow into Mono Lake. Inflow from Rush Creek is estimated by summing Mono Gate One Return Ditch (STAID 5007), Grant Lake Spill (STAID5078), Parker Creek below Conduit (STAID5003) and Walker Creek below Conduit (STAID5002). Lee Vining Creek below

Conduit (STAID5009) and Dechambeau Creek above Diversion (STAID5049) are used to estimate inflow from Lee Vining and Dechambeau Creeks, respectively.

The contribution of Mill and Wilson Creek into Mono Lake cannot be precisely determined due to a lack of direct measure, and therefore the input amounts we report should be considered estimates. The estimated combined contribution of Mill Creek and Wilson Creek was calculated by summing USGS Stations Mill Creek below Lundy Lake (10287069) and Lundy Power Plant Tailrace (10287195). This calculation will overestimate flows to Mono Lake as diversions to Conway Ranch and the Restoration Ponds have not been subtracted.

Springs

Representative photos of the spring monitoring sites were compiled. The 2019 flow measurements were compared with values obtained during the previous spring survey of 2014. Descriptive statistics were calculated for spring discharge water temperatures. Data on conductivity, Sulphur strand, H_2 gas presence, and Tufa tower presence were compiled and reported.

3.1.3 Hydrology Results

Lake Elevation

In 2019, Mono Lake experienced a period of increasing lake level (Figure 3-2). Lake level was at its lowest level in January at 6,381.1 feet. Lake level increased through the early spring months, stabilizing briefly from April to May at 6381.7 feet. Snowmelt in summer resulted in another one-foot increase to the maximum 2019 level of 6,382.7 feet in August. Following the end of runoff, lake level retracted to a stable level of 6,382.1 feet November through December.

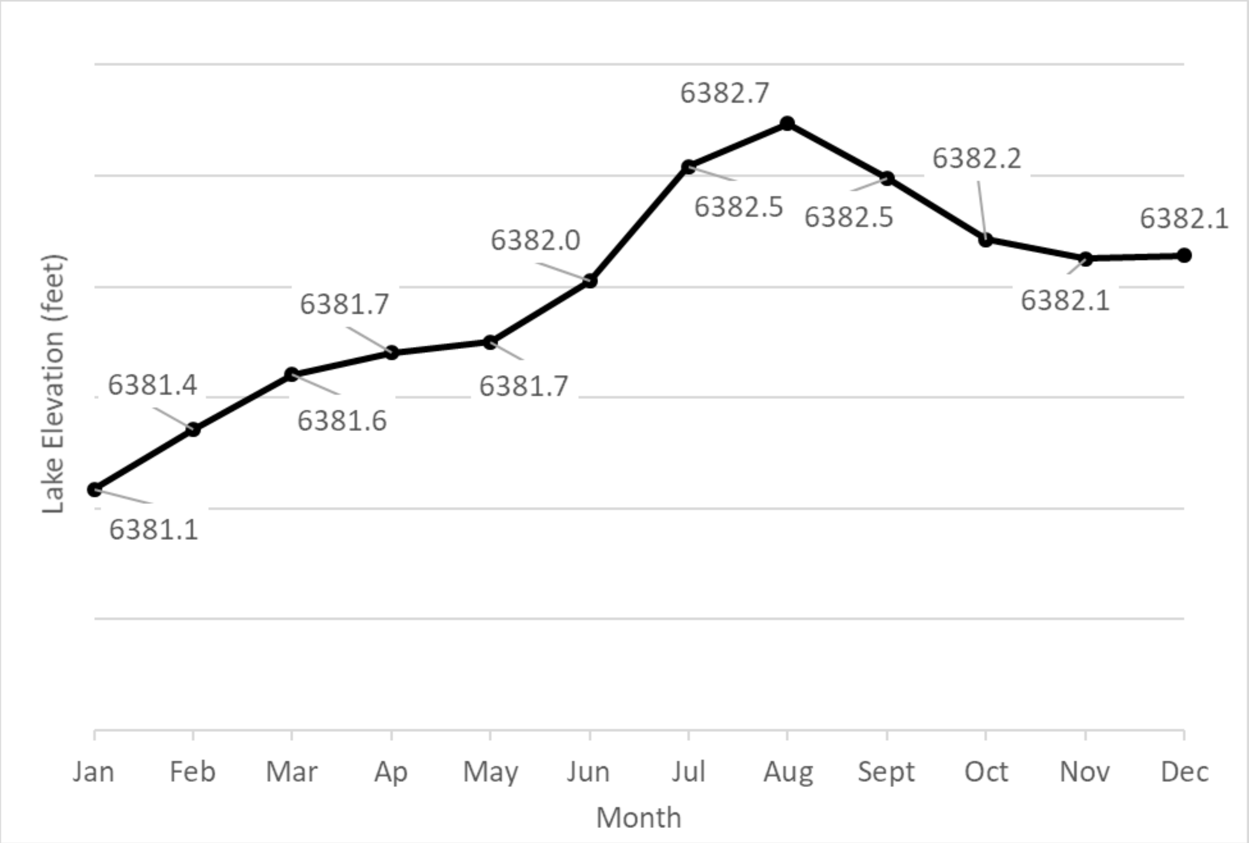


Figure 3-2. Mono Lake Monthly Elevation - 2019

The 2018-2019 Runoff year was “Wet/Normal” at 151,818 acre-feet, or 124% of the long-term average. Since Decision 1631, there have been three distinct wet periods even though the magnitude and duration of the wet periods has decreased progressively. The first wet period lasted from 1995 to 1998 and averaged 146% of normal; the second wet period only lasted two years (2005 to 2006) and averaged 153% of normal; the third wet period also lasted two years (2010 to 2011) and averaged 130% of Normal. Following this third wet period was an extended drought that resulted in the driest 5-year period on record. The year 2017 marked the end of this extended dry period, and was the second wettest on record with 195% of normal, or an “Extreme Wet year”.

The implementation of Decision 1631 appears to have resulted in a stabilization of Mono Lake elevation (Figure 3-3). From 1994 to 2019, Mono Lake has experienced four periods of increasing elevation, and three subsequent decreases, through a total elevation range of 8.0 feet (Figure 3-3). Since export amounts are now regulated, and greatly reduced as compared to historic export amount prior to Decision 1631, variations in lake level are largely driven by climate and runoff. The highest elevation the lake has achieved since 1994 has been 6,384.7

feet, which occurred in July 1999. During a period of extended drought from 2012-2016, the lake elevation dropped almost 7 feet to a low of 6,376.8 feet in October 2016, the lowest level since implementation of the Order. Following the "Extreme Wet" runoff year of 2016-2017, followed by a "Normal" and then "Wet Normal" year, the lake level has shown some recovery from the extreme low point of 2016 (Figure 3-3).

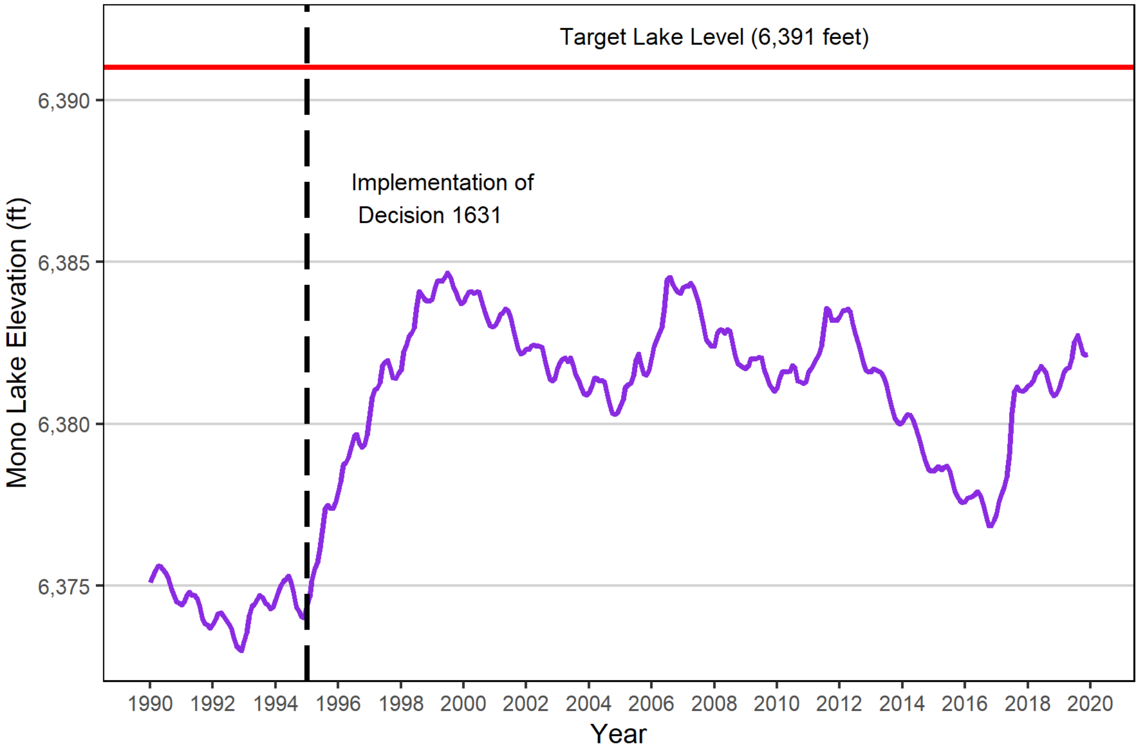


Figure 3-3. Mono Lake Elevation between 1990 and 2019

Since Decision 1631, there have been four periods of lake level increase associated with above- average runoff.

Stream Flows

In 2019, the input from Rush Creek was 89,466 acre-feet or approximately 42% greater than the long-term average (Table 3-4). Since 1990, Rush Creek has provided the largest inputs to Mono Lake averaging 63,081 acre-foot discharge, with a peak discharge in 2017 of 145,349. Lee Vining Creek input in 2019 was 48,687 acre-feet, or 22% above the long-term average of 39,601 acre-foot, with a peak discharge of 91,133 acre-feet in 2017. Input from the two major tributaries (Rush and Lee Vining Creeks) in 2019 was 138,154 acre-feet, or 141% of the long-term average since re-watering in 1982. The input from Dechambeau Creek in 2019 was 1,096 acre-feet, or 42% above the long-term mean. DeChambeau Creek has averaged 769 acre-feet since 1944 and has contributed less than 1% of total annual input since 1990. The estimated contribution of Mill Creek and Wilson Creek combined in 2019 was 27,762 acre-feet, or 48% greater than the long-term average. The combined flow of Mill and Wilson Creek has contributed approximately 15% of annual Mono Lake inputs since 1990.

Table 3-4. Annual Flow Volume in Acre-Feet of Five Mono Lake Tributaries Based on Water Year

Year	Rush Creek	Lee Vining Creek	DeChambeau Creek	Mill/Wilson Creek
1990	71,047	18,644	326	9,115
1991	35,714	20,562	265	8,726
1992	44,632	20,799	179	10,590
1993	77,461	42,279	440	18,711
1994	56,776	29,377	451	11,118
1995	94,596	66,443	911	31,899
1996	91,842	56,284	1,244	25,558
1997	82,424	66,317	1,486	30,913
1998	93,178	62,335	1,326	27,114
1999	58,047	46,204	1,151	19,473
2000	50,497	40,432	750	16,370
2001	49,357	31,034	576	13,272
2002	45,900	36,599	406	12,708
2003	49,028	30,778	530	15,199
2004	47,644	31,872	550	15,116
2005	72,766	55,367	995	26,640
2006	108,899	75,861	1,460	32,149
2007	38,428	24,091	998	10,173
2008	45,159	25,632	588	13,265
2009	36,570	30,654	586	15,769
2010	57,622	34,776	672	19,330
2011	96,433	65,454	1,151	29,997
2012	46,535	19,487	927	11,272
2013	34,776	18,320	476	10,416
2014	31,893	20,048	340	8,540
2015	32,754	16,525	273	8,485
2016	44,242	28,421	276	15,232
2017	145,349	91,133	1,433	45,411
2018	63,397	33,625	1,211	21,721
2019	89,466	48,687	1,096	27,762

Springs

Dense vegetation and high water levels (compared to Spring Survey 2014) made it difficult to access some spring sources. Most sites were heavily vegetated (Figure 3-4 to Figure 3-41), and in some areas, obscuring flow at the spring head, especially those along the north shore, namely Perseverance, Coyote Marsh and Martini (Figure 3-17 to Figure 3-19). In contrast, several spring sites along the East Shore notably Warm B (Figure 3-12), Twin Warm (Figure 3-14) and Pebble (Figure 3-15) were denuded, due to grazing and trampling by the large feral horse population that frequently uses the East and Southeast shore. Hot Tufa Tower (Figure 3-4), located along the South Shore, was completely submerged and inaccessible for surveying, so no data are provided.

Figure 3-4. M06 – Hot Tufa Tower

Figure 3-5. M02 –Southern Comfort

Figure 3-6. M03 – Sand Flat

Figure 3-7. M04 – Sandpiper

Figure 3-8. M05 – Goose (East)

Figure 3-9. M02 – Teal

Figure 3-10. M07 – Crooked

Figure 3-11. M08 - Abalos

Figure 3-12. M11 – Warm B

Figure 3-13. M09 – Warm Springs Marsh

Figure 3-14. M10 – Twin Warm

Figure 3-15. M12 – Pebble

Figure 3-16. M17 – Bug Warm

Figure 3-17. M18 – Perseverance

Figure 3-18. M15 – Coyote Marsh

Figure 3-19. M16 – Martini

Figure 3-20. M14 – Gull Bath (East)

Figure 3-21. M13 – Gull Bath (West)

Figure 3-22. M23.5 – Villette

Figure 3-23. M21 – County Park No. 1

Figure 3-24. M20 – County Park No. 2

Figure 3-25. M195 – County Park No. 3

Figure 3-26. M23 – County Park No. 4

Figure 3-27. M22 – County Park No. 4.5

Figure 3-28. M25 – County Park No. 5

Figure 3-29. M24 – County Park No. 6

Figure 3-30. M29 – County Park No. 7

Figure 3-31. M28 – County Park No. 8

Figure 3-32. M26 – County Park No. 9

Figure 3-33. M27 – Black Point Seep

Figure 3-34. M33 – Shrimp Farm

Figure 3-35. M34 – Fractured Rock

Figure 3-36. M32 – Andy Thom Creek

Figure 3-37. M30 – Lee Vining Delta

Figure 3-38. M34.5 – Babylon

Figure 3-39. M31 – Babylon 2.0

Figure 3-40. M35.5 – Charlie's

Figure 3-41. M35 – Charlie's 2.0

Flow Measurements

Of the 38 spring sites surveyed, 30 sites provided measurable direct flow to Mono Lake, one was submerged four sites exhibited flow too low to be measured (="trace"), and one site (Southern Comfort), does not have a spring channel to the lake by which flows can be measured. In 2019, the total spring input to Mono Lake from the 30 sites providing direct flow was measured at 108.36 gpm. Overall, flow from the springs into Mono Lake in 2019 increased by 44.17 gpm compared to that measured in the 2014 Spring Survey. Twenty-two spring sites exhibited increases in flow as compared to the 2014 Spring Survey, including flow from new springs. Flow at *Charlie's 2.0* was not included in this total as it contributes to the overall flow measured at *Charlie'*s, which is also indicated in Table 3-5. Five spring sites exhibited decreases in flow. Flow at three sites remained the same, not including trace flow comparisons.

Table 3-5. Comparison of spring flow measurements, 2014 vs. 2019

2014 Hot Tufa Tower and County Park No. 5 were not included in *Total Difference* flow calculations. Southern Comfort could not be measured as there was no discharge to the lake.

2019 ID	Spring	Flow (gpm)		
		2014	2019	Difference (+/-)
South Shore				
M01	Hot Tufa Tower	1.50	Submerged	NA
M02	Southern Comfort	1.12	No Flow	-1.12
Southeast Shore				
M03	Sand Flat	0.75	0.75	0
M04	Sandpiper	2.92	2.77	-0.15
M05	Goose (East)	8.45	10.32	+1.87
M06	Teal	1.50	5.61	+4.11
M07	Crooked	1.50	2.24	+0.74
M08	Abalos	0.75	1.50	+0.75
East Shore				
M09	Warm B	0.39	0.43	+0.04
M10	Warm Springs Marsh	Trace	Trace	0
M11	Twin Warm	0.22	0.64	+0.42
M12	Pebble	No Flow	0.22	+0.22
M13	Bug Warm	Trace	0.40	+0.40
North Shore				
M14	Perseverance	Trace	Trace	0
M15	Coyote Marsh	Trace	Trace	0
M16	Martini	Trace	Trace	0
Northwest Shore				
M17	Gull Bath (East)	10.47	13.46	+2.99
M18	Gull Bath (West)	1.72	1.72	0
M19	Villette	Dry	Trace	0
M20	County Park No. 1	0.60	0.42	-0.18
M21	County Park No. 2	0.60	1.05	+0.45
M22	County Park No. 3	0.75	0.49	-0.26
M23	County Park No. 4	0.75	0.75	0
M23.5	County Park No. 4.5	Did Not Exist	0.90	+0.90
M24	County Park No. 5	1.50	Did Not Measure	NA
M25	County Park No. 6	2.39	6.51	+4.12
M26	County Park No. 7	2.24	3.96	+1.72
M27	County Park No. 8	9.20	13.84	+4.64
M28	County Park No. 9	1.50	1.87	+0.37
M29	Black Point Seep	4.04	4.86	+0.82
West Shore				
M30	Shrimp Farm	3.22	5.76	+2.54
M31	Fractured Rock	2.62	3.96	+1.34
M32	Andy Thom Creek	2.02	19.22	+17.20
Southwest Shore				
M33	Lee Vining Delta	2.17	2.39	+0.22
M34	Babylon	1.94	1.27	-0.67
M34.5	Babylon 2.0	Did Not Exist	0.29	+0.29
M35	Charlie’s	0.37	0.75	+0.38
M35.5	Charlie’s 2.0	Did Not Exist	Combined with M35	NA
Total		67.19	108.36	+44.17

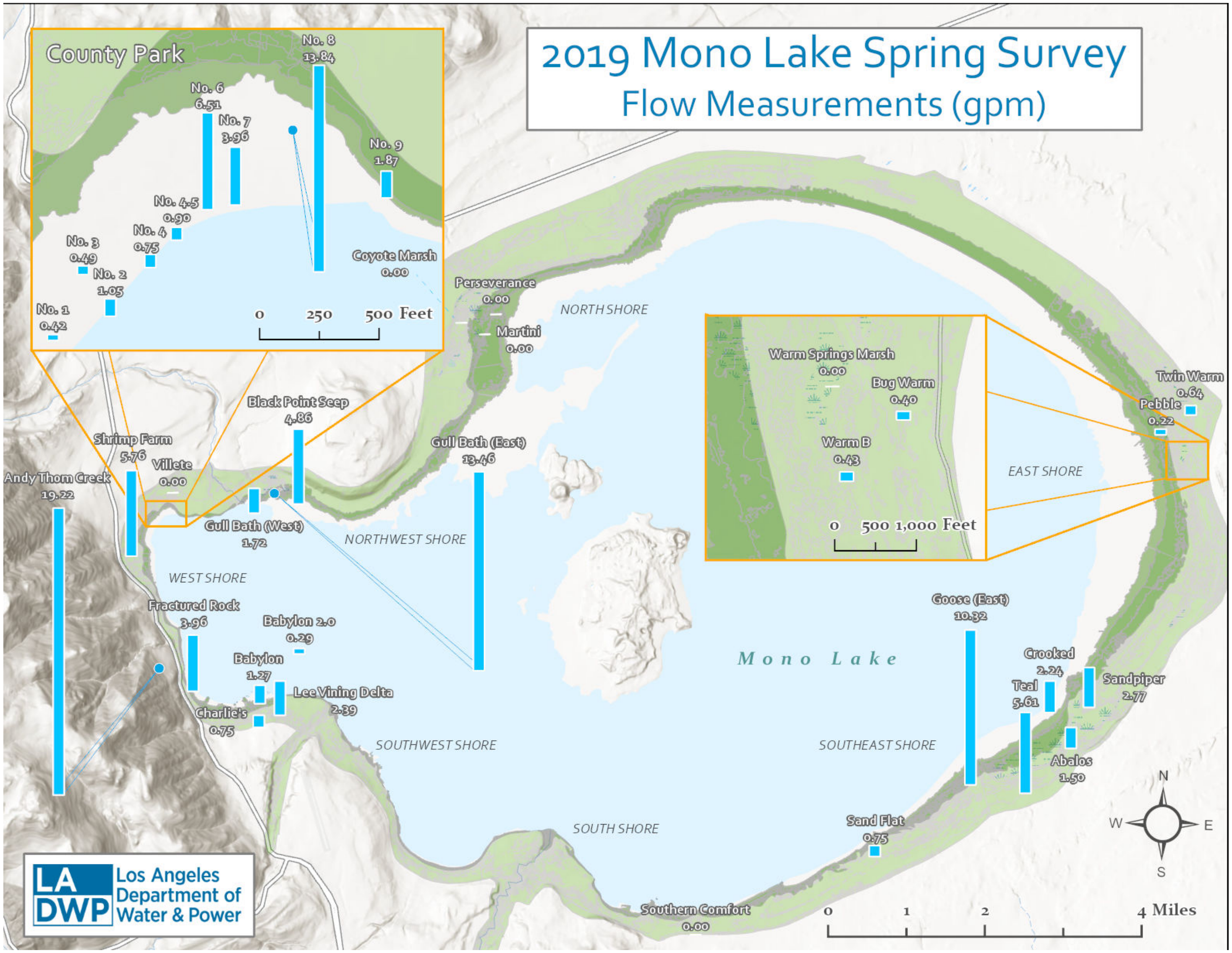


Figure 3-42. 2019 Spring Flow Measurements

Water Temperature

The water temperature of Mono Lake spring outflow ranged from 38.5°F to 91.6°F (Table 3-6, Figure 3-43). The mean water temperature of spring discharge was 56.1°F +/- 12.2°F Std Dev and the majority of the springs (29 of 37) fell within this temperature range. The water from five springs were significantly warmer than the mean: Southern Comfort, Warm B, Twin Warm, Bug Warm and Coyote Marsh. Temperature measurements of the discharge from three of the springs was significantly cooler than the mean: Sandpiper, Crooked, and Warm Springs Marsh.

Conductivity

Spring conductivity measurements varied from 41 µS/cm to 3,500 µS/cm, and exhibited spatial patterns (Table 3-6, Figure 3-44). Springs along the southwest, west, and northwest shores exhibited relatively low conductivity levels (41-300 µS/cm); the southeast shore spring had relatively moderate conductivity levels (340-620 µS/cm); the north shore springs had moderately high conductivity levels (520-2200 µS/cm); and the south and east shore springs had relatively high conductivity levels (1900-3500 µS/cm).

Table 3-6. 2019 Spring Monitoring Data

2019 ID	Spring	Flow (gpm)	Measurment Method	Temp. (°F)	Elec. Cond. (uS/cm)	Sulfur Strands	H2S Gas	Tufa Tower	Clarity
South Shore									
M01	Hot Tufa Tower	Submerged	NA	NA	NA	N	N	N	NA
M02	Southern Comfort	No Flow	NA	91.6	2500	Y	N	N	Cloudy
Southeast Shore									
M03	Sand Flat	0.75	Estimate	55.0	340	N	N	Y	Murky
M04	Sandpiper	2.77	Current Meter	38.5	620	N	N	N	Clear
M05	Goose (East)	10.32	Current Meter	53.8	440	N	N	Y	Cloudy
M06	Teal	5.61	Estimate	54.5	385	N	N	Y	Cloudy
M07	Crooked	2.24	Estimate	40.5	425	N	N	N	Clear
M08	Abalos	1.50	Estimate	55.0	420	N	N	N	Clear
East Shore									
M09	Warm B	0.43	Weir	74.8	3200	N	N	N	Clear
M10	Warm Springs Marsh	Trace	Estimate	37.2	3300	N	N	N	Murky
M11	Twin Warm	0.64	Weir	92.7	3500	N	N	N	Clear
M12	Pebble	0.22	Weir	64.6	1900	N	N	N	Clear
M13	Bug Warm	0.40	Weir	80.6	3100	N	N	N	Clear
North Shore									
M14	Perseverance	Trace	Estimate	58.5	1200	N	N	N	Clear
M15	Coyote Marsh	Trace	Estimate	69.4	520	N	N	N	Clear
M16	Martini	Trace	Estimate	63.0	2200	N	N	N	Clear
Northwest Shore									
M17	Gull Bath (East)	13.46	Current Meter	51.3	165	N	N	Y	Clear
M18	Gull Bath (West)	1.72	Estimate	50.9	295	N	N	Y	Cloudy
M19	Villette	Trace	NA	53.8	175	N	N	Y	Dirty
M20	County Park No. 1	0.42	Weir	51.3	185	N	N	Y	Clear
M21	County Park No. 2	1.05	Current Meter	51.6	145	N	Y	Y	Clear
M22	County Park No. 3	0.49	Current Meter	50.7	175	N	N	Y	Cloudy
M23	County Park No. 4	0.75	Estimate	50.1	240	N	N	Y	Clear
M23.5	County Park No. 4.5	0.90	Weir	51.6	195	N	N	Y	Clear
M24	County Park No. 5	Did Not Measure	NA	52.5	155	N	N	Y	Clear
M25	County Park No. 6	6.51	Current Meter	52.7	190	N	N	Y	Cloudy
M26	County Park No. 7	3.96	Current Meter	53.8	310	N	N	Y	Clear
M27	County Park No. 8	13.84	Current Meter	54.5	180	N	N	N	Clear
M28	County Park No. 9	1.87	Current Meter	54.7	185	N	N	N	Clear
M29	Black Point Seep	4.86	Current Meter	53.1	210	N	N	Y	Clear
West Shore									
M30	Shrimp Farm	5.76	Current Meter	55.4	210	N	N	N	Clear
M31	Fractured Rock	3.96	Current Meter	64.0	300	N	N	N	Clear
M32	Andy Thom Creek	19.22	Current Meter	44.2	41	N	N	N	Clear
Southwest Shore									
M33	Lee Vining Delta	2.39	Current Meter	50.4	250	N	N	Y	Clear
M34	Babylon	1.27	Current Meter	50.7	155	N	N	Y	Clear
M34.5	Babylon 2.0	0.29	Weir	50.9	160	N	N	y	Clear
M35	Charlie's	0.75	Estimate	50.0	105	N	N	Y	Cloudy
M35.5	Charlie's 2.0	Combined with M35	Estimate	49.8	95	N	N	Y	Murky

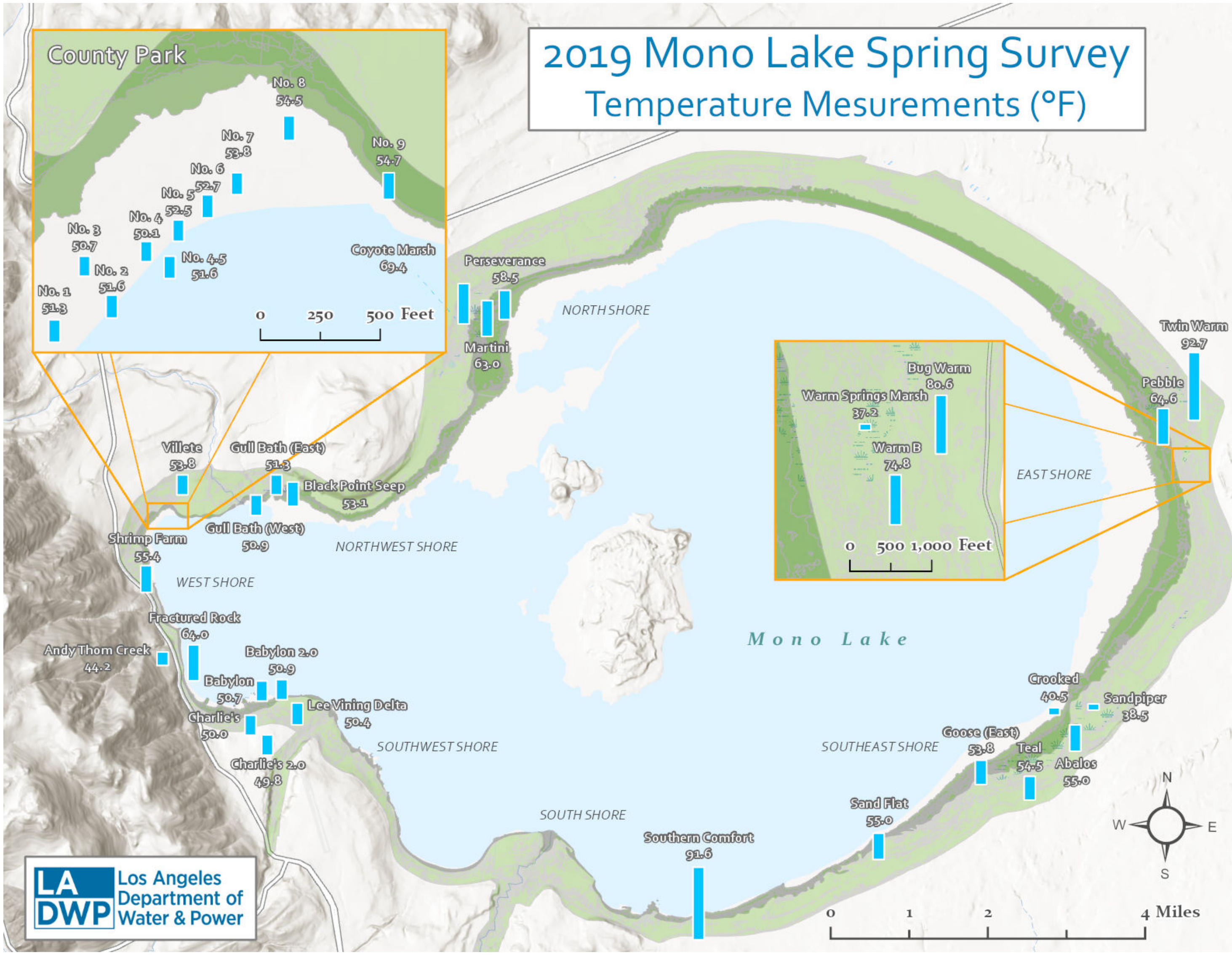


Figure 3-43. 2019 Mono Lake Spring Water Temperatures (°F)

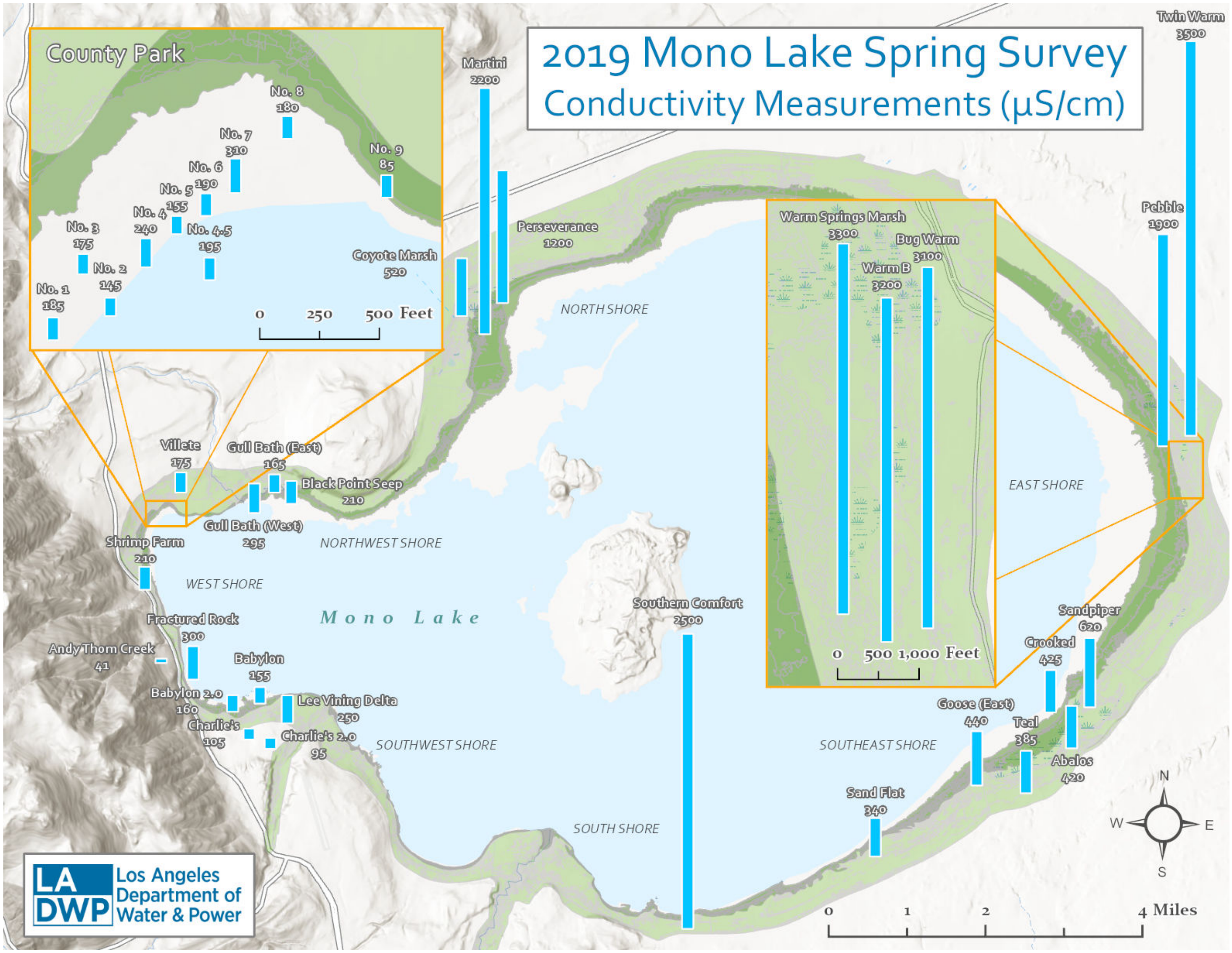


Figure 3-44. 2019 Mono Lake Spring Conductivity (µS/cm)

3.1.4 Hydrology Discussion

Lake Elevation

Mono Lake experienced an overall increase in lake level as compared to 2018. At the final lake level read in December (6382.1 feet), Mono Lake was 1.2 feet higher than in December 2018. Due to a late runoff, the maximum level for 2019 of 6,382.7 feet did not occur until August.

Climatic factors may be influencing Mono Lake and lake level recovery. Mono Lake has not yet reached the target lake elevation, although the implementation of Decision 1631 has stabilized the lake level. Decision 1631 now regulates export amounts and lake level appears to be largely driven by climate and runoff.

Stream Flows

The 2019 runoff resulted in above-average total stream discharge into Mono Lake from the five primary tributaries. The increased stream discharge contributed to the increase in lake level observed in 2019. Runoff in the Mono Basin is typified by dry periods interrupted by short wet periods, except in the late 1930s to early 1940s, the late 1970s to 1980s, and the late 1990s when wet periods were found to last longer than the more recent wet periods (LADWP 2018).

Springs

Spring flow in the Mono Basin comes from several different sources leading to variation in discharge volume, water temperature, and conductivity between springs. Spring source can also contribute to variability in response to runoff, lake level and other factors. Springs are numerous along the west and northwest shore and contribute the majority of inflow. Springs in these areas are also fresh as recharge from the east slope of the Sierra Nevada is freshwater, which essentially overcuts all denser and heavier saline water within and underneath the lake east of the shoreline up to 2,000 feet (Rogers et al. 1992). Along the south shore, there is a high gradient of flow to this area from the Mono Craters. This results in an intermediate level of groundwater recharge from the deep water table, and therefore little shallow level spring activity. Springs along the east and southeastern shore likely attribute most of their flow to fault activity. High temperature readings of some springs in this area may be due to water ponding from low flow. High conductivity readings in this area are likely a result of extensive evaporation due to the shallow groundwater in the area. Springs along the north shore may be receiving recharge from the Bodie Hills to the north of Mono Lake. Spring activity along the north shore is low, likely due to low rainfall and low recharge from the Bodie Hills, the presence of low permeability sediments, and low groundwater surface.

The detection of three new springs in proximity to other sampled springs could be attributed to an increase in runoff over the past two years. It is uncertain as to whether these springs were present at the time of the 2014 survey because there are no notes indicating they were in the survey area in 2014. It is unclear if they were present but not measured, or were not flowing at the time. Only a subset of springs are included in the spring sampling program, and thus not all springs are monitored. However, we propose it is highly likely they were not present because 2014, the last survey year, was towards the end of the last drought period from 2011 to 2015.

The largest increase in flow from 2014 to 2019 occurred at springs on the west, northwest, and southeast shores. Increases in flow in some western springs (*Andy Thom Cre*ek, *County Park No. 6*, *County Park No. 8*, and *Gull Bath (East)*) are likely attributed to the same phenomenon that caused the apparition of three new springs in the same areas (i.e., high infiltration from runoff over the past two years after four years of drought). Increases in flow in the southeast are likely attributed to the same mechanism, but by runoff from the Cowtrack Mountain range, located a few miles southeast of Mono Lake. Little to no flow was observed from springs on the east and north shores, comparable to the lack of flow in those areas in 2014. This is likely due to the low elevation gradient between the east shore of Mono Lake and the Excelsior Mountains to the east. The case is the same for springs on the north shore, which may only receive low recharge from the Bodie Hills.

The water temperature for the majority of spring discharge was 56.1°F +/- 12.2 Std Dev. The five springs for which temperature measurements were significantly warmer than the mean are likely driven by hydrothermal groundwater flow. Although temperature is generally indicative of flow mechanism, various factors can affect temperature readings in the field, including but not limited to the flow rates, vegetation densities, and shading at the points of measurement.

High conductivity in water is caused by the presence of salts that promote a high electrical current, which also contributes to high levels of total dissolved solids (TDS). The relative levels of conductivity respective to their shores help indicate the origins of groundwater seepage. Groundwater in the western shores of Mono Lake originates from runoff from the east slope of the Sierra Nevada. The low levels of conductivity at springs on these shores is likely attributed to a high elevation gradient, because there is less exposure to salts at the surface and less of a retention time for the water to be exposed to said salts. Water on the southeast shore has moderate conductivity levels indicating that there is likely more shallow groundwater activity occurring, which attributes to more salt exposure. Higher conductivity measurements in the north shore are also likely attributed to further shallow groundwater activity. The low flow from these springs indicate that there is likely more of a retention time for water to be exposed to salts.

Hydrothermally driven groundwater typically carries sodium bicarbonate-chloride and other related salts, which explains the high levels of conductivity in the south and east shores, which have high temperatures at springs. Because of the low groundwater elevation gradient in this area, hydrothermal activity is likely the main mechanism in bringing groundwater to the surface. Thus, at these springs, high levels of conductivity correlate to high temperatures.

3.2 Limnology

Mono Lake supports a relatively simple yet productive aquatic ecosystem. Planktonic and benthic algae form the foundation of the food chain in the lake. The phytoplankton community is primarily composed of coccoid chlorophytes (*Picosystis* spp.), coccoid cyanobacteria, and several diatoms (primarily *Nitzschia* spp.) (Jellison and Melack 1993). Filamentous blue-green algae (*Oscillatoria* spp.) and filamentous green algae (*Ctenocladus circinnatus*) and the diatom *Nitzchia frustulum* dominant the benthic algal community.

Secondary producers in Mono Lake consist of invertebrate species. The most abundant secondary producer in the pelagic zone is the Mono Lake brine shrimp (*Artemia monica*). In the littoral zone, secondary producers including the alkali fly (*Ephydra hians*), long-legged fly (*Hydrophorus plumbeus*), biting midges (*Cuciloides occidentalis*), and deer fly (*Chrysops* spp.) graze on benthic algae (Jones and Stokes Associates, Inc 1993).

Within the hydrographically closed basin, the particular water chemistry of Mono Lake is influenced by climate, water inputs, evaporative losses, and the chemical composition of the surrounding soils and rocks. The waters are saline and alkaline, and contain high levels of sulfates, chlorides, and carbonates. For the period 1938-1950, the salinity of Mono Lake was approximately 50 g/L, and by 1964 salinity had increased to 75 g/L, and up to 100 g/L by 1982 (Vorster 1985). Since implementation of Decision 1631, the salinity has varied from 72.4 to 97.8 g/L, which is approximately two to three times as salty as ocean water. The lake water is also highly alkaline, with a pH of approximately 10, due to the high levels of carbonates dissolved in the water.

The limnological monitoring program at Mono Lake is one component of the Plan and is required under SWRCB Order No. 98-05. 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 1996a). The limnological monitoring program has four components: meteorology, physical/chemical analysis, chlorophyll *a*, and brine shrimp population monitoring.

An intensive limnological monitoring program at Mono Lake has been funded by 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 have been conducting the limnological monitoring program at Mono Lake since July 2012.

Laboratory support including the analysis of ammonium and chlorophyll *a* has been provided by Environmental Science Associates (ESA), Davis, California since 2012.

This report summarizes the results of monthly limnological field sampling conducted in 2019, and discusses the results in the context of the entire period of record. In addition, past findings are summarized to evaluate long term trends in water chemistry parameters and Artemia population dynamics.

3.2.1 Limnological Monitoring Methodologies

Methodologies for both the field sampling and the 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 are consistent and follow those identified in *Field and Laboratory Protocols* except where noted.

Meteorology

One meteorological station on Paoha Island provided the majority of the weather data. 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 (6,391 feet) 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 were downloaded in December 19, 2019.

At the Paoha Island station, wind speed and direction are measured by a RM Young wind monitor 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. Ten-minute averages of relative humidity and air temperature (Vaisalia HMP35C), and total rainfall (Campbell Scientific TE525MM-L tipping bucket) are also stored. The minimum detection limit for the tipping bucket gage is 1 mm of water. The tipping bucket is not heated; therefore the instrument is less accurate during periods of freezing due to the sublimation of ice and snow.

In addition to the Paoha Island station, monthly total precipitation has been recorded at the LADWP Cain Ranch site since May 1931. Due to inconsistent precipitation readings of the Paoha Island weather station, daily precipitation recorded at Cain Ranch is reported.
The monthly average maximum and minimum temperatures dating from October 1950 were obtained from the Western Regional Climate Center (www.wrcc.dri.edu) and analyzed to gain better insight into climatic trends.

The daily mean wind speed, maximum mean wind speed, and relative humidity are calculated from 10-minute averaged data from the Paoha Island site. Winter temperature is calculated by averaging the monthly average maximum (or minimum) temperature from December of the previous year and January and February of the subsequent year. More specifically, the monthly average from December 2018 is combined with the monthly average from January and February 2019 to obtain the winter average for 2019. Summer temperature is calculated as the average monthly temperature between June and August.

Field Sampling and Laboratory Procedures

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 3-45) on the dates listed in Table 3-7. The water depth at each station at a lake elevation of 6384.5 feet (1,946 m) is indicated on Figure 3-45. Stations 1-6 are considered western sector stations, and stations 7-12 are eastern sector stations. No sampling was conducted in February due to a large amount snow preventing an access to the lake. Monitoring was conducted on two separate days: 1) the first day for dissolved oxygen, ammonium, and chlorophyll *a* sampling, and 2) the second day for *Artemia* sampling, CTD casting, and Secchi readings. Surveys were generally conducted around the 15th of each month.

Table 3-7. Mono Lake Limnology Sampling Dates for 2019

Month	Sampling Dates	
	DO, NH_4, Chla	Artemia, CTD, Secchi
Feb		
Mar	3/15/2019	3/18/2019
Apr	4/18/2019	4/17/2019
May	5/14/2019	5/13/2019
Jun	6/12/2019	6/13/2019
Jul	7/18/2019	7/19/2019
Aug	8/16/2019	8/12/2019
Sep	9/10/2019	9/11/2019
Oct	10/16/2019	10/15/2019
Nov	11/14/2019	11/13/2019
Dec	12/19/2019	12/17/2019

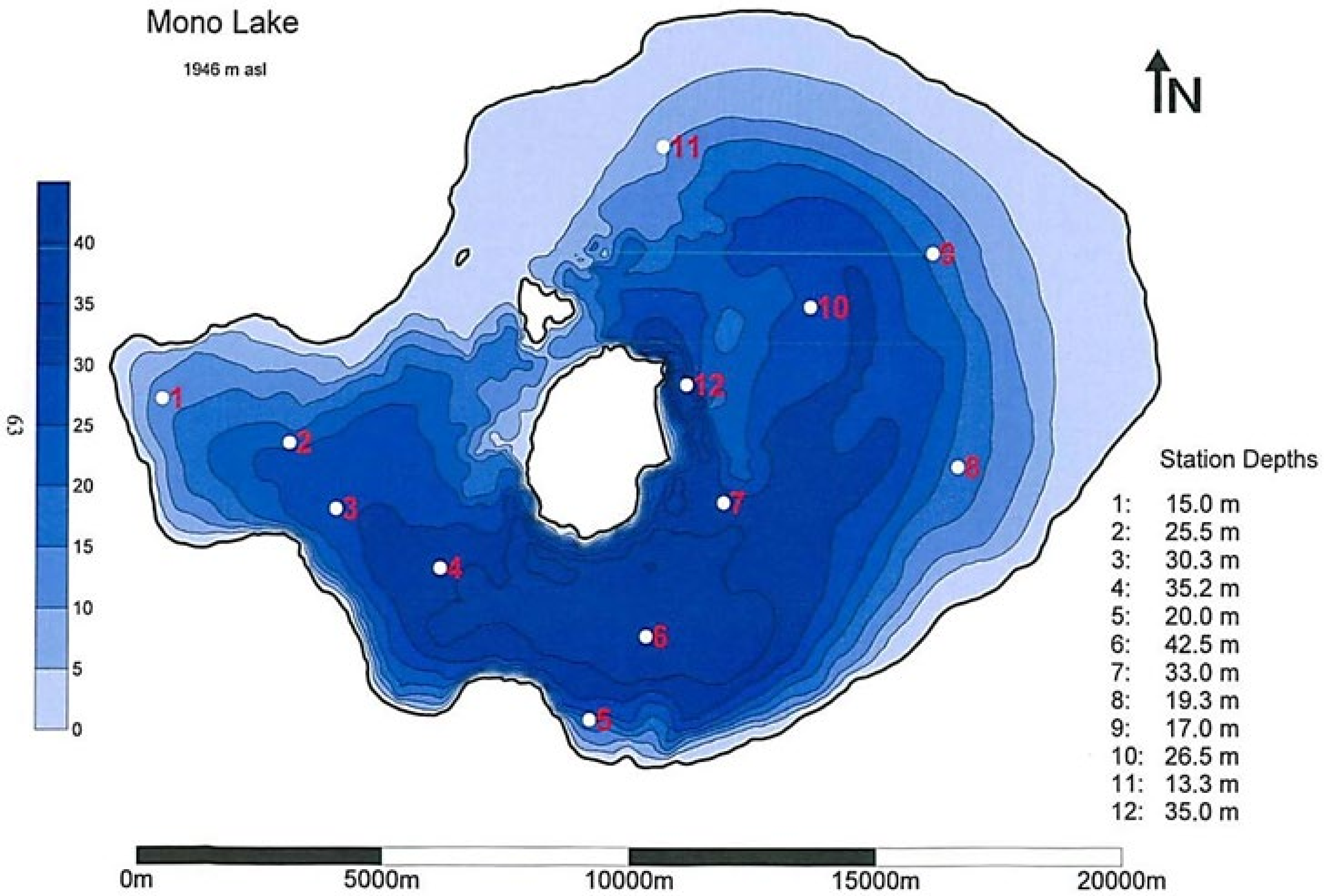


Figure 3-45. Sampling Stations at Mono Lake and Associated Station Depths

Physical and Chemical

Transparency

Lake transparency is measured at all 12 stations using a Secchi disk each month.

Temperature, Conductivity, and Salinity

A Sea-Bird high-precision conductivity temperature-depth (CTD) profiler is used to record conductivity at 9 stations (2, 3, 4, 5, 6, 7, 8, 10 and 12) on a monthly basis. The Sea-Bird CTD is programmed to collect data at 250 millisecond intervals. During sampling, the CTD is initially lowered just below the surface of the water for 40 seconds during the pump delay time. The CTD is then lowered at a rate of approximately 0.5 meter/second with data collected at approximately 12.5 centimeter depth intervals. In situ, conductivity measurements at Station 6 are corrected for temperature (25˚C). Conductivity and temperature readings at the depth closest to a whole number are assigned to that depth and reported at one meter intervals beginning at one meter in depth down to the lake bottom. Salinity expressed in g/L is calculated based on the equation presented by Jellison in past compliance reports (LADWP 2004).

Dissolved Oxygen

Dissolved oxygen is measured at one centrally located station (Station 6) with a Yellow Springs Instruments Rapid Pulse Dissolved Oxygen Sensor (YSI model 6562). Readings are 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.

Ammonium Sampling

Monitoring of ammonium in the epilimnion is conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. Ammonium is sampled at eight discrete depths (2, 8, 12, 16, 20, 24, 28, and 35 meters) at Station 6 using a vertical Van Dorn sampler. Samples for ammonium analyses are 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 are transported on dry ice back to the laboratory transfer station. The ammonium samples are stored frozen until delivered to the University of California Davis Analytical Laboratory (UCDAL) located in Davis, California and kept frozen until analysis.

Starting in August 2012, the methodology used for ammonium testing changed due to a change in laboratory. In July 2012, the flow injection analysis used by UCDAL for ammonium testing was tested on high salinity Mono Lake water and found to give results comparable to previous years, although this method has a detection limit of approximately 2.8 µM. Immediately prior to analysis, frozen samples are allowed to thaw and equilibrate to room temperature, and are shaken briefly to homogenize. Samples are heated with salicylate and hypochlorite in an alkaline phosphate buffer (APHA 1998a, APHA 1998b, Hofer 2003, Knepel 2003). EDTA (Ethylenediaminetetraacetic acid) is added in order to prevent precipitation of calcium and magnesium, and sodium nitroprusside is added in order to enhance sensitivity. Absorbance of the reaction product is 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 are calculated based on absorbance in relation to a standard solution.

Chlorophyll *a* Sampling

Monitoring of chlorophyll *a* in the epilimnion was conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. Chlorophyll was sampled at station 6 at seven discrete depths (2, 8, 12, 16, 20, 24, and 28 meters) using a vertical Van Dorn sampler. Water samples are filtered into opaque bottles through a 120 µm sieve to remove all life stages of *Artemia*. Chlorophyll *a* samples are kept cold and transported on ice back to the laboratory transfer station located in Sacramento, CA. The determination of chlorophyll *a* is conducted through 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 mailed overnight in dry ice to the University of Maryland Center for Environmental Science Chesapeake Biological Laboratory (CBL), located in Solomons, Maryland. Sample filter pads are 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 are 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 is avoided.

The fluorometer used in support of this analysis is 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 Sampling*

The *Artemia* population was sampled by one vertical net tow at each of 12 stations (Figure 3-45). 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.

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 (1924). Adults were sexed and the reproductive status of adult females 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 completed for 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 were weighed on an analytical balance immediately upon removal from the oven.

Calculation of long-term *Artemia* population statistics follows the method proposed by Jellison and Rose (2011). Daily values of adult *Artemia* between sampling dates are linearly interpolated using the R package *zoo*. The mean, median, peak and centroid day (calculated center of abundance of adults) are then calculated for the time period May 1 through November 30, during which adult *Artemia* population is most abundant. Long-term statistics are determined by calculating the mean, minimum, and maximum values for the time period 1979-2019.

Artemia *Fecundity*

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.

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

3.2.2 Limnology Data Analysis

Salinity and Mono Lake Elevation

The salinity of Mono Lake is directly influenced by water inputs and lake elevation due to the hydrographically closed nature of the basin. Salinity is a key parameter influencing the structure of aquatic algal and invertebrate communities of closed lake systems (Herbst and Blinn 1998, Verschuren et al. 2000). High salinity has been shown to negatively affect the survival, growth, reproduction, and cyst hatching of *Artemia* in Mono Lake (Starrett and Perry 1985, Dana and Lenz 1986). Negative effects are accentuated when salinity approaches the tolerance level, which ranges from 159 g/L to 179 g/L (Dana and Lenz 1986). Even though the salinity level in Mono Lake has not neared the tolerance level for *Artemia*, the salinity level is higher than the pre-export period. The pre-diversion salinity was estimated to be 48 g/L (Dana and Lenz 1986) at a lake level around 6,417 feet. As of December 2019, salinity ranged between 81.3 g/L and 94.3 g/L at Station 6 at the lake levels ranging between 6,381 and 6,382 feet. Long-term relationships between lake levels and salinity at three different depths (between 0 and 10 m, between 11 and 20 m, and deeper than 21 m) were examined in this section. Lake elevation data collected as part of the hydrologic monitoring program (Section 3.1.1) was used for this analysis.

Artemia Population Peak

Meromixis has been demonstrated to affect the *Artemia* population in Mono Lake as stratification prevents the release of hypolimnetic ammonium during meromixis. During periods of meromixis, ammonium accumulates in the hypolimnion. With a weakening chemocline, ammonium supply to the epilimnion or mixolimnion increases. This process also allows oxygenation of the hypolimnion, which remains suboxic to anoxic during meromixis. Usually one year after the breakdown of meromixis, the *Artemia* population booms. In this section, the annual *Artemia* population mean during monomixis and meromixis is quantitatively compared to ammonium, Mono Lake input, and salinity to illustrate the importance of the lake mixing regime to *Artemia* population dynamics.

A Temporal Shift in Monthly Artemia Population

A temporal shift in peak *Artemia* population or centroid has been noted by Jellison in previous years' compliance reports. LADWP also has reported a continuation of this trend in the *Artemia* instar population (LADWP 2017). Two water parameters, chlorophyll *a* and temperature, have been demonstrated to affect development of *Artemia*. For instance, spring generation *Artemia* raised at high food densities develop more quickly and begin reproducing earlier. In addition, the abundance of algae may likely affect year-to-year changes in *Artemia* abundance (Jellison and Melack 1993). Cysts of Mono Lake brine shrimp require three months of dormancy in cold (<5°C) water to hatch (Dana 1981, Thun and Starrett 1986) and the summer generation of *Artemia* grows much more quickly than the spring counterpart because of warmer epilimnetic water temperature. For adult development, summer epilimnetic water temperature could affect *Artemia* abundance even though other factors such as food availability confounds growth rate (Jones and Stokes Associates 1994). In this section, monthly *Artemia* abundance (adult and instar) is quantitatively and qualitatively compared to monthly readings of chlorophyll *a* and temperature in order to understand the mechanisms associated with the temporal shifts in *Artemia* population abundance. All analyses were performed using the statistical software, R (The R Project for Statistical Computing).

3.2.3 Limnology Results

Meteorology

Wind Speed and Direction

Mean daily wind-speed from January 1 to December 19, 2019 varied from 0.35 to 12.67 m/sec with an overall mean for this time period of 3.29 m/sec (Figure 3-46). The daily maximum 10-min averaged wind speed (5.11 m/sec) on Paoha Island averaged almost twice as much as the mean daily wind speed. The maximum recorded 10-min reading of 18.76 m/sec occurred on February 26th. As has been the case in previous years, winds were predominantly from the south (mean 174.1 degrees).

Air Temperature

Hourly average air temperature recorded at Paoha Island in 2019 ranged from a low of -13.55°C on February 6 to a high of 31.55°C on July 19 (Figure 3-47). Daily average temperature ranged from -7.87°C to 23.39°C. Daily average winter temperature (January through February) ranged from -7.87°C to 5.25°C with an average maximum daily winter temperature of 4.78°C. The average maximum daily summer temperature (June through August) was 26.76°C while the average minimum daily summer temperature was 11.37°C.

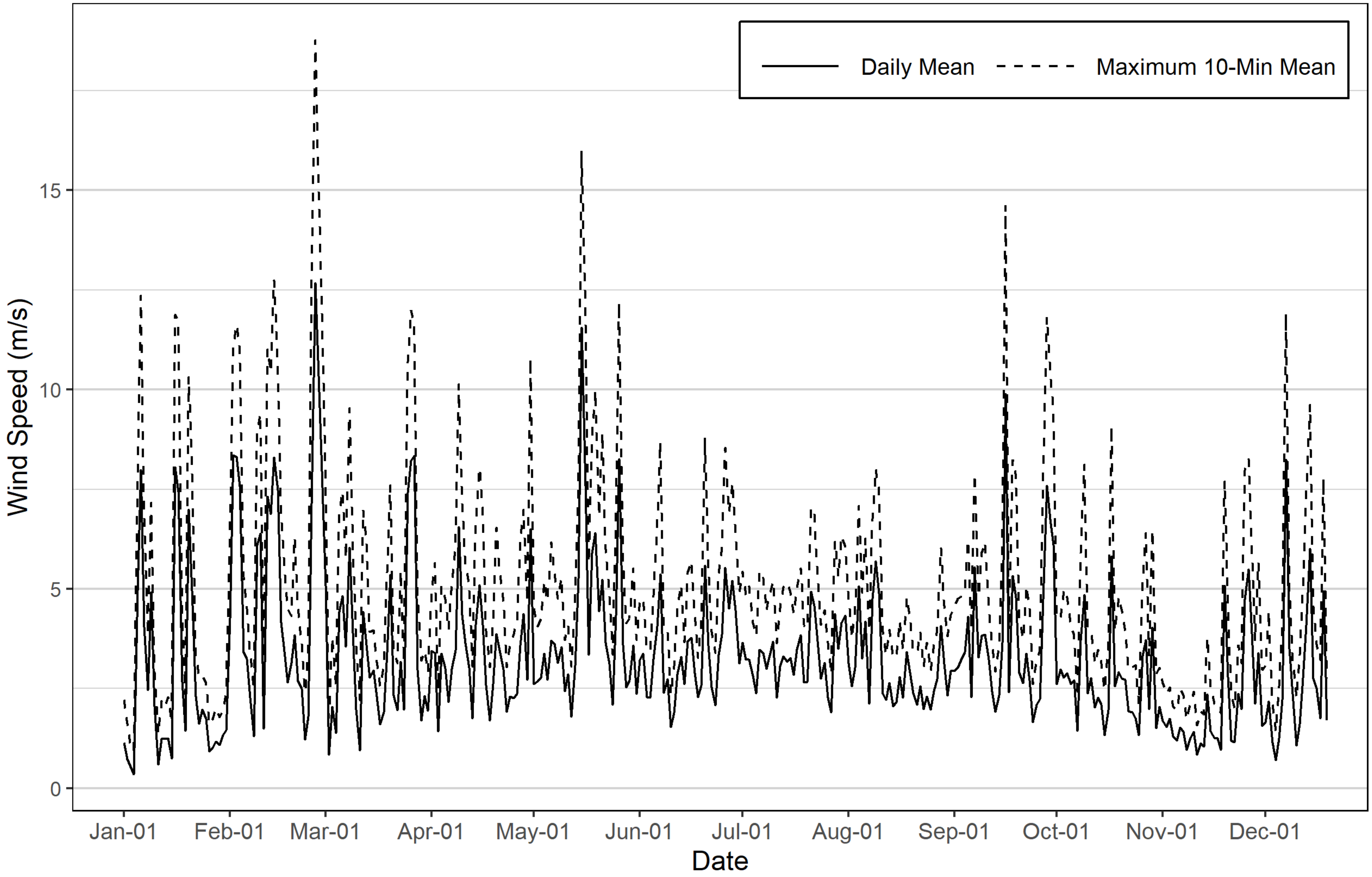


Figure 3-46. Daily Mean and Mean Maximum 10-Minute Wind Speed

Wind speed was recorded at Paoha Island from January 1 to December 19, 2019.

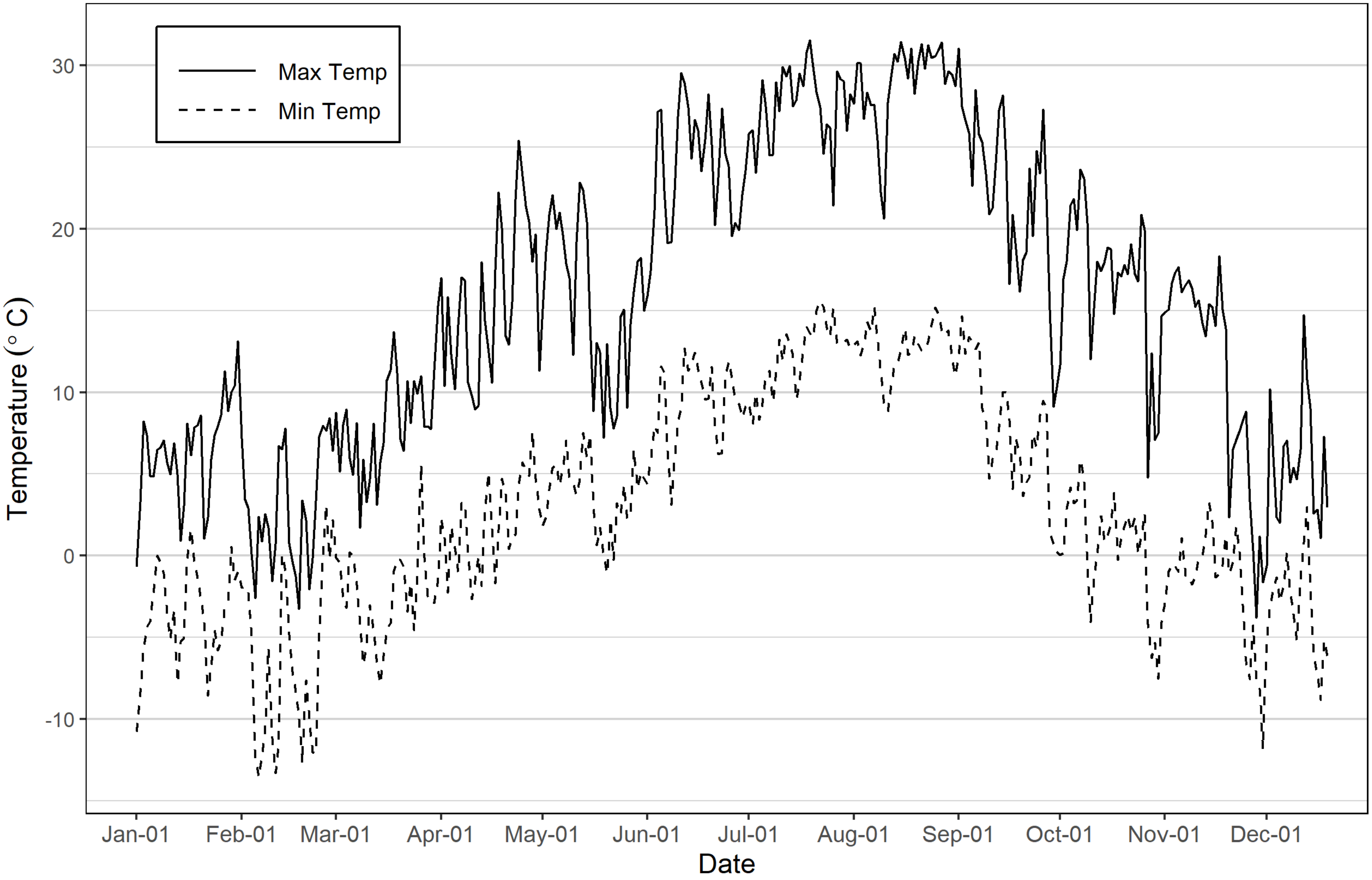


Figure 3-47. Minimum and Maximum Daily Temperature (°C)

Air temperature was recorded at Paoha Island from January 1 to December 19, 2019.

Relative Humidity and Precipitation

The mean relative humidity for the period between January 1 and December 19, 2019 was 56.79% (Figure 3-48). The total precipitation between January 1 and December 31 measured at LADWP Cain Ranch was 10.6 inches. Precipitation events were more frequent in winter, spring and early summer in 2019 and the largest single day total precipitation of 1.06 inch was recorded on February 2 (Figure 3-49). In January and February, 4.63 inches of precipitation was recorded. Spring months produced 3.3 inches of precipitation followed by much lower summer month precipitation (1.27 inches). Between August and October, no precipitation was recorded. November precipitation was only 0.42 inch. December precipitation was 1.02 inch. The greatest frequency of days with precipitation (14) occurred in the month of February.

Long Term Trends in Temperature and Precipitation

The year 2019 started with a warm January followed by very cold February and March (Figure 3-50). May was below normal while April and August were above normal. As compared to the long-term average (LTA), the winter of 2018-19 appeared colder during the day (below normal maximum average temperature) but warmer during the night (above normal minimum average temperature) (Figure 3-51). It was the sixth year in row that the minimum winter temperature was above the long-term average. The winter of 2018-19 was colder than that of 2017-18. The summer of 2019 was cooler than the previous 3 years, but warmer than LTA for both maximum and minimum temperatures (Figure 3-52). Winter precipitation in 2018-19 (5.0 in) was ranked 36th in 88 years and 100% of the long-term average (5.0 in) while summer precipitation was ranked 30th in 89 years and 119% of the long-term average (Figure 3-53, Figure 3-54). The winter preceding the 2019 monitoring year was somewhat cooler with average precipitation, and summer of 2019 was warmer and somewhat wetter. There is no clear long term trend for average summer and winter temperatures except for increasing average summer minimum temperatures ($r=0.57$, $p<0.0001$). This trend has been much stronger since 1973 ($r=0.81$, $p<0.0001$) indicating there has been a very strong warming trend in summer minimum temperature from the beginning of the limnology monitoring in 1979. A similar short-term warming trend was observed for summer maximum and winter minimum temperatures, but starting in 1982 ($r=0.49$, $p= 0.0016$) and 1983 ($r=0.49$, $p=0.0021$) respectively.

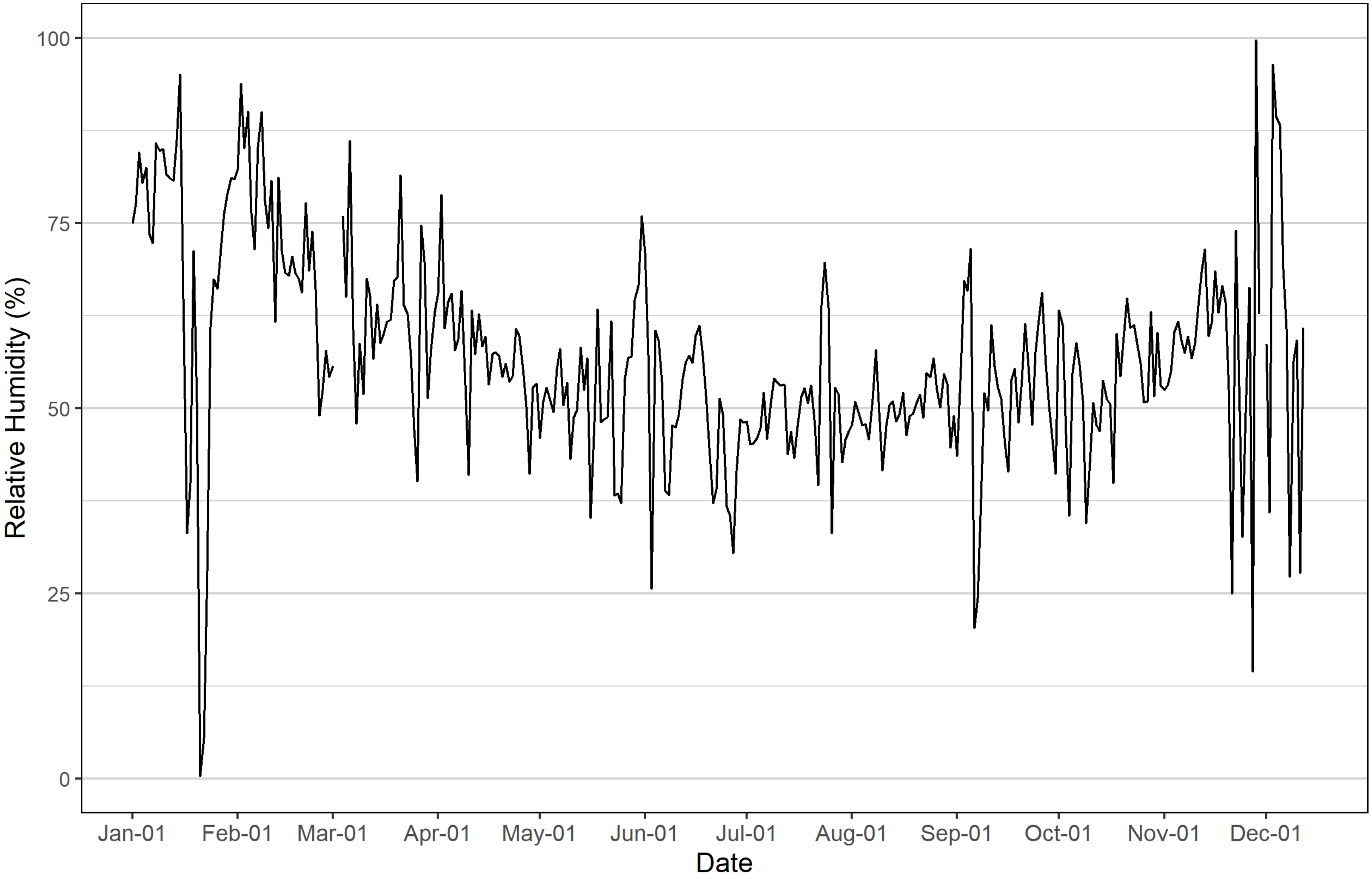


Figure 3-48. Mean Daily Relative Humidity (%)

Relative humidity was recorded at Paoha Island from January 1 to December 19, 2019.

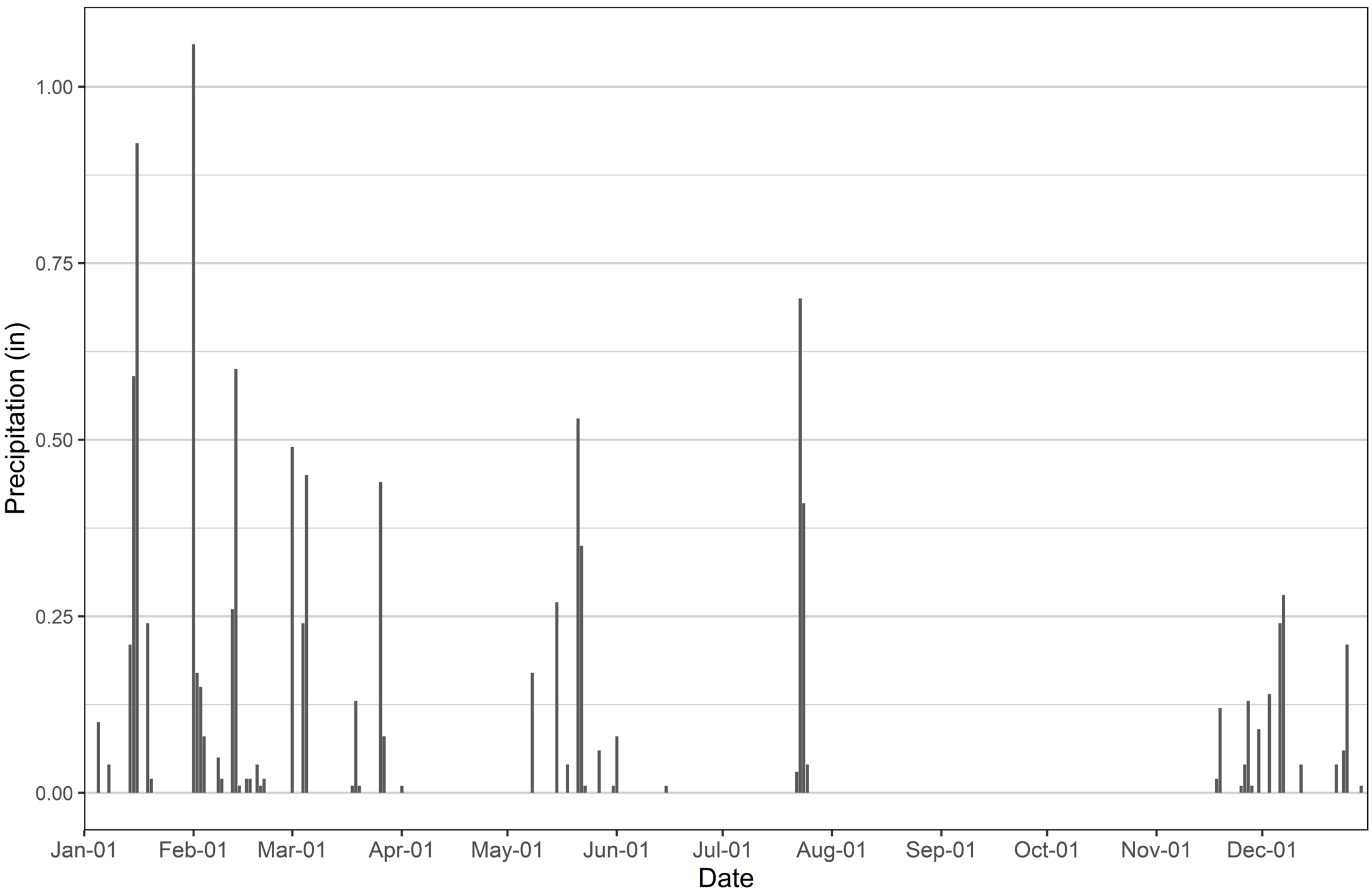


Figure 3-49 Total Daily Precipitation (mm)

Precipitation was recorded at Cain Ranch from January 1 to December 31, 2019.

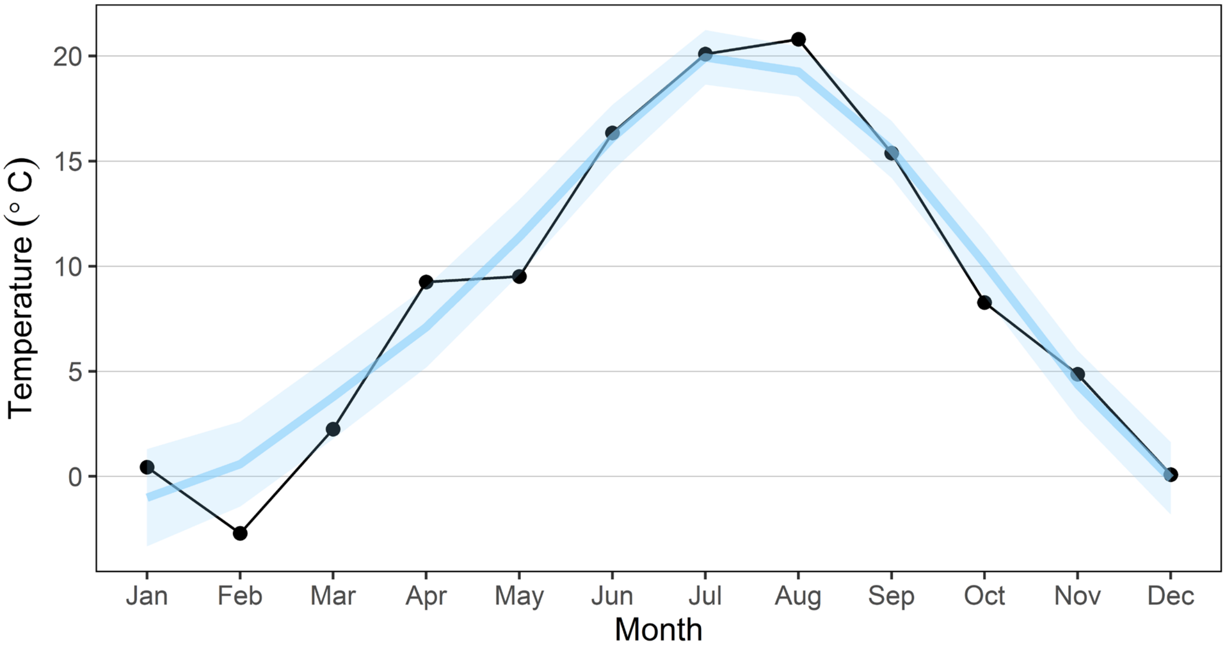


Figure 3-50 Monthly temperature in 2019 compared to the long-term averages

Long term average monthly temperature was calculated using records at Mono Lake (Station Number 045779-3) between 1951 and 1988, and Lee Vining (Station Number 044881) since 1989; data obtained from Western Regional Climate Center. A blue line indicates the long-term average monthly temperature and the shaded area indicates the standard errors of the respective months.

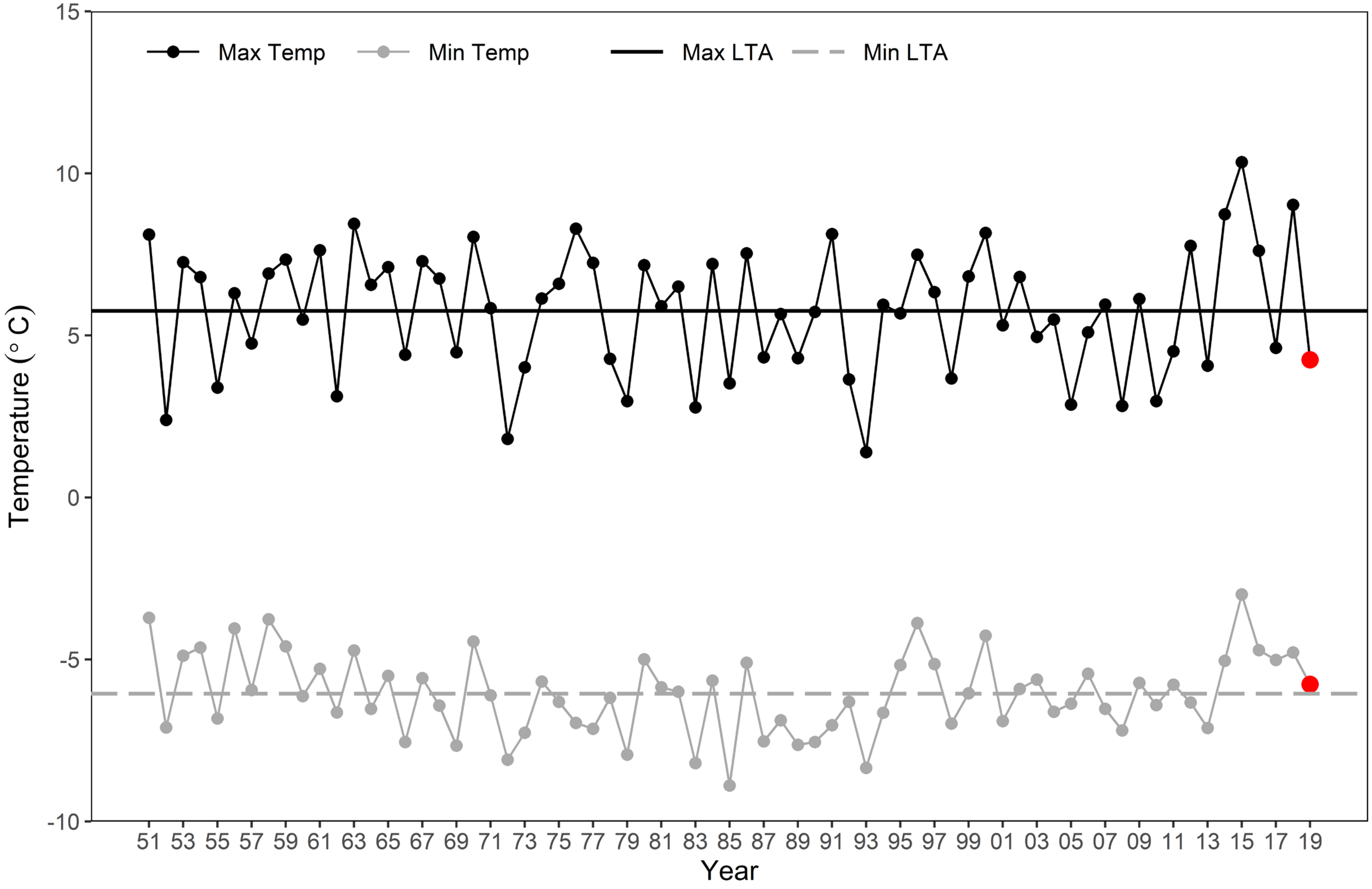


Figure 3-51. Average Temperature during Winter Months (December through February)

Temperature was recorded at Mono Lake (Station Number 045779-3 obtained) between 1951 and 1988 and at Lee Vining (Station Number 044881) since 1989; data obtained from Western Regional Climate Center.

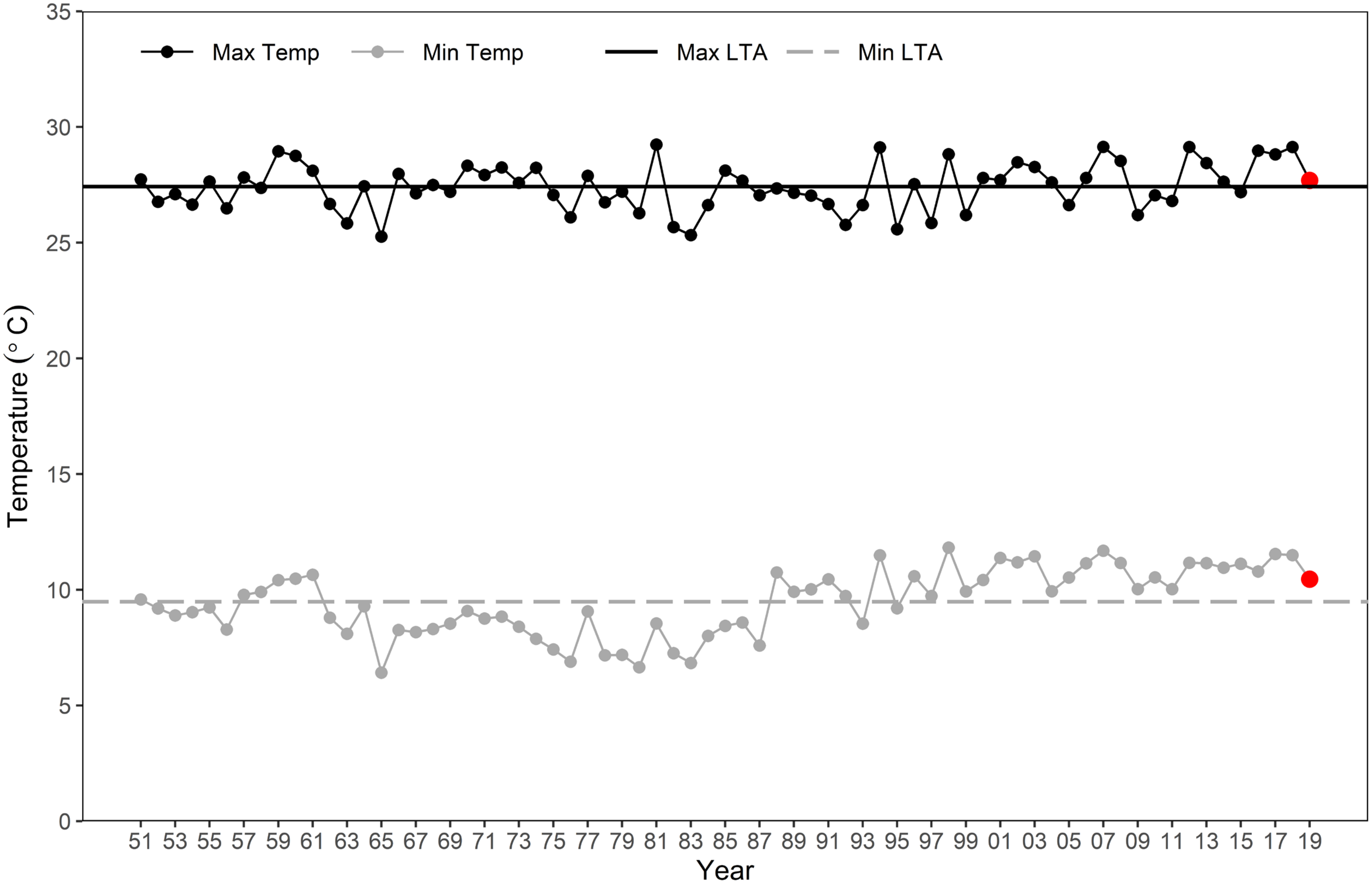


Figure 3-52. Average Temperature during Summer Months (June through August)

Temperature was recorded at Mono Lake (Station Number 045779-3) between 1951 and 1988 and at Lee Vining (Station Number 044881) since 1989; data obtained from Western Regional Climate Center.

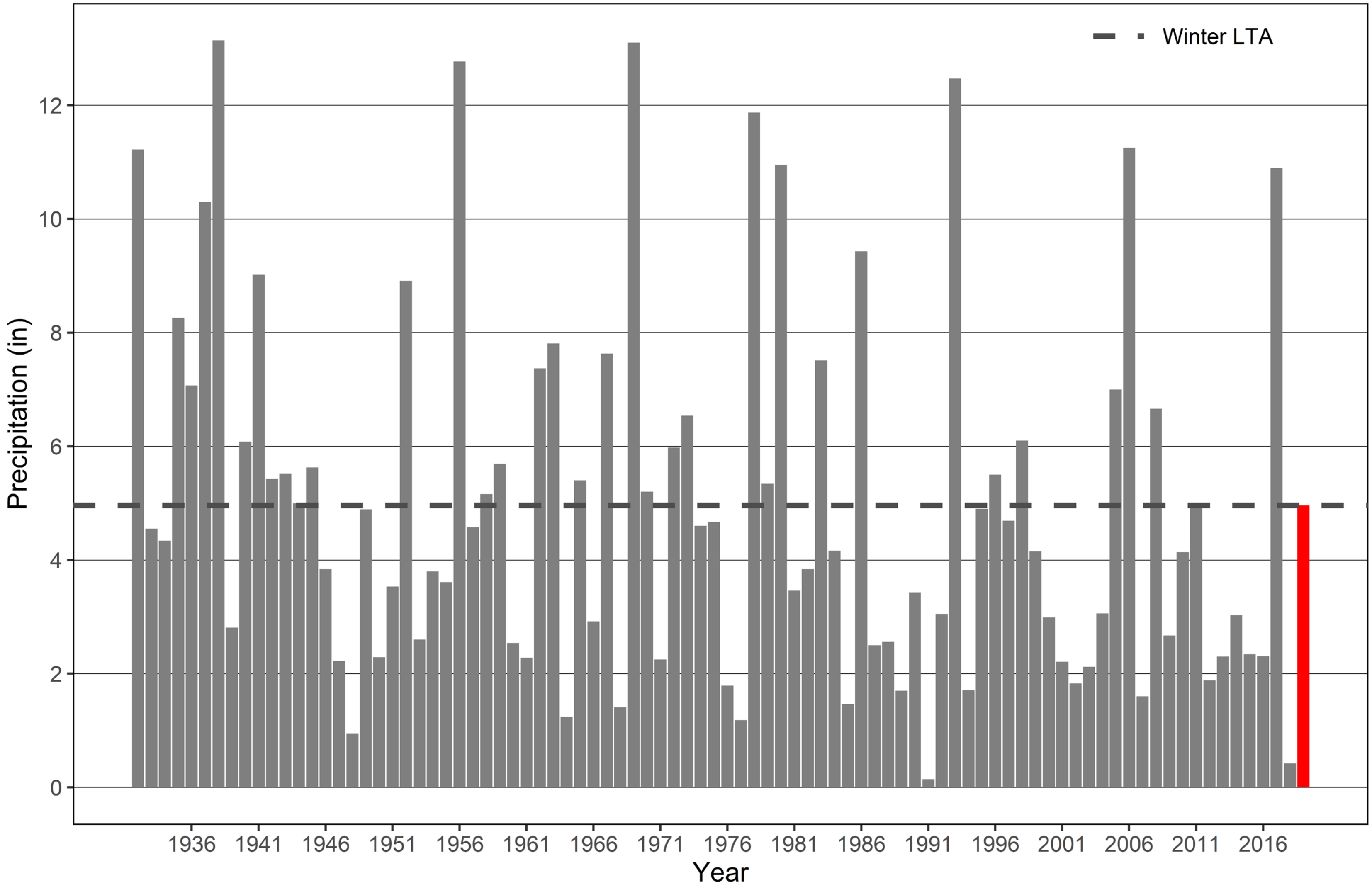


Figure 3-53. Total Winter Precipitation (December through February)

Precipitation recorded at LADWP Cain Ranch since 1932.

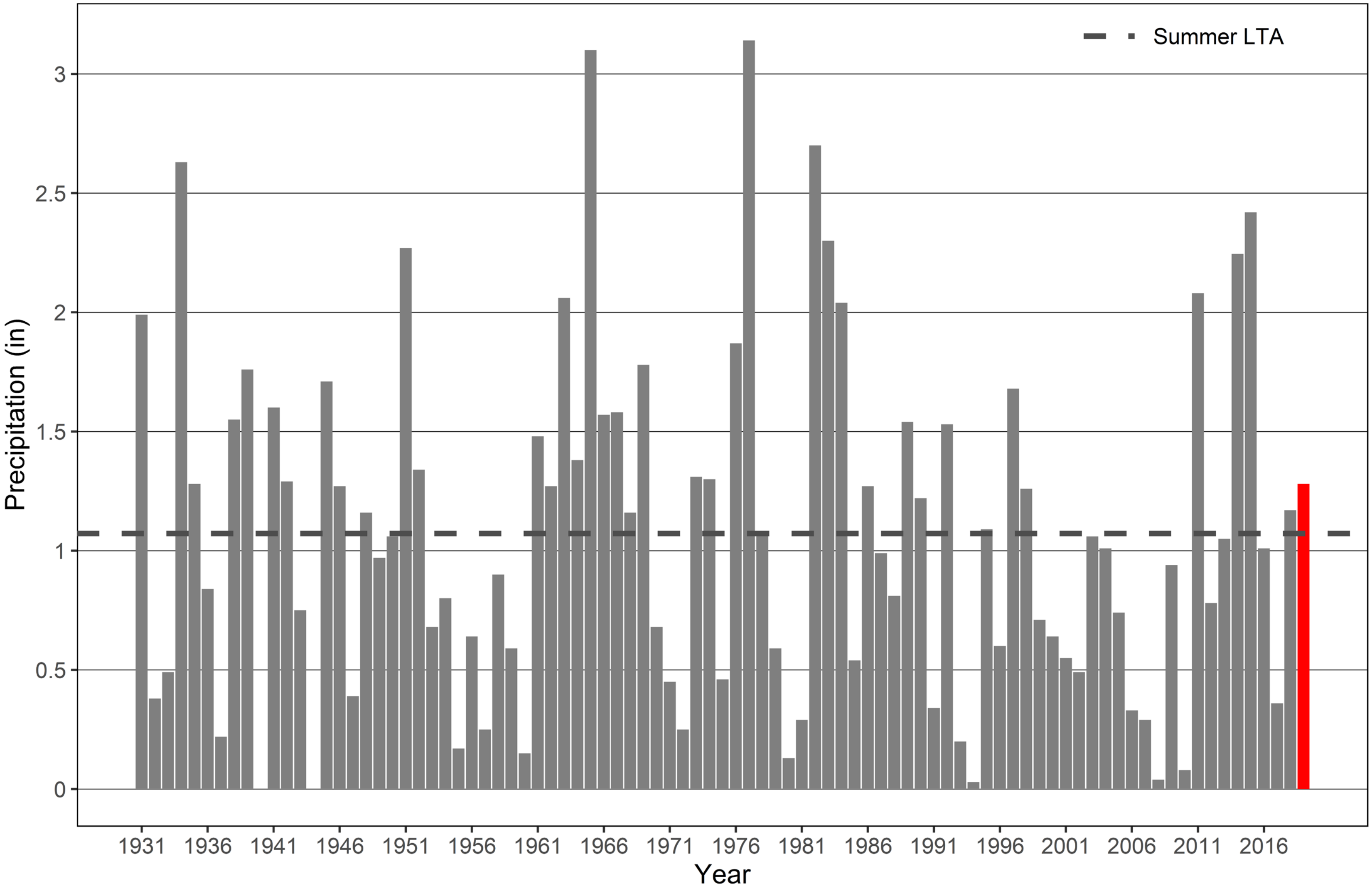


Figure 3-54. Total Summer Precipitation (June through August)

Precipitation recorded at LADWP Cain Ranch since 1932.

Physical and Chemical

Mono Lake Surface Elevation

The average monthly surface elevation of Mono Lake in January 2019 was 6381.1 feet, almost identical to the average January elevation from 2018 (Figure 3-55). Water Year 2018-19 produced 151,818 acre-feet of runoff in Mono Basin, 124% of the long term average and ranked 23rd since 1935. Input from two major tributaries (Rush and Lee Vining Creeks) was 143,569 acre-feet, 141% of the long-term average since re-watering in 1982. The lake level rose 1.6 feet from January to the year's peak at 6382.7 feet in August but dropped to 6382.1 feet at the year's end. It was mentioned in the 2018 report that at the lake elevation around 6,381 feet the combined input of 100% Normal would be necessary to prevent the lake elevation from falling; but not be enough to raise a lake level. During Water Year 2018-19, the input was 141% and was sufficient to raise the lake level.

Transparency

Average lake-wide transparency in 2019 ranged from 0.47 m to 3.59 m in August, and transparency from March through June remained below 1 m (Table 3-8, Figure 3-56). Transparency of Mono Lake during the summer improved from 0.47 m in June to 2.87 m in July to 3.59 m in August as *Artemia* grazing reduced midsummer phytoplankton. This improvement in lake-wide transparency and Secchi depth continued until September. There was high variability in Secchi depths across the lake in July as two northwestern stations (Stations 1 and 2) showed much higher clarity than the rest of stations. The reading at Station 1 was 4.2 m or1.8 m deeper than the highest reading among stations in the east. Secchi depths became more uniform in August and September among all 12 stations. The maximum lake-wide average depth in 2019 was 3.6 m, very similar to what recorded in 2018 (3.5 m) but much lower than that of 2017 (5.8 m).

Beginning in 2014, maximum transparency progressively worsened each year; 1.5 m in 2014, 0.9 m in 2015 and 0.6 m in 2016; however, this trend was finally reversed in 2017 even though it still lagged behind historically (Figure 3-57, Figure 3-58). The annual maximum reading in 2019 was higher than values recorded between 2014 and 2016, but much lower than the historical average of 7.4 m. In 2019, the input flow of Rush and Lee Vining Creeks combined peaked on June 20 with estimated combined flow of 1,010 cfs, which corresponded to an approximate 0.08 exceeding probability and 12.5 years recurrence interval based on daily flow data available since 1990. The peak inflow in 2019 was much higher than 2018 as peak flows from Lee Vining and Rush Creeks occurred on the same calendar day in 2019. The annual peak flow occurred two weeks later than 2018 and roughly at the same time as 2017 even though the combined peak in 2019 was two third of what recorded in 2017. Even though historically still low, higher input flow into Mono Lake was able to help maintaining improved clarity during 2019 monitoring.

A trend of declining transparency appears to have started after 2007, and Secchi depths have not exceeded 10 m since then. Mono Basin has not experienced two or more years of wet conditions (>136.5% of Normal) since the two-year wet period between 2005 and 2006. Sporadic occurrences of single wet years may improve transparency temporarily, but are not enough to reverse the apparent long-term trend of declining transparency. The year 2019 fell short for having two wet years in three years (124% of Normal). Warming summer and winter temperatures may also contribute to longer growing season for phytoplankton, resulting in less transparency.

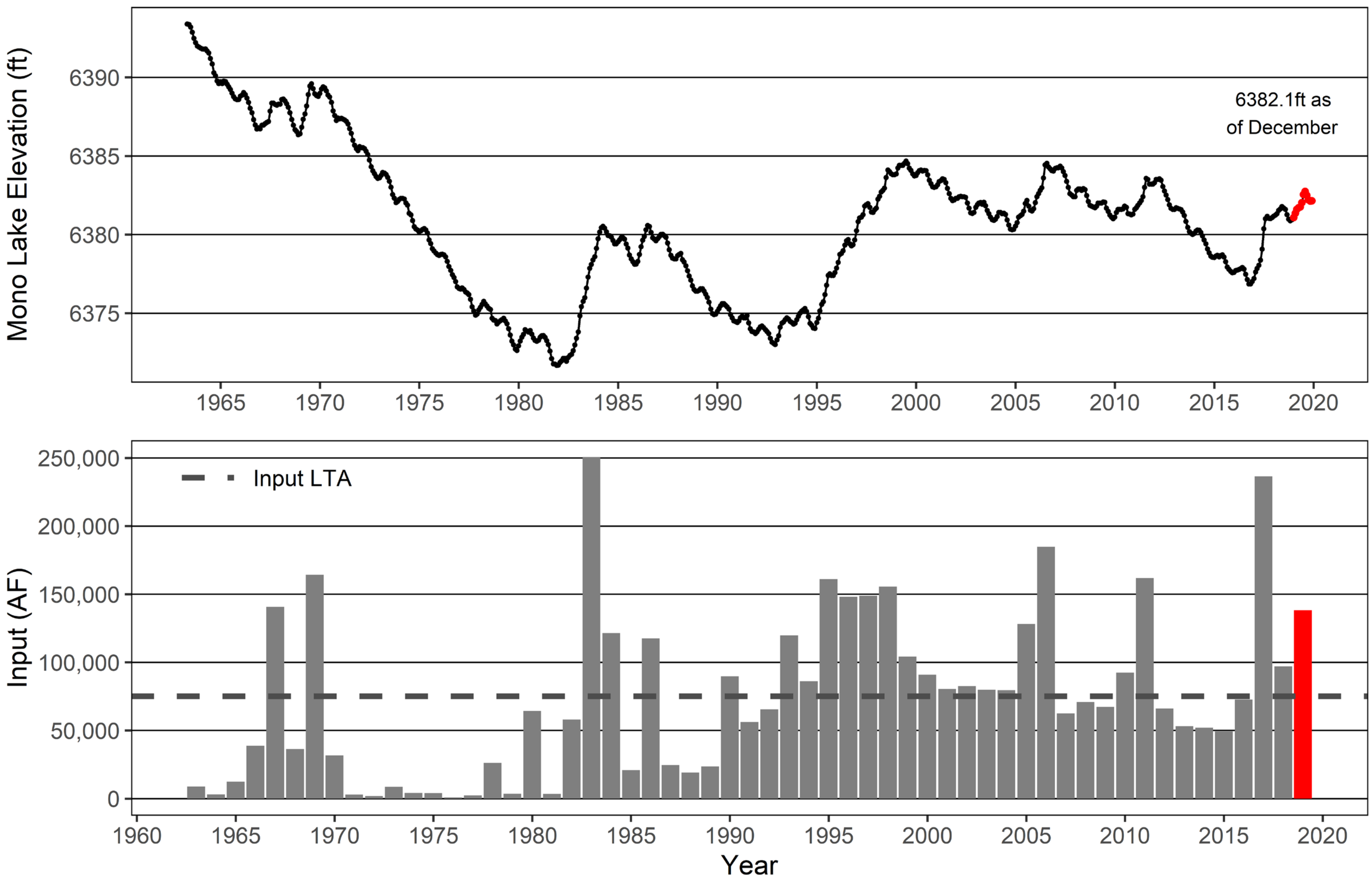


Figure 3-55. Mono Lake Surface Elevation (top) and Combined Inflow of Rush and Lee Vining Creeks (bottom)

Mono Lake elevation and input data since 1967 were presented as monthly flow volume of all tributaries to Rush Creek did not become available until 1967.

Table 3-8. Secchi Depths (m) between March and December in 2019

	Sampling Month										
Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western Sector											
1		0.9	0.5	0.5	0.5	4.2	4	3.5	0.6	0.9	0.8
2		0.8	0.45	0.55	0.5	3.5	4	3.5	0.8	0.9	0.7
3		0.75	0.5	0.55	0.5	2.6	3.8	3.5	1	0.9	0.8
4		0.8	0.5	0.5	0.4	3	3.5	3.5	0.9	0.95	0.7
5		0.7	0.5	0.55	0.5	2.9	4	3.5	0.9	0.9	0.7
6		0.7	0.45	0.55	0.5	2.75	3.8	3.5	1	0.95	0.8
AVG		0.78	0.48	0.53	0.48	3.16	3.85	3.50	0.87	0.92	0.75
SE		0.08	0.03	0.03	0.04	0.60	0.20	0.00	0.15	0.03	0.05
Eastern Sector											
7		0.6	0.5	0.55	0.5	2.6	3.5	3.5	1.1	0.9	0.7
8		0.6	0.5	0.55	0.5	2.4	3	3.5	0.7	0.9	0.7
9		0.7	0.55	0.55	0.45	2.6	3.5	3.5	0.8	0.95	0.8
10		0.7	0.55	0.55	0.4	2.5	3.5	3.5	0.9	1	0.8
11		0.6	0.6	0.5	0.5	2.5	3.5	3.5	0.8	0.95	0.7
12		0.7	0.55	0.5	0.4	2.9	3	3	0.8	0.95	0.6
AVG		0.65	0.54	0.53	0.46	2.58	3.33	3.42	0.85	0.94	0.72
SE		0.05	0.04	0.03	0.05	0.17	0.26	0.20	0.14	0.04	0.08
Total Lakewide											
AVG		0.71	0.51	0.53	0.47	2.87	3.59	3.46	0.86	0.93	0.73
SE		0.71	0.51	0.53	0.47	2.87	3.59	3.46	0.86	0.93	0.73

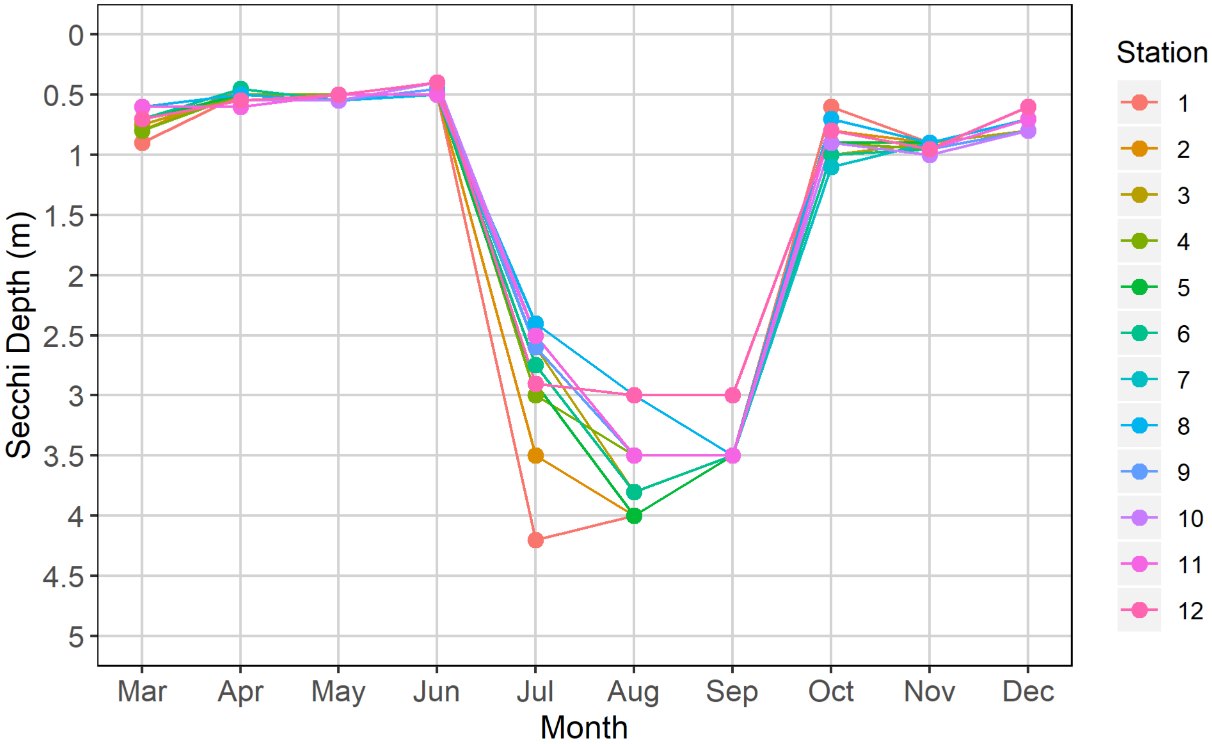
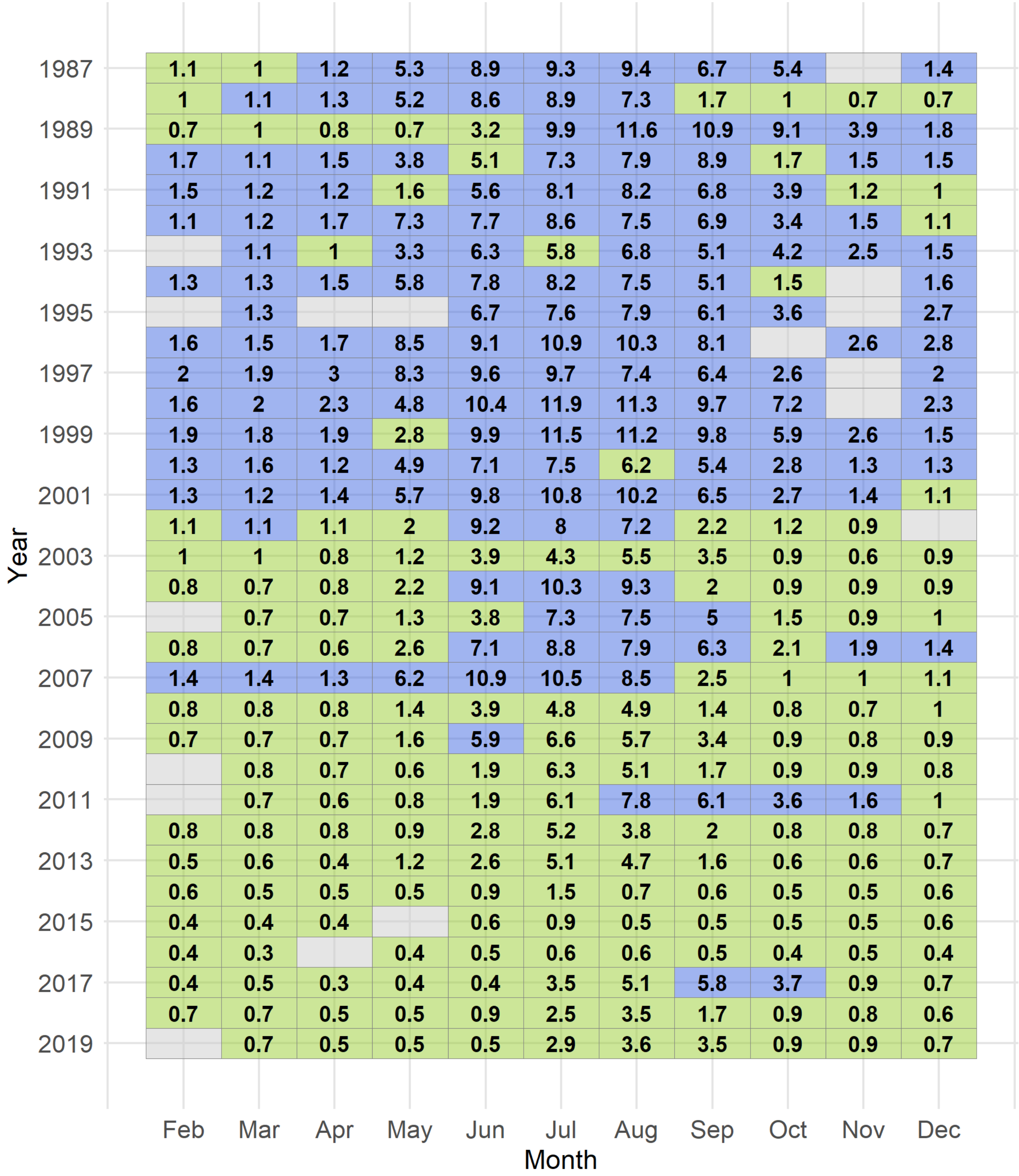


Figure 3-56. Lake-wide Secchi Depths in 2019 by Station



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	1.1	1	1.2	5.3	8.9	9.3	9.4	6.7	5.4		1.4
	1	1.1	1.3	5.2	8.6	8.9	7.3	1.7	1	0.7	0.7
1989	0.7	1	0.8	0.7	3.2	9.9	11.6	10.9	9.1	3.9	1.8
	1.7	1.1	1.5	3.8	5.1	7.3	7.9	8.9	1.7	1.5	1.5
1991	1.5	1.2	1.2	1.6	5.6	8.1	8.2	6.8	3.9	1.2	1
	1.1	1.2	1.7	7.3	7.7	8.6	7.5	6.9	3.4	1.5	1.1
1993		1.1	1	3.3	6.3	5.8	6.8	5.1	4.2	2.5	1.5
	1.3	1.3	1.5	5.8	7.8	8.2	7.5	5.1	1.5		1.6
1995		1.3			6.7	7.6	7.9	6.1	3.6		2.7
	1.6	1.5	1.7	8.5	9.1	10.9	10.3	8.1		2.6	2.8
1997	2	1.9	3	8.3	9.6	9.7	7.4	6.4	2.6		2
	1.6	2	2.3	4.8	10.4	11.9	11.3	9.7	7.2		2.3
1999	1.9	1.8	1.9	2.8	9.9	11.5	11.2	9.8	5.9	2.6	1.5
	1.3	1.6	1.2	4.9	7.1	7.5	6.2	5.4	2.8	1.3	1.3
2001	1.3	1.2	1.4	5.7	9.8	10.8	10.2	6.5	2.7	1.4	1.1
	1.1	1.1	1.1	2	9.2	8	7.2	2.2	1.2	0.9	
2003	1	1	0.8	1.2	3.9	4.3	5.5	3.5	0.9	0.6	0.9
	0.8	0.7	0.8	2.2	9.1	10.3	9.3	2	0.9	0.9	0.9
2005		0.7	0.7	1.3	3.8	7.3	7.5	5	1.5	0.9	1
	0.8	0.7	0.6	2.6	7.1	8.8	7.9	6.3	2.1	1.9	1.4
2007	1.4	1.4	1.3	6.2	10.9	10.5	8.5	2.5	1	1	1.1
	0.8	0.8	0.8	1.4	3.9	4.8	4.9	1.4	0.8	0.7	1
2009	0.7	0.7	0.7	1.6	5.9	6.6	5.7	3.4	0.9	0.8	0.9
		0.8	0.7	0.6	1.9	6.3	5.1	1.7	0.9	0.9	0.8
2011		0.7	0.6	0.8	1.9	6.1	7.8	6.1	3.6	1.6	1
	0.8	0.8	0.8	0.9	2.8	5.2	3.8	2	0.8	0.8	0.7
2013	0.5	0.6	0.4	1.2	2.6	5.1	4.7	1.6	0.6	0.6	0.7
	0.6	0.5	0.5	0.5	0.9	1.5	0.7	0.6	0.5	0.5	0.6
2015	0.4	0.4	0.4		0.6	0.9	0.5	0.5	0.5	0.5	0.6
	0.4	0.3		0.4	0.5	0.6	0.6	0.5	0.4	0.5	0.4
2017	0.4	0.5	0.3	0.4	0.4	3.5	5.1	5.8	3.7	0.9	0.7
	0.7	0.7	0.5	0.5	0.9	2.5	3.5	1.7	0.9	0.8	0.6
2019		0.7	0.5	0.5	0.5	2.9	3.6	3.5	0.9	0.9	0.7

Figure 3-57. Long-term Lake-wide Average Secchi Depths (m)

Blue-colored cells indicate above the long-term average of the respective month while green-colored cells indicate below the long-term average of the respective month.

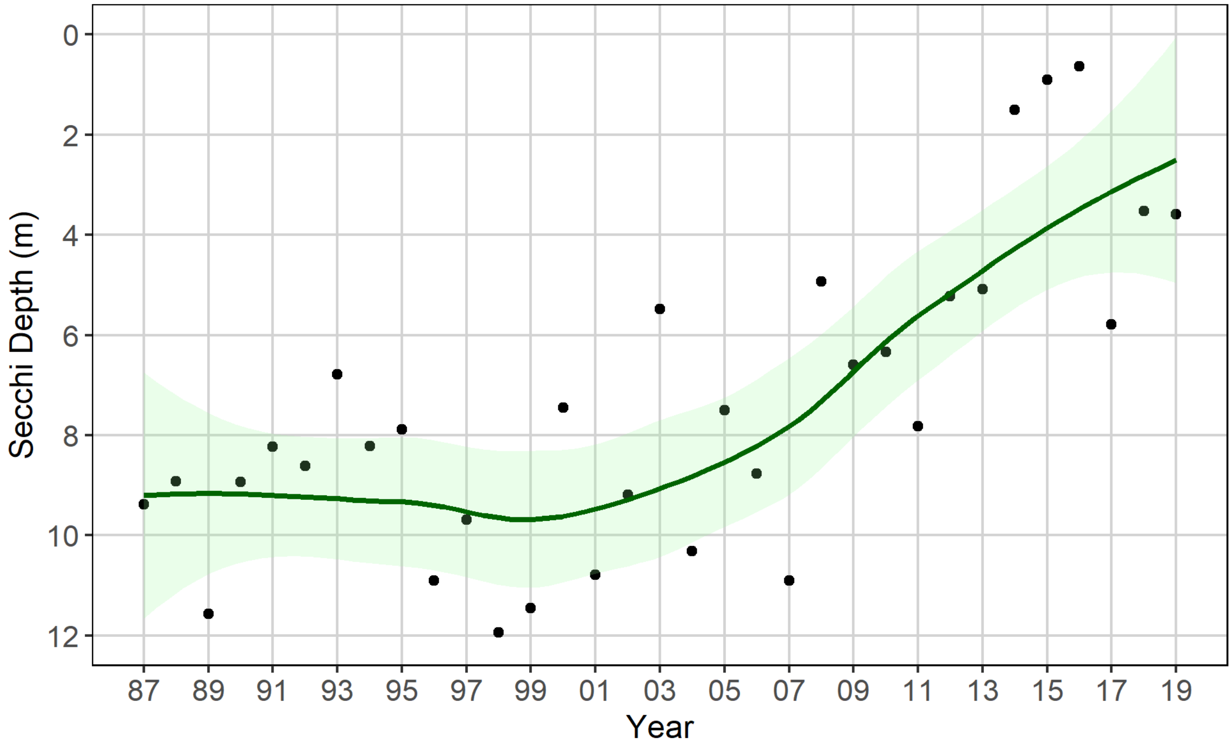


Figure 3-58. Trend in Annual Maximum Secchi Depth Readings (m)

Water Temperature

The water temperature data from Station 6 indicate that Mono Lake started to become thermally stratified in spring and remained stratified until November and became isothermal in December in 2019 (Table 3-9, Figure 3-59). By mid-May a thermocline (as indicated by the greater than 1°C change per meter depth), had formed at 6 to 7 m and remained between 8 and 12 m into October. Thermal stratification weakened in November and the lake was essentially isothermal in December.

Average water temperature in the epilimnion and hypolimnion remained mostly below normal throughout 2019 (Figure 3-60, Figure 3-61). Higher than normal epilimnion water temperature in April is most likely due to warmer conditions that prevailed in April. In spite of warm August air temperatures, hypolimnion water temperatures remained below normal due to the 141% of Normal combined input from Rush and Lee Vining Creeks. Hypolimnion water temperature remained fairly stable through 2019 due to persistence of the chemocline established in 2017, resulting in somewhat warmer than normal temperatures during winter months but cooler than normal during the rest of the year.

Conductivity

Epilimnetic specific conductivity began to decrease in April with onset of snowmelt driven runoff, and continued to decline through August to the lowest conductivity of any depth at 77.3 mS/cm (Table 3-10, Figure 3-62). The largest vertical range in specific conductivity (12.8 mS/cm) was observed in August as well, and a vertical range above 10 mS/cm persisted between July and September. Rapid changes in specific conductivity remained between 7 and 12 m from July to September, but ceased to exist in November, indicating weakening chemocline.

Table 3-9. Water Temperature (°C) Depth Profile at Station 6 in 2019

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	4.8	8.1	14.1	16.0	22.3	20.6	19.4	12.3	9.0	4.5
2	-	4.2	8.4	13.7	14.9	22.2	20.6	19.5	12.6	9.0	4.4
3	-	3.6	8.4	13.0	14.3	22.2	20.7	19.5	12.7	9.0	4.5
4	-	3.3	8.2	12.4	13.5	20.7	20.7	19.5	12.7	9.0	4.5
5	-	3.2	8.1	12.1	12.1	18.7	20.5	19.5	12.7	9.0	4.5
6	-	3.1	8.1	11.4	11.5	16.6	18.4	19.5	12.7	9.0	4.5
7	-	3.0	8.0	9.7	10.9	13.1	16.1	19.4	12.7	9.2	4.5
8	-	3.0	6.9	7.3	10.5	11.5	13.7	15.8	12.7	9.3	4.5
9	-	2.9	5.9	6.1	9.8	10.6	11.8	12.9	12.5	9.4	4.5
10	-	2.8	4.8	5.2	9.2	9.8	9.7	10.5	12.4	9.3	4.5
11	-	2.6	4.2	4.6	7.5	9.0	8.4	9.2	11.3	9.3	4.5
12	-	2.3	3.6	4.3	6.6	8.1	7.6	7.8	9.7	9.3	4.5
13	-	2.3	3.4	4.0	5.8	7.3	6.7	6.6	8.1	8.7	4.6
14	-	2.3	3.4	3.6	5.0	6.2	6.1	5.8	7.2	7.3	4.6
15	-	2.4	3.3	3.6	4.6	5.3	5.3	5.3	6.4	6.5	4.6
16	-	2.5	3.2	3.6	4.3	4.9	4.9	5.0	5.7	5.8	5.4
17	-	2.7	3.3	3.5	4.1	4.7	4.7	4.8	5.2	5.5	5.7
18	-	3.1	3.4	3.6	4.2	4.6	4.6	4.7	5.0	5.1	5.4
19	-	3.7	3.7	3.8	4.3	4.5	4.6	4.7	4.8	4.9	5.1
20	-	4.1	3.9	4.0	4.3	4.6	4.6	4.6	4.8	4.8	5.0
21	-	4.5	4.2	4.3	4.4	4.5	4.7	4.7	4.8	4.8	4.8
22	-	4.7	4.4	4.5	4.5	4.6	4.7	4.7	4.8	4.8	4.8
23	-	4.9	4.6	4.7	4.6	4.6	4.7	4.7	4.8	4.8	4.8
24	-	5.0	4.7	4.8	4.6	4.7	4.7	4.7	4.8	4.8	4.8
25	-	5.1	4.8	4.8	4.7	4.7	4.7	4.7	4.8	4.8	4.8
26	-	5.2	4.9	4.9	4.7	4.7	4.7	4.7	4.7	4.8	4.8
27	-	5.3	5.0	4.9	4.8	4.8	4.7	4.7	4.7	4.8	-
28	-	5.3	5.1	5.0	4.8	4.8	4.7	4.7	4.7	4.8	-
29	-	5.4	5.2	5.0	4.9	4.8	4.7	4.8	4.8	4.8	-
30	-	5.4	5.2	5.1	4.9	4.8	4.8	4.8	4.8	4.8	-
31	-	5.5	5.3	5.1	4.9	4.8	4.8	4.8	4.8	4.8	-
32	-	5.5	5.3	5.1	4.9	4.8	4.8	4.8	4.8	4.8	-
33	-	5.5	5.3	5.1	4.9	4.8	4.8	4.8	4.8	4.8	-
34	-	5.5	5.4	5.1	5.0	4.8	4.8	4.8	4.8	4.8	-
35	-	5.5	5.4	5.2	5.0	4.9	4.8	4.8	4.8	4.8	-
36	-	5.5	5.4	5.2	5.0	4.9	4.8	4.8	4.8	4.8	-
37	-	5.5	5.4	5.2	5.0	4.9	4.8	4.8	4.8	4.8	-
38	-	5.5	5.4	5.2	5.0	4.9	4.8	4.8	4.8	4.8	-
39	-	5.5	5.4	5.2	-	4.9	4.8	4.8	4.8	4.8	-
40	-	5.5	5.4	5.2	-	-	-	-	-	4.8	-

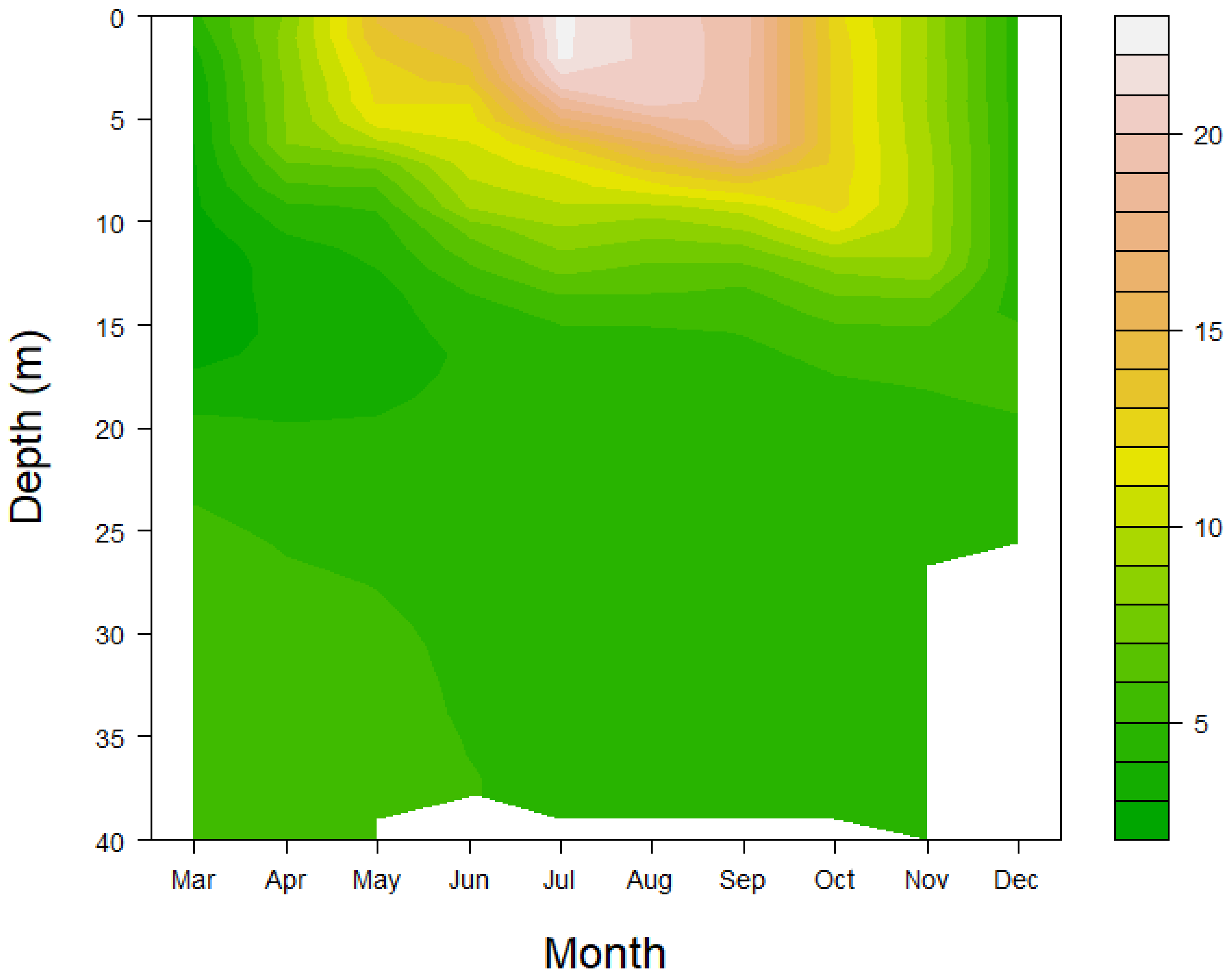
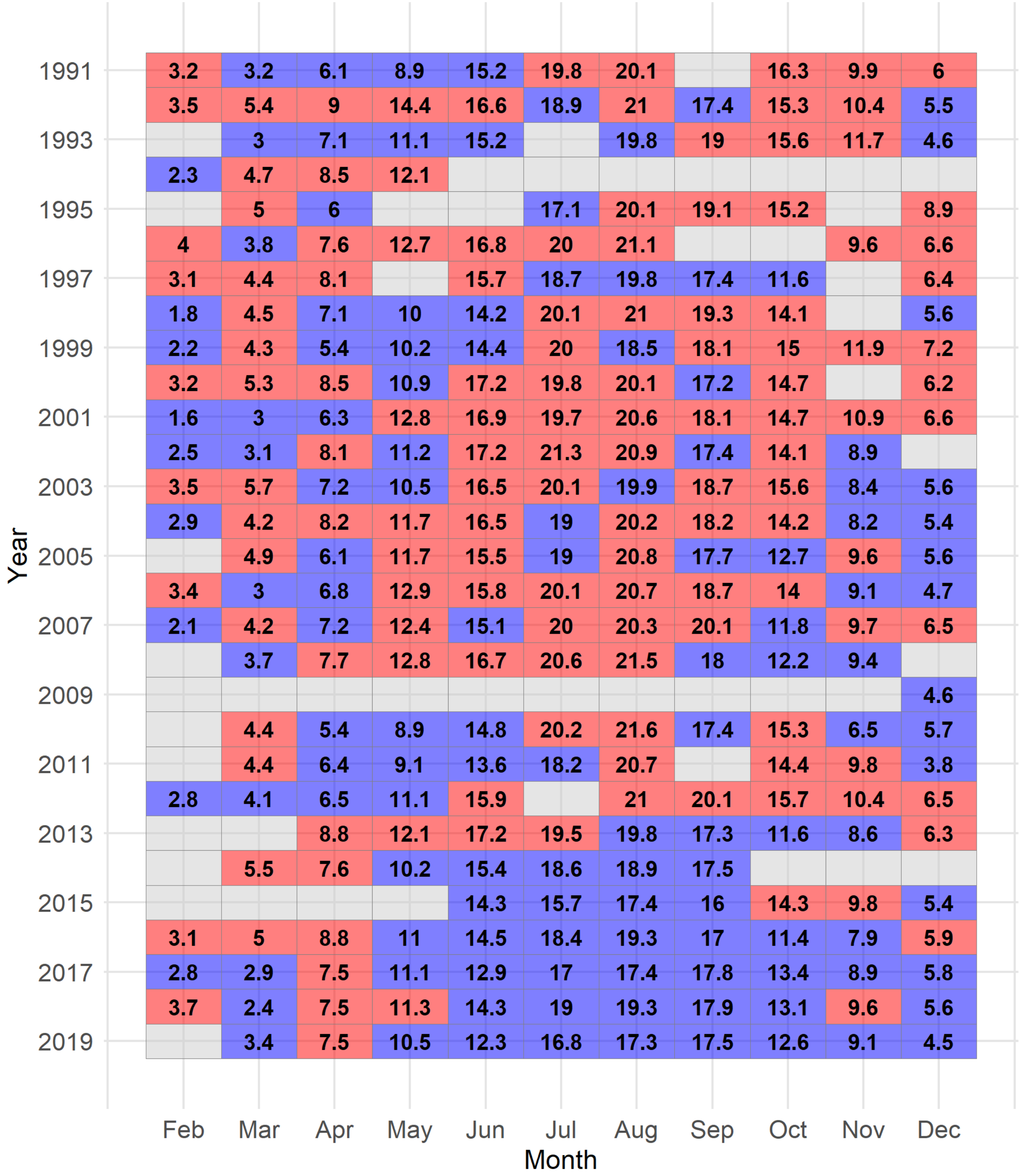


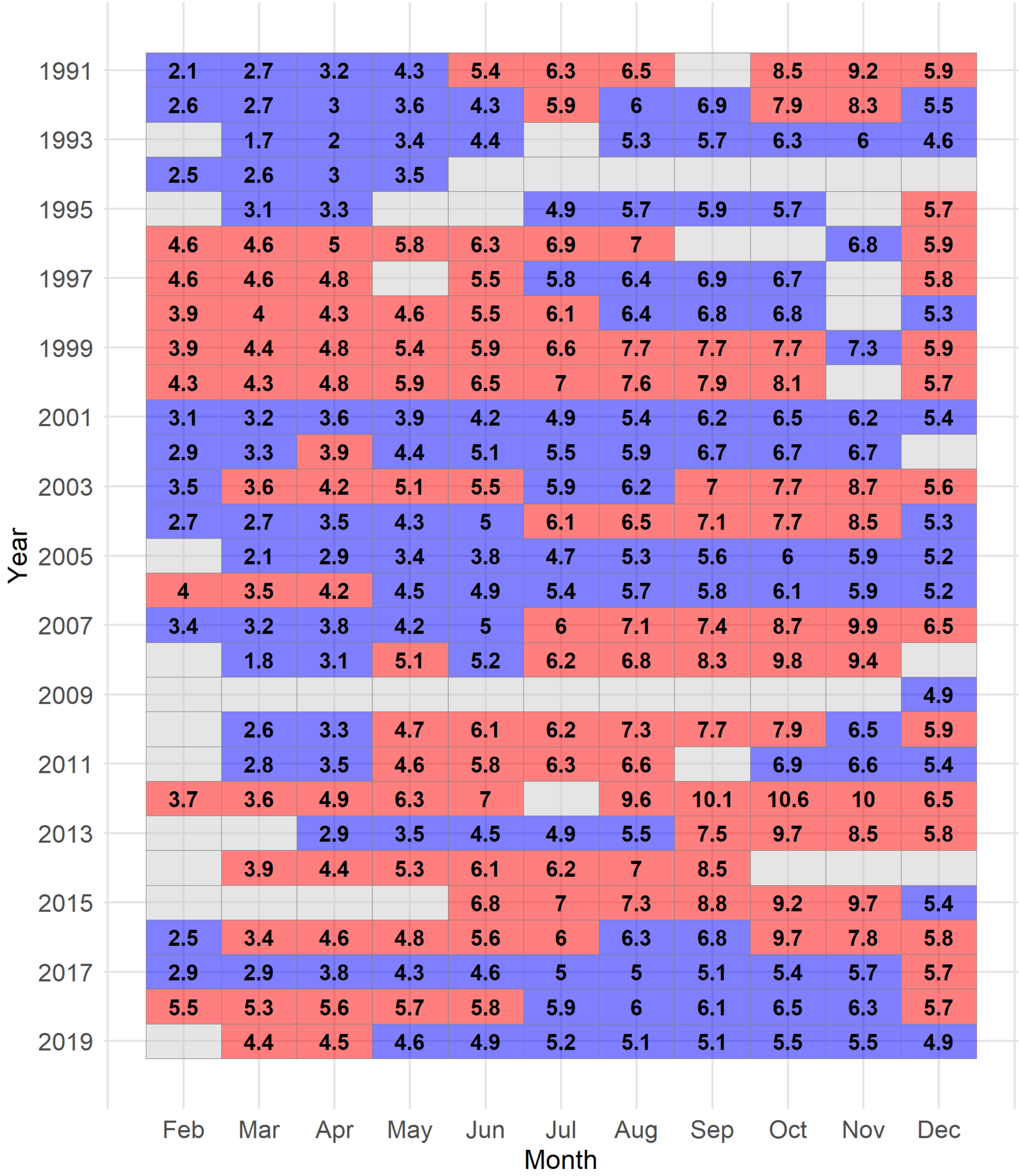
Figure 3-59. Water Temperature (°C) Depth Profile at Station 6 in 2019



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	3.2	3.2	6.1	8.9	15.2	19.8	20.1		16.3	9.9	6
	3.5	5.4	9	14.4	16.6	18.9	21	17.4	15.3	10.4	5.5
1993		3	7.1	11.1	15.2		19.8	19	15.6	11.7	4.6
	2.3	4.7	8.5	12.1							
1995		5	6			17.1	20.1	19.1	15.2		8.9
	4	3.8	7.6	12.7	16.8	20	21.1			9.6	6.6
1997	3.1	4.4	8.1		15.7	18.7	19.8	17.4	11.6		6.4
	1.8	4.5	7.1	10	14.2	20.1	21	19.3	14.1		5.6
1999	2.2	4.3	5.4	10.2	14.4	20	18.5	18.1	15	11.9	7.2
	3.2	5.3	8.5	10.9	17.2	19.8	20.1	17.2	14.7		6.2
2001	1.6	3	6.3	12.8	16.9	19.7	20.6	18.1	14.7	10.9	6.6
	2.5	3.1	8.1	11.2	17.2	21.3	20.9	17.4	14.1	8.9	
2003	3.5	5.7	7.2	10.5	16.5	20.1	19.9	18.7	15.6	8.4	5.6
	2.9	4.2	8.2	11.7	16.5	19	20.2	18.2	14.2	8.2	5.4
2005		4.9	6.1	11.7	15.5	19	20.8	17.7	12.7	9.6	5.6
	3.4	3	6.8	12.9	15.8	20.1	20.7	18.7	14	9.1	4.7
2007	2.1	4.2	7.2	12.4	15.1	20	20.3	20.1	11.8	9.7	6.5
		3.7	7.7	12.8	16.7	20.6	21.5	18	12.2	9.4	
2009											4.6
		4.4	5.4	8.9	14.8	20.2	21.6	17.4	15.3	6.5	5.7
2011		4.4	6.4	9.1	13.6	18.2	20.7		14.4	9.8	3.8
	2.8	4.1	6.5	11.1	15.9		21	20.1	15.7	10.4	6.5
2013			8.8	12.1	17.2	19.5	19.8	17.3	11.6	8.6	6.3
		5.5	7.6	10.2	15.4	18.6	18.9	17.5			
2015					14.3	15.7	17.4	16	14.3	9.8	5.4
	3.1	5	8.8	11	14.5	18.4	19.3	17	11.4	7.9	5.9
2017	2.8	2.9	7.5	11.1	12.9	17	17.4	17.8	13.4	8.9	5.8
	3.7	2.4	7.5	11.3	14.3	19	19.3	17.9	13.1	9.6	5.6
2019		3.4	7.5	10.5	12.3	16.8	17.3	17.5	12.6	9.1	4.5

Figure 3-60. Average Water Temperature (°C) between 1 and 10 m at Station 6

Red-colored cells indicate above the long-term average of the respective month while blue-colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	2.1	2.7	3.2	4.3	5.4	6.3	6.5		8.5	9.2	5.9
	2.6	2.7	3	3.6	4.3	5.9	6	6.9	7.9	8.3	5.5
1993		1.7	2	3.4	4.4		5.3	5.7	6.3	6	4.6
	2.5	2.6	3	3.5							
1995		3.1	3.3			4.9	5.7	5.9	5.7		5.7
	4.6	4.6	5	5.8	6.3	6.9	7			6.8	5.9
1997	4.6	4.6	4.8		5.5	5.8	6.4	6.9	6.7		5.8
	3.9	4	4.3	4.6	5.5	6.1	6.4	6.8	6.8		5.3
1999	3.9	4.4	4.8	5.4	5.9	6.6	7.7	7.7	7.7	7.3	5.9
	4.3	4.3	4.8	5.9	6.5	7	7.6	7.9	8.1		5.7
2001	3.1	3.2	3.6	3.9	4.2	4.9	5.4	6.2	6.5	6.2	5.4
	2.9	3.3	3.9	4.4	5.1	5.5	5.9	6.7	6.7	6.7	
2003	3.5	3.6	4.2	5.1	5.5	5.9	6.2	7	7.7	8.7	5.6
	2.7	2.7	3.5	4.3	5	6.1	6.5	7.1	7.7	8.5	5.3
2005		2.1	2.9	3.4	3.8	4.7	5.3	5.6	6	5.9	5.2
	4	3.5	4.2	4.5	4.9	5.4	5.7	5.8	6.1	5.9	5.2
2007	3.4	3.2	3.8	4.2	5	6	7.1	7.4	8.7	9.9	6.5
		1.8	3.1	5.1	5.2	6.2	6.8	8.3	9.8	9.4	
2009											4.9
		2.6	3.3	4.7	6.1	6.2	7.3	7.7	7.9	6.5	5.9
2011		2.8	3.5	4.6	5.8	6.3	6.6		6.9	6.6	5.4
	3.7	3.6	4.9	6.3	7		9.6	10.1	10.6	10	6.5
2013			2.9	3.5	4.5	4.9	5.5	7.5	9.7	8.5	5.8
		3.9	4.4	5.3	6.1	6.2	7	8.5			
2015					6.8	7	7.3	8.8	9.2	9.7	5.4
	2.5	3.4	4.6	4.8	5.6	6	6.3	6.8	9.7	7.8	5.8
2017	2.9	2.9	3.8	4.3	4.6	5	5	5.1	5.4	5.7	5.7
	5.5	5.3	5.6	5.7	5.8	5.9	6	6.1	6.5	6.3	5.7
2019		4.4	4.5	4.6	4.9	5.2	5.1	5.1	5.5	5.5	4.9

Figure 3-61. Average Water Temperature (°C) between 11 and 38 m at Station 6

Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.

Table 3-10. Conductivity (mS/cm at 25°C) Depth Profile at Station 6 in 2019

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	85.4	83.6	81.4	80.7	77.5	77.3	78.7	80.8	82.3	85.4
2	-	86.0	83.5	81.4	81.0	77.5	77.6	78.5	81.0	82.5	85.4
3	-	86.5	83.6	81.5	81.1	77.5	77.7	78.5	81.0	82.5	85.5
4	-	86.9	83.5	82.1	81.3	77.4	77.6	78.5	81.1	82.6	85.5
5	-	87.1	83.7	82.2	81.7	79.1	77.6	78.5	81.1	82.6	85.5
6	-	87.2	83.7	82.0	82.2	78.8	78.9	78.5	81.1	82.6	85.5
7	-	87.3	83.7	81.7	82.3	80.8	79.9	78.7	81.2	82.7	85.5
8	-	87.4	84.2	83.3	82.7	82.1	80.6	80.1	81.1	82.7	85.5
9	-	87.4	84.1	84.4	82.9	82.4	81.0	81.2	81.2	82.6	85.5
10	-	87.5	85.5	85.4	83.2	82.9	82.6	82.4	81.3	82.7	85.5
11	-	87.5	85.9	86.2	84.2	83.0	83.7	83.0	82.0	82.8	85.5
12	-	88.3	87.0	86.4	84.9	83.8	84.3	84.0	82.9	82.9	85.5
13	-	88.4	87.4	86.6	85.4	84.3	84.9	85.0	84.2	83.2	85.5
14	-	88.6	87.4	87.5	86.2	85.2	85.6	86.0	85.0	84.7	85.5
15	-	88.7	88.4	87.7	86.8	86.5	86.2	86.6	85.9	85.7	85.5
16	-	88.8	88.6	87.9	87.2	87.4	87.5	87.3	86.8	86.4	86.8
17	-	89.2	89.1	88.1	87.8	87.7	88.0	88.1	87.6	87.3	86.8
18	-	90.0	89.6	88.9	88.7	88.3	88.7	88.8	88.3	88.1	87.6
19	-	90.3	90.1	89.3	89.3	88.9	89.2	89.2	88.7	88.6	88.3
20	-	90.5	90.5	90.0	89.6	89.3	89.5	89.4	89.0	89.0	88.8
21	-	90.3	90.5	90.2	89.8	89.6	89.6	89.5	89.2	89.2	89.0
22	-	90.4	90.5	90.4	89.9	89.7	89.7	89.6	89.4	89.3	89.2
23	-	90.3	90.3	90.2	90.0	89.9	89.7	89.6	89.5	89.4	89.3
24	-	90.5	90.3	90.3	90.1	89.9	89.8	89.7	89.6	89.5	89.4
25	-	90.3	90.4	90.3	90.1	89.9	89.9	89.7	89.6	89.6	89.4
26	-	90.3	90.4	90.3	90.1	90.0	89.9	89.8	89.7	89.6	89.5
27	-	90.2	90.3	90.3	90.2	90.0	89.9	89.8	89.7	89.7	-
28	-	90.3	90.3	90.3	90.2	90.0	89.9	89.9	89.7	89.7	-
29	-	90.3	90.3	90.3	90.2	90.0	90.0	89.9	89.8	89.7	-
30	-	90.3	90.3	90.3	90.2	90.1	90.0	89.9	89.8	89.7	-
31	-	90.3	90.3	90.3	90.2	90.1	90.0	89.9	89.8	89.8	-
32	-	90.2	90.3	90.3	90.2	90.1	90.0	90.0	89.8	89.8	-
33	-	90.3	90.3	90.3	90.2	90.1	90.0	90.0	89.8	89.8	-
34	-	90.3	90.3	90.3	90.2	90.1	90.0	90.0	89.8	89.8	-
35	-	90.3	90.3	90.3	90.2	90.1	90.0	90.0	89.9	89.8	-
36	-	90.3	90.3	90.3	90.3	90.1	90.1	90.0	89.9	89.8	-
37	-	90.3	90.3	90.3	90.2	90.1	90.1	90.0	89.9	89.8	-
38	-	90.3	90.3	90.3	90.2	90.1	90.1	90.0	89.9	89.8	-
39	-	90.3	90.3	90.3	-	90.1	90.1	90.0	89.9	89.8	-
40	-	90.3	90.3	90.3	-	-	-	-	-	89.8	-

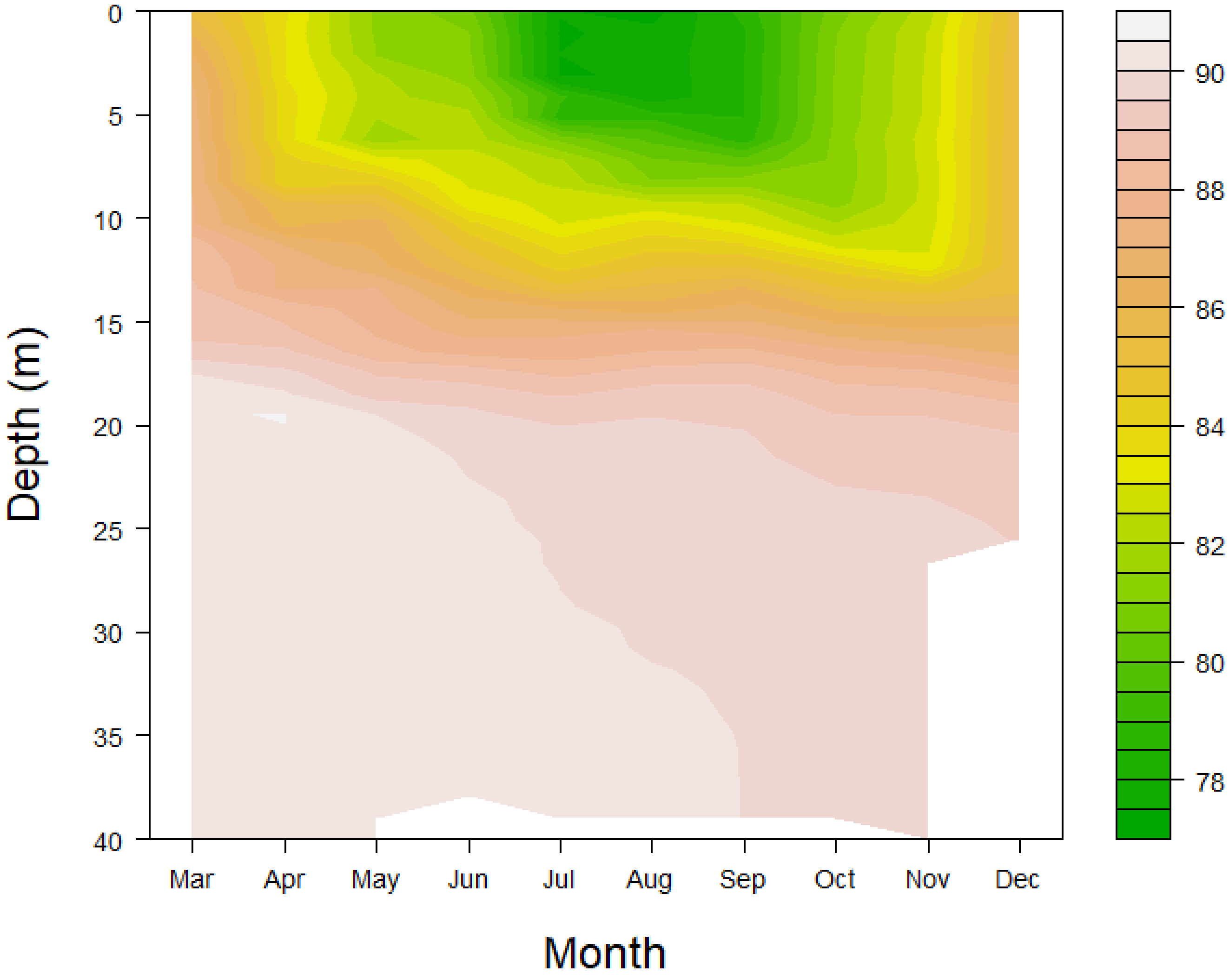
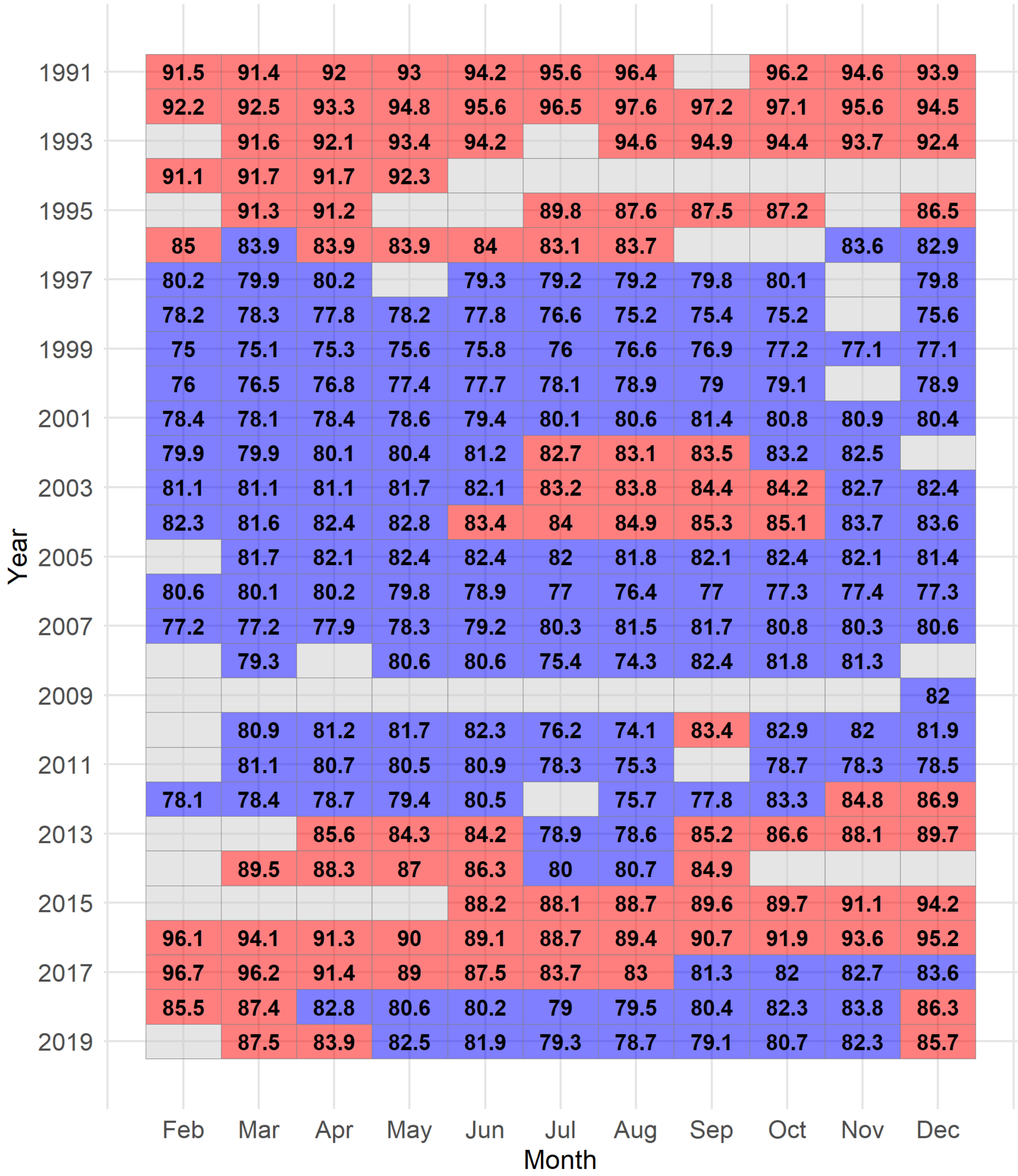


Figure 3-62. Conductivity (mS/cm) Depth Profile at Station 6 in 2019

Salinity

Salinity expressed in g/L at 2 different depth classes (between 1 and 10 m and between 11 and 38 m) was presented in Figure 3-63 and Figure 3-64. Salinity in the epilimnion was slightly lower than what was observed in 2018 due to higher runoff in 2019. In December, however, epilimnetic salinity increased to 85.7 g/L, above the long-term average, which was lower than what observed in 2018, but 2 g/L higher than the 2017 level. Salinity in the hypolimnion remained higher than normal throughout 2019, but lower than 2017 and 2018. A difference between epilimnetic and hypolimnetic salinity declined to 3 g/L in December, indicating deepening or weakening chemocline as epilimnetic water continued to become more saline with evaporative concentration and reduced lake input.

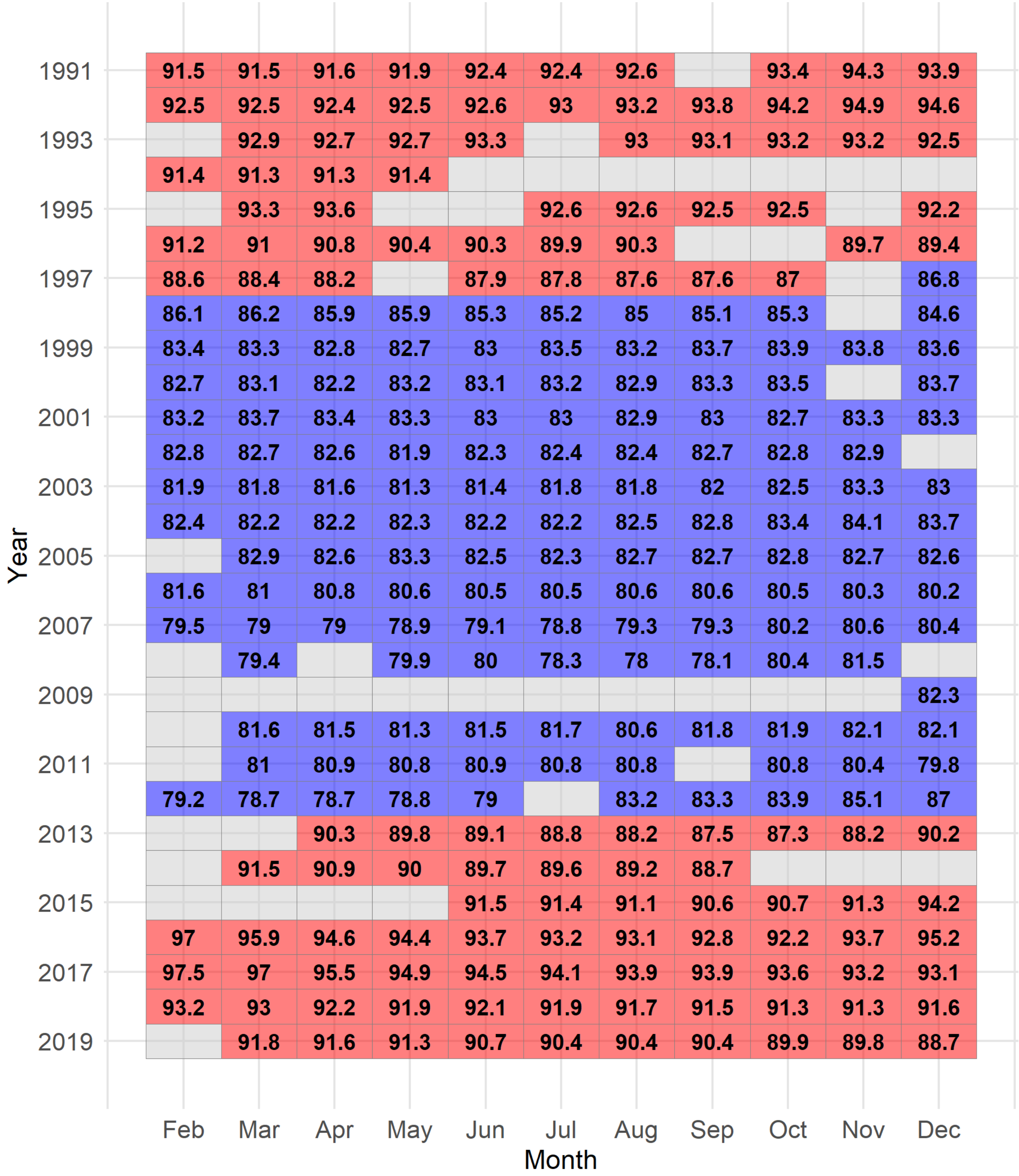
Mono Lake water was less salty at shallower depths in 2019 but continued to become saltier at deeper depths in spite of the recent decreasing trend due to the almost record breaking runoff in 2017. Due to the extremely dry condition that persisted between 2012 and 2015 the lake level dropped from 6,383.5 feet in May 2012 to 6,377.0 feet in December 2016. During the same period, the salinity level increased from 75.7 g/L (August 2012) to 95.3 g/L in the epilimnion and from 79.0 g/L (June 2012) to 95.2 g/L in the hypolimnion. As a result, the salinity level at the beginning of 2019 was lowest since 2012 but still almost 10 g/L higher than during the meromixis between 1995 and 2002.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	91.5	91.4	92	93	94.2	95.6	96.4		96.2	94.6	93.9
	92.2	92.5	93.3	94.8	95.6	96.5	97.6	97.2	97.1	95.6	94.5
1993		91.6	92.1	93.4	94.2		94.6	94.9	94.4	93.7	92.4
	91.1	91.7	91.7	92.3							
1995		91.3	91.2			89.8	87.6	87.5	87.2		86.5
	85	83.9	83.9	83.9	84	83.1	83.7			83.6	82.9
1997	80.2	79.9	80.2		79.3	79.2	79.2	79.8	80.1		79.8
	78.2	78.3	77.8	78.2	77.8	76.6	75.2	75.4	75.2		75.6
1999	75	75.1	75.3	75.6	75.8	76	76.6	76.9	77.2	77.1	77.1
	76	76.5	76.8	77.4	77.7	78.1	78.9	79	79.1		78.9
2001	78.4	78.1	78.4	78.6	79.4	80.1	80.6	81.4	80.8	80.9	80.4
	79.9	79.9	80.1	80.4	81.2	82.7	83.1	83.5	83.2	82.5	
2003	81.1	81.1	81.1	81.7	82.1	83.2	83.8	84.4	84.2	82.7	82.4
	82.3	81.6	82.4	82.8	83.4	84	84.9	85.3	85.1	83.7	83.6
2005		81.7	82.1	82.4	82.4	82	81.8	82.1	82.4	82.1	81.4
	80.6	80.1	80.2	79.8	78.9	77	76.4	77	77.3	77.4	77.3
2007	77.2	77.2	77.9	78.3	79.2	80.3	81.5	81.7	80.8	80.3	80.6
		79.3		80.6	80.6	75.4	74.3	82.4	81.8	81.3	
2009											82
		80.9	81.2	81.7	82.3	76.2	74.1	83.4	82.9	82	81.9
2011		81.1	80.7	80.5	80.9	78.3	75.3		78.7	78.3	78.5
	78.1	78.4	78.7	79.4	80.5		75.7	77.8	83.3	84.8	86.9
2013			85.6	84.3	84.2	78.9	78.6	85.2	86.6	88.1	89.7
		89.5	88.3	87	86.3	80	80.7	84.9			
2015					88.2	88.1	88.7	89.6	89.7	91.1	94.2
	96.1	94.1	91.3	90	89.1	88.7	89.4	90.7	91.9	93.6	95.2
2017	96.7	96.2	91.4	89	87.5	83.7	83	81.3	82	82.7	83.6
	85.5	87.4	82.8	80.6	80.2	79	79.5	80.4	82.3	83.8	86.3
2019		87.5	83.9	82.5	81.9	79.3	78.7	79.1	80.7	82.3	85.7

Figure 3-63. Average Salinity (g/L) between 1 and 10 m at Station 6

Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	91.5	91.5	91.6	91.9	92.4	92.4	92.6		93.4	94.3	93.9
	92.5	92.5	92.4	92.5	92.6	93	93.2	93.8	94.2	94.9	94.6
1993		92.9	92.7	92.7	93.3		93	93.1	93.2	93.2	92.5
	91.4	91.3	91.3	91.4							
1995		93.3	93.6			92.6	92.6	92.5	92.5		92.2
	91.2	91	90.8	90.4	90.3	89.9	90.3			89.7	89.4
1997	88.6	88.4	88.2		87.9	87.8	87.6	87.6	87		86.8
	86.1	86.2	85.9	85.9	85.3	85.2	85	85.1	85.3		84.6
1999	83.4	83.3	82.8	82.7	83	83.5	83.2	83.7	83.9	83.8	83.6
	82.7	83.1	82.2	83.2	83.1	83.2	82.9	83.3	83.5		83.7
2001	83.2	83.7	83.4	83.3	83	83	82.9	83	82.7	83.3	83.3
	82.8	82.7	82.6	81.9	82.3	82.4	82.4	82.7	82.8	82.9	
2003	81.9	81.8	81.6	81.3	81.4	81.8	81.8	82	82.5	83.3	83
	82.4	82.2	82.2	82.3	82.2	82.2	82.5	82.8	83.4	84.1	83.7
2005		82.9	82.6	83.3	82.5	82.3	82.7	82.7	82.8	82.7	82.6
	81.6	81	80.8	80.6	80.5	80.5	80.6	80.6	80.5	80.3	80.2
2007	79.5	79	79	78.9	79.1	78.8	79.3	79.3	80.2	80.6	80.4
		79.4		79.9	80	78.3	78	78.1	80.4	81.5	
2009											82.3
		81.6	81.5	81.3	81.5	81.7	80.6	81.8	81.9	82.1	82.1
2011		81	80.9	80.8	80.9	80.8	80.8		80.8	80.4	79.8
	79.2	78.7	78.7	78.8	79		83.2	83.3	83.9	85.1	87
2013			90.3	89.8	89.1	88.8	88.2	87.5	87.3	88.2	90.2
		91.5	90.9	90	89.7	89.6	89.2	88.7			
2015					91.5	91.4	91.1	90.6	90.7	91.3	94.2
	97	95.9	94.6	94.4	93.7	93.2	93.1	92.8	92.2	93.7	95.2
2017	97.5	97	95.5	94.9	94.5	94.1	93.9	93.9	93.6	93.2	93.1
	93.2	93	92.2	91.9	92.1	91.9	91.7	91.5	91.3	91.3	91.6
2019		91.8	91.6	91.3	90.7	90.4	90.4	90.4	89.9	89.8	88.7

Figure 3-64. Average Salinity (g/L) between 11 and 38 m at Station 6

Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.

Dissolved Oxygen

In 2019, dissolved oxygen (DO) concentrations in the upper mixed layer (< 11 m) started at above 10.0 mg/L in March and declined through spring and summer reaching the lowest level in August due to increased grazing pressure on phytoplankton populations by *Artemia* (Table 3-11, Figure 3-65). In December, DO values recovered, exceeding 8.0 mg/L. The chemocline established in 2017 remained throughout 2018 and 2019. In 2019 the chemocline started around 11 m in March and strengthened over summer, but deepened to 15 m in December. Below the chemocline, DO remained anoxic (<0.5 mg/L) or suboxic (<1.5 mg/L) throughout 2019. The anoxic condition was found at 11 m in August and migrated downward to 16 m in December. The absence of autumn holomixis resulted in the anoxic condition remaining below 16 m to the end of the year.

Average DO concentrations in the upper mixing layer (depth between 1 and 15 m) in 2019 remained above the long-term average (Figure 3-66). Below 10 m average DO concentrations remained either slightly above suboxic, suboxic or anoxic throughout 2019, and the 2019 average was third lowest since 1994 following 2017 and 2018 (Figure 3-67).

Table 3-11. Dissolved Oxygen* (mg/L) Depth Profile at Station 6 in 2019

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	10.0	7.2	9.3	8.1	6.0	5.0	6.1	7.1	8.0	8.0
2	-	10.2	7.1	9.1	8.6	5.9	5.0	6.1	7.0	8.2	8.1
3	-	10.3	7.0	8.8	9.1	5.8	5.0	6.1	7.0	8.2	8.2
4	-	10.3	6.9	8.3	9.2	5.8	5.1	6.1	6.9	8.0	8.2
5	-	10.2	6.8	8.7	9.2	5.7	5.2	6.1	6.8	7.7	8.3
6	-	10.1	7.0	7.5	8.6	6.4	5.2	6.1	6.8	7.6	8.4
7	-	10.1	6.9	7.0	6.5	6.4	5.1	6.1	6.5	7.4	8.6
8	-	10.0	6.6	6.2	5.5	6.3	7.8	6.1	6.8	7.3	8.8
9	-	9.8	5.5	5.5	5.7	6.3	7.9	11.4	6.7	7.3	9.0
10	-	9.4	5.1	5.0	4.5	4.2	3.0	6.1	6.7	7.2	9.3
11	-	9.2	4.9	3.4	4.0	1.4	0.4	0.6	6.6	6.9	9.4
12	-	7.9	4.3	1.7	2.6	1.4	0.3	0.5	3.8	5.2	9.5
13	-	6.3	2.9	1.1	1.0	1.7	0.2	0.5	0.5	4.1	9.4
14	-	5.9	1.7	1.1	0.9	1.8	0.2	0.6	0.4	0.2	9.4
15	-	3.7	0.8	1.1	0.9	2.0	0.2	0.6	0.4	0.1	9.1
16	-	1.7	0.6	1.0	0.8	1.8	0.2	0.6	0.4	0.1	0.7
17	-	0.6	0.5	1.0	0.8	1.1	0.2	0.6	0.4	0.1	0.5
18	-	0.4	0.5	1.0	0.8	1.2	0.2	0.6	0.4	0.1	0.4
19	-	0.2	0.4	0.9	0.8	1.1	0.2	0.6	0.4	0.1	0.3
20	-	0.1	0.4	0.8	0.7	1.0	0.2	0.6	0.4	0.1	0.3
21	-	0.1	0.4	0.8	0.7	1.0	0.2	0.6	0.4	0.1	0.2
22	-	0.1	0.4	0.7	0.6	0.9	0.2	0.6	0.4	0.1	0.2
23	-	0.1	0.3	0.7	0.6	0.9	0.2	0.7	0.4	0.1	0.2
24	-	0.1	0.3	0.6	0.6	0.7	0.2	0.7	0.4	0.1	0.2
25	-	0.1	0.3	0.6	0.6	0.5	0.2	0.7	0.4	0.1	0.1
26	-	0.1	0.2	0.5	0.5	0.4	0.2	0.7	0.4	0.1	0.1
27	-	0.1	0.2	0.6	0.6	0.3	0.2	0.7	0.4	0.1	0.1
28	-	0.1	0.2	0.5	0.5	0.3	0.3	0.7	0.4	0.1	0.1
29	-	0.1	0.2	0.5	0.6	0.3	0.3	0.8	0.4	0.1	0.1
30	-	0.1	0.2	0.5	0.5	0.3	0.3	0.8	0.4	0.1	0.1
31	-	0.1	0.2	0.5	0.5	0.3	0.4	0.8	0.5	0.1	0.1
32	-	0.1	0.1	0.5	0.5	0.3	0.4	0.8	0.5	0.1	0.1
33	-	0.1	0.1	0.5	0.6	0.3	0.4	0.8	0.5	0.1	0.1
34	-	0.1	0.1	0.4	0.5	0.3	0.4	0.8	0.5	0.1	0.1
35	-	0.1	0.1	0.4	0.5	0.3	0.4	0.8	0.5	0.1	0.1
36	-	0.1	0.1	0.4	0.5	0.3	0.4	0.8	0.5	0.1	0.1
37	-	0.1	0.1	0.4	0.5	0.3	0.4	0.8	0.5	0.1	0.1
38	-	0.1	0.1	0.4	0.5	0.3	0.4	0.8	0.5	0.1	0.1
39	-	0.1	0.1	0.4	0.5	0.3	0.4	0.9	0.5	0.1	0.1
40	-	0.1	0.1	0.4	-	0.3	0.4	0.9	0.5	0.1	0.1

*YSI probe error (+/- 0.2 mg/L).

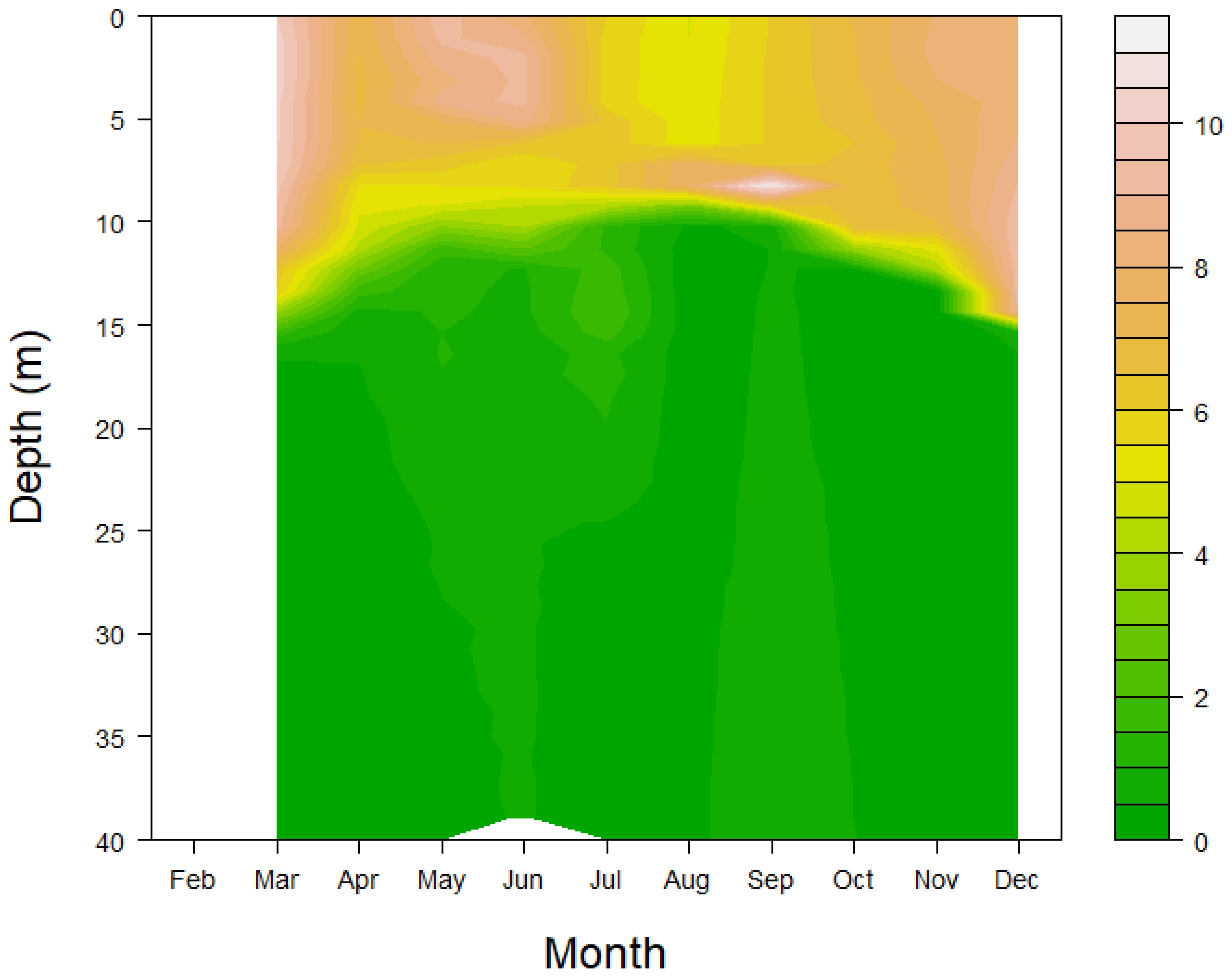
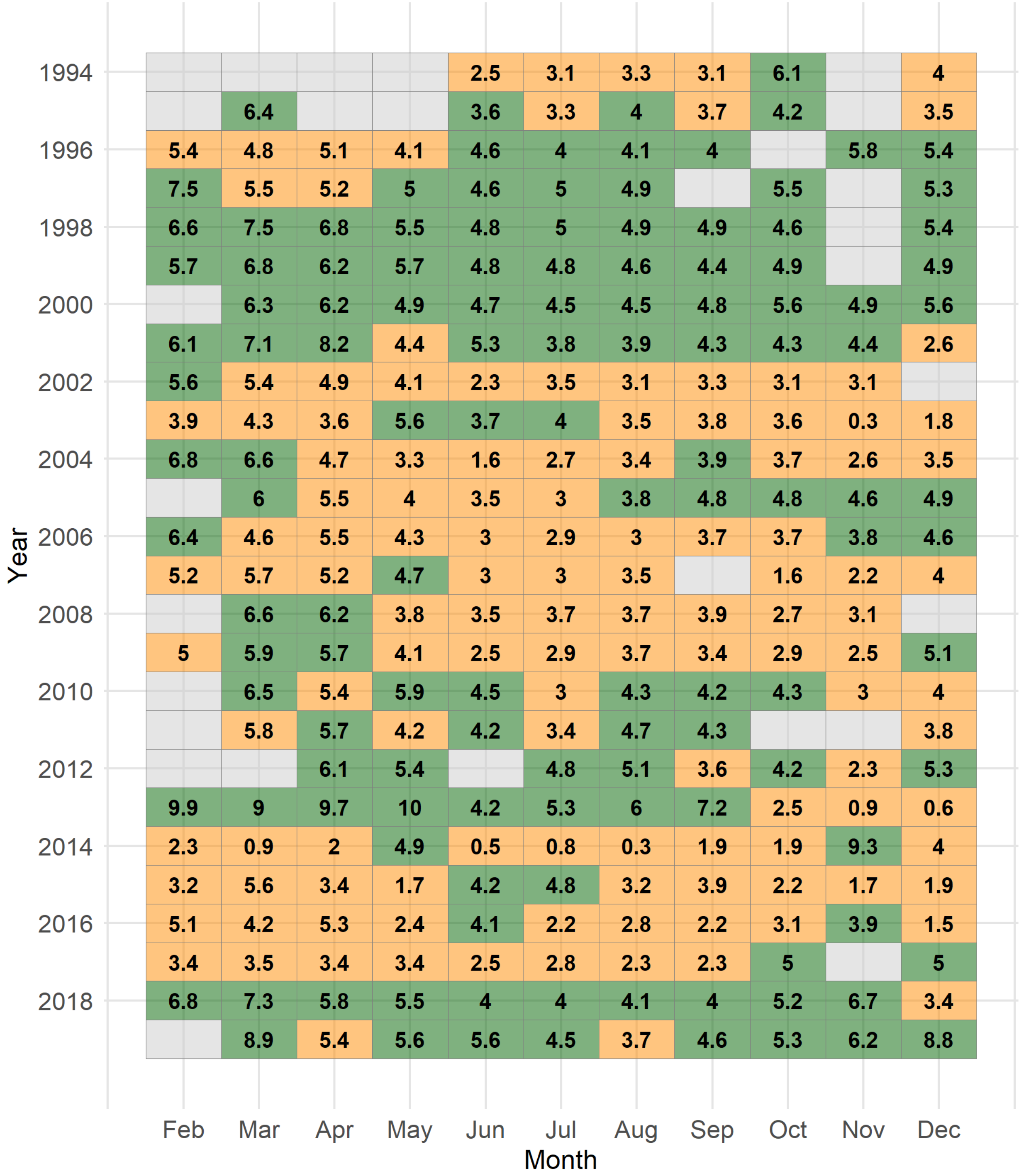


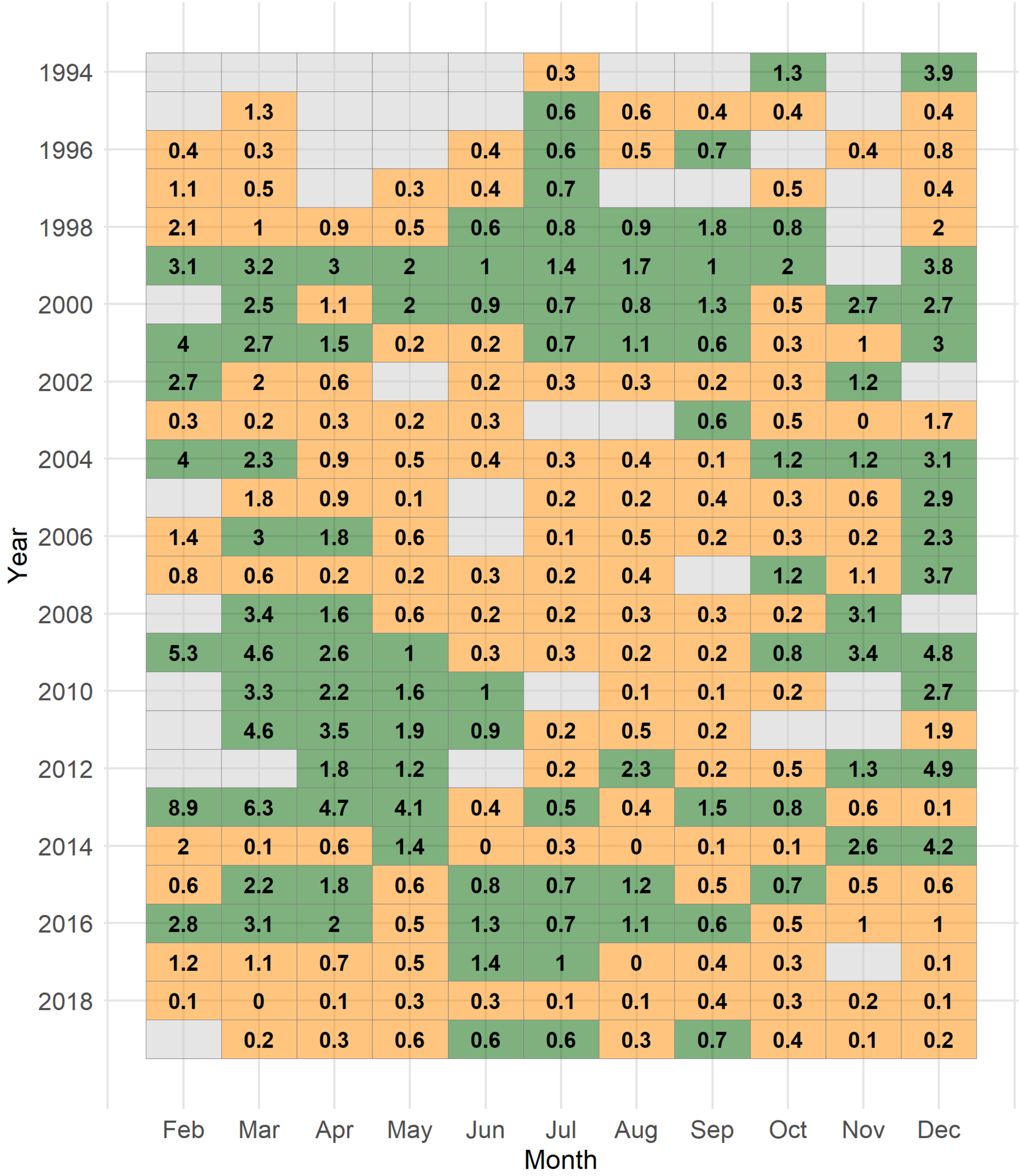
Figure 3-65. Dissolved Oxygen (mg/L) Depth Profiles at Station 6 in 2019



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					2.5	3.1	3.3	3.1	6.1		4
		6.4			3.6	3.3	4	3.7	4.2		3.5
1996	5.4	4.8	5.1	4.1	4.6	4	4.1	4		5.8	5.4
	7.5	5.5	5.2	5	4.6	5	4.9		5.5		5.3
1998	6.6	7.5	6.8	5.5	4.8	5	4.9	4.9	4.6		5.4
	5.7	6.8	6.2	5.7	4.8	4.8	4.6	4.4	4.9		4.9
2000		6.3	6.2	4.9	4.7	4.5	4.5	4.8	5.6	4.9	5.6
	6.1	7.1	8.2	4.4	5.3	3.8	3.9	4.3	4.3	4.4	2.6
2002	5.6	5.4	4.9	4.1	2.3	3.5	3.1	3.3	3.1	3.1	
	3.9	4.3	3.6	5.6	3.7	4	3.5	3.8	3.6	0.3	1.8
2004	6.8	6.6	4.7	3.3	1.6	2.7	3.4	3.9	3.7	2.6	3.5
		6	5.5	4	3.5	3	3.8	4.8	4.8	4.6	4.9
2006	6.4	4.6	5.5	4.3	3	2.9	3	3.7	3.7	3.8	4.6
	5.2	5.7	5.2	4.7	3	3	3.5		1.6	2.2	4
2008		6.6	6.2	3.8	3.5	3.7	3.7	3.9	2.7	3.1	
	5	5.9	5.7	4.1	2.5	2.9	3.7	3.4	2.9	2.5	5.1
2010		6.5	5.4	5.9	4.5	3	4.3	4.2	4.3	3	4
		5.8	5.7	4.2	4.2	3.4	4.7	4.3			3.8
2012			6.1	5.4		4.8	5.1	3.6	4.2	2.3	5.3
	9.9	9	9.7	10	4.2	5.3	6	7.2	2.5	0.9	0.6
2014	2.3	0.9	2	4.9	0.5	0.8	0.3	1.9	1.9	9.3	4
	3.2	5.6	3.4	1.7	4.2	4.8	3.2	3.9	2.2	1.7	1.9
2016	5.1	4.2	5.3	2.4	4.1	2.2	2.8	2.2	3.1	3.9	1.5
	3.4	3.5	3.4	3.4	2.5	2.8	2.3	2.3	5		5
2018	6.8	7.3	5.8	5.5	4	4	4.1	4	5.2	6.7	3.4
		8.9	5.4	5.6	5.6	4.5	3.7	4.6	5.3	6.2	8.8

Figure 3-66. Average Dissolved Oxygen (mg/L) at Station 6 between 1 and 15 m

Orange colored cells indicate above the long-term average of the respective month while green colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994						0.3			1.3		3.9
		1.3				0.6	0.6	0.4	0.4		0.4
1996	0.4	0.3			0.4	0.6	0.5	0.7		0.4	0.8
	1.1	0.5		0.3	0.4	0.7			0.5		0.4
1998	2.1	1	0.9	0.5	0.6	0.8	0.9	1.8	0.8		2
	3.1	3.2	3	2	1	1.4	1.7	1	2		3.8
2000		2.5	1.1	2	0.9	0.7	0.8	1.3	0.5	2.7	2.7
	4	2.7	1.5	0.2	0.2	0.7	1.1	0.6	0.3	1	3
2002	2.7	2	0.6		0.2	0.3	0.3	0.2	0.3	1.2	
	0.3	0.2	0.3	0.2	0.3			0.6	0.5	0	1.7
2004	4	2.3	0.9	0.5	0.4	0.3	0.4	0.1	1.2	1.2	3.1
		1.8	0.9	0.1		0.2	0.2	0.4	0.3	0.6	2.9
2006	1.4	3	1.8	0.6		0.1	0.5	0.2	0.3	0.2	2.3
	0.8	0.6	0.2	0.2	0.3	0.2	0.4		1.2	1.1	3.7
2008		3.4	1.6	0.6	0.2	0.2	0.3	0.3	0.2	3.1	
	5.3	4.6	2.6	1	0.3	0.3	0.2	0.2	0.8	3.4	4.8
2010		3.3	2.2	1.6	1		0.1	0.1	0.2		2.7
		4.6	3.5	1.9	0.9	0.2	0.5	0.2			1.9
2012			1.8	1.2		0.2	2.3	0.2	0.5	1.3	4.9
	8.9	6.3	4.7	4.1	0.4	0.5	0.4	1.5	0.8	0.6	0.1
2014	2	0.1	0.6	1.4	0	0.3	0	0.1	0.1	2.6	4.2
	0.6	2.2	1.8	0.6	0.8	0.7	1.2	0.5	0.7	0.5	0.6
2016	2.8	3.1	2	0.5	1.3	0.7	1.1	0.6	0.5	1	1
	1.2	1.1	0.7	0.5	1.4	1	0	0.4	0.3		0.1
2018	0.1	0	0.1	0.3	0.3	0.1	0.1	0.4	0.3	0.2	0.1
		0.2	0.3	0.6	0.6	0.6	0.3	0.7	0.4	0.1	0.2

Figure 3-67. Average Dissolved Oxygen (mg/L) at Station 6 between 16 and 38 m

Orange colored cells indicate above the long-term average of the respective month while green colored cells indicate below the long-term average of the respective month.

Ammonium

Ammonium levels were low (<2.8 µM) in the epilimnion throughout the year while ammonium continued to accumulate at depths at or below 20 m (Table 3-12, Figure 3-68). In this section, hypolimnion was referred as depths below 20 m in order to clearly demonstrate continuous accumulation of ammonium at the depth below 20 m. Ammonium levels at 12 m briefly increased above the detectable level in May and September, but remained below the detectable level for the rest of the year. The hypolimnetic ammonium level dropped in summer months but increased to the annual maximum in December as *Artemia* carcasses and fecal pellets sank deeper, and declined slightly in November and December with reduced *Artemia* activity. At the 35 m sampling depth, ammonium levels continued to rise throughout the year and reached the maximum level of 158.6 µM in December. Holomixis never occurred in 2019 as the lake remained stratified throughout the year at a depth between 10 and 15 m. A very low epilimnetic ammonium level was observed across the other 6 stations (Table 3-13).

The minimum detectable level of 2.8 µM makes a historical comparison difficult especially for the epilimnion as an arbitrary value (2 µM) has been substituted for <2.8 µM, which may not reflect actual values. Historically, average ammonium values less than 1 µM have been recorded. In 2019, above normal epilimnetic ammonium levels were found in March, April, and September, however this result may be attributable to the current detection limit of the lab instrument (Figure 3-69).

Hypolimnetic ammonium levels are continuing to rise and exceeded the long-term average in March, October, November and December (Figure 3-70). Hypolimnetic ammonium levels in 2019 were higher than what observed during the two most recent meromictic events (which were relatively short), but lagged behind the levels observed during the second recorded meromixis, which lasted much longer. The hypolimnetic accumulation level in 2019 (135.1 µM in November) exceeded the levels during two brief meromixis events in 2005-2007 and 2011 (80.6 µM in November 2007 and 83 µM in November 2011, respectively). During the second meromixis event between 1995 and 2002, hypolimnetic ammonium levels rose from 50.4 µM in September 1995, to 613.5 µM in August 2001, and remained above 100 µM for a total of almost 8 years (1996 and 2003). It is notable that the large meromixis event between 1995 and 2002 appears to have had a longer lasting effect on hypolimnetic ammonium levels as hypolimnetic ammonium levels remained higher than years between 2012 and 2017.

Table 3-12. Ammonium (µM) at Station 6 in 2019

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	3.3	<2.8	<2.8	<2.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	-	<2.8	<2.8	11.1	<2.8	<2.8	<2.8	8.9	<2.8	<2.8	<2.8
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	-	4.4	8.3	57.7	16.1	22.7	24.9	29.9	40.5	35.5	3.3
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	-	67.6	58.2	102.0	48.8	58.2	73.7	88.1	90.9	127.5	91.5
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	-	114.8	103.7	-	96.5	85.4	114.8	114.8	120.9	125.8	113.6
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	-	122.0	113.6	105.3	112.5	98.7	125.3	118.1	135.8	140.3	139.1
29	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-
35	-	129.7	129.7	119.2	117.0	111.4	134.2	123.1	143.0	146.9	158.6

Laboratory detection limit of 2.8µm.

Ammonium sample at 24m from May was not processed in the lab.

Table 3-13. 9-meter Integrated Values for Ammonium (µm) in 2019

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
2	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
5	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
6	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	3.3	<2.8	<2.8	<2.8
7	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	2.8
8	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	2.8
11	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
Mean	-	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	3.3	<2.8	<2.8	2.8
SE	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Laboratory detection limit of 2.8µm.

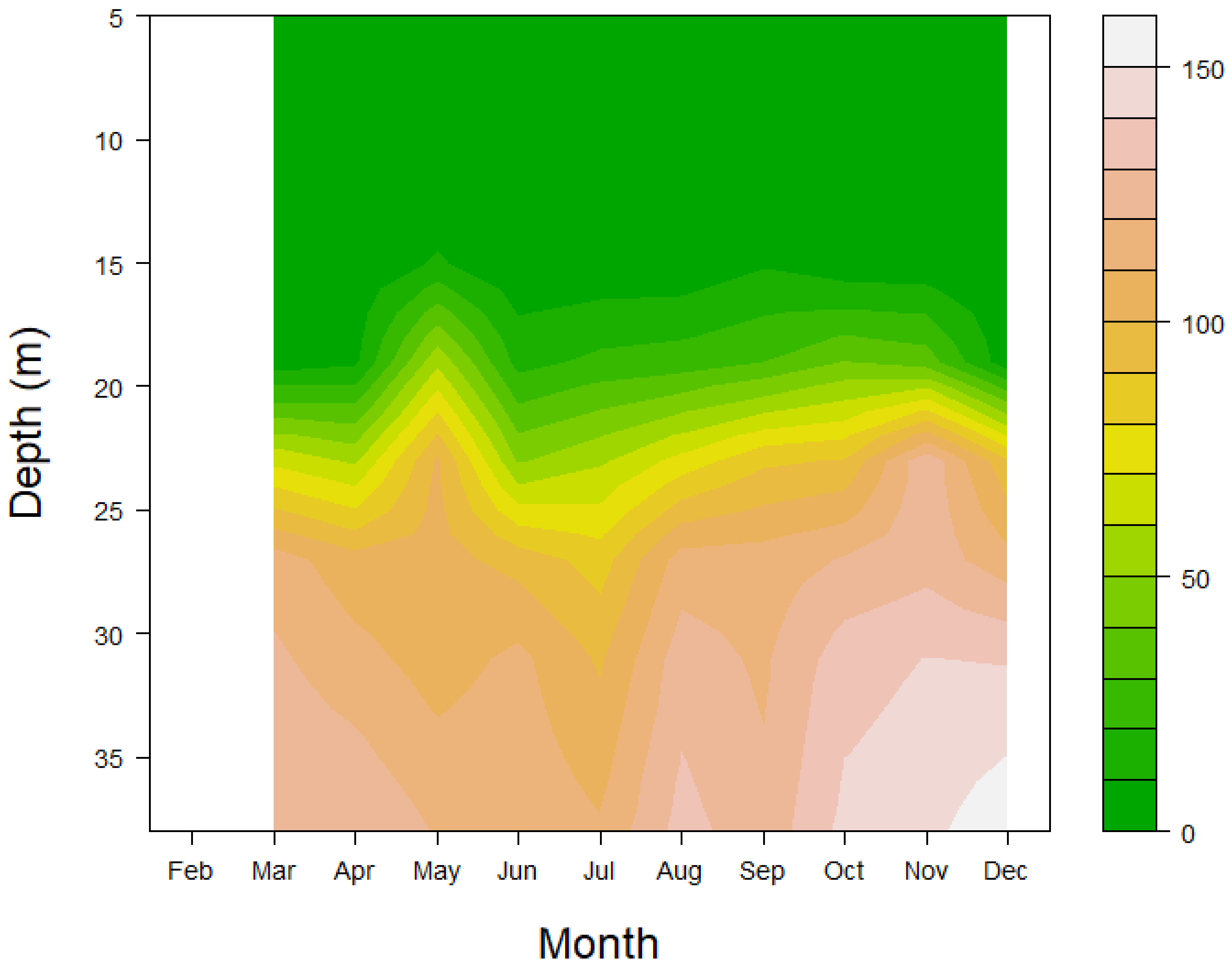
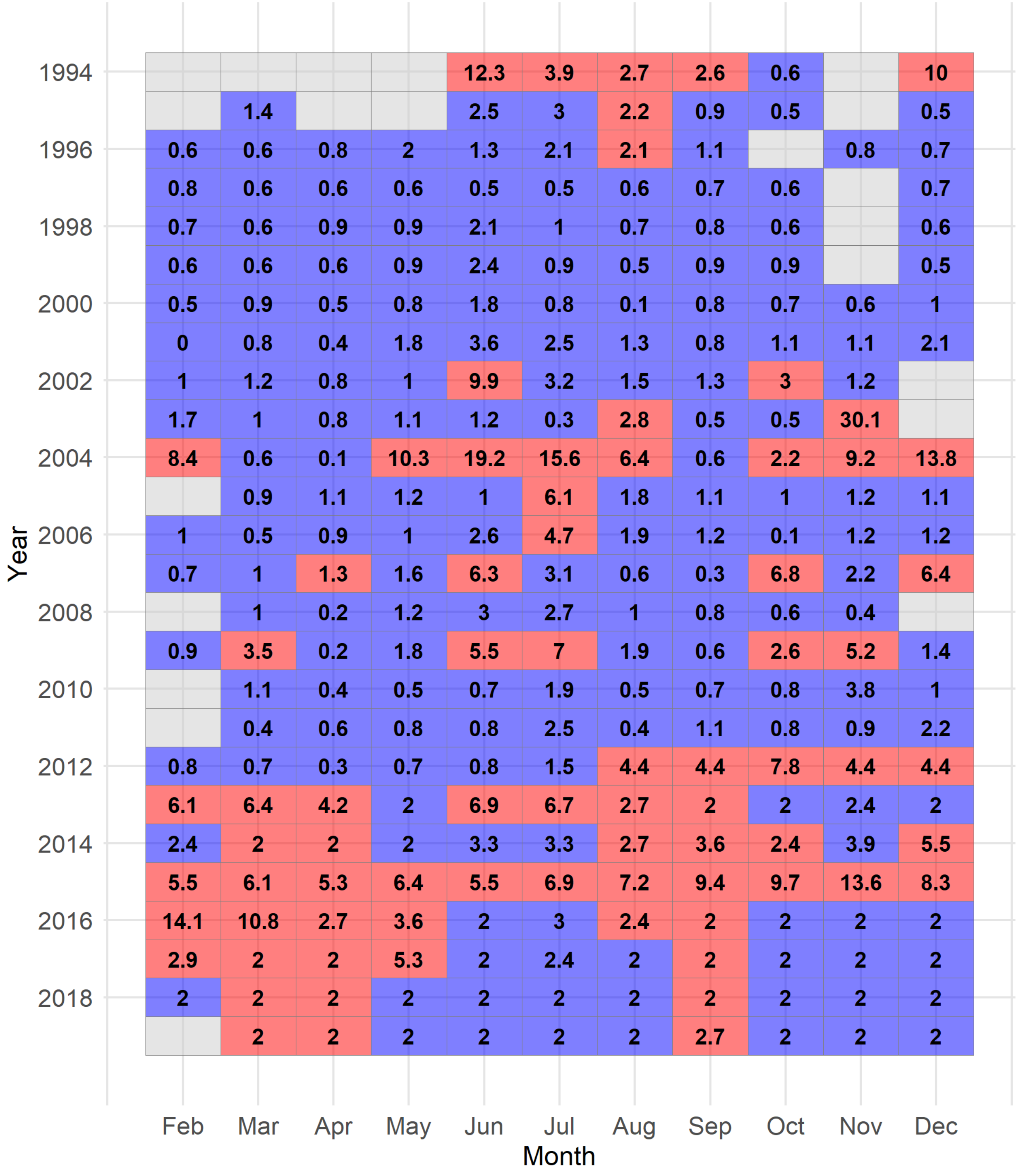


Figure 3-68. Ammonium (µm) Depth Profile at Station 6 in 2019

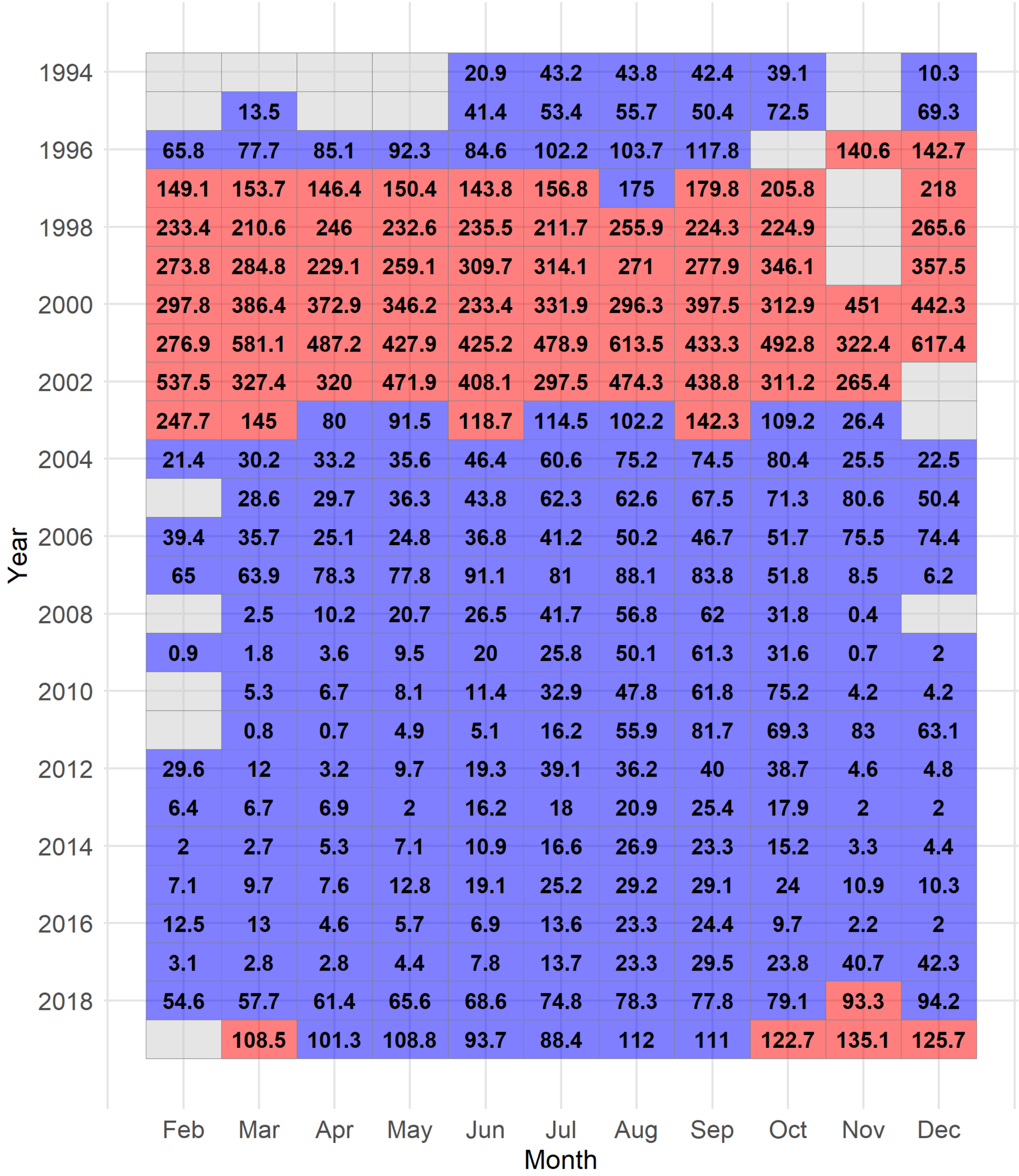
The sample at 35 m in May was not processed.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					12.3	3.9	2.7	2.6	0.6		10
		1.4			2.5	3	2.2	0.9	0.5		0.5
1996	0.6	0.6	0.8	2	1.3	2.1	2.1	1.1		0.8	0.7
	0.8	0.6	0.6	0.6	0.5	0.5	0.6	0.7	0.6		0.7
1998	0.7	0.6	0.9	0.9	2.1	1	0.7	0.8	0.6		0.6
	0.6	0.6	0.6	0.9	2.4	0.9	0.5	0.9	0.9		0.5
2000	0.5	0.9	0.5	0.8	1.8	0.8	0.1	0.8	0.7	0.6	1
	0	0.8	0.4	1.8	3.6	2.5	1.3	0.8	1.1	1.1	2.1
2002	1	1.2	0.8	1	9.9	3.2	1.5	1.3	3	1.2	
	1.7	1	0.8	1.1	1.2	0.3	2.8	0.5	0.5	30.1	
2004	8.4	0.6	0.1	10.3	19.2	15.6	6.4	0.6	2.2	9.2	13.8
		0.9	1.1	1.2	1	6.1	1.8	1.1	1	1.2	1.1
2006	1	0.5	0.9	1	2.6	4.7	1.9	1.2	0.1	1.2	1.2
	0.7	1	1.3	1.6	6.3	3.1	0.6	0.3	6.8	2.2	6.4
2008		1	0.2	1.2	3	2.7	1	0.8	0.6	0.4	
	0.9	3.5	0.2	1.8	5.5	7	1.9	0.6	2.6	5.2	1.4
2010		1.1	0.4	0.5	0.7	1.9	0.5	0.7	0.8	3.8	1
		0.4	0.6	0.8	0.8	2.5	0.4	1.1	0.8	0.9	2.2
2012	0.8	0.7	0.3	0.7	0.8	1.5	4.4	4.4	7.8	4.4	4.4
	6.1	6.4	4.2	2	6.9	6.7	2.7	2	2	2.4	2
2014	2.4	2	2	2	3.3	3.3	2.7	3.6	2.4	3.9	5.5
	5.5	6.1	5.3	6.4	5.5	6.9	7.2	9.4	9.7	13.6	8.3
2016	14.1	10.8	2.7	3.6	2	3	2.4	2	2	2	2
	2.9	2	2	5.3	2	2.4	2	2	2	2	2
2018	2	2	2	2	2	2	2	2	2	2	2
		2	2	2	2	2	2	2.7	2	2	2

Figure 3-69. Average Ammonium (µm) at Station 6 at 2 and 8 m

An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm. Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					20.9	43.2	43.8	42.4	39.1		10.3
		13.5			41.4	53.4	55.7	50.4	72.5		69.3
1996	65.8	77.7	85.1	92.3	84.6	102.2	103.7	117.8		140.6	142.7
	149.1	153.7	146.4	150.4	143.8	156.8	175	179.8	205.8		218
1998	233.4	210.6	246	232.6	235.5	211.7	255.9	224.3	224.9		265.6
	273.8	284.8	229.1	259.1	309.7	314.1	271	277.9	346.1		357.5
2000	297.8	386.4	372.9	346.2	233.4	331.9	296.3	397.5	312.9	451	442.3
	276.9	581.1	487.2	427.9	425.2	478.9	613.5	433.3	492.8	322.4	617.4
2002	537.5	327.4	320	471.9	408.1	297.5	474.3	438.8	311.2	265.4	
	247.7	145	80	91.5	118.7	114.5	102.2	142.3	109.2	26.4	
2004	21.4	30.2	33.2	35.6	46.4	60.6	75.2	74.5	80.4	25.5	22.5
		28.6	29.7	36.3	43.8	62.3	62.6	67.5	71.3	80.6	50.4
2006	39.4	35.7	25.1	24.8	36.8	41.2	50.2	46.7	51.7	75.5	74.4
	65	63.9	78.3	77.8	91.1	81	88.1	83.8	51.8	8.5	6.2
2008		2.5	10.2	20.7	26.5	41.7	56.8	62	31.8	0.4	
	0.9	1.8	3.6	9.5	20	25.8	50.1	61.3	31.6	0.7	2
2010		5.3	6.7	8.1	11.4	32.9	47.8	61.8	75.2	4.2	4.2
		0.8	0.7	4.9	5.1	16.2	55.9	81.7	69.3	83	63.1
2012	29.6	12	3.2	9.7	19.3	39.1	36.2	40	38.7	4.6	4.8
	6.4	6.7	6.9	2	16.2	18	20.9	25.4	17.9	2	2
2014	2	2.7	5.3	7.1	10.9	16.6	26.9	23.3	15.2	3.3	4.4
	7.1	9.7	7.6	12.8	19.1	25.2	29.2	29.1	24	10.9	10.3
2016	12.5	13	4.6	5.7	6.9	13.6	23.3	24.4	9.7	2.2	2
	3.1	2.8	2.8	4.4	7.8	13.7	23.3	29.5	23.8	40.7	42.3
2018	54.6	57.7	61.4	65.6	68.6	74.8	78.3	77.8	79.1	93.3	94.2
		108.5	101.3	108.8	93.7	88.4	112	111	122.7	135.1	125.7

Figure 3-70. Average Ammonium (µm) at Station 6 at and below 20 m

An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm. Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month. An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm.

Phytoplankton

Seasonal changes were noted in the phytoplankton community, as measured by chlorophyll *a* concentration (Table 3-14, Table 3-15, and Figure 3-71). At Station 6, chlorophyll *a* level started to increase with warming temperatures reaching the initial peaks in May in the epilimnion but continued to increase until August or September below 12 m and remained elevated for the rest of the year. The initial rise was due to warming temperature followed by dampening of the initial peak caused by increased *Artemia* activity in summer. After the summer low, epilimnetic chlorophyll *a* level continued to rise for the remainder of the year due to declining *Artemia* activity. The epilimnetic chlorophyll *a* level (between 2 and 8 m) was highest in December (34.8 µg/L) and lowest in August (2.3 µg/L) while the hypolimnetic chlorophyll *a* level (≤12 m) was highest in August (59.2 µg/L) and lowest in April (30.3 µg/L). At Station 6, the minimum level was higher than both 2017 and 2018 (Figure 3-72).

The lake-wide mean chlorophyll *a* level based on the 9-m integrated samples decreased throughout the spring and reached the lowest level at 3.1 µg/L lake-wide in August as *Artemia* grazing intensified. The minimum level was lower than the long-term August average, but higher than the minimum level observed in 2018 (Figure 3-73). Chlorophyll *a* level in the epilimnion is generally lower during meromixis and higher during monomixis, particularly in spring and winter months based on the 9-m integrated samples (Figure 3-73). During the period of monomixis between 1988 and 1994 (years between 1988 and 1989 are the breakdown period), chlorophyll *a* levels as high as 104 µg/L were observed. Even with the elevated chlorophyll *a* levels in spring during this monomictic period, the level plunged down below 1 µg/L in early summer and remained mostly below 5 µg/L until October. With successive monomixis events, however, elevated chlorophyll *a* levels were found lasting into early summer and resuming in September until the last monomixis. As initially noted in the 2014 chlorophyll *a* levels remained above 10 µg/L (except July, 2014) throughout the entire year. This period coincided with the driest 5-year period on record and also very low *Artemia* population abundance. Mean *Artemia* abundance between 2014 and 2016 was the lowest abundance for a 3-year period on record. Low population and earlier *Artemia* peaks may have attributed to higher chlorophyll *a* level throughout summer months and peaks in late fall or winter. The year 2019 marked the third year of the current meromixis, and epilimnetic chlorophyll *a* level were much lower than the preceding monomixis; however, the levels were still higher than the levels found during the second meromixis.

Hypolimnetic chlorophyll *a* levels in 2019 were lower than the preceding monomixis; however, were mostly above normal throughout the year and much higher than the levels observed during the second meromixis (Figure 3-74).

Table 3-14. Chlorophyll a (µg /L) Depth Profile at Station 6 in 2019

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	-	28.4	28.6	26.2	21.8	4.6	3.8	2.7	13.6	17.4	36.4
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	-	33.2	32.4	40.5	23.3	16.0	5.0	2.0	11.4	17.7	33.2
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	-	37.7	21.7	36.1	28.3	47.1	58.7	69.9	29.2	19.8	37.1
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	-	41.0	26.6	46.3	42.7	50.3	60.5	50.5	57.1	62.2	41.9
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	-	42.2	33.7	60.2	47.3	53.1	53.7	54.1	58.0	55.3	53.0
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	-	64.0	41.3	-	55.6	58.0	63.0	57.3	59.6	47.0	57.2
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	-	52.8	27.9	56.5	57.4	56.4	60.3	45.4	59.2	60.2	61.3

Chlorophyll a sample at 24m from May was not processed in the lab.

Table 3-15. 9-meter Integrated Values for Chlorophyll a (µg/L) in 2019

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	41.4	27.6	29.1	16.1	7.9	2.5	6.4	14.5	20.7	40.2
2	-	42.7	34.4	25.6	17.6	7.8	3.6	3.7	13.3	19.5	37.1
5	-	26.1	20.2	27.3	18.3	4.0	3.3	2.2	14.8	20.4	37.3
6	-	34.3	27.1	27.1	11.1	1.4	1.5	1.9	13.8	17.4	37.2
7	-	41.3	39.2	24.9	15.6	6.9	3.9	4.0	11.8	19.8	37.4
8	-	42.1	31.6	25.4	19.1	3.6	3.1	3.1	12.0	17.4	39.9
11	-	24.4	26.8	24.7	21.6	10.7	3.9	2.9	12.0	17.1	36.6
Mean	-	36.1	29.6	26.3	17.1	6.0	3.1	3.4	13.2	18.9	37.9
SE	-	3.0	2.3	0.6	1.2	1.2	0.3	0.6	0.5	0.6	0.6

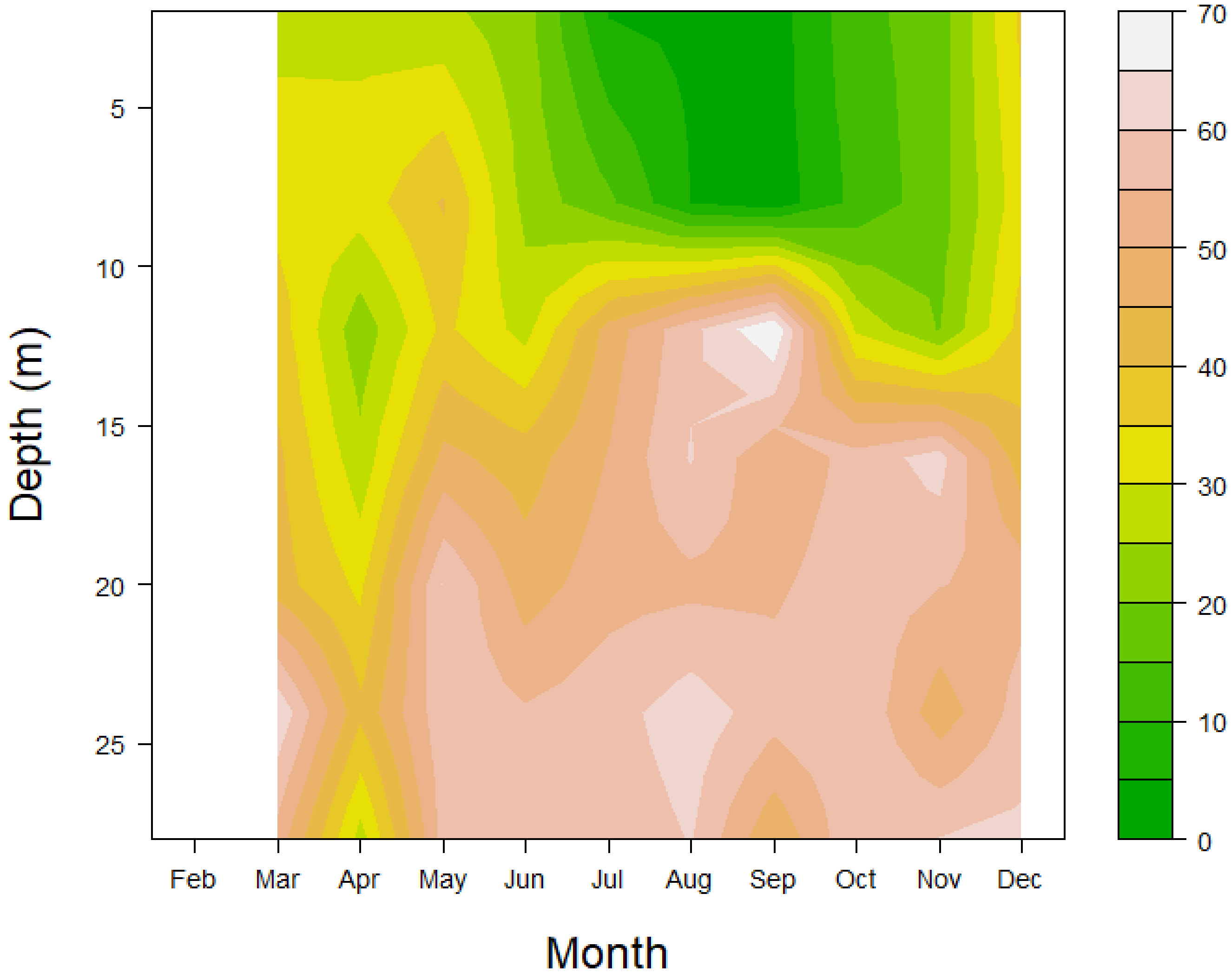
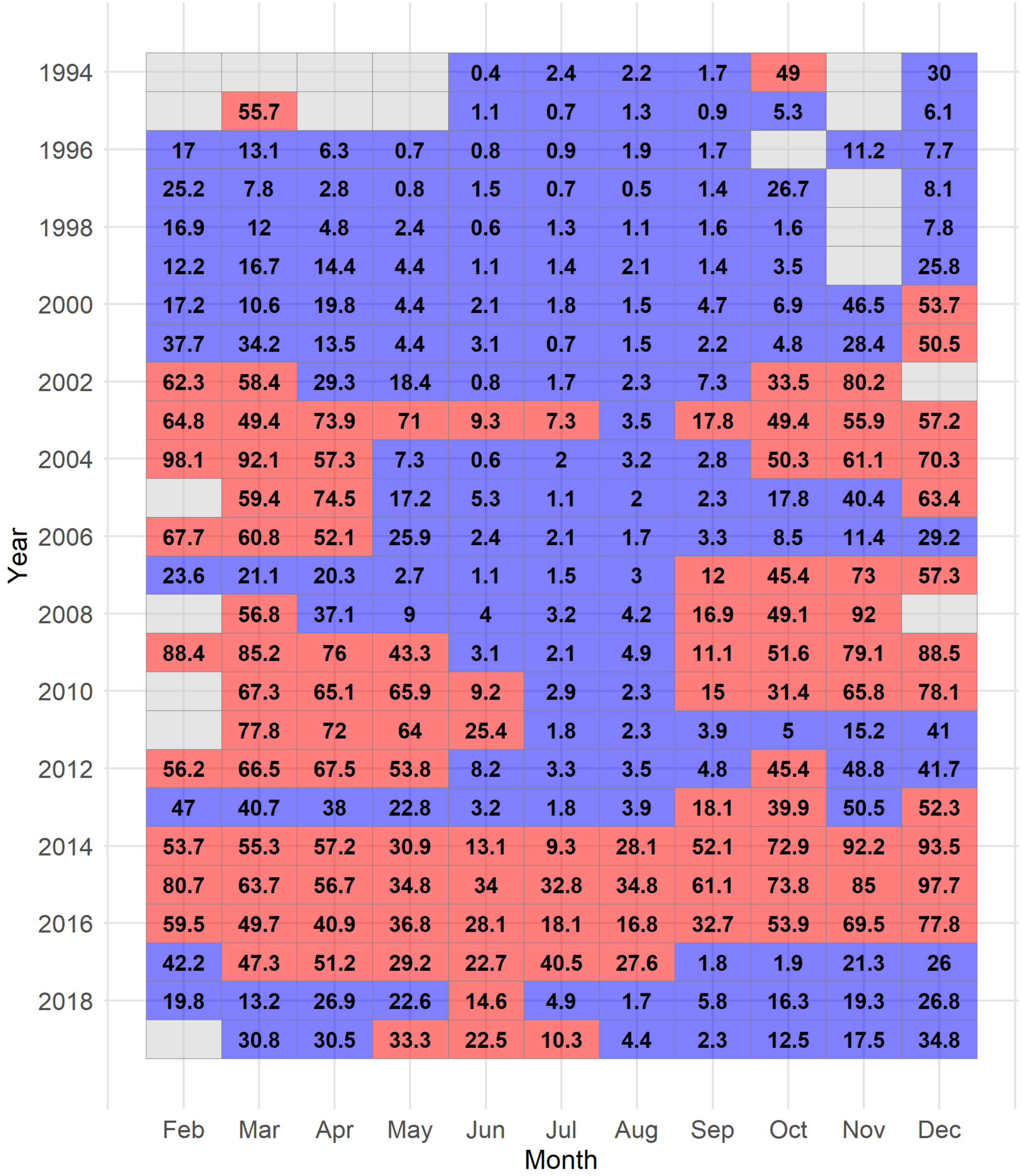


Figure 3-71. Chlorophyll a (µg/L) Depth Profile at Station 6 in 2019

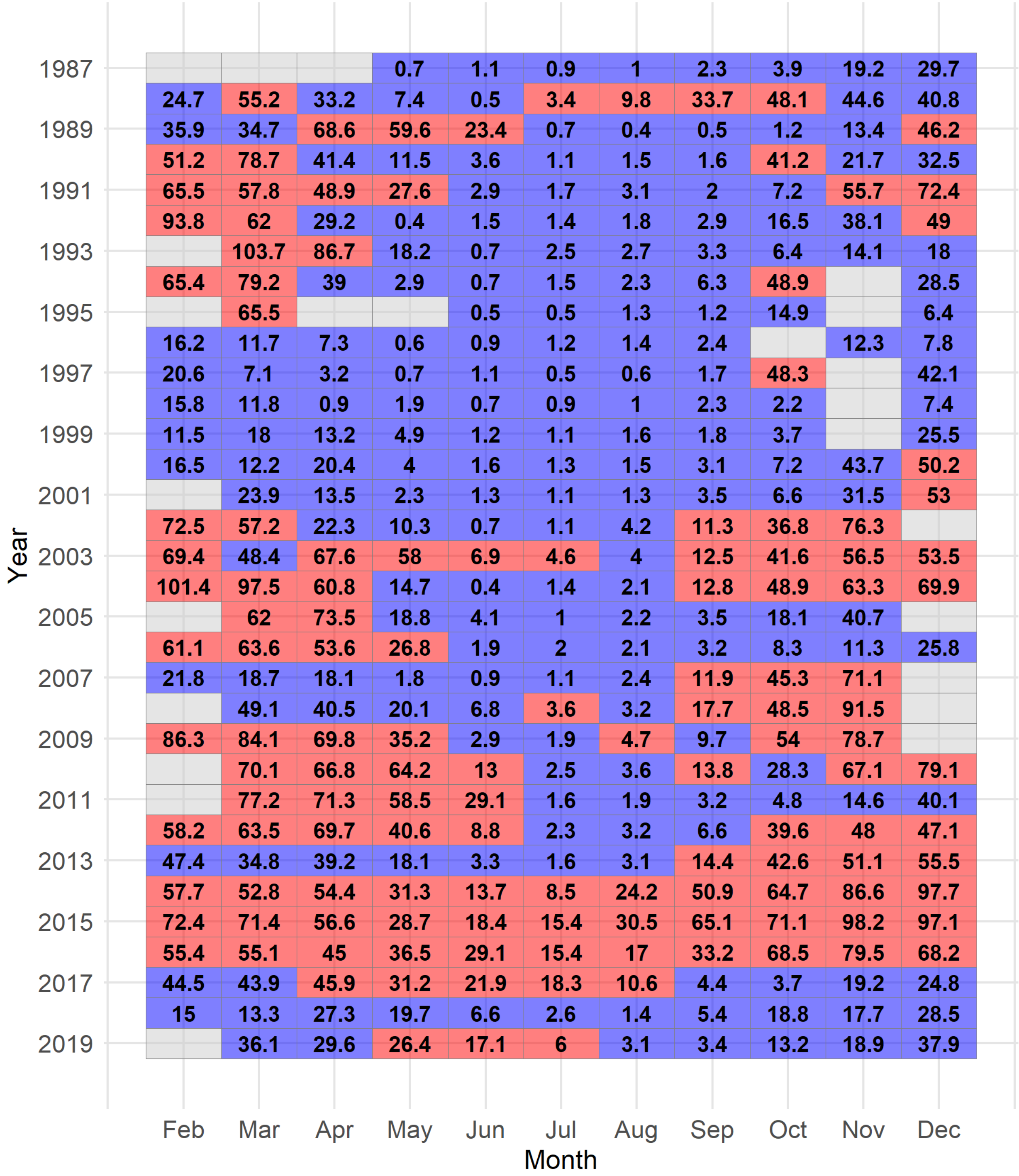
The sample at 24 m in May was not processed.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					0.4	2.4	2.2	1.7	49		30
		55.7			1.1	0.7	1.3	0.9	5.3		6.1
1996	17	13.1	6.3	0.7	0.8	0.9	1.9	1.7		11.2	7.7
	25.2	7.8	2.8	0.8	1.5	0.7	0.5	1.4	26.7		8.1
1998	16.9	12	4.8	2.4	0.6	1.3	1.1	1.6	1.6		7.8
	12.2	16.7	14.4	4.4	1.1	1.4	2.1	1.4	3.5		25.8
2000	17.2	10.6	19.8	4.4	2.1	1.8	1.5	4.7	6.9	46.5	53.7
	37.7	34.2	13.5	4.4	3.1	0.7	1.5	2.2	4.8	28.4	50.5
2002	62.3	58.4	29.3	18.4	0.8	1.7	2.3	7.3	33.5	80.2	
	64.8	49.4	73.9	71	9.3	7.3	3.5	17.8	49.4	55.9	57.2
2004	98.1	92.1	57.3	7.3	0.6	2	3.2	2.8	50.3	61.1	70.3
		59.4	74.5	17.2	5.3	1.1	2	2.3	17.8	40.4	63.4
2006	67.7	60.8	52.1	25.9	2.4	2.1	1.7	3.3	8.5	11.4	29.2
	23.6	21.1	20.3	2.7	1.1	1.5	3	12	45.4	73	57.3
2008		56.8	37.1	9	4	3.2	4.2	16.9	49.1	92	
	88.4	85.2	76	43.3	3.1	2.1	4.9	11.1	51.6	79.1	88.5
2010		67.3	65.1	65.9	9.2	2.9	2.3	15	31.4	65.8	78.1
		77.8	72	64	25.4	1.8	2.3	3.9	5	15.2	41
2012	56.2	66.5	67.5	53.8	8.2	3.3	3.5	4.8	45.4	48.8	41.7
	47	40.7	38	22.8	3.2	1.8	3.9	18.1	39.9	50.5	52.3
2014	53.7	55.3	57.2	30.9	13.1	9.3	28.1	52.1	72.9	92.2	93.5
	80.7	63.7	56.7	34.8	34	32.8	34.8	61.1	73.8	85	97.7
2016	59.5	49.7	40.9	36.8	28.1	18.1	16.8	32.7	53.9	69.5	77.8
	42.2	47.3	51.2	29.2	22.7	40.5	27.6	1.8	1.9	21.3	26
2018	19.8	13.2	26.9	22.6	14.6	4.9	1.7	5.8	16.3	19.3	26.8
		30.8	30.5	33.3	22.5	10.3	4.4	2.3	12.5	17.5	34.8

Figure 3-72. Average Chlorophyll a (µg/L) at Station 6 at 2 and 8 m

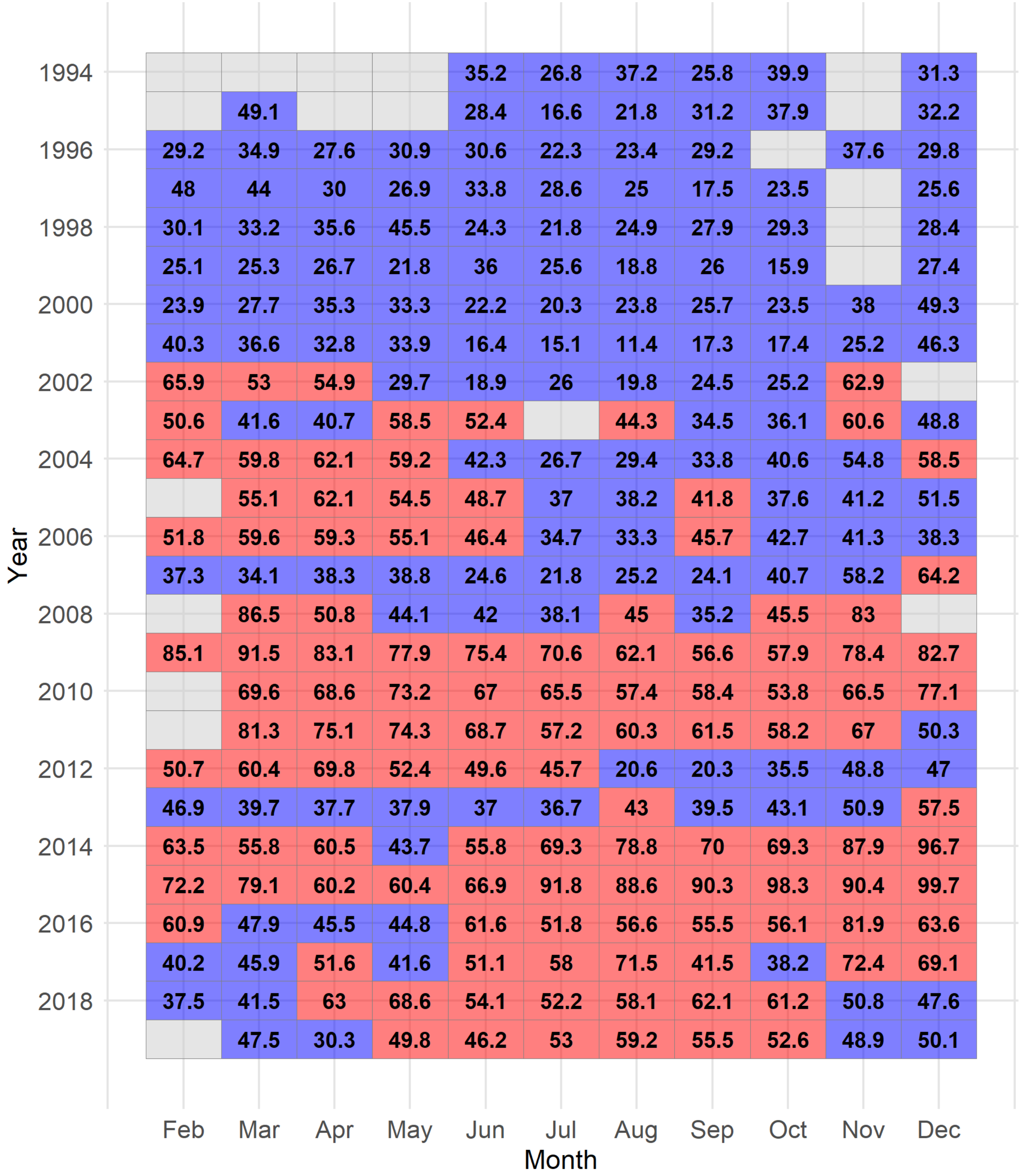
Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.9	1	2.3	3.9	19.2	29.7
	24.7	55.2	33.2	7.4	0.5	3.4	9.8	33.7	48.1	44.6	40.8
1989	35.9	34.7	68.6	59.6	23.4	0.7	0.4	0.5	1.2	13.4	46.2
	51.2	78.7	41.4	11.5	3.6	1.1	1.5	1.6	41.2	21.7	32.5
1991	65.5	57.8	48.9	27.6	2.9	1.7	3.1	2	7.2	55.7	72.4
	93.8	62	29.2	0.4	1.5	1.4	1.8	2.9	16.5	38.1	49
1993		103.7	86.7	18.2	0.7	2.5	2.7	3.3	6.4	14.1	18
	65.4	79.2	39	2.9	0.7	1.5	2.3	6.3	48.9		28.5
1995		65.5			0.5	0.5	1.3	1.2	14.9		6.4
	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
	15.8	11.8	0.9	1.9	0.7	0.9	1	2.3	2.2		7.4
1999	11.5	18	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
	16.5	12.2	20.4	4	1.6	1.3	1.5	3.1	7.2	43.7	50.2
2001		23.9	13.5	2.3	1.3	1.1	1.3	3.5	6.6	31.5	53
	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	58	6.9	4.6	4	12.5	41.6	56.5	53.5
	101.4	97.5	60.8	14.7	0.4	1.4	2.1	12.8	48.9	63.3	69.9
2005		62	73.5	18.8	4.1	1	2.2	3.5	18.1	40.7	
	61.1	63.6	53.6	26.8	1.9	2	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	11.9	45.3	71.1	
		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	78.7	
		70.1	66.8	64.2	13	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
	58.2	63.5	69.7	40.6	8.8	2.3	3.2	6.6	39.6	48	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
	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
	55.4	55.1	45	36.5	29.1	15.4	17	33.2	68.5	79.5	68.2
2017	44.5	43.9	45.9	31.2	21.9	18.3	10.6	4.4	3.7	19.2	24.8
	15	13.3	27.3	19.7	6.6	2.6	1.4	5.4	18.8	17.7	28.5
2019		36.1	29.6	26.4	17.1	6	3.1	3.4	13.2	18.9	37.9

Figure 3-73. Average Lake-wide 9m Integrated Chlorophyll a (µg/L)

Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					35.2	26.8	37.2	25.8	39.9		31.3
		49.1			28.4	16.6	21.8	31.2	37.9		32.2
1996	29.2	34.9	27.6	30.9	30.6	22.3	23.4	29.2		37.6	29.8
	48	44	30	26.9	33.8	28.6	25	17.5	23.5		25.6
1998	30.1	33.2	35.6	45.5	24.3	21.8	24.9	27.9	29.3		28.4
	25.1	25.3	26.7	21.8	36	25.6	18.8	26	15.9		27.4
2000	23.9	27.7	35.3	33.3	22.2	20.3	23.8	25.7	23.5	38	49.3
	40.3	36.6	32.8	33.9	16.4	15.1	11.4	17.3	17.4	25.2	46.3
2002	65.9	53	54.9	29.7	18.9	26	19.8	24.5	25.2	62.9	
	50.6	41.6	40.7	58.5	52.4		44.3	34.5	36.1	60.6	48.8
2004	64.7	59.8	62.1	59.2	42.3	26.7	29.4	33.8	40.6	54.8	58.5
		55.1	62.1	54.5	48.7	37	38.2	41.8	37.6	41.2	51.5
2006	51.8	59.6	59.3	55.1	46.4	34.7	33.3	45.7	42.7	41.3	38.3
	37.3	34.1	38.3	38.8	24.6	21.8	25.2	24.1	40.7	58.2	64.2
2008		86.5	50.8	44.1	42	38.1	45	35.2	45.5	83	
	85.1	91.5	83.1	77.9	75.4	70.6	62.1	56.6	57.9	78.4	82.7
2010		69.6	68.6	73.2	67	65.5	57.4	58.4	53.8	66.5	77.1
		81.3	75.1	74.3	68.7	57.2	60.3	61.5	58.2	67	50.3
2012	50.7	60.4	69.8	52.4	49.6	45.7	20.6	20.3	35.5	48.8	47
	46.9	39.7	37.7	37.9	37	36.7	43	39.5	43.1	50.9	57.5
2014	63.5	55.8	60.5	43.7	55.8	69.3	78.8	70	69.3	87.9	96.7
	72.2	79.1	60.2	60.4	66.9	91.8	88.6	90.3	98.3	90.4	99.7
2016	60.9	47.9	45.5	44.8	61.6	51.8	56.6	55.5	56.1	81.9	63.6
	40.2	45.9	51.6	41.6	51.1	58	71.5	41.5	38.2	72.4	69.1
2018	37.5	41.5	63	68.6	54.1	52.2	58.1	62.1	61.2	50.8	47.6
		47.5	30.3	49.8	46.2	53	59.2	55.5	52.6	48.9	50.1

Figure 3-74. Average Chlorophyll a (µg/L) at Station 6 between 12 and 28 m

Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.

<u>Artemia</u> Population and Biomass

Artemia population data are presented in Table 3-16 through Table 3-18 with lake-wide 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.

<u>*Artemia* Population</u>

No sampling was conducted in February, and hatching of overwintering cysts could not detected until March. All instars in mid-March were instar age classes 1 and 2. Instar abundance increased through spring to a peak of 45,835 +/- 3,731 m^{-2} in April. Adult *Artemia* were absent in March and April. The peak monthly lake-wide *Artemia* abundance for 2019 occurred in May (59,665 +/-10,942 m^{-2}). A proportion of adults started to increase in June as the proportion increased from 8% in May to 86% in August. The instar analysis indicated a diverse age structure of instars 1-7 and juveniles (instars 8-11) between May and June, and abundance of each age class started to decline in July even though all age classes existed. In May, females with cysts were first recorded. Females with cyst abundance peaked at 9,906 +/- 967 m^{-2} in August and high abundance was maintained through November. By July, hatching and growth decreased significantly, with instars and juveniles comprising only 21% of the population as compared to 93% in May. The highest adult *Artemia* abundance occurred in August (26,531 +/- 2,668 m^{-2}) and dropped below 10,000 m^{-2} in October, 5,000 m^{-2} in November, and below 1,000 m^{-2} in December.

Table 3-16. Artemia Lake-wide and Sector Population Means (per m^2 or m^{-2}) in 2019

	Instars		Adult Total	Adult Males	Adult Female Total	Ad Female Ovigery Classification				Total *Artemia*
	1-7	8-11				empty	undif	cysts	naup	
Lake-wide										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	16,460	0	0	0	0	0	0	0	0	16,460
Apr	45,835	0	0	0	0	0	0	0	0	45,835
May	37,988	17,062	4,614	4,588	27	0	0	27	0	59,665
Jun	8,102	19,034	13,467	8,598	4,869	3,528	80	402	858	40,604
Jul	4,210	3,504	23,682	14,229	9,453	592	277	8,356	227	31,396
Aug	3,239	1,008	26,531	15,099	11,431	857	353	9,906	315	30,778
Sep	1,783	416	14,419	8,407	6,012	466	19	5,445	82	16,618
Oct	926	293	9,925	5,161	4,764	158	44	4,436	126	11,145
Nov	2,141	266	4,687	2,135	2,552	123	32	2,308	90	7,094
Dec	1,753	150	329	195	134	16	5	102	11	2,232
Western Sector										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	6,258	0	0	0	0	0	0	0	0	6,258
Apr	46,841	0	0	0	0	0	0	0	0	46,841
May	26,720	9,068	2,522	2,468	54	0	0	54	0	38,310
Jun	6,546	12,314	12,931	8,558	4,373	3,246	54	322	751	31,791
Jul	3,554	3,882	28,131	17,998	10,133	580	328	8,898	328	35,567
Aug	3,655	1,185	32,416	18,805	13,612	1,008	429	11,847	328	37,256
Sep	2,067	504	18,124	10,562	7,562	479	25	6,907	151	20,695
Oct	920	208	6,503	3,756	2,748	88	13	2,622	25	7,631
Nov	1,500	227	3,375	1,610	1,765	63	22	1,582	98	5,101
Dec	504	69	211	129	82	16	0	63	3	785
Eastern Sector										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	26,663	0	0	0	0	0	0	0	0	26,663
Apr	44,829	0	0	0	0	0	0	0	0	44,829
May	49,256	25,057	6,707	6,707	0	0	0	0	0	81,019
Jun	9,658	25,755	14,004	8,638	5,366	3,810	107	483	966	49,416
Jul	4,865	3,126	19,233	10,461	8,772	605	227	7,814	126	27,224
Aug	2,823	832	20,645	11,394	9,251	706	277	7,965	302	24,300
Sep	1,500	328	10,713	6,251	4,462	454	13	3,983	13	12,541
Oct	933	378	13,347	6,566	6,781	227	76	6,251	227	14,658
Nov	2,782	306	5,999	2,659	3,340	183	41	3,034	82	9,087
Dec	3,003	230	447	262	186	16	9	142	19	3,680

Table 3-17. Standard Errors (SE) of Artemia Sector Population Means (per m^2 or m^{-2}) from Table 3-16 in 2019

	Instars		Adult	Adult	Adult Female	Ad Female Ovigery Classification				Total
	1-7	8-11	Total	Males	Total	empty	undif	cysts	naup	*Artemia*
Lake-wide										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	6,475	-	-	-	-	-	-	-	-	6,475
Apr	3,731	-	-	-	-	-	-	-	-	3,731
May	6,006	4,248	1,106	1,109	27	0	0	27	0	10,942
Jun	723	2,523	942	713	504	449	58	120	155	3,456
Jul	338	287	2,758	1,879	998	94	64	869	96	2,944
Aug	438	228	2,668	1,623	1,099	150	123	967	73	2,853
Sep	197	71	1,351	824	588	68	14	547	29	1,439
Oct	107	65	1,465	601	878	39	17	816	41	1,480
Nov	298	47	930	351	588	37	12	548	18	1,184
Dec	522	42	71	38	37	6	2	29	5	600
Western Sector										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	2,211	-	-	-	-	-	-	-	-	2,211
Apr	4,305	-	-	-	-	-	-	-	-	4,305
May	3,566	4,498	1,385	1,378	54	0	0	54	0	8,849
Jun	597	1,177	1,426	1,157	412	421	54	118	180	2,101
Jul	438	380	4,751	3,001	1,810	176	126	1,517	185	5,318
Aug	652	429	3,627	2,081	1,684	230	229	1,503	61	3,476
Sep	233	121	1,065	777	537	91	25	512	39	904
Oct	176	92	932	406	543	16	13	540	25	934
Nov	136	33	441	214	247	18	8	236	20	402
Dec	171	17	57	38	32	10	0	20	3	212
Eastern Sector										
Feb	-	-	-	-	-	-	-	-	-	-
Mar	11,745	-	-	-	-	-	-	-	-	11,745
Apr	6,505	-	-	-	-	-	-	-	-	6,505
May	9,758	5,796	1,310	1,310	0	0	0	0	0	16,311
Jun	987	2,927	1,324	949	921	825	107	216	263	4,133
Jul	371	401	1,724	919	962	87	34	950	46	1,704
Aug	592	182	2,075	1,328	759	194	106	592	141	2,635
Sep	291	64	1,186	723	521	109	13	449	13	1,282
Oct	139	83	1,972	798	1,214	68	28	1,149	52	1,958
Nov	455	88	1,710	622	1,101	67	23	1,026	32	2,101
Dec	737	69	115	56	64	8	4	52	8	839

Table 3-18. Percentage in Different Classes of Artemia Population Means from Table 3-16 in 2019

	Instars		Instar	Adult	Adult	Adult Female	Ad Female Ovigery Classification				Ovigerous
	1-7	8-11	%	Total	Males	Total	empty	undif	cysts	naup	Female%
Lake-wide											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0	100	0	0	0	0	0	0	0	0
May	64	29	92	8	8	0.04	0	0	100	0	100
Jun	20	47	67	33	21	12	72	6	30	64	28
Jul	13	11	25	75	45	30	6	3	94	3	94
Aug	11	3	14	86	49	37	7	3	94	3	93
Sep	11	3	13	87	51	36	8	0.3	98	1	92
Oct	8	3	11	89	46	43	3	1	96	3	97
Nov	30	4	34	66	30	36	5	1	95	4	95
Dec	79	7	85	15	9	6	12	4	87	9	88
Western Sector											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0	100	0	0	0	0	0	0	0	0
May	70	24	93	7	6	0.1	0	0	100	0	100
Jun	21	39	59	41	27	14	74	5	29	67	26
Jul	10	11	21	79	51	28	6	3	93	3	94
Aug	10	3	13	87	50	37	7	3	94	3	93
Sep	10	2	12	88	51	37	6	0.4	98	2	94
Oct	12	3	15	85	49	36	3	0.5	99	1	97
Nov	29	4	34	66	32	35	4	1	93	6	96
Dec	64	9	73	27	16	10	19	0	95	5	81
Eastern Sector											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0	100	0	0	0	0	0	0	0	0
May	61	31	92	8	8	0	0	0	0	0	0
Jun	20	52	72	28	17	11	71	7	31	62	29
Jul	18	11	29	71	38	32	7	3	96	2	93
Aug	12	3	15	85	47	38	8	3	93	4	92
Sep	12	3	15	85	50	36	10	0.3	99	0.3	90
Oct	6	3	9	91	45	46	3	1	95	3	97
Nov	31	3	34	66	29	37	5	1	96	3	95
Dec	82	6	88	12	7	5	8	6	83	11	92

Instar Analysis

The instar analysis, shows patterns similar to those of the lake-wide and sector analysis, but provide more insight into *Artemia* reproductive cycles occurring at the lake (Figure 3-75). Instars 2 were proportionally more abundant than Instars 1 in March and April. It is likely that the proportional abundance of Instars 1 was higher in February as overwintering cysts were hatching. By May all age classes (1 through 7) of instars and juveniles were present and comprised approximately 92% of the *Artemia* population while adults comprised the remainder (8%). The proportion of instars and juveniles combined fell precipitously beginning in July, and numbers remained low until November.

The presence of late-stage instars and juveniles throughout the monitoring year indicate continuous maturing and breeding. Instar abundance peaked broadly between April and May immediately began to decline recording the lowest abundance in October. Abundance of Instars 1 and 2 started to rise in November coinciding slight increase in in females with naupliar eggs (ovoviviparous) in October, suggesting hatching of nauplii rather than cysts could have been responsible for the increase in Instars 1 and 2 during these months.

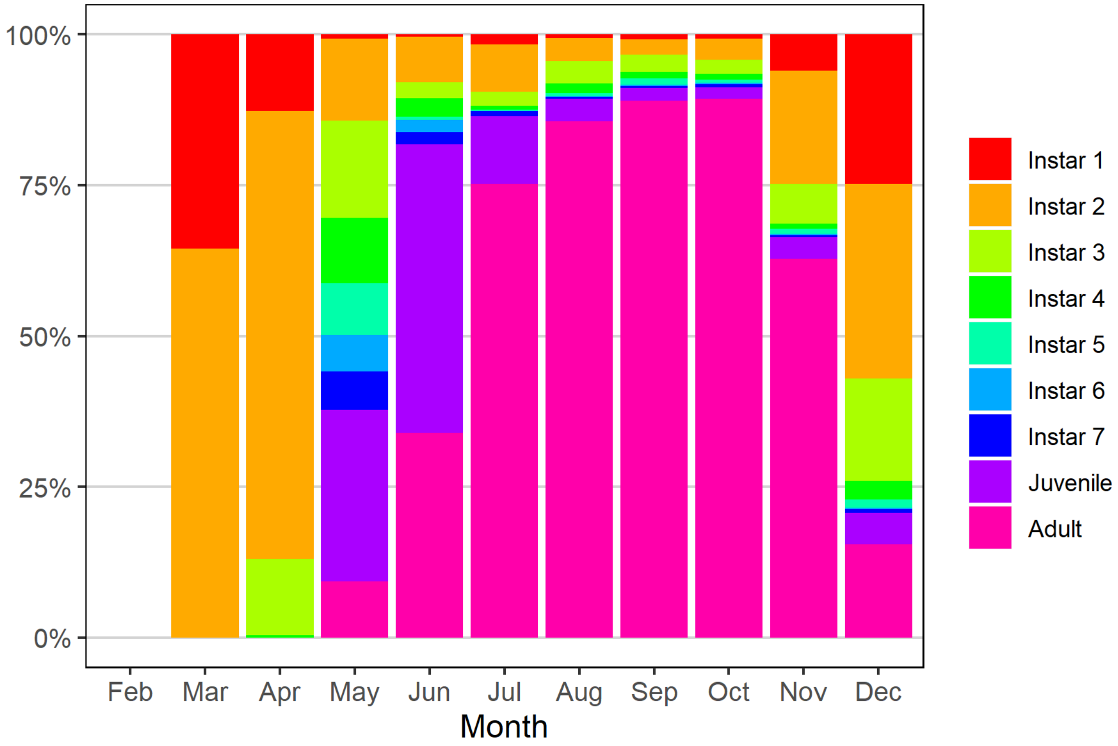


Figure 3-75. Compositional Changes of Artemia Instars and Adults in 2019

Biomass

Mean lake-wide *Artemia* biomass exceeded 10 g/m^2 between June and September peaking at 18.3 g/m^2 in August (Table 3-19). Mean biomass was below 10 g/m^2 in October (8.7 g/m^2), declined to 4.29 g/m^2 by November, and reached the yearly low of 0.4 g/m^2 in December. Peak mean biomass was much higher in the western sector than in the eastern sector as was the pattern observed in 2018. Mean biomass were higher in the western sector from July through September.

Table 3-19. Artemia Mean Biomass (g/m^2) in 2019

Month	Lake-wide	Western Sector	Eastern Sector
Feb	-	-	-
Mar	0.6	0.3	0.8
Apr	1.3	1.1	1.6
May	5.9	3.4	8.5
Jun	11.3	9.6	13.0
Jul	17.9	20.6	15.1
Aug	18.3	22.1	14.6
Sep	11.1	13.7	8.6
Oct	8.7	5.6	11.8
Nov	4.3	3.2	5.4
Dec	0.4	0.3	0.5

Reproductive Parameters and Fecundity Analysis

By June, fecund females were plentiful enough to conduct fecundity analysis. In mid-June, approximately 28% of females were ovigerous, with 30% oviparous (cyst-bearing), 64% ovoviviparous (naupliar eggs) and 6% undifferentiated eggs (Table 3-16, Table 3-20, and Figure 3-76). From July through November, over 90% of females were ovigerous with the majority (92 to 97%) oviparous. The percent of ovigerous female was 100% in May due to one individual female carrying cysts recorded at Station 6.

The lake-wide mean fecundity declined through the summer into early fall, and then sharply increased again in October. The lake-wide mean fecundity was initially 32.0 +/- 1.5 egg per brood in June, decreased to 23.6 +/- 1.3 eggs per brood by September, and rebounded to 34.9 +/- 1.9 in October. The majority of fecund females were oviparous between July and October. The overall pattern remained the same between the western and eastern sectors but a number of eggs and female lengths were much higher and longer in the eastern sector. Typically, mean female lengths are positively correlated with mean eggs per brood, and 2019 followed this pattern. Mean female size was highest in October (9.8 mm) when mean brood size was also largest (37.9 +/- 1.9 eggs per brood).

Table 3-20. Artemia Fecundity Summary in 2019

	# of Eggs/Brood				Female Length (mm)		
Month	Mean	SE	% Cyst	% Indented	Mean	SE	n
Lakewide							
Jun	32.0	1.5	88.3	26.7	9.4	0.1	7
Jul	29.0	1.1	95.9	45.2	9.2	0.1	7
Aug	24.4	1.2	94.6	55.4	9.4	0.1	7
Sep	23.6	1.3	95.9	42.5	9.4	0.1	1
Oct	37.9	1.9	93.2	47.3	9.8	0.1	6
Western Sector							
Jun	31.7	2.5	86.2	27.6	9.4	0.1	4
Jul	28.5	1.4	95.2	47.6	9.2	0.1	4
Aug	23.0	1.4	90.9	52.3	9.3	0.1	4
Sep	22.9	1.5	92.9	38.1	9.3	0.1	1
Oct	34.2	2.2	93.3	51.1	9.7	0.1	4
Eastern Sector							
Jun	32.2	1.9	90.3	25.8	9.3	0.2	3
Jul	29.6	1.8	96.8	41.9	9.1	0.2	3
Aug	26.4	2.0	100	60.0	9.4	0.1	3
Sep	24.7	2.4	100.0	48.4	9.6	0.1	1
Oct	43.6	3.3	93.1	41.4	10.0	0.2	2

“n” represents number of stations sampled. 10 individuals were sampled at each station.

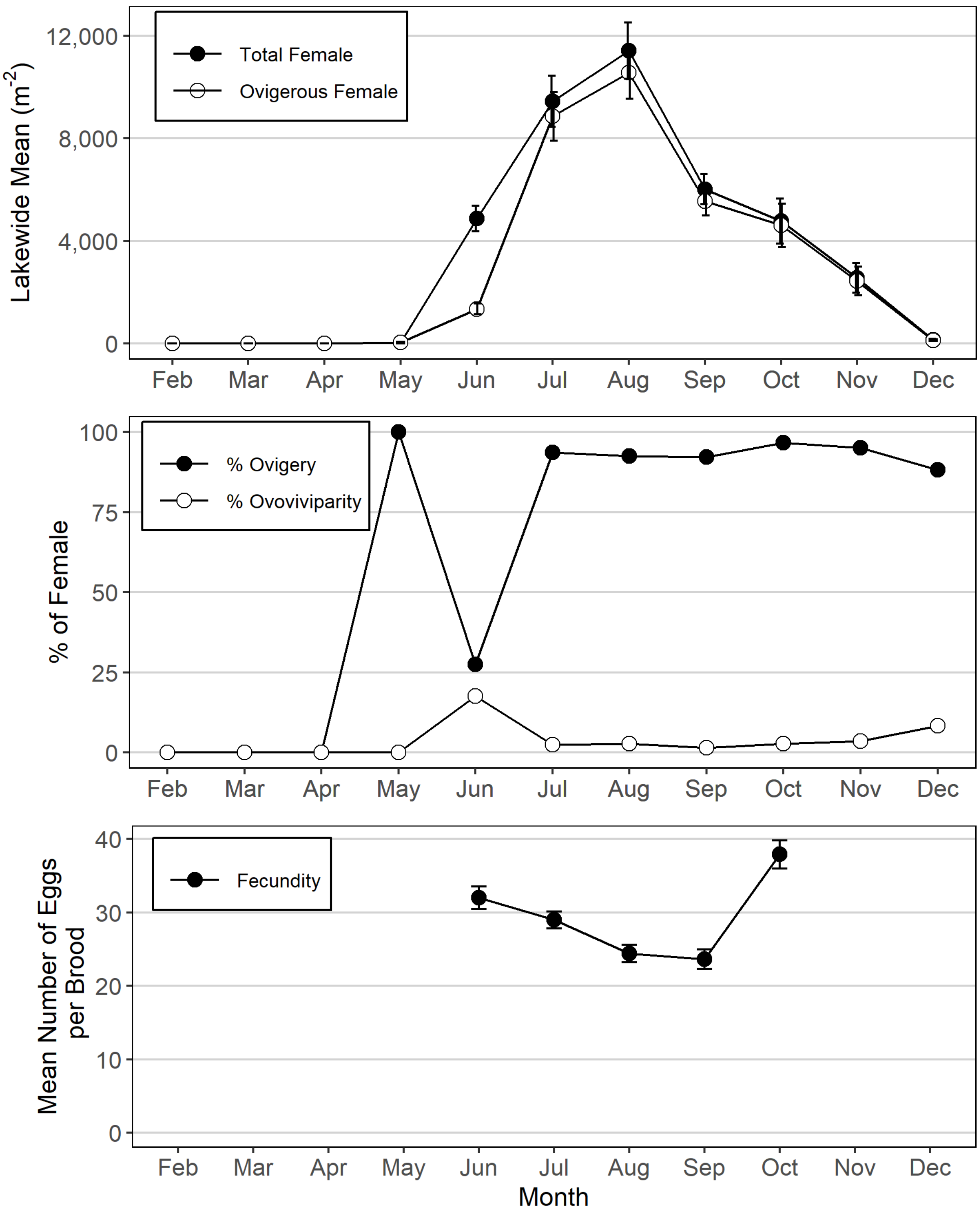


Figure 3-76. Artemia Reproductive Parameters and Fecundity between June and October in 2019

Artemia Population Statistics

The annual mean adult *Artemia* population increased slightly to 13,541 m^{-2} in 2019 from 12,120 m^{-2} in 2018, but still remained much lower than the long-term average of 18,653 m^{-2} (Table 3-21). The 5-year running average of the population mean (2015 to 2019) was the second lowest due to low abundance in 2015 and 2016. The centroid increased slightly to 221 days (August 9th) from 216 days in 2018 and remained above 220 days for the third time in last four years, once again breaking the previously observed declining trend (Figure 3-77). The 2019 population peak was below the long-term average, but approached the long-term average in August and followed the long-term average curve for the rest of 2019 except September (Figure 3-78).

In 2019, the monthly average adult abundance peaked in August as the centroid indicated, and the August abundance was the above the long-term average for the first time since 2013 (Figure 3-79). For the third year in row the monthly average was above the long-term average in October and November. The monthly average instar abundance peaked in April but remained below the long-term average (Figure 3-80). The peak in April was much lower than what has been observed during the previous six years; however, the May average instar abundance was above the long-term average, which might have contributed to a later adult monthly peak in 2019.

Table 3-21. Summary Statistics of Adult *Artemia* Abundance between May 1 and November 30

Year	Mean	Median	Peak	Centroid
1979	14,118	12,286	31,700	216
1980	14,643	10,202	40,420	236
1981	32,010	21,103	101,670	238
1982	36,643	31,457	105,245	252
1983	17,812	16,314	39,917	247
1984	17,001	19,261	40,204	212
1985	18,514	20,231	33,089	218
1986	14,667	17,305	32,977	190
1987	23,952	22,621	54,278	226
1988	27,639	25,505	71,630	207
1989	36,359	28,962	92,491	249
1990	20,005	16,775	34,930	230
1991	18,129	19,319	34,565	226
1992	19,019	19,595	34,648	215
1993	15,025	16,684	26,906	217
1994	16,602	18,816	29,408	212
1995	15,584	17,215	24,402	210
1996	17,734	17,842	34,616	216
1997	14,389	16,372	27,312	204
1998	19,429	21,235	33,968	226
1999	20,221	21,547	38,439	225
2000	10,550	9,080	22,384	210
2001	20,031	20,037	38,035	209
2002	11,569	9,955	25,533	200
2003	13,778	12,313	29,142	203
2004	32,044	36,909	75,466	180
2005	17,888	15,824	45,419	192
2006	21,518	20,316	55,748	186
2007	18,826	17,652	41,751	186
2008	11,823	12,524	27,606	189
2009	25,970	17,919	72,086	181
2010	14,921	7,447	46,237	191
2011	21,343	16,893	48,918	194
2012	16,324	11,302	53,813	179
2013	26,033	31,275	54,347	196
2014	13,467	7,602	42,298	194
2015	7,676	5,786	18,699	185
2016	10,687	10,347	18,498	220
2017	15,158	15,536	26,064	221
2018	12,120	12,024	21,836	216
2019	13,541	12,590	26,531	221
Mean	18,653	17,414	42,762	210
Min	7,676	5,786	18,498	179
Max	36,643	36,909	105,245	252

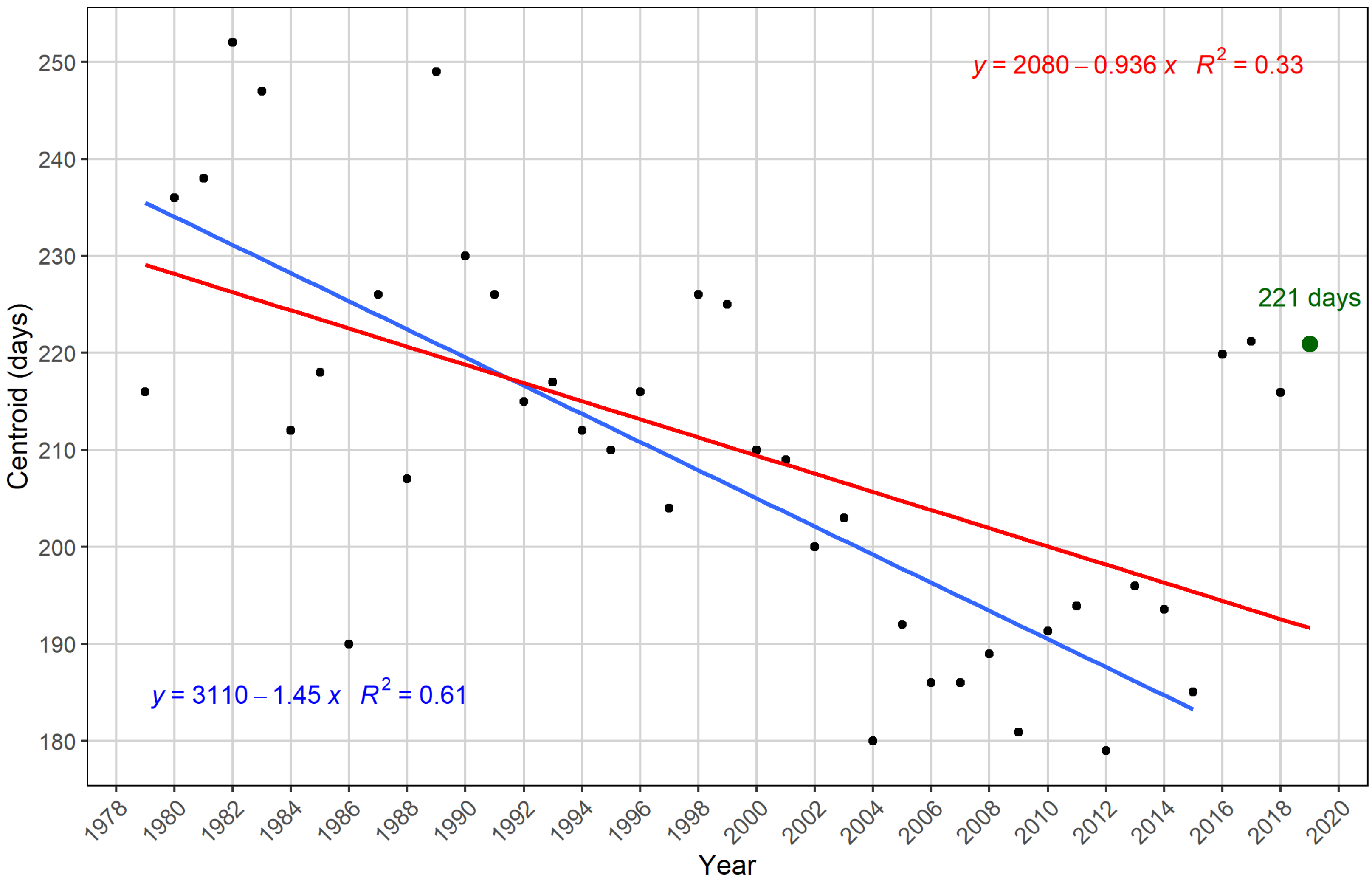


Figure 3-77. Adult *Artemia* Population Centroid

A green dot indicates a value in 2019. The blue line indicates the linear trend between 1979 and 2015 while the red line indicates the linear trend for all monitoring years.

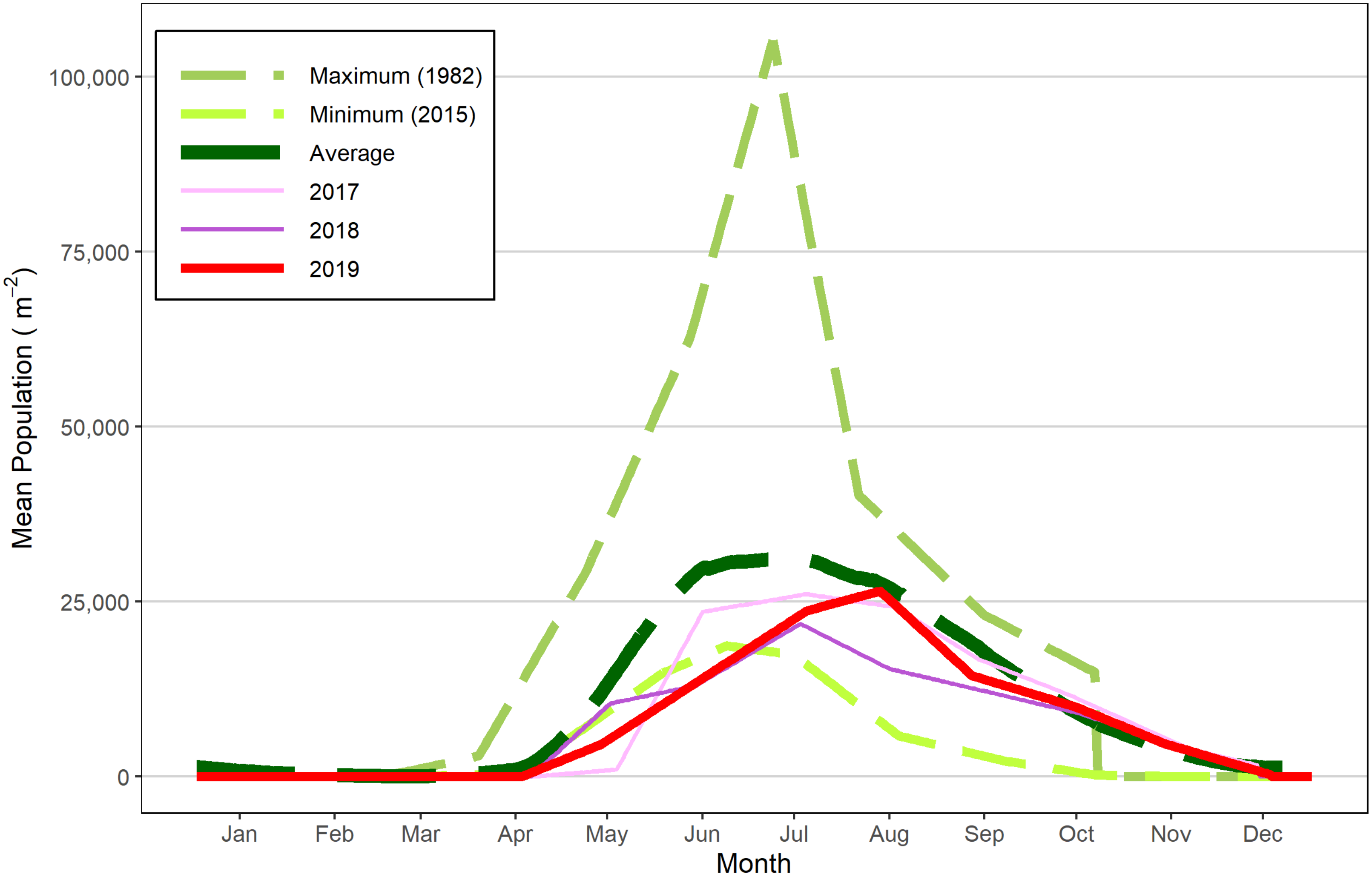
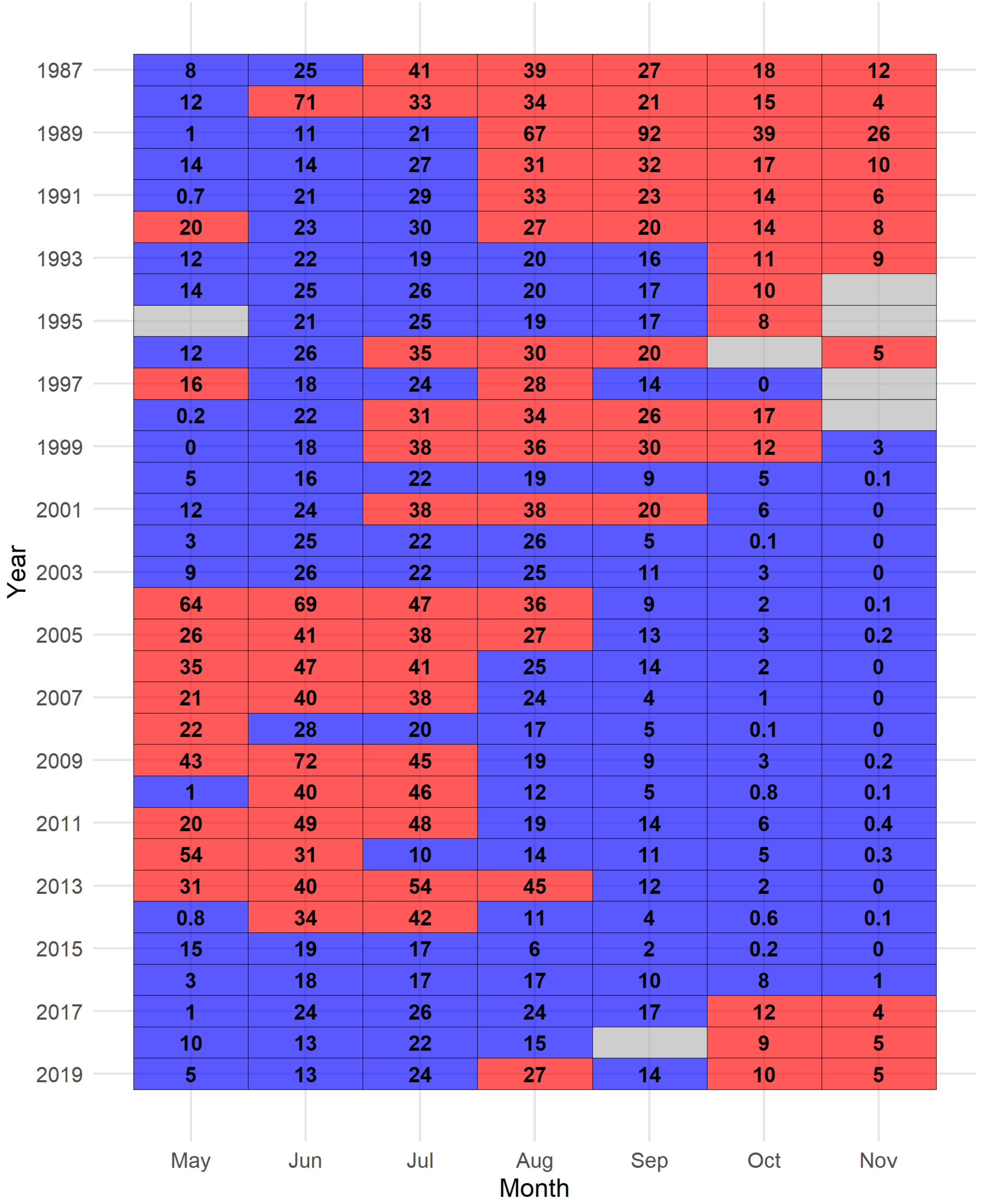


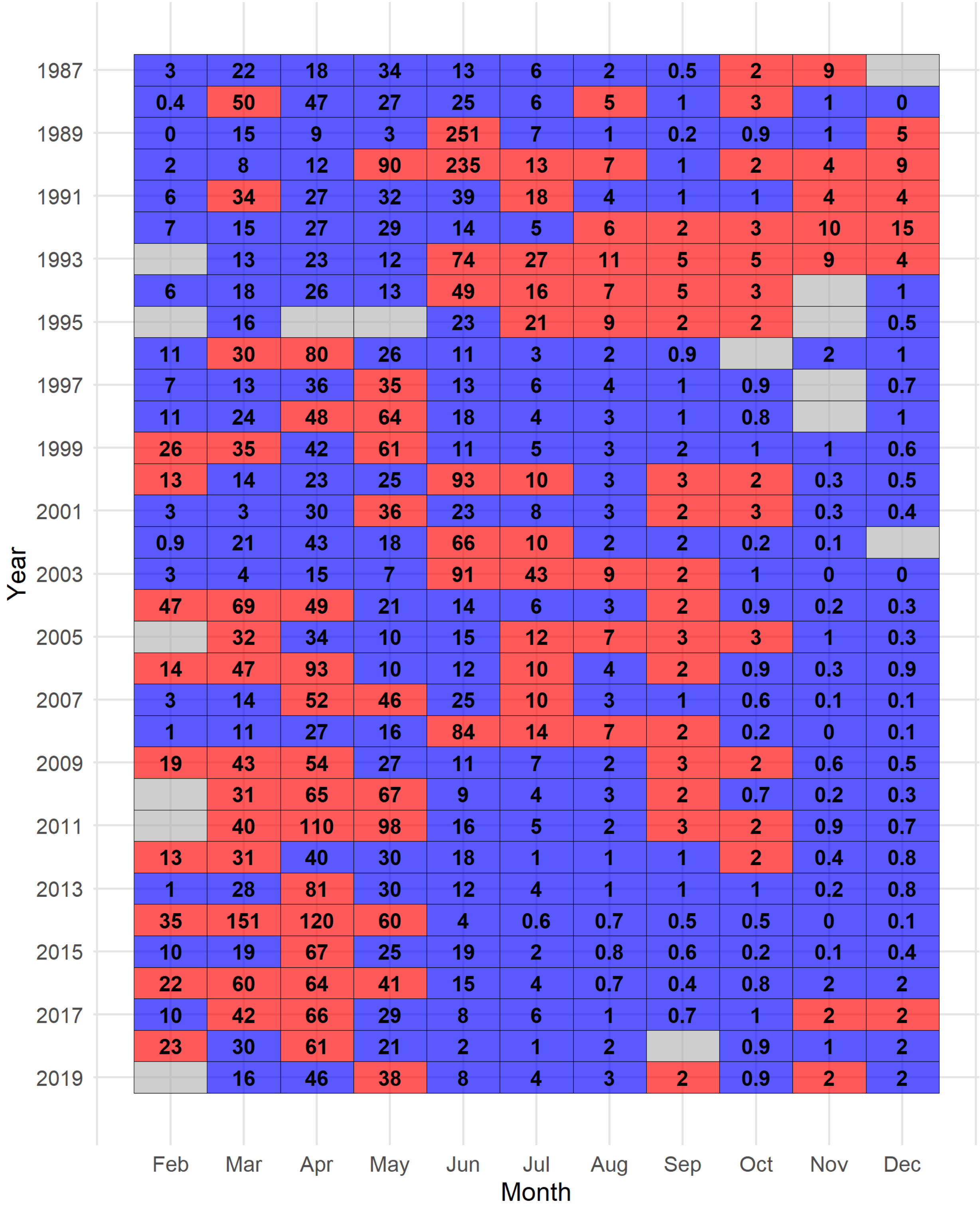
Figure 3-78. Mean lake-wide adult *Artemia* Population (m^{-2}) since 1987



Year	May	Jun	Jul	Aug	Sep	Oct	Nov
1987	8	25	41	39	27	18	12
	12	71	33	34	21	15	4
1989	1	11	21	67	92	39	26
	14	14	27	31	32	17	10
1991	0.7	21	29	33	23	14	6
	20	23	30	27	20	14	8
1993	12	22	19	20	16	11	9
	14	25	26	20	17	10	
1995		21	25	19	17	8	
	12	26	35	30	20		5
1997	16	18	24	28	14	0	
	0.2	22	31	34	26	17	
1999	0	18	38	36	30	12	3
	5	16	22	19	9	5	0.1
2001	12	24	38	38	20	6	0
	3	25	22	26	5	0.1	0
2003	9	26	22	25	11	3	0
	64	69	47	36	9	2	0.1
2005	26	41	38	27	13	3	0.2
	35	47	41	25	14	2	0
2007	21	40	38	24	4	1	0
	22	28	20	17	5	0.1	0
2009	43	72	45	19	9	3	0.2
	1	40	46	12	5	0.8	0.1
2011	20	49	48	19	14	6	0.4
	54	31	10	14	11	5	0.3
2013	31	40	54	45	12	2	0
	0.8	34	42	11	4	0.6	0.1
2015	15	19	17	6	2	0.2	0
	3	18	17	17	10	8	1
2017	1	24	26	24	17	12	4
	10	13	22	15		9	5
2019	5	13	24	27	14	10	5

Figure 3-79. Monthly Average Adult *Artemia* Abundance of 12 Stations

Values are in m^{-2} divided by a thousand (e.g. 7.9 = 7,900). Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	3	22	18	34	13	6	2	0.5	2	9	
	0.4	50	47	27	25	6	5	1	3	1	0
1989	0	15	9	3	251	7	1	0.2	0.9	1	5
	2	8	12	90	235	13	7	1	2	4	9
1991	6	34	27	32	39	18	4	1	1	4	4
	7	15	27	29	14	5	6	2	3	10	15
1993		13	23	12	74	27	11	5	5	9	4
	6	18	26	13	49	16	7	5	3		1
1995		16			23	21	9	2	2		0.5
	11	30	80	26	11	3	2	0.9		2	1
1997	7	13	36	35	13	6	4	1	0.9		0.7
	11	24	48	64	18	4	3	1	0.8		1
1999	26	35	42	61	11	5	3	2	1	1	0.6
	13	14	23	25	93	10	3	3	2	0.3	0.5
2001	3	3	30	36	23	8	3	2	3	0.3	0.4
	0.9	21	43	18	66	10	2	2	0.2	0.1	
2003	3	4	15	7	91	43	9	2	1	0	0
	47	69	49	21	14	6	3	2	0.9	0.2	0.3
2005		32	34	10	15	12	7	3	3	1	0.3
	14	47	93	10	12	10	4	2	0.9	0.3	0.9
2007	3	14	52	46	25	10	3	1	0.6	0.1	0.1
	1	11	27	16	84	14	7	2	0.2	0	0.1
2009	19	43	54	27	11	7	2	3	2	0.6	0.5
		31	65	67	9	4	3	2	0.7	0.2	0.3
2011		40	110	98	16	5	2	3	2	0.9	0.7
	13	31	40	30	18	1	1	1	2	0.4	0.8
2013	1	28	81	30	12	4	1	1	1	0.2	0.8
	35	151	120	60	4	0.6	0.7	0.5	0.5	0	0.1
2015	10	19	67	25	19	2	0.8	0.6	0.2	0.1	0.4
	22	60	64	41	15	4	0.7	0.4	0.8	2	2
2017	10	42	66	29	8	6	1	0.7	1	2	2
	23	30	61	21	2	1	2		0.9	1	2
2019		16	46	38	8	4	3	2	0.9	2	2

Figure 3-80. Monthly Average Instar *Artemia* Abundance of 12 Stations

Values are in m^{-2} divided by a thousand (e.g. 7.9 = 7,900). Red colored cells indicate above the long-term average of the respective month while blue colored cells indicate below the long-term average of the respective month.

Analysis of Long Term Trends

Salinity and Mono Lake Elevation

The salinity of Mono Lake is closely associated with lake elevation across all monitoring stations, and relationships are much stronger for salinity measured at shallower depths (Table 3-22). The strongest correlation was found at Station 6 (r = -0.93, corresponding to the coefficient of determination (r^2) of 0.86). Further analysis revealed that the relationship had begun to shift in 2008 (Figure 3-81). The relationship was much stronger before 2008 ($r^2 = 0.95$) compared to $r^2 = 0.75$ since 2008. Variability is much higher since 2008 and as evident from intersecting two slopes, both higher and lower salinity values appear to correspond to lower lake levels. Increasing variability is more clearly demonstrated in Figure 3-82. Beginning in 2008 annual range of salinity between 0 and 10 m has exceeded 5 g/L every year in spite of meromixis events in 2011 and since 2017. In 2017, a range of salinity exceeded 15 g/L at all stations. At Station 6 salinity started at 96.6 g/L in February reaching the lowest level in September at 80.9 g/L, resulting in an annual range of 15.7 g/L.

Table 3-22. Relationships between Salinity and Lake Elevation for 3 Different Depth Classes

	Depth		
Station	1 to 10m	11 to 20m	21 to 38m
2	-0.92	-0.87	-
3	-0.89	-0.86	-
4	-0.90	-0.85	-0.60
5	-0.88	-0.87	-
6	-0.93	-0.86	-0.63
7	-0.92	-0.86	-
8	-0.88	-0.88	-
10	-0.88	-0.82	-
12	-0.86	-0.85	-0.62

Monthly average lake elevations were used. Stations 1 and 9 were not included due to a lack of long-term data, and Station 11 was not included because of its shallow depth.

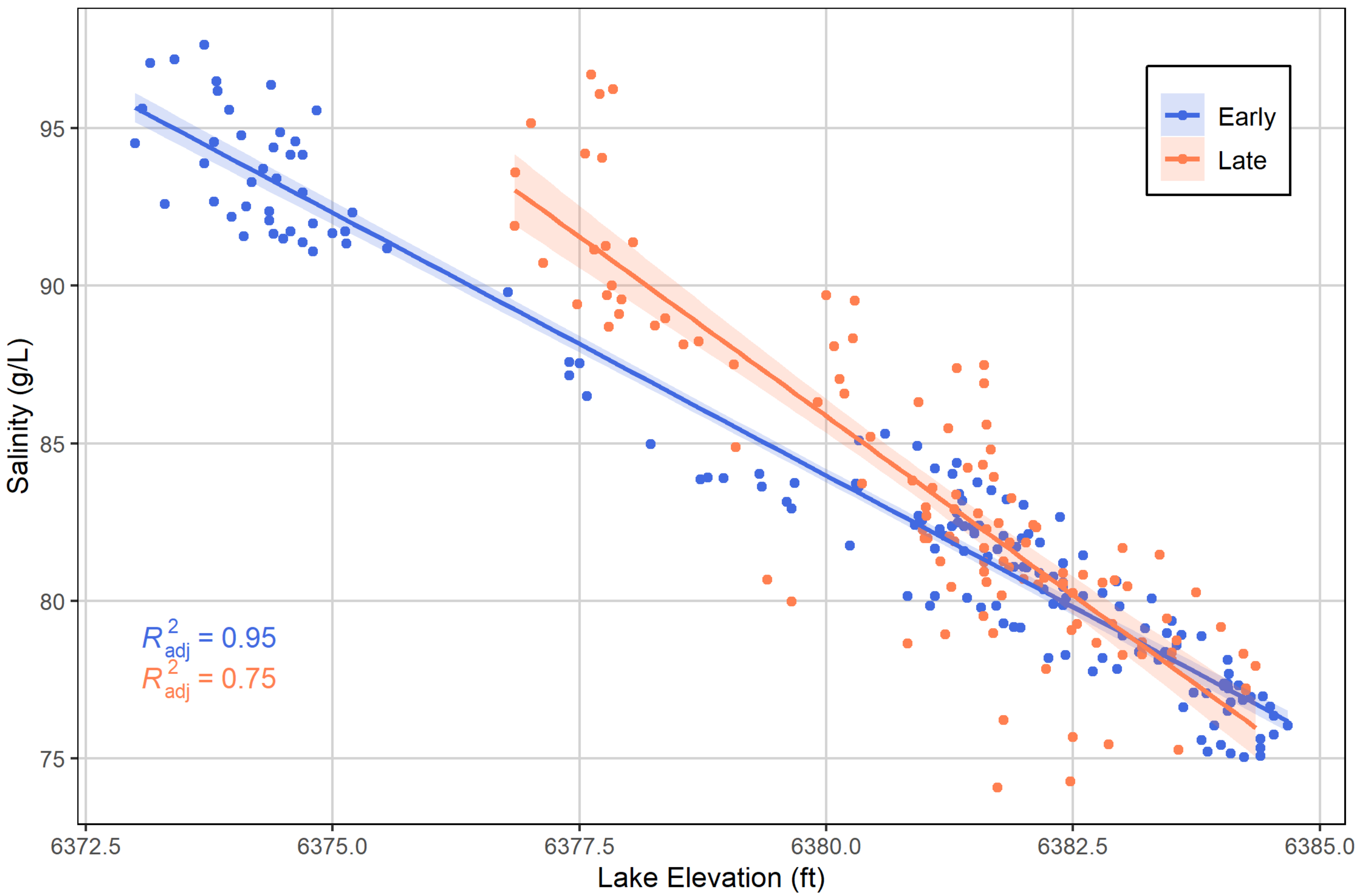


Figure 3-81. Difference in Slopes between Two Periods of Monitoring Years: Earlier (1991-2007) and Later (2008-2019) based on Salinity (g/L) Measured between 1 and 10 m of Depth at Station 6

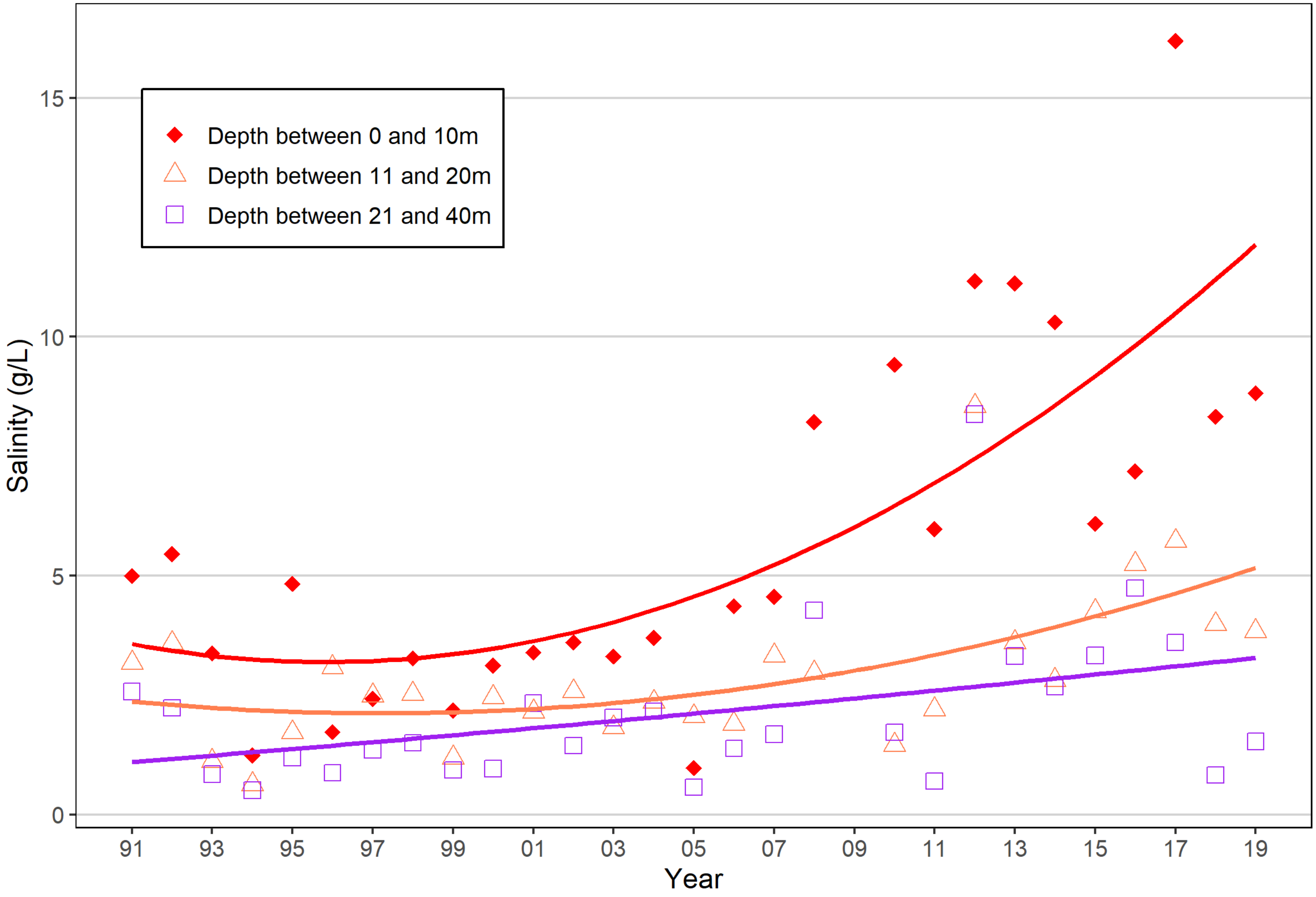


Figure 3-82. Inter-Annual Range of Monthly Salinity Readings (g/L) at Station 6

Artemia Population Peak

A year following the breakdown of meromixis has coincided with high adult *Artemia* abundance at Mono Lake as nutrients which are previously contained in the hypolimnion become fully available for phytoplankton throughout the water column (Figure 3-83). The long-term data show that 1989 and 2004 had the second and third highest adult density in the period of record (1979 to 2019). It appears the longer the period of meromixis, the higher the peak of *Artemia* population when meromixis breaks. The last two meromixis events which only lasted one to two years resulted in smaller peaks. Mono Lake became meromictic in 2017 for the fifth time on record and remained so through 2019, and this is expected to eventually lead to a peak.

Lake-wide mean *Artemia* population peaked in 1989, 2004, 2009, and 2013 and showed a declining trend with an average decline of approximately 500 m^{-2} per year. According to this relationship, the *Artemia* population would be approximately 22,860 m^{-2} if the current meromixis breaks in 2020. This predicted peak would be indistinguishable from any other monomictic years, which have ranged from 7,676 m^{-2} to 27,639 m^{-2}. As will be discussed later, higher accumulation of ammonium in the hypolimnion during the latest meromixis, however, should result in a higher *Artemia* population peak when the current meromixis breaks. The simple linear relationship, therefore, may not adequately describe temporal trends of *Artemia* population peaks. In spite of a declining trend of peaks, *Artemia* abundance during peak years was significantly different from that during non-peak years ($P = 0.0001$) as peak years averaged 30,102 m^{-2} compared to 15,828 m^{-2} during non-peak years (Table 3-23). The following sections will examine the effect of meromixis on the *Artemia* population in Mono Lake.

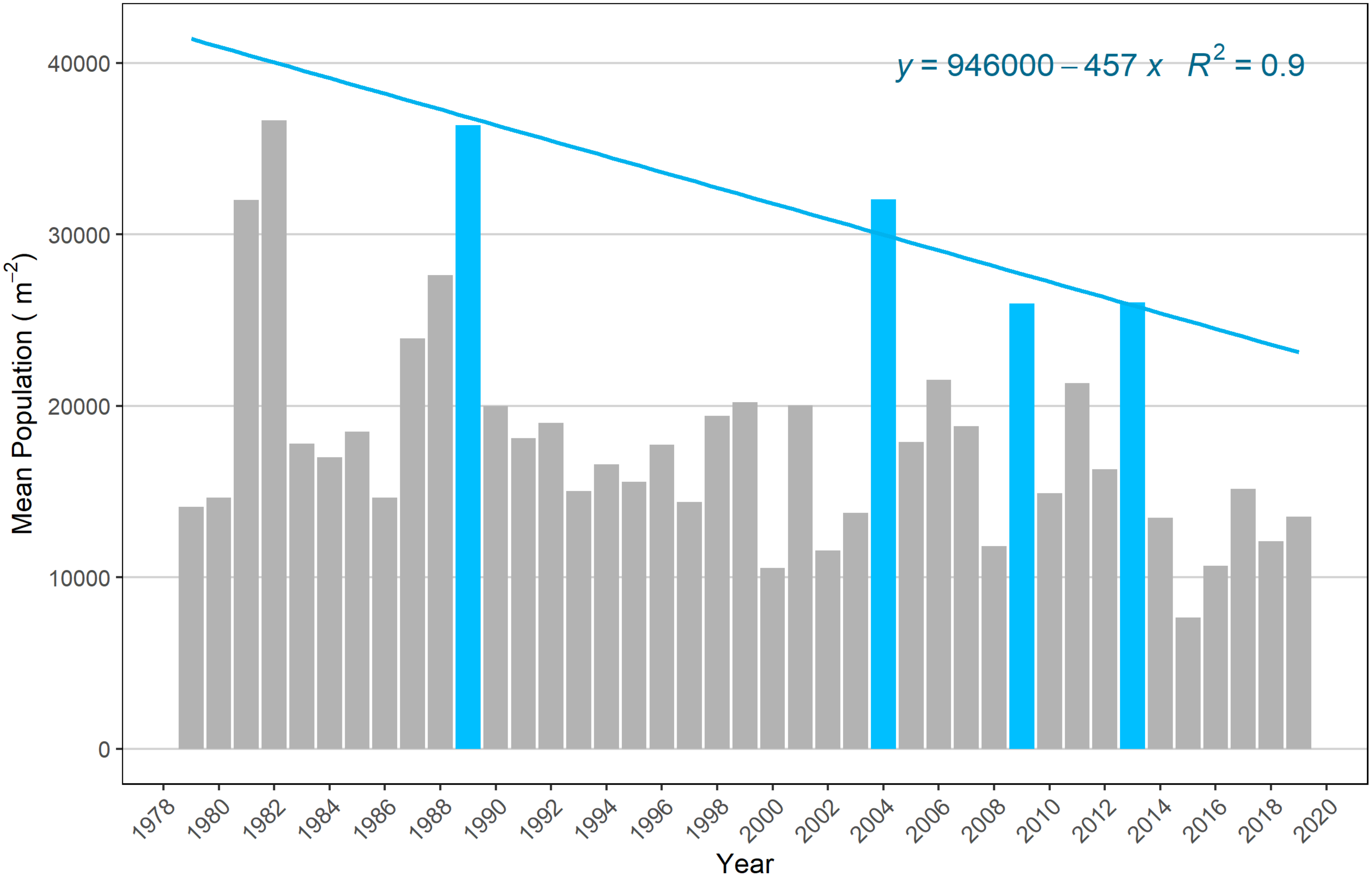


Figure 3-83. Mean Lake-wide Adult *Artemia* Population (per m^2)

Years with a blue colored bar indicate years with peak *Artemia* abundance occurring subsequent to the onset of monomixis. The blue line indicates the temporal trend of peak *Artemia* abundance of 4 years (1989, 2004, 2009, and 2013).

Ammonium (NH4)

Ammonium recorded at the deepest monitoring depths (28 and 35 m) shows trends similar to *Artemia* population peaks. Peak monthly accumulation of ammonium prior to the *Artemia* population peak during the second meromixis was 1,131 µM in August 2001 (Figure 3-84) with the average rate of accumulation being 124 µM/year. For successive peaks, ammonium accumulation dropped to 107 µM in 2007 and 105 µM in 2011. Decline of *Artemia* population peaks during the same period indicates the importance of nutrient build-up which appeared to be proportional to the duration of meromixis. The other factor affecting ammonium accumulation is an initial depth of a chemocline. Jellison reported that the deep chemocline resulted in mixing at 23 to 24 m of depth allowing upward fluxes of ammonia in early 2006, resulting disruption of continuous ammonia accumulation and lower peak than what could have been if ammonium were allowed accumulate continuously for three years (LADWP 2006). Contrary the depth of chemocline in 2017 never went below 12 m through the winter of 2017-18. The maximum accumulation during the current meromixis has been 149 µM as of December 2019. This value is almost one magnitude smaller than the peak during the second meromixis, but higher than the peak accumulation during the previous two meromictic events.

When meromixis breaks down, accumulated ammonium became available throughout the water column. A nutrient boost above 10 m of depth was apparent in 2004 but only slightly in 2009 and 2013 (Figure 3-85). Fluctuation in ammonium availability above 10 m, however, does not follow the clear pattern of hypolimnetic ammonium accumulation as more ammonium was available in 2016, a monomictic year which did not immediately follow a meromixis event, than in 2004 and 2009. Lower epilimnetic ammonium availability during the third and fourth meromixis may explain reduced *Artemia* peaks following the meromixis.

Table 3-23. *Artemia* Population Summary during Meromixis and Monomixis

		Peak				
Meromixis	Duration	Year	Artemia abundance (m^{-3})	Average *Artemia* between peaks (m^{-3})	Reduction following a peak	NH_4 accumulation during meromixis (µM)*
1983-1987	5	1989	36,359		45%	NA
				16,576		
1995-2002	8	2004	32,044		44%	1,131
				17,514		
2005-2007	3	2009	25,970		43%	107
				17,529		
2011	1	2013	26,033		48%	105
				12,108		
2017-						149
Average			30,102	15,828	45%	

* Maximum monthly NH_4 reading during a meromictic event recorded at depths of 28 and 35m at Station 6.

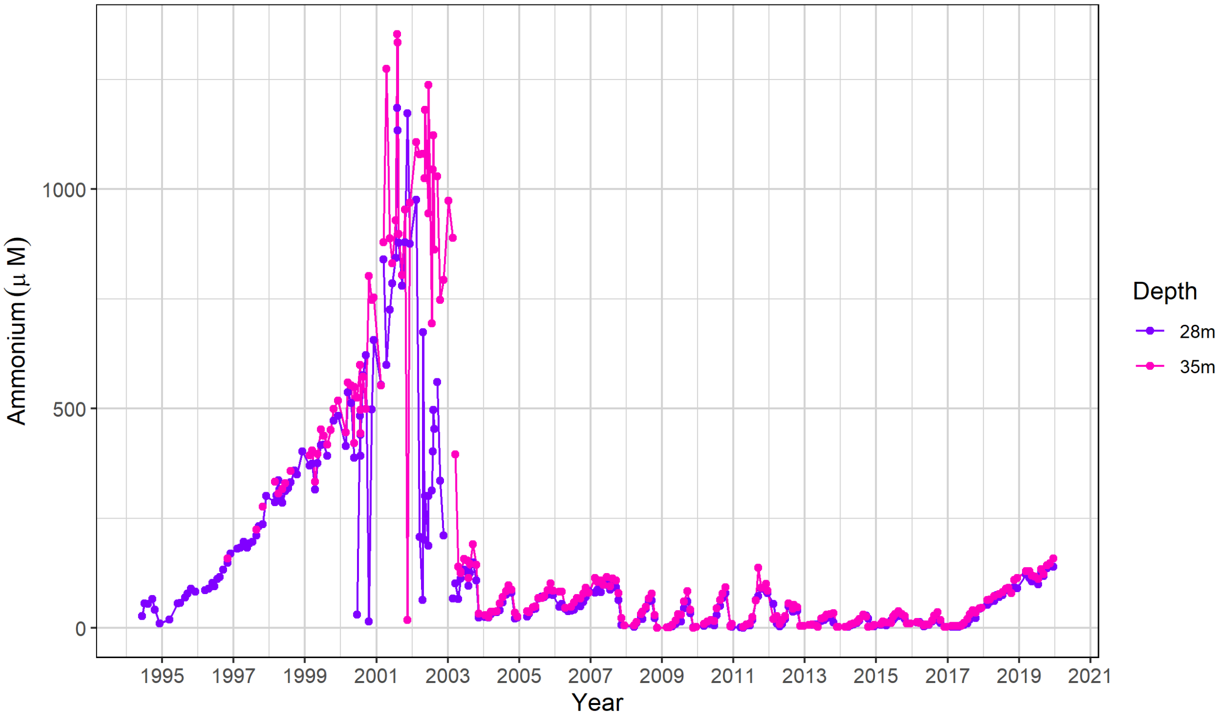


Figure 3-84. Ammonium Accumulation at 28 and 35 m of Depths at Station 6

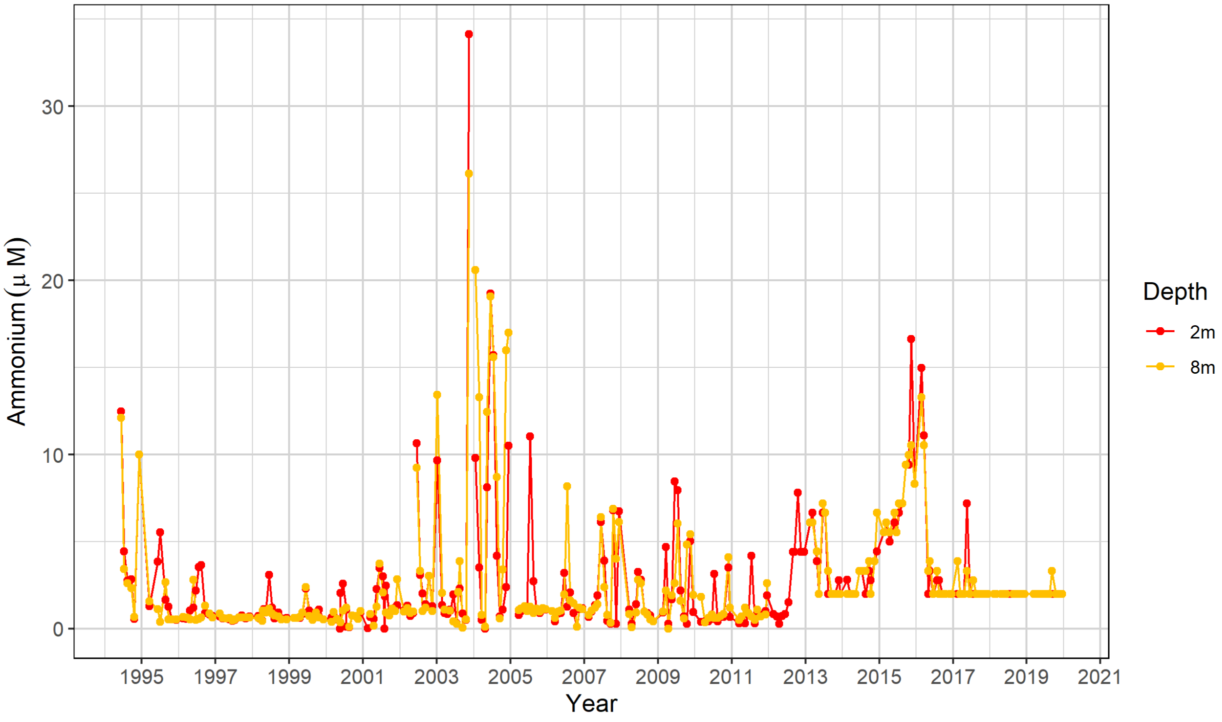


Figure 3-85. Ammonium Accumulation at 2 and 8 m of Depths at Station 6

Mono Lake Input

The second meromixis was by far the longest recorded meromixis lasting from 1995 to 2002. This extended meromixis was influenced by very high fresh water input, the majority of which occurred between 1995 and 1999, during which 717,670 AF of water discharged into Mono Lake, the highest 5-year total on record (Table 3-24). Mean annual Mono Basin runoff totals during the first meromixis were higher than during the second meromixis (179,139 AF between 1982 and 1986 compared to 164,880 AF between 1995 and 1999); however, due to export from Mono Basin, inflow to Mono Lake was smaller during the first meromixis than the second. As a result, the lake level rose by 10.3 feet during the second meromixis compared to 6.8 feet during the first. Based solely on freshwater influx, the second meromixis should have produced a much higher *Artemia* peak than the first meromixis, but this was not the case.

The rise in the lake level in 2017 was comparable to what was observed during the third meromixis (2005 to 2007) with only one year of extremely high input. Due to the above normal runoff in 2019, the total input during the current meromixis has exceeded the third meromixis. Subsequently, the *Artemia* peak following the current meromixis could be higher than previous two peaks in terms of magnitude. Meromixis is maintained with sustained high inflow to Mono Lake; the longer the period of sustained high flow, the longer and stronger the meromixis. Based on Mono Basin Runoff since 1935, a probability of having a wet period equivalent to the one between 1995 and 1999 is less than 0.02%, and it is even smaller for the wet period between 1982 and 1986 (<0.01%). These events have happened twice since 1935; thus, it could happen but is unlikely given the warming and drier climatic trend.

Table 3-24. Mono Lake Input during Meromixis and Monomixis

Meromixis	Total Input (10^3 AF)	Input responsible to form meromixis			Average Input (10^3 AF) for all other years	Lake Elevation Change (ft)
		Year	Total (10^3 AF)	Average (10^3 AF)		
1983-1987	535	1983-1986	510	128		6.8
					61	
1995-2002	971	1995-1999	718	144		10.3
					83	
2005-2007	375	2005-2006	313	156		4.0
					73	
2011	162	2011	162	162		2.0
					59	
2017-?	472	2017	236	236		5.5
Average				165	69	

Salinity

With a large influx of freshwater, epilimnetic salinity declines. During the second meromixis, the salinity gradient slowly developed with the onset of meromixis peaking at 16.2 g/L in August 1998 and disappearing in 2003, a year before the *Artemia* population peak (Figure 3-86). During the third meromixis, however, the salinity gradient did not continuously grow. The salinity gradient weakened at the end of 2005 and re-established in 2006 due to deep chemocline, resulting in a much weaker chemocline at the end of meromixis in 2007. The meromixis in 2011 failed to create a salinity gradient which was distinguishable from monomictic years, and the peak gradient only reached 8.3 g/L, and quickly disappeared. During the latest meromixis, the gradient was near 0 g/L at the beginning of 2017 due to holomixis at the end of 2016. Mono Lake quickly stratified reaching the maximum gradient of 22.9 g/L in September due to the second largest inflow of freshwater on record. The gradient in 2018 and 2019, however, exceeded 15 g/L annually, but dropped down below 7 g/L during winter months. Consequently, the gradient shows a saw-tooth like pattern instead of a broader continuous pattern observed during the second meromixis.

Annual peaks of gradient appear to be increasing in the beginning in 2008. During monomictic years prior to 2008, the annual peak mostly remained at or below 5 g/L. Since 2008, the annual peak has exceeded 8 g/L except one year in 2015. The peak reached 18.6 g/L in July of 2014, which was higher than the peak annual gradient observed during the second meromixis. A relationship between annual peak gradient and Mono Lake input is poor and only explains 16% of variations (Figure 3-87). It is possible for high salinity to lead larger gradient upon freshwater input; however, this does not fully explain increasing annual gradient since 2008 (Figure 3-88). High preceding salinity should result in higher gradient upon influx of freshwater as the case between 1995 and 1999 and in 2017. Between 2008 and 2012, however, relatively low preceding salinity resulted in higher annual peaks. In 2014, maximum salinity in March was 91.9 g/L, comparable to the 1997 value, and Mono Lake input 51,941 acre-feet compared to 148,740 acre-feet in 1997; yet, the annual peak gradient in 2014 was 18.6 g/L compared to 14.6 g/L in 1997. Similarly, the 2013 peak was 12.7g/L in spite of 53,094 acre-feet of input with the preceding salinity value of 91 g/L. It appears that the salinity gradient has been becoming greater in recent years regardless of preceding Mono Lake conditions.

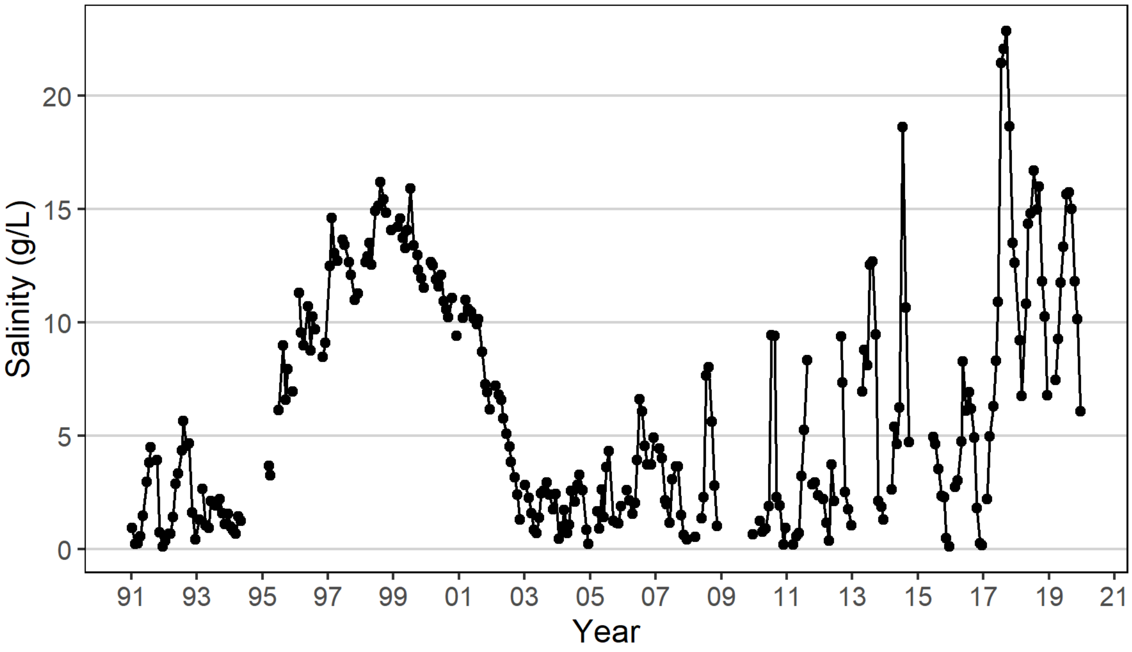


Figure 3-86. A Range of Salinity through Water Column at Station 6

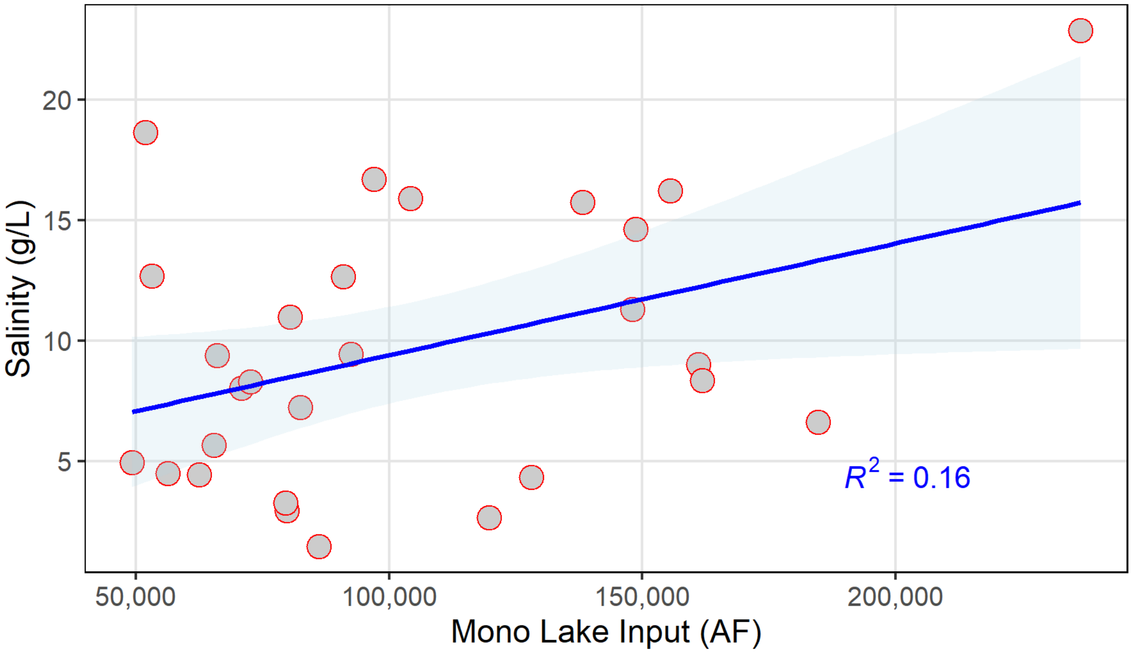
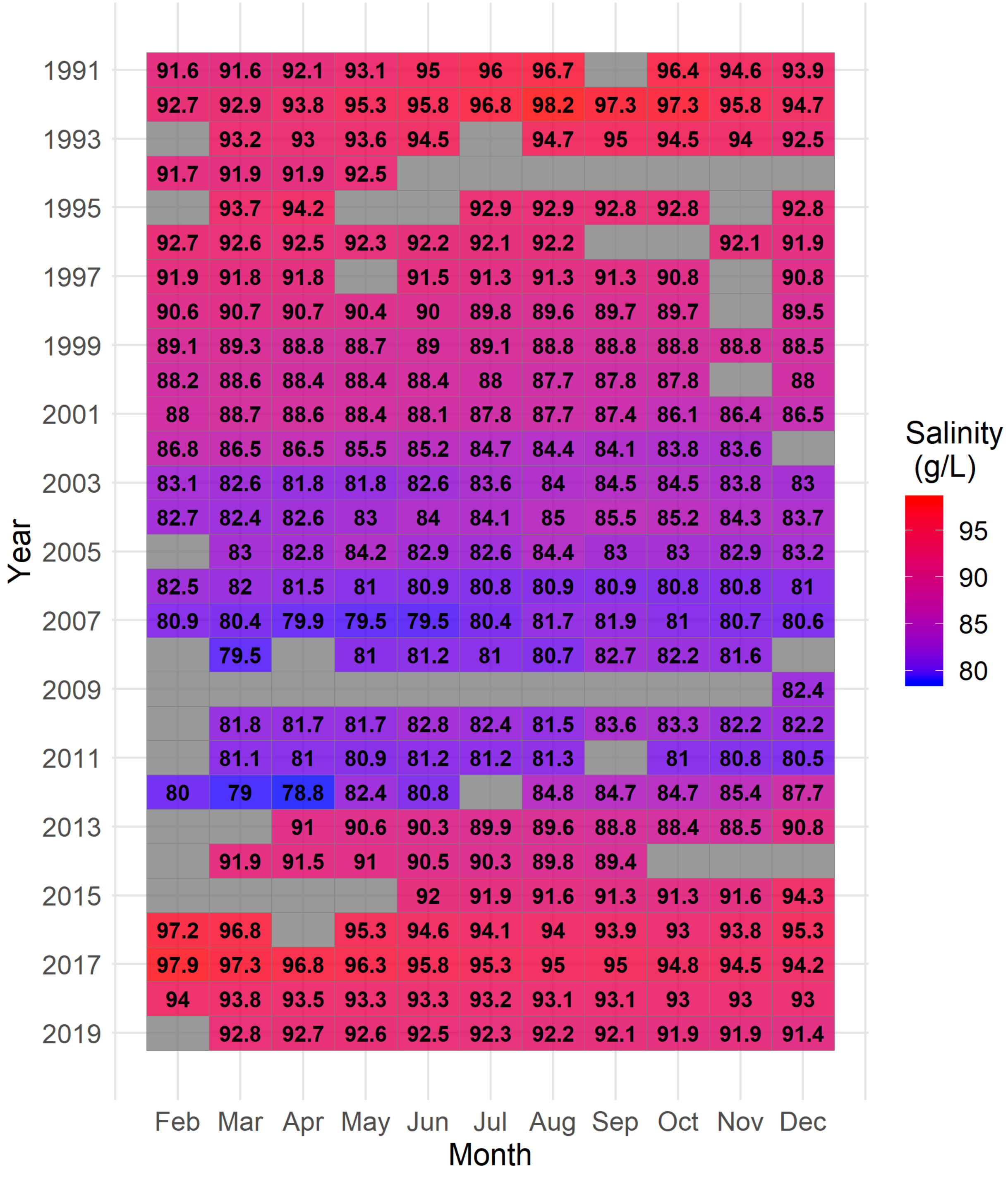


Figure 3-87. Annual Peak Range of Salinity and Mono Lake Input at Station 6



Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	91.6	91.6	92.1	93.1	95	96	96.7		96.4	94.6	93.9
	92.7	92.9	93.8	95.3	95.8	96.8	98.2	97.3	97.3	95.8	94.7
1993		93.2	93	93.6	94.5		94.7	95	94.5	94	92.5
	91.7	91.9	91.9	92.5							
1995		93.7	94.2			92.9	92.9	92.8	92.8		92.8
	92.7	92.6	92.5	92.3	92.2	92.1	92.2			92.1	91.9
1997	91.9	91.8	91.8		91.5	91.3	91.3	91.3	90.8		90.8
	90.6	90.7	90.7	90.4	90	89.8	89.6	89.7	89.7		89.5
1999	89.1	89.3	88.8	88.7	89	89.1	88.8	88.8	88.8	88.8	88.5
	88.2	88.6	88.4	88.4	88.4	88	87.7	87.8	87.8		88
2001	88	88.7	88.6	88.4	88.1	87.8	87.7	87.4	86.1	86.4	86.5
	86.8	86.5	86.5	85.5	85.2	84.7	84.4	84.1	83.8	83.6	
2003	83.1	82.6	81.8	81.8	82.6	83.6	84	84.5	84.5	83.8	83
	82.7	82.4	82.6	83	84	84.1	85	85.5	85.2	84.3	83.7
2005		83	82.8	84.2	82.9	82.6	84.4	83	83	82.9	83.2
	82.5	82	81.5	81	80.9	80.8	80.9	80.9	80.8	80.8	81
2007	80.9	80.4	79.9	79.5	79.5	80.4	81.7	81.9	81	80.7	80.6
		79.5		81	81.2	81	80.7	82.7	82.2	81.6	
2009											82.4
		81.8	81.7	81.7	82.8	82.4	81.5	83.6	83.3	82.2	82.2
2011		81.1	81	80.9	81.2	81.2	81.3		81	80.8	80.5
	80	79	78.8	82.4	80.8		84.8	84.7	84.7	85.4	87.7
2013			91	90.6	90.3	89.9	89.6	88.8	88.4	88.5	90.8
		91.9	91.5	91	90.5	90.3	89.8	89.4			
2015					92	91.9	91.6	91.3	91.3	91.6	94.3
	97.2	96.8		95.3	94.6	94.1	94	93.9	93	93.8	95.3
2017	97.9	97.3	96.8	96.3	95.8	95.3	95	95	94.8	94.5	94.2
	94	93.8	93.5	93.3	93.3	93.2	93.1	93.1	93	93	93
2019		92.8	92.7	92.6	92.5	92.3	92.2	92.1	91.9	91.9	91.4

Figure 3-88. Monthly Maximum Salinity at Station 6

A Temporal Shift in Monthly *Artemia* Abundance

Figure 3-79 and Figure 3-80 demonstrate a temporal shift in monthly *Artemia* abundance for adults and instars. Figure 3-79 can be broken down into four 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), 3) 2004 to 2016 (mostly monomictic state with two short periods of meromixis), 4) 2017 to present (the most recent meromixis). During the first period, the above average monthly abundance was mostly occurring between August and November (red colored cells). With onset of the meromixis in 1995, the occurrences had shifted to between July and October. Above-average monthly abundances were mostly observed between May and July from 2004 to 2014. Since 2017, above-average monthly abundances started occurring in October and November while earlier months show lower abundance. The very similar pattern was observed for instars (Figure 3-80) except the above average monthly instar abundance was still occurring between February and May during the fourth period.

A comparison of adult population abundance between May to July (summer) and August to November (fall) shows a similar pattern as the average abundance between these two periods were similar throughout the 1990s and started to diverge greatly after 2003, but started to converge again in 2016 (Figure 3-89). Since 2017, adult abundance in October and November was found mostly above the long-term average. Instar population, on the other hand, maintains the divergence as the early month average between February and May continues to rise while the later month average between June and December continues to fall (Figure 3-90).

Mean instar abundance between February and April was compared to four types of adult population measures: 1) lake-wide annual mean (Mean), 2) lake-wide annual peak (Peak), 3) lake-wide maximum monthly (Adult Max), 4) lake-wide mean monthly between June and September (Adult Mean). In spite of apparent relationships between adult and instar abundance, the relationships were not clearly demonstrated (Figure 3-91).

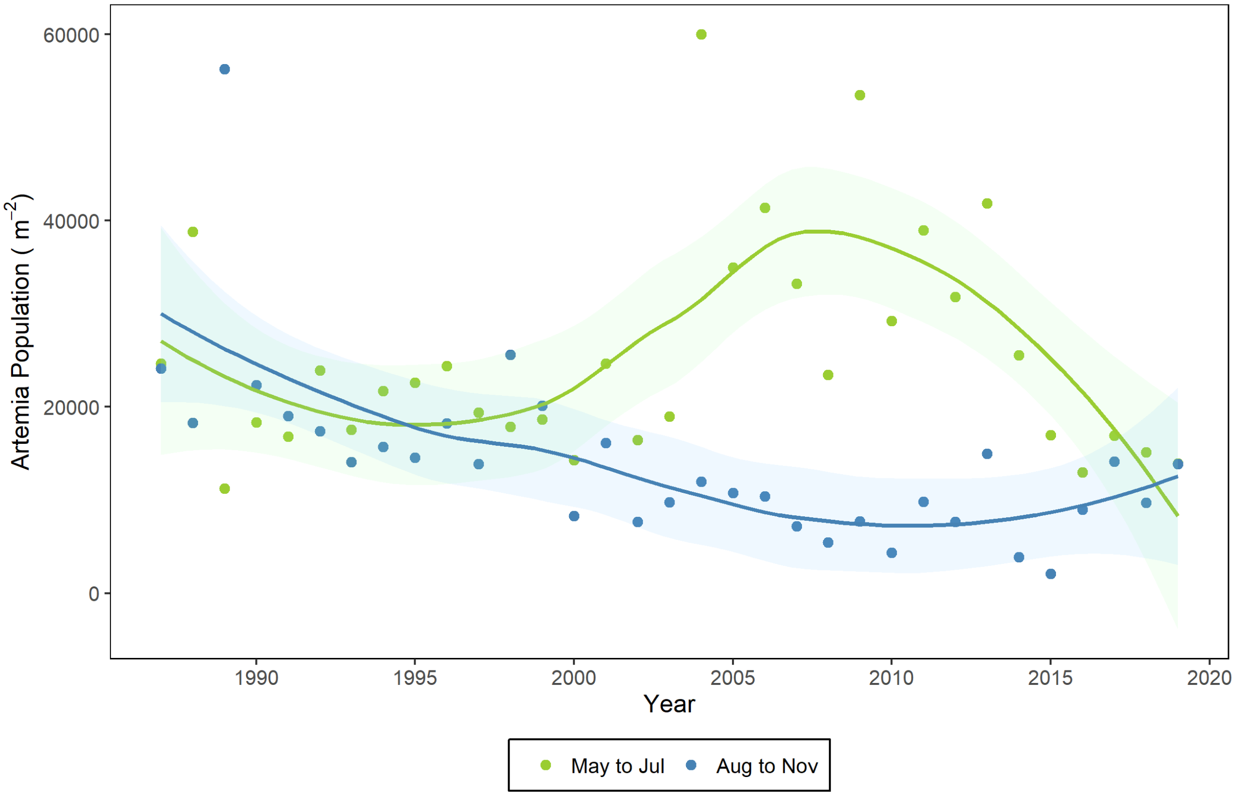


Figure 3-89. Comparison of Mean Lake-wide Adult *Artemia* Population (per m^2) between Earlier and Later Months

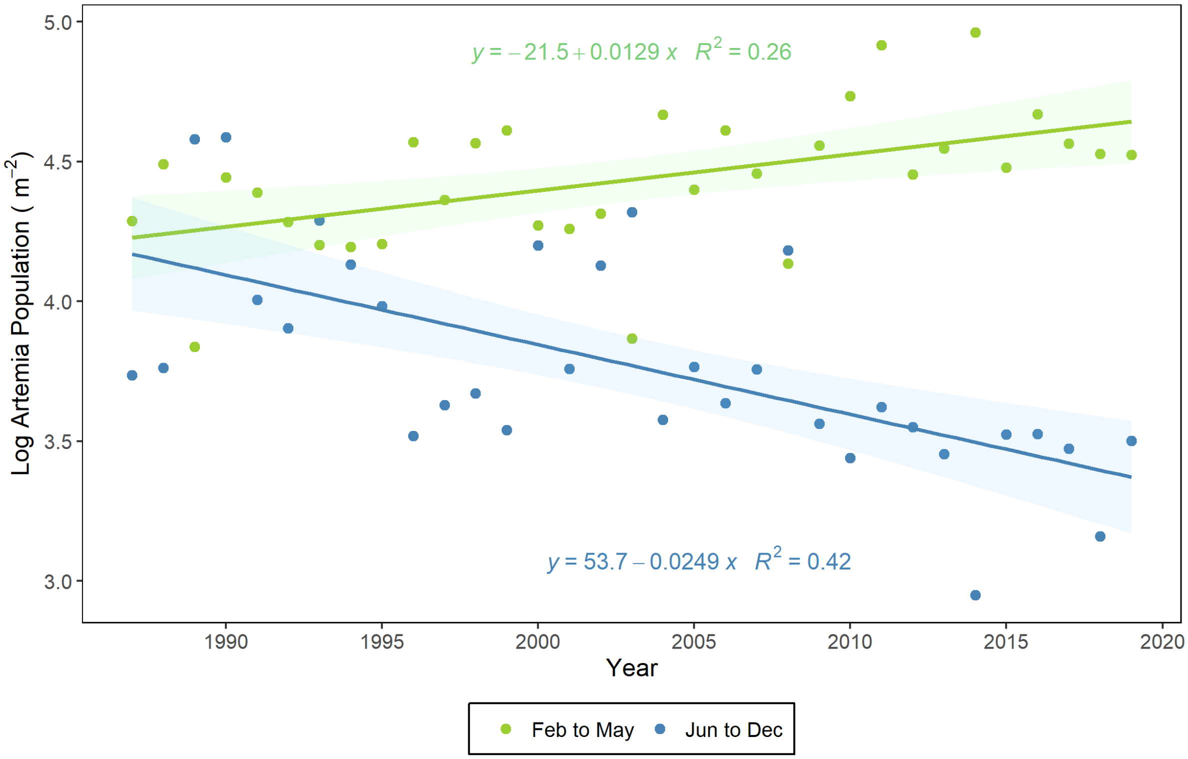


Figure 3-90. Comparison of Mean Lake-wide Instar Artemia Population (per m^2) between Earlier and Later Months

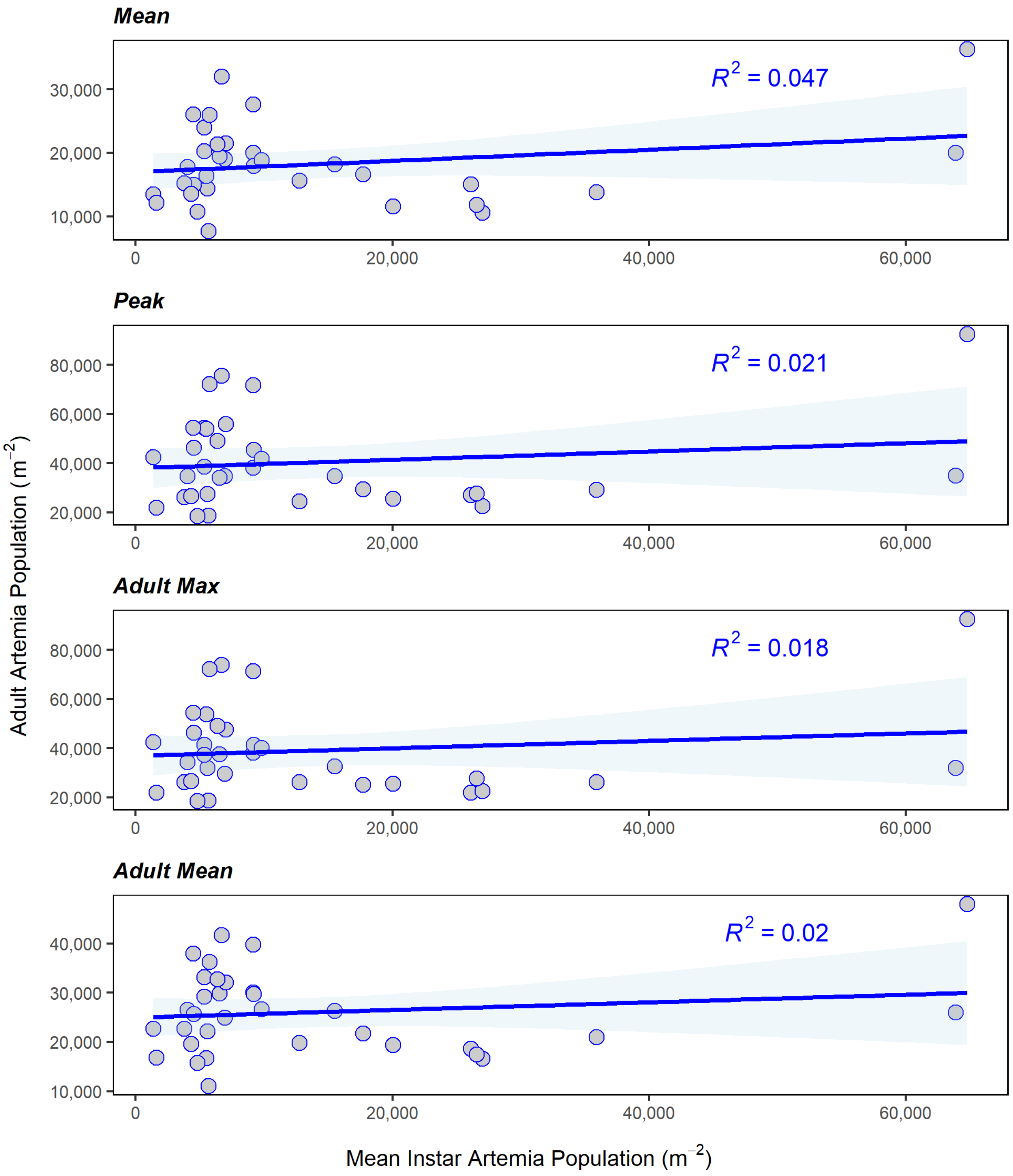


Figure 3-91. Relationships between Adult and Mean Instar *Artemia* Abundance

"Mean" and "Peak" are annual lake-wide statistics while "Adult Max" and "Adult Mean" are based on monthly lake-wide averages.

Chlorophyll *a*

Increasing food abundance in earlier months (spring to early summer) could facilitate higher growth rates of *Artemia*. Annual fluctuations of chlorophyll *a* during spring months show a positive trend at deeper depths throughout the year and at shallower depths in late spring to summer (Figure 3-72, Figure 3-74, and Figure 3-92). The positive trend has been reversed during the last three years as a fluctuation of chlorophyll *a* levels shows a cyclic pattern following the lake stratification regime as lower chlorophyll levels are found during meromictic years while higher levels are found during monomictic years. Data prior to 1995 is not available for the analysis; thus, it is not possible to assess whether a positive trend has existed including data prior to 1995. Chlorophyll levels should have been higher during the monomixis in the early 90's; and this coincided with earlier monthly population peaks between 1992 and 1995. The positive trend, therefore, may be the artifact of duration of the data; however, increasing trends of chlorophyll *a* in spring until 2017 coincide with earlier peaks of *Artemia* population.

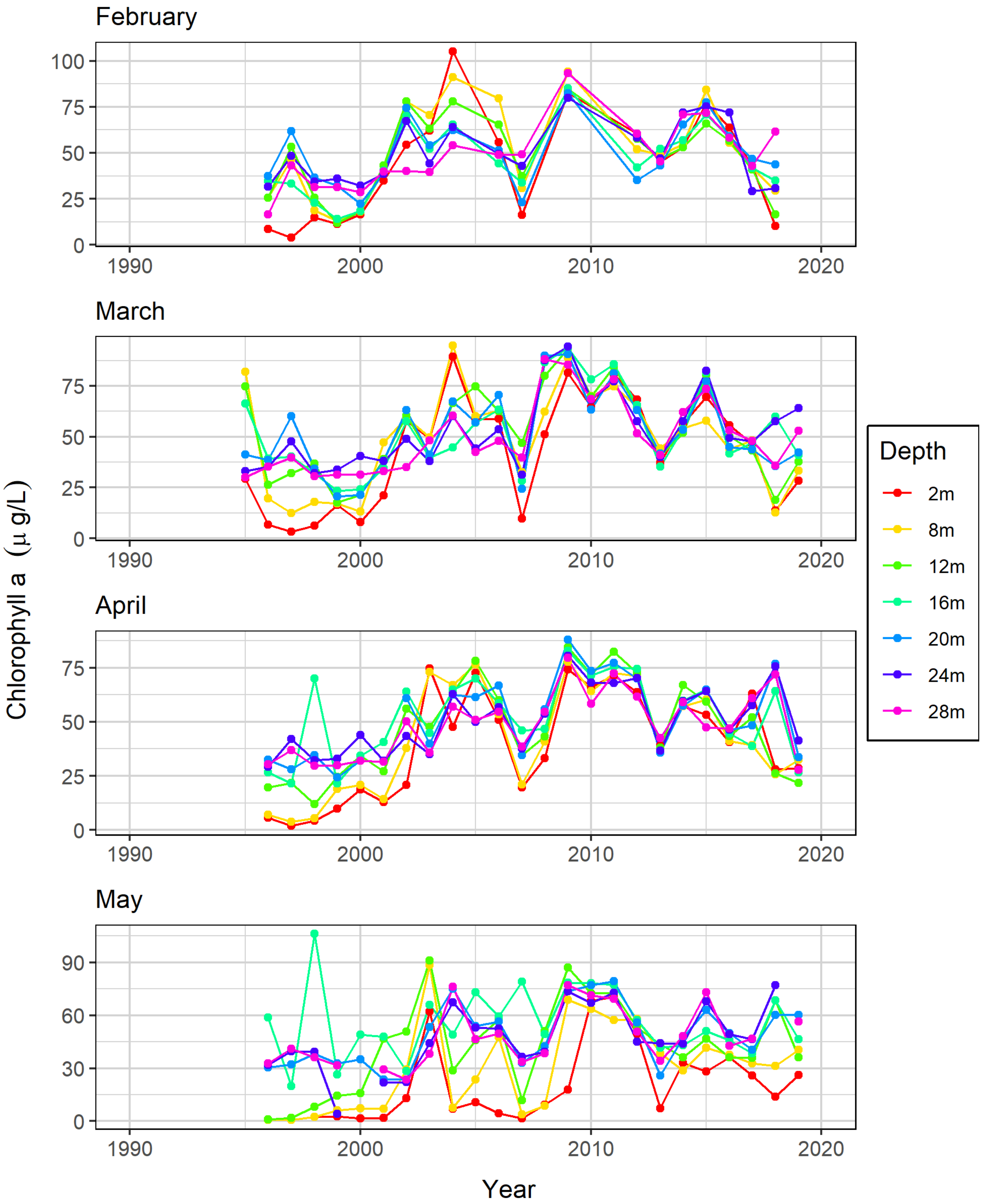


Figure 3-92. Chlorophyll *a* Level over Time at All Depths at Station 6 between February and May

Water Temperature

Following an obligate period of dormancy, warmer water temperatures during spring hatch periods are found to lead to shorter hatching times (Dana et al. 1988). Hypolimnetic water temperature remains relatively high during meromixis, reducing convection across the chemocline, and resulting in relatively warm and stable water temperature conditions in the hypolimnion. High intra-annual variability in water temperature due to holomixis during monomictic years obscures a long-term trend; however, the stable water temperature enables detection of a temporal trend. When the second meromixis (1995-2002) was compared to the latest meromixis (2017 to present), hypolimnetic water temperature during the latest meromixis was higher by approximately 0.6°C than the second meromixis (Figure 3-93). The long-term trend, however, became more evident when seasonally summarized data were used especially for summer months (Figure 3-94). Winter and spring hypolimnetic water temperature is highly influenced by the annual and long-term mixing regime; however, there is an increasing trend in water temperature after 2008. Summer hypolimnetic water temperature shows a much stronger positive linear trend for the entire period. Between 1 and 10 m of depth, however, a trend for summer months is reversed while winter and spring months show no trend (Figure 3-95). The epilimnetic water temperature was particularly low since 2015. In the hypolimnion, water temperature appears to be rising especially after the second meromixis meanwhile water temperature in the epilimnion shows a falling trend in summer. The rising hypolimnion water temperature is consistent with the trend found for *Artemia* instar monthly abundance, but earlier instar monthly peaks does not fully translate into earlier adult peaks especially since 2015 partially due to cooler summer time epilimnetic water temperatures.

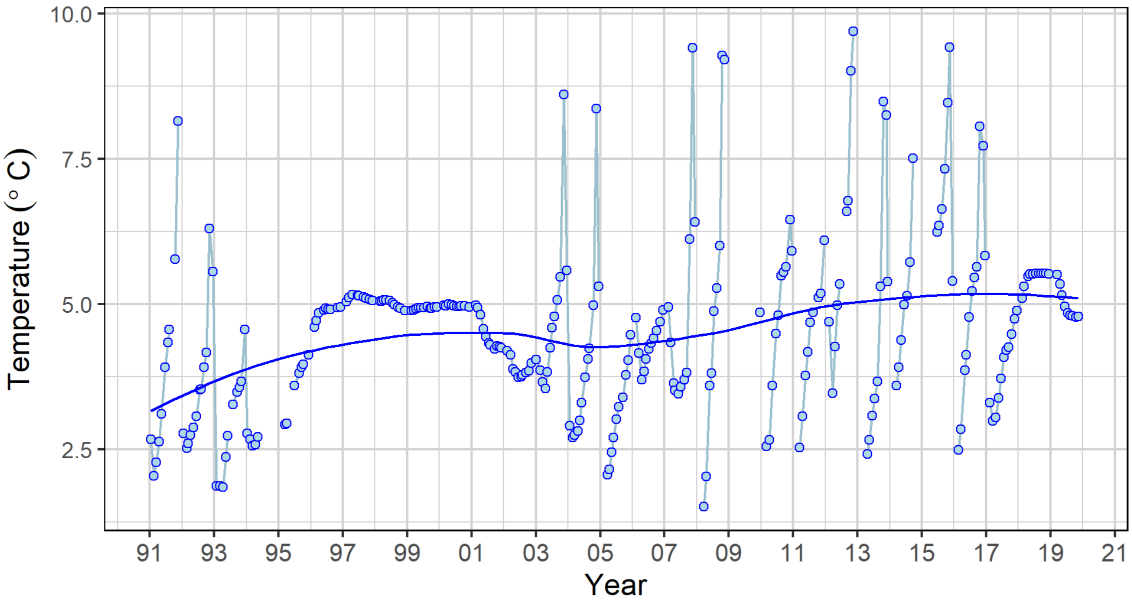


Figure 3-93. Average Water Temperature between 30 and 40 m of Depths at Station 6

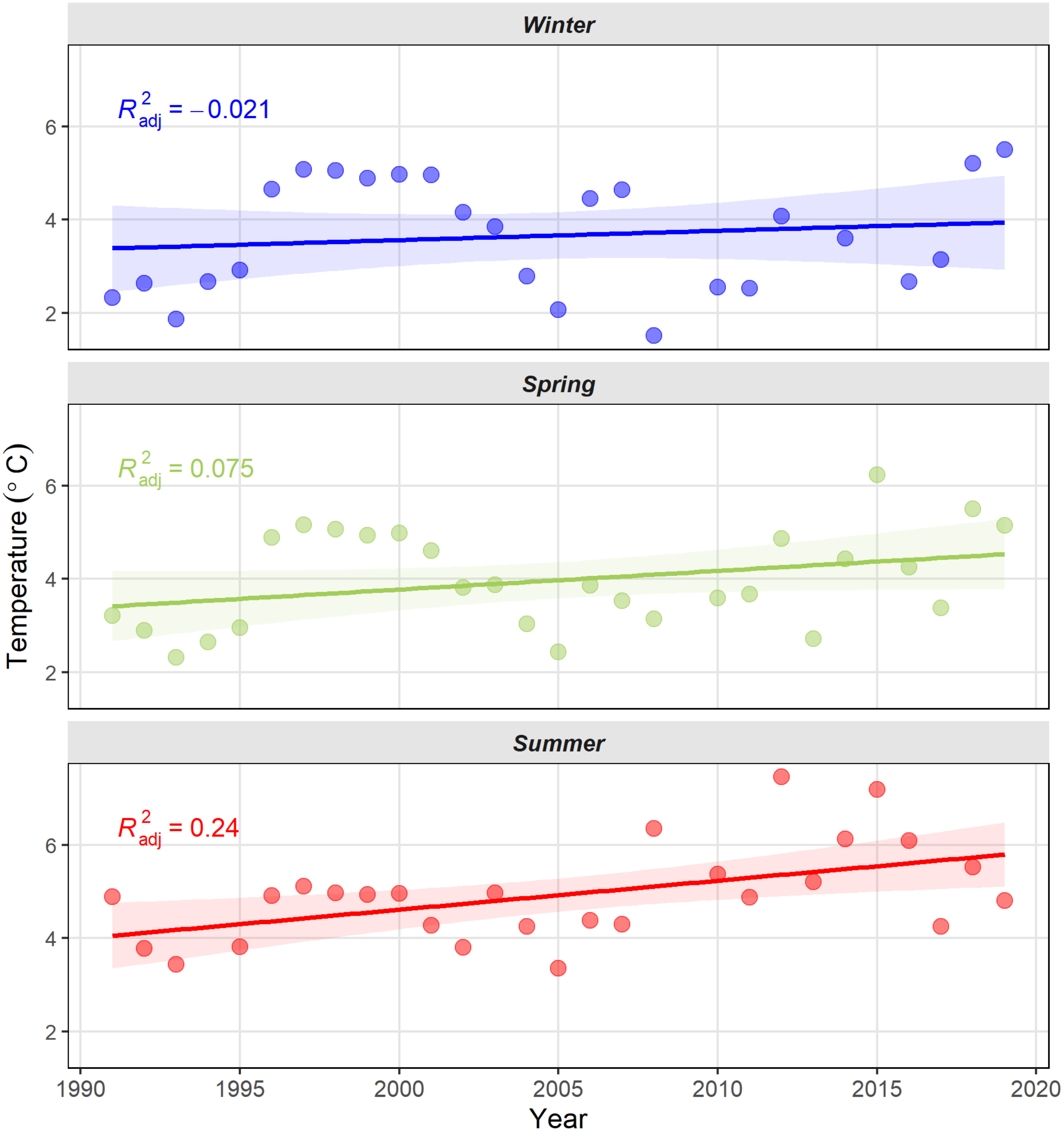


Figure 3-94. Average Water Temperature between 30 and 40 m of Depth during Winter (January to March), Spring (April to June), and Summer (July to October) Months at Station 6

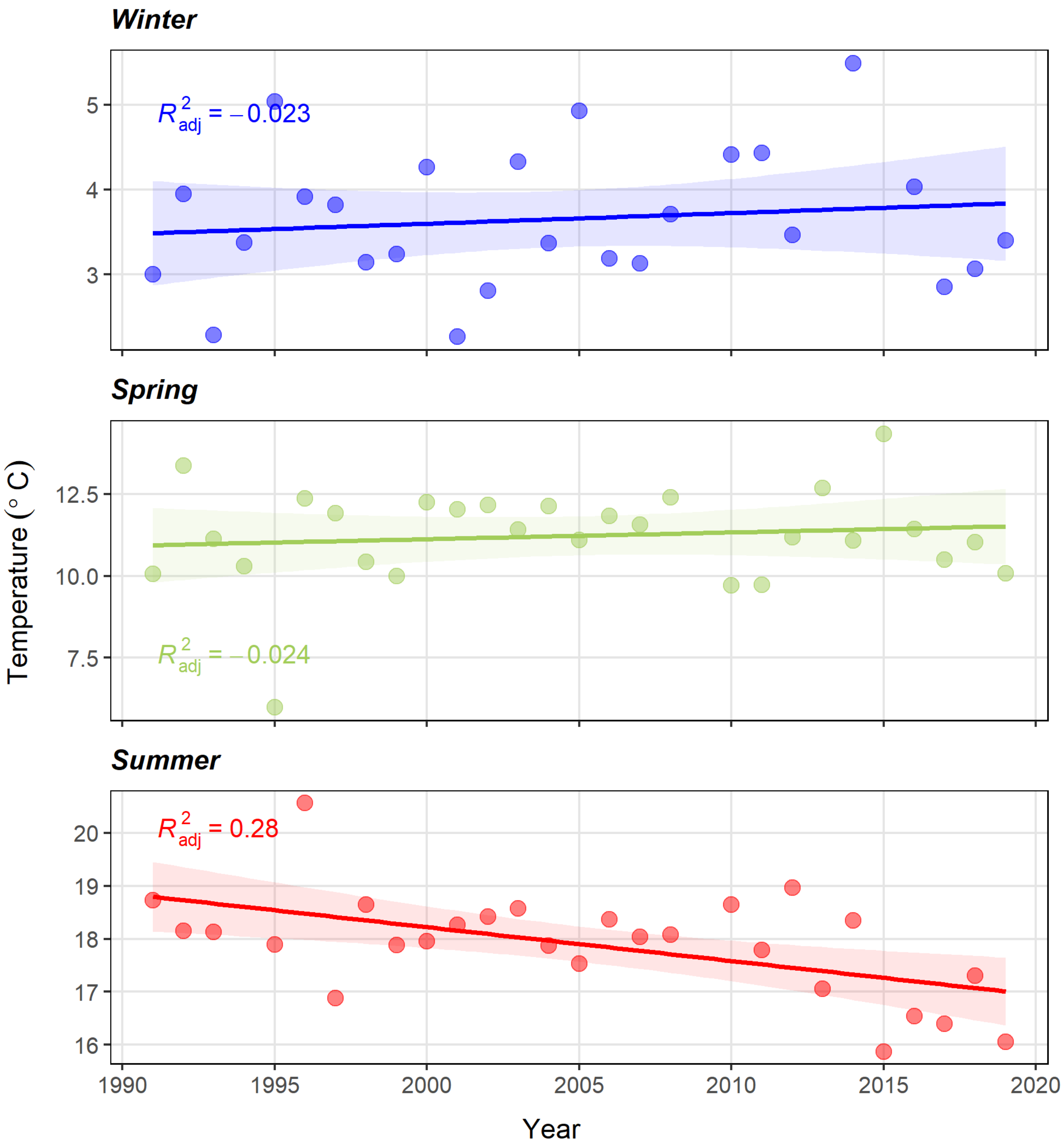


Figure 3-95. Average Water Temperature between 1 and 10 m of Depth during Winter (January to March), Spring (April to June), and Summer (July to October) Months at Station 6

3.2.4 Limnology Discussion

2019 Condition

The 2019 monitoring year marked the beginning of the 3rd year of a meromictic event that started in 2017 with the second largest Mono Lake input on record. Mono Lake rose by 4.0 feet in 2017 and rose 1.6 feet from 6,381.1 feet in January to 6,382.7 feet in August before dropping down to 6.382.1 in November in 2019. The chemocline weakened but persisted throughout the year. As a result, the hypolimnion remained suboxic to anoxic, and ammonium remained deprived from the epilimnion and accumulated in the hypolimnion. The *Artemia* population increased slightly to 13,541 m^{-2} in 2019 from 12,120 m^{-2} in 2018 but remained below the long-term average of 18,653 m^{-2}. Clarity of the lake improved slightly in 2019, mainly due to the combined high input of Rush and Lee Vining Creeks, although clarity still remained considerably below the long-term average of 7.4 m. For the fourth year in row, the centroid remained above 220 days reversing the long-term declining trend. Peak monthly instar and adult *Artemia* population abundance occurred in April and August, respectively, which is consistent with the long-term trend for instar peak but not for adult peak. Hypolimnetic water temperature during spring months was approximately 5°C in 2019, slightly higher than during the second meromixis. Chlorophyll *a* levels throughout water column in spring also show an increasing trend since 1995 until 2017. Warmer water temperature in spring may have favored earlier instar peak in 2019. The adult peak, however, did not happen until August, and a declining trend of epilimnetic water temperature could be partially responsible for slower maturity of *Artemia*, resulting in a later peak. The *Artemia* population drops consistently during the year immediately following the population peak by an average of 45%. Between 2013 and 2014 the abundance dropped from 26,033 m^{-2} to 13,467 m^{-2} (48%); thus, the 2019 abundance of 13,541 m^{-2} falls within the range of non-peak year mean based on the 2013 peak.

Long-Term Trend

There has been a clear temporal shift in peak abundance of *Artemia* instars and adults (Figure 3-79, Figure 3-80), which are reflected on a strong linear negative trend of centroid days (calculated center of abundance of adults) with respect to monitoring years (Figure 3-77). After the second meromixis, the timing of adult and instar population peaks shifted earlier. This trend was still maintained in 2015 even though it was not noticeable due to low population abundance. In 2016, the adult population peak became broader; such that, higher population abundance was maintained into August, which was responsible for higher centroid days. In 2019, a higher than normal August population was recorded for the first time since 2013. Adult population abundance was also elevated in October and November since 2017. The second meromixis appeared to have facilitated earlier occurrences of high *Artemia* abundance between May and July and subsequent two short meromictic events helped to maintain that trend until the five-year drought. Average monthly abundance between August and November clearly showed a declining trend, which reached the lowest in 2015 and since then rebounded even though these numbers were still lower than earlier years of monitoring. Drought and warmer climatic condition should enhance earlier hatching and growth of *Artemia*, resulting earlier population peaks for both instars and adult. The recent decline in population abundance during earlier months and upward swing during later months, however, suggests the climate variable alone cannot sufficiently explain a temporal trend of *Artemia* monthly peaks.

The lake mixing regime makes a detection of long-term trends in salinity and water temperature difficult. However, comparisons of these two parameters between two meromictic events (1995-2003 and 2017-present) reveals slightly higher salinity and water temperature at the depth below 30 m. On a seasonal basis, salinity and water temperature also show increasing trends especially since the end of the second meromixis. These findings are aligned with the regional climatic trends.

Future Condition

Future limnological condition of Mono Lake will largely depend on future runoff conditions. A lack of prolonged meromixis leads to smaller *Artemia* peaks and lower abundance during subsequent monomixis. Since the end of the second meromixis (1995-2002), the longest duration of a wet period is two years (2005 to 2006) which resulted in three years of meromixis. The latest meromixis (2017 to present) developed due to the second highest runoff in Mono Basin on record and maintained by the average of 108% of Normal Mono Basin runoff since then. The latest meromixis, even though showing signs of weakening, should last throughout 2020 and most likely will result in *Artemia* population peak in 2021. Ammonium accumulation between 2005 and 2007 was much smaller than the accumulation level between 1995 and 2002 due to the deeper chemocline allowing upward fluxes of nutrients earlier and also shorter duration of the meromixis. The current meromixis began with almost record breaking runoff in 2017 creating the shallower and stronger chemocline, which, in turn, has enabled continuous accumulation of hypolimnetic ammonium. The accumulation level has been much lower than during the second meromictic event but higher than the previous two meromictic events. The expected *Artemia* population peak should be lower than the one observed in 2003 but higher than the ones observed in 2008 and 2013.

A lack of sustained high freshwater input will not be able to reverse the trend of increasing salinity. When the lake level dropped by 6.8 feet salinity increased by 21 g/L to 96.6 g/L at the lake level of 6,377 feet. Not only does Mono Lake becomes saltier with a receding lake level, but evidence also suggests the lake has become saltier than before. Mono Lake is saltier now than at the equivalent lake levels between 1990s and 2010s. At 6,377 feet salinity was 96.6 g/L in 2017 while at equivalent lake elevation salinity was 85.1 g/L in August 1995. It is not clear what is causing the discrepancies in salinity; but lake level could further drop with drier and warmer climate forecasted for much of California in future (Ficklin et al. 2013). *Artemia* population appears to be able to survive and thrive in the salinity levels during monitoring years. However, further decline in the lake level could result in much higher salinity, which could approach the tolerance level (Dana and Lenz 1986).

The *Artemia* population declined to the lowest abundance on record in 2015 in response to the driest year on record; however, it has rebounded since then, showing resiliency of the *Artemia* population in Mono Lake. Historically the *Artemia* population also has demonstrated resiliency. The *Artemia* population has rebounded in spite of the lake level declining to the lowest level of the past century at 6,371.6 feet in December 1981 as Mono Lake input has started to increase. Salinity in the beginning of 2017 was the highest since 1991 despite of the lake level being almost 4 feet higher than during the early 1990s. Salinity affects survival, growth, reproduction, and cyst hatching of *Artemia* (Starrett and Perry 1985, Dana and Lenz 1986). Five years of drought between 2012 and 2016, the worst five year period on record, has resulted in the lake level declining from 6,383.6 feet in April 2012 to 6,376.8 feet in October 2016; consequently salinity between 0 and 10 m of depth increased from 75.7 g/L in August 2012 to 96.6 g/L in February 2017. Increasing salinity most likely contributed to lower *Artemia* abundance. With the second largest input into Mono Lake salinity decreased to 80.9 g/L in September and remained at 83.7 g/L in December in 2017. The *Artemia* population responded positively to declining salinity by increasing from 7,676 m^{-2} in 2015 to 15,158 m^{-2} in 2017. An amount of runoff determines lake level and salinity. Higher inputs helped the *Artemia* population to rebound in 2017, but an exceeding probability of such an event is 2% and an exceeding events of two or more years of such an event occurring consecutively is even smaller. Opportunity of the *Artemia* population recovery, prolonged meromixis, and a large reduction in salinity may become scarcer in future.

The *Artemia* population is strongly influenced by strength and duration of meromixis. Lower salinity certainly will result in a weaker salinity gradient or chemocline, such that Mono Lake could become holomictic much more easily than the current state. Without a strong and long lasting chemocline, ammonium accumulation would be lower, which would result in a lower *Artemia* population peak. A higher Mono Lake elevation, therefore, may have very limited impact on the lake's *Artemia* population; however, lower salinity associated with a higher Mono Lake level could lead to "*invasions by predators or competitors of the brine shrimp, which could reduce productivity of the brine shrimp population*" (Jones and Stokes Associates, 1994). At the same time more diverse invertebrate fauna could lead to increased food sources for shorebird and waterfowl populations.

3.3 Vegetation Status in Lake-Fringing Wetlands

3.3.1 Lake-fringing Wetland Monitoring Methodologies

Digital photographs were taken from a helicopter in order to document annual changes in shoreline conditions. Due to the dynamic nature of the Mono Lake shoreline, aerial or satellite imagery studies and subsequent mapping performed at five year intervals are not sufficient to evaluate rapid shoreline changes that occur. Annual aerial photographs are therefore a requirement of Order 98-05, and document waterfowl habitat conditions, providing more complete information to assess shoreline changes at Mono Lake.

Annual aerial photography is conducted at the three waterfowl survey areas - Mono Lake, Bridgeport Reservoir and Crowley Reservoir. Shoreline subareas were established at each waterfowl survey areas for use in evaluating the spatial distribution of waterfowl, and photos were taken of each subarea. At Mono Lake, the 15 shoreline subareas (Figure 3-96) followed those established in Jehl (2002), except for minor adjustments made in order to provide the observer with obvious landmarks that are easily seen during aerial waterfowl surveys. Bridgeport Reservoir has three shoreline survey areas (Figure 3-97) and Crowley Reservoir seven (Figure 3-98). In 2019, still photos of lake-fringing habitats were taken from a helicopter on October 8 by Deborah House, Mono Basin Waterfowl Program Director.

3.3.2 Lake-fringing Wetland Photo Compilation

The annual photographs of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoir were reviewed and compiled. Representative photos from each shoreline subarea were selected. The annual photos, combined with field notes, were used to evaluate and subjectively describe shoreline conditions in 2019.

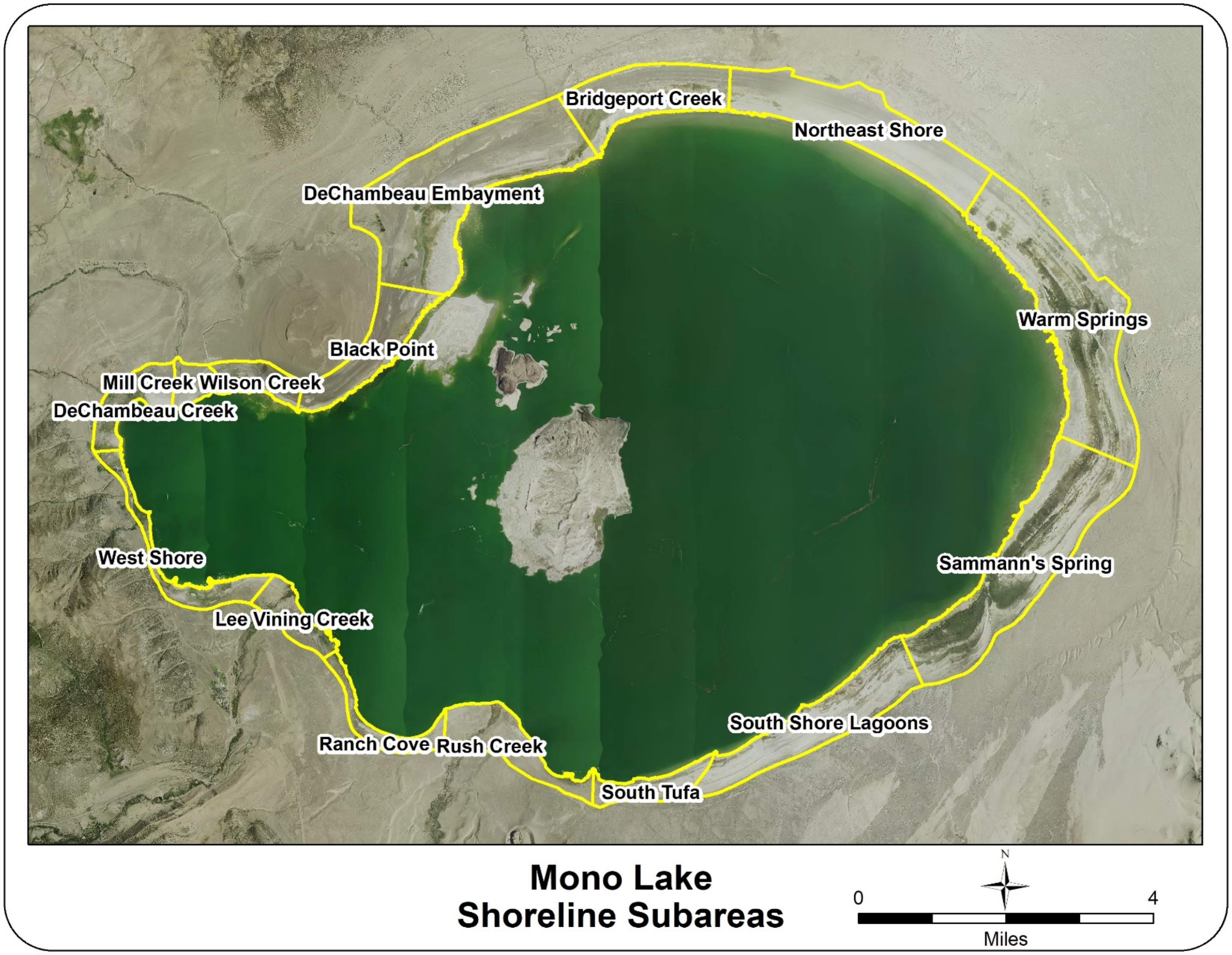


Figure 3-96. Mono Lake shoreline subareas

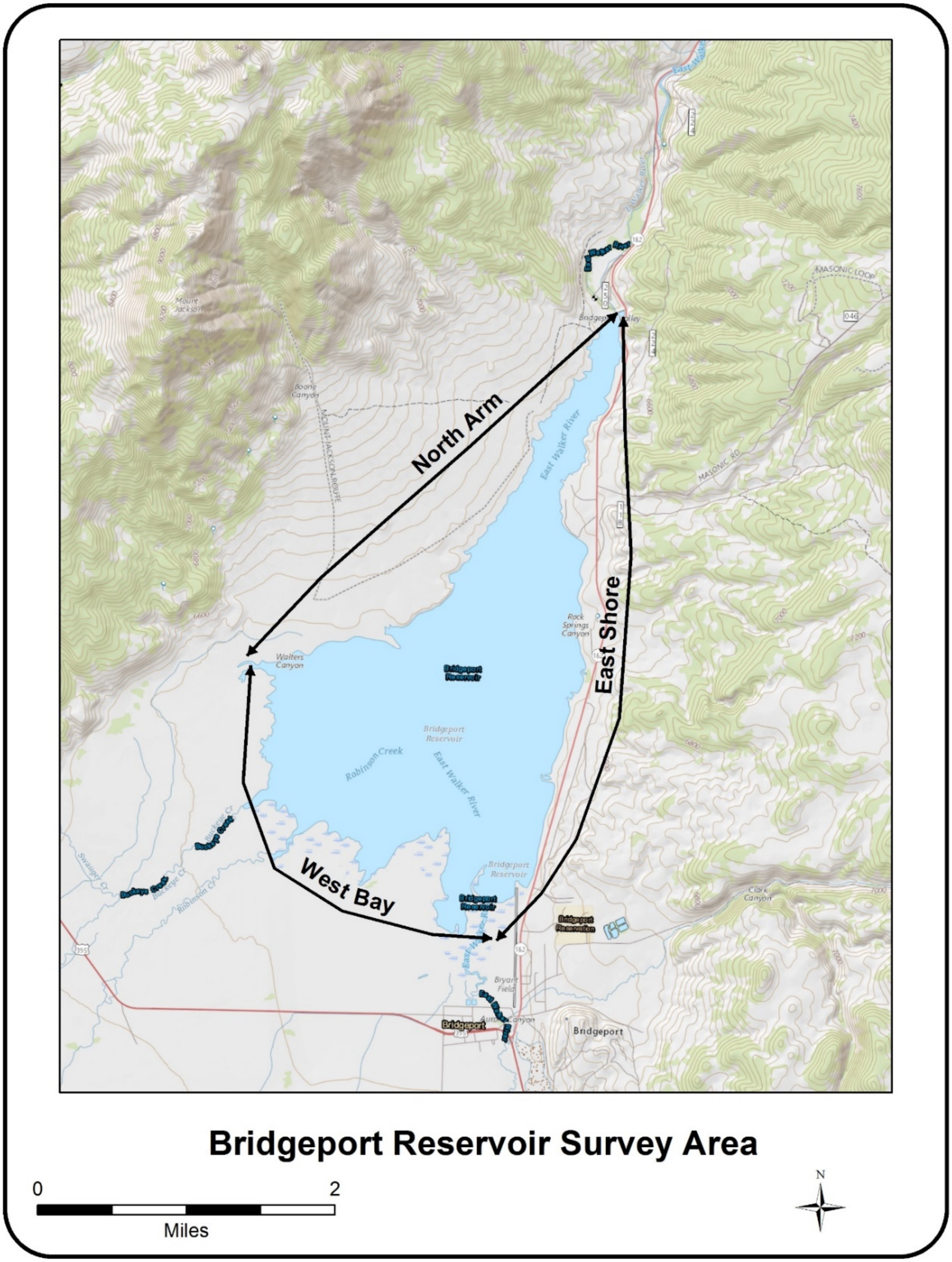


Figure 3-97. Bridgeport Reservoir Shoreline Subareas

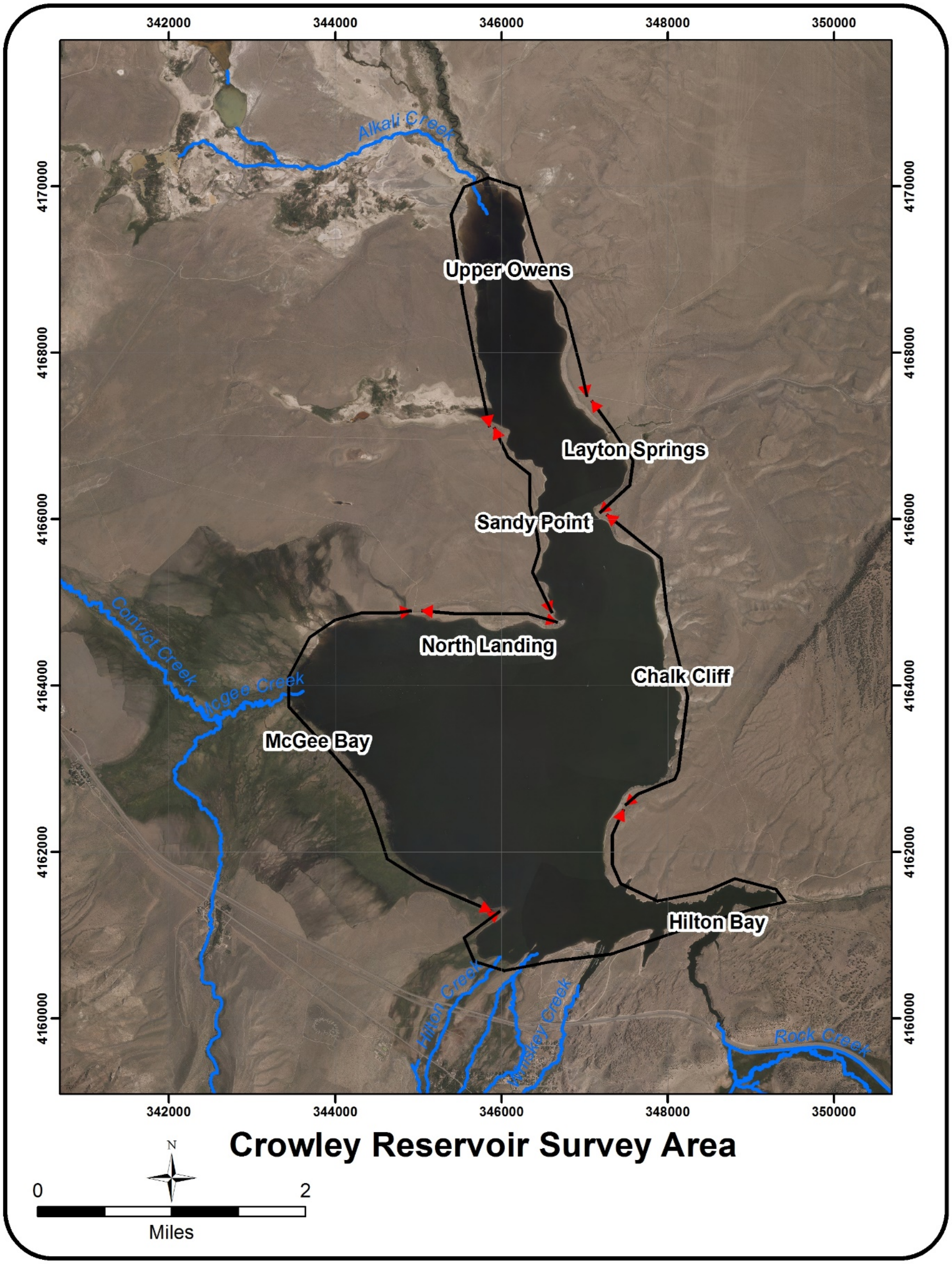


Figure 3-98. Crowley Reservoir Shoreline Subareas

3.3.3 Lake-fringing Wetland Survey Area Conditions

Mono Lake Shoreline Subareas

Black Point (BLPO)

The Black Point (BLPO) shoreline area lies at the base of a volcanic hill on the northwest shore of Mono Lake. The shoreline in this area is composed of fairly dry, loose volcanic soils. At lower lake elevations, barren shoreline and alkali meadow predominate. In the western portion of BLPO, dry alkali meadow exists as a linear strip paralleling the shoreline. In the eastern portion of the shoreline area, unmapped springs exist, alkali meadow generally extends to the shoreline creating improved foraging habitat for waterfowl. Based on a review of annual photos, brackish ponds form in the BLPO area at lake elevations above 6,382 feet, but have been absent at lake elevations below this level. In 2019, the western portion of the Black Point shoreline area was barren and dry (Figure 3-99), while the eastern half supported numerous small brackish ponds (Figure 3-100).

Figure 3-99. Black Point Shoreline Area, Western Half

Figure 3-100. Black Point Shoreline Area, Eastern Half

Bridgeport Creek (BRCR)

This shoreline area is at the terminus of the Bridgeport Creek (BRCR) drainage, however there is no surface flow of water in the creek near the lakeshore. There are several springs in this area, most of which are slightly brackish and support small brackish ponds. The other wetland resources in Bridgeport Creek are alkaline wet meadow, with small amounts of wet meadow and marsh. Waterbird use is often most concentrated at the western end of this area, where spring flow has consistently reached the shoreline at all elevations observed. At higher lake elevations, brackish ponds develop along much of the length of this shoreline area. With decreasing lake elevations, barren lake bed increases substantially without a subsequent expansion of vegetation, and brackish ponds disappear. The bathymetry indicates a gradual offshore slope in this area, and there is a shallow shelf just offshore (LADWP 2018). In 2019, the eastern portion supported primarily dry meadow vegetation and shoreline ponds were absent (Figure 3-101). The western portion of BRCR was fairly dry in 2019, supporting only one small brackish pond (Figure 3-102).

Figure 3-101. Bridgeport Creek Shoreline Area, Eastern Portion

Figure 3-102. Bridgeport Creek Shoreline Area, Western Portion

DeChambeau Creek (DECR)

The DeChambeau Creek (DECR) shoreline area is along the northwest shore of Mono Lake. The flows in DeChambeau Creek are intermittent, and do not consistently reach the lakeshore. The DECR area has abundant shoreline freshwater resources due to the numerous springs.

The freshwater springs at DeChambeau Creek support wet meadow, mudflats, and riparian scrub. During periods of declining lake levels, wet meadow vegetation expands onto exposed mudflats due to the abundance of freshwater spring flow. During periods of subsequent increasing lake elevations, the wet meadow vegetation, mudflats, and playa become inundated, leaving little exposed shoreline. The drop in lake elevation after 2011 resulted in erosional headcutting along several of the spring channels, and increased spring channel depths near the lake shore. Increases in barren lake bed area with declining lake elevation are much less substantial in the DECR. An area of ria is expected to occur at the outflow of each spring, although the extent of ria offshore is expected to vary with spring flow. The bathymetry indicates a gradual offshore slope only near the shore in this area (LADWP 2018).

In 2019, wetland vegetation extended to the shoreline throughout most of the DECR area, leaving only a narrow band of barren shoreline and mudflat habitat (Figure 3-103). A small beaver dam near shore was first noted in this area in 2014. Beaver activity has since resulted in the die off of coyote willow and the creation of small ponds just off shore (Figure 3-104).

Figure 3-103. The DeChambeau Creek Area, Looking Northeast

Lake level increase inundated shoreline vegetation, and shoreline mudflats in fall 2019.

Figure 3-104. The DeChambeau Creek Area, Looking Southwest

In the center of the photo there is an area of dead, gray *Salix exigua*. This is where there is beaver activity and flooding.

DeChambeau Embayment (DEEM)

The DeChambeau Embayment (DEEM) area lies just east of the DeChambeau Ranch, and the DeChambeau and County Restoration ponds. Water management has changed significantly in the DEEM area as historically, Wilson Creek discharged to the lake in the DeChambeau Embayment area, and irrigation of the DeChambeau Ranch may have also influenced the conditions.

The wetland resources in DeChambeau embayment include alkaline wet meadow, small amounts of marsh, and several small brackish ponds. There are fresh, slightly brackish and moderately brackish springs in this area, the largest of which - Perseverance Spring - is slightly brackish. Spring flow has reached the lake at all elevations observed.

The bathymetry of the shoreline and offshore area is more complex than other subareas. Very shallow sloping topography exists nearshore in the southern portion of the subarea, with a deeper bay just offshore. Tufa blocks litter the entire subarea, and are most often visible in the southern portion of this area due to the topography and shallow nearshore waters (Figure 3-105). At the higher lake elevations observed, the tufa blocks become partially to completely submerged and the shallow nearshore areas expand. As the lake level drops, this shoreline area experiences rapid increases in the acreage of barren lake bed and a land bridge forms with an offshore island, as was last seen in 2015. At more extreme low lake levels, such as those observed in 2016, the geographic extent of the tufa blocks in the eastern portion of the subarea were revealed (LADWP 2018). The eastern portion of the shoreline in this subarea has a gradually sloping shoreline which extends offshore.

In 2019, small, isolated brackish ponds were present, primarily along the eastern extent of the shoreline (Figure 3-106).

Figure 3-105. DeChambeau Embayment, Western Extent

The western extent of this shoreline area, looking northeast.

Figure 3-106. DeChambeau Embayment, Eastern Extent

The eastern extent of this shoreline area, looking northeast.

Lee Vining Creek (LVCR)

Lee Vining Creek (LVCR), 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 during the remainder of the year. Peak flows typically occur in June or July in any given year, but may 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 1996b). Channel maintenance and flushing flows, referred to as “stream restoration flows” were established in order to mimic seasonal snowmelt runoff, with the magnitude of the flow based on the hydrological conditions for the year (SWRCB 1994).

Lee Vining Creek is a woody riparian system. The lower reaches of Lee Vining Creek and its delta support small patches of wet meadow vegetation. The creek supplies abundant freshwater year round, which remains confined to the main channel under low flow conditions, but inundates the lower floodplain under high flow conditions. At higher lake levels, the delta becomes flooded with lake water, inundating the willows and wet meadows close to shore, resulting in some dieback of willows and freshwater emergent vegetation from salt water stress. During periods of descending lake elevations, freshwater ponds may form behind littoral bars. At the extreme low lake elevation observed in 2016, extensive drying of the delta meadows occurred. Ria extends offshore beyond the mapping boundary of Lee Vining Creek subarea, due to flows from Lee Vining Creek, however this waterfowl resource is not captured by landtype mapping (LADWP 2018).

Bathymetry of the area indicates limited shallow water areas near shore. Shallow sloping areas of water are limited to the delta and near the tufa grove, but depths rapidly increase lake-ward (LADWP 2018).

In 2019, the lake level was such that the southern portion of the delta was partially inundated by lake water (Figure 3-107). In the northern portion of the delta, vegetation encroachment of the fresh water pond near shore resulted in little open water. Dense wetland vegetation covered most of the delta leaving little exposed playa.

Figure 3-107. Lee Vining Creek Delta

Mill Creek (MICR)

Mill Creek (MICR), Mono Lake's third largest tributary originates in Lundy Canyon.
The Mill Creek delta is dominated by dense stands of shrub willow (Figure 3-108). Beaver activity in the delta since at least 2012 has resulted in fresh water ponds in amongst the willows. No springs have been identified in this area, however freshwater often enters the lake at several points in the delta due to seepage through the loose volcanic soils. Previous bathymetry studies have indicated the creek mouth constitutes the only shallow areas in the Mill Creek delta area.

High flows over the last three years have created a deep channel at the mouth of the creek. Just upstream of the creek mouth, the channel forms a deep glide up to 6 feet deep that supported high densities of brine shrimp in 2019.

Figure 3-108. Mill Creek Delta

Northeast Shore (NESH)

In the Northeast Shore (NESH) area, extensive areas of barren playa dominate at most lake elevations as the groundwater is too saline to support vegetation. Barren playa comprises 99% of the Northeast Shore area, and only small amounts of alkali meadow are present.

At the higher lake elevations, extensive ponds have formed along the length of the shoreline segment. Although there are no known mapped springs in this reach, some are evident (D. House, pers. obs.) (Figure 3-109). Ephemeral ponds observed along Northeast Shore at elevated lake elevations are presumed to be brackish as flow from springs in adjacent subareas are likely contributing to creation of these ponds. Salinity of these ephemeral ponds may also be influenced by groundwater input. Historically, large perennial brackish ponds were present along the northeast shore. These historic ponds persisted in depressional areas above the high water mark and above the target lake level for Mono Lake. In contrast to the perennial nature of these historic ponds, the ponds observed along the northeast shore have only been observed to persist a single season. Bathymetry studies indicates a very gradual sloped shoreline in this subarea. In 2019, the Northeast Shore area consisted primarily of dry playa, as is typical (Figure 3-110).

Figure 3-109. An Unnamed Spring Along Northeast Shore

Figure 3-110 Northeast Shore, Looking North

The salinity of the groundwater in this area prevents vegetative growth.

Ranch Cove (RACO)

The Ranch Cove (RACO) shoreline area is a relatively small area located between Rush Creek and Lee Vining Creek. The shoreline area is narrow and generally dry, supporting primarily coyote willow (*Salix exigua*), rabbitbrush, upland scrub, and barren playa. This shoreline area has not shown significant changes with lake elevation. Waterfowl resources are limited in this area, and there is no direct spring flow evident.

Bathymetry shows essentially no shallow area in this shoreline subarea, and a steeply sloped shoreline. As is typical, in 2019 Ranch Cove showed no onshore ponds or direct spring input (Figure 3-111).

Figure 3-111. Ranch Cove Shoreline Area, Looking Southwest.

Rush Creek (RUCR)

Rush Creek (RUCR), 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 dating back to the 1860s of diversion of Rush Creek flows for irrigation. Water diversion by LADWP for export 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. Floodplain incision then drained shallow groundwater tables and left former side channels stranded above the newly incised main stream channel (SWRCB 1994). Under Decision 1631, LADWP developed a stream restoration plan and has undertaken projects to rehabilitate Rush Creek (LADWP 1996b). 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 wetland resources available at Rush Creek are primarily meadow and woody riparian vegetation (*Salix* spp.) and the creek supplies abundant freshwater year round. Just upstream of the delta, the floodplain is a broad meadow supporting scattered shrub willows. At higher lake levels or high creek flows, flooding has extended across the delta mouth. During periods of lake elevation recession, much channel braiding exists in the delta. From 2002 through 2014, side channels distributed water through the lower floodplain, creating saturated conditions, fresh water channels, and a stable fresh water pond along the eastern edge. In 2014, headcutting along the mainstem resulted in channel erosion, and side channel abandonment. By the following summer of 2015, pond and channels used by breeding waterfowl in the delta area disappeared as the lower floodplain experienced significant drying. Rush Creek flows create an area of ria that is expected to extend well beyond the delta.

In 2019 much of the delta area was fairly shallow due to sediment deposition. Partial sandbars existed in the mouth, creating protected areas within the delta (Figure 3-112). The long glide just upstream of the delta continues to be was present and attracted many of the waterfowl seen in the Rush Creek delta area.

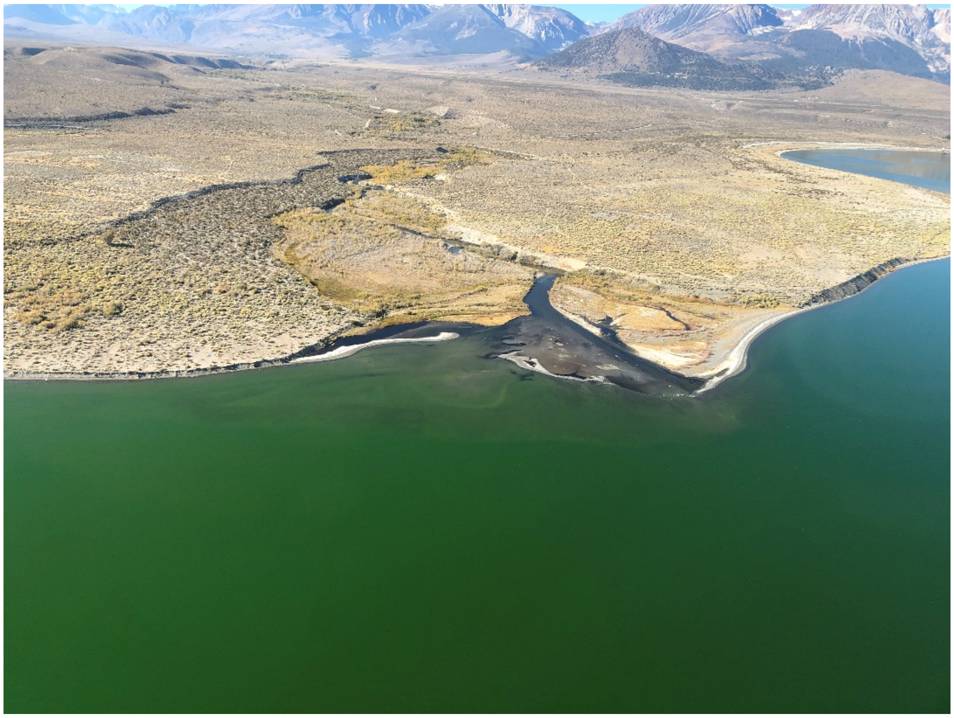


Figure 3-112. Rush Creek Delta

Features of the delta in 2019 include shallow waters due to sediment deposition, and a broken sandbar at the mouth, creating protected areas of ria in the delta.

Simons Spring (SASP)

The Simons Spring subarea (SASP) includes the southeastern portion of the lakeshore. Located centrally in the subarea is the Simons Spring faultline, a conspicuous feature on the landscape. Several large springs arise from the fault, conducting groundwater to the surface (Rogers et al. 1992). Being subject to the action of longshore currents, shoreline features of Simons Spring are dynamic, particularly west of Simons Spring faultline. Due to the shoreline gradient, small changes in lake elevation result in large changes in the degree of shoreline flooding.

Open fresh water ponds are a prominent feature of the Simons Spring area, however their presence tends to be ephemeral, especially west of Simons Spring fault. Over the years, longshore currents have resulted in the development of several parallel littoral bars west of the Simons Springs faultline. These littoral bars retain upgradient spring flow and support the creation of ponds, wet meadow, and marsh behind the sandbars. During periods of increasing lake level, lake water inundates areas supporting wetland vegetation upgradient of littoral bars. The vegetation dies back due to salt stress, opening up areas previously grown over with marsh or meadow. During subsequent decreases in lake level, open fresh water ponds have developed, supported by inflow from up gradient springs. Many of the freshwater springs in this area reach the lakeshore through breaks in littoral bars, creating extensive mudflats on exposed playa. Although there may be a physical connection between the mudflats and lake water, the very shallow ponds formed on shore are fresh due to the high spring flow, and are colonized within 1-2 years by wet meadow vegetation. In summer of 2015, headcutting commenced along the westernmost spring channels with the continued decline in lake elevation. This resulted in a drying of the exposed playa in the westernmost part of this subarea. Terminal and Abalos spring at the faultline did not experience headcutting, and mudflats remained, and supported most of the bird activity in this area.

Just east of the Simons Spring faultline, permanent to semi-permanent brackish water ponds are generally present year-round. The remainder of the subarea to the east lacks spring flow to the lake and supports alkali wet meadow up gradient and barren playa on shore.

Although not mapped as a landtype in this area, ria likely occurs due to the multiple areas of spring flow that reach the lake shore. The bathymetry indicates a more gradual offshore slope in the western half of the subarea, a steep offshore slope where the tufa towers of the faultline reach shore, and an increasing shallow slope to the east (LADWP2018).

In 2019, increases in lake elevation resulted in the inundation of wetland vegetation and shoreline ponds (Figure 3-113). Brine fly were noticeably abundant along the entire length of the Simons Spring shoreline area, and especially in areas where flooding had inundated shoreline vegetation. Shoreline ponds were present along much of the length of the shoreline east of the fault line in 2019 (Figure 3-114). The wetland vegetation around several of the springs have been heavily grazed by feral horses that have colonized the area.

Figure 3-113. Simon's Spring, West of the Faultline

Increasing lake elevation in 2019 resulted in the inundation of wetland vegetation and shoreline freshwater ponds by lake water.

Figure 3-114. Simon's Spring, East of the Faultline

Shoreline ponds were present along much of the length of the shoreline in this area in 2019.

South Shore Lagoons (SSLA)

The South Shore Lagoons is a broad stretch of shoreline with scattered waterfowl habitat features. Waterfowl habitat features include permanent freshwater ponds supported by springs, and seasonal to semi-permanent ponds supported by groundwater, and ephemeral brackish ponds. Like Simons Spring, the shoreline configuration in the South Shore Lagoons subarea is influenced by longshore currents.

At the western border of the subarea, a pond exists along a faultline. This pond has been ephemeral, and its presence a function of lake elevation. At the higher lake elevations observed (approximately 6,383 feet), the pond has been full. Below approximately 6282.5 feet, the pond experiences notable contraction in size and as at elevations below 6,381.9 feet has been absent.

Sandflat Spring is an isolated freshwater spring supporting two small freshwater ponds, an upper pond, and a lower pond, surrounded by coyote willow. These were open water ponds until 2014, when water speedwell (*Veronica anagallis-aquatica*) and cattails (*Typha* sp.) encroached and enclosed the open water.

At the east end of the subarea is the Goose Springs complex. Goose Springs is a large spring complex that forms a series of interconnected freshwater ponds surrounded by wet meadow and marsh. In some years, the development of a littoral bar downgradient has captured spring flow, creating large onshore ponds that can be either fresh or brackish.

Away from the immediate shoreline in this subarea, the terrain is sandy hummocks with numerous small, depressions supporting alkali meadow in most years. Groundwater levels in this area have been found to be responsive to lake elevation changes (Rodgers et al. 1992) due to the high topographic gradient and very permeable soils. In 2006 and 2007 when the lake elevation was at its highest observed (above 6,385 feet), these scattered wetlands filled with groundwater, creating a series of scattered fresh water ponds in the South Shore Lagoons subarea.

In 2019, the brackish lagoon at the western extent of the subarea was flooded (Figure 3-115). Vegetation encroachment has also impacted waterfowl habitat at Sand Flat Spring and very little open water was present in either the upper or lower ponds (Figure 3-116). In the Goose Springs area of South Shore Lagoons, the formation of a narrow littoral bar formed an extensive brackish pond on shore (Figure 3-117). Multiple ponds were present in the Goose Springs area including fresh water ponds at the spring heads, a large open freshwater pond downstream of the springheads, and a large brackish pond immediately on shore (Figure 3-118).

Figure 3-115. South Shore Lagoons, West

The brackish lagoon at the western extent of the subarea was flooded again in 2019.

Figure 3-116. Sand Flat Spring

There was very little open water in either the upper or lower pond due to vegetation encroachment.

Figure 3-117. Overview of the Goose Springs Area

Increasing lake levels through the summer of 2019, resulted in the inundation of a shoreline pond immediately downstream of Goose Springs.

Figure 3-118. Goose Springs

In 2019, multiple ponds were present including fresh water ponds at the spring heads, a large open freshwater pond downstream of the springheads, and a large brackish pond immediately on shore.

South Tufa (SOTU)

The South Tufa area (SOTU) is the primary visitor access point to the Mono Lake shoreline and includes a large display of tufa towers. The western portion of the survey area, just east of the tufa towers differs notably in terms of waterbird habitat from the eastern portion, just east of a small tufa prominence onshore between the South Tufa access point and Navy Beach. In the western portion, the shoreline is narrow, the offshore topography steep, and the brackish springs creating wet mudflat conditions under most lake levels observed. East of the prominence the shoreline is very gradually sloped onshore as well as offshore. The eastern portion supports an ephemeral brackish pond whose presence has varied as a function of lake elevation and season. At somewhat intermediate lake elevations, the pond has persisted from summer through fall. In periods of lower lake elevation the brackish pond has been present in summer, but generally dries by fall.

During the summer of 2019, the lake elevation was such that there was very little exposed beach on the west half (Figure 3-119). A narrow brackish shoreline pond extended the length of the eastern portion from summer through fall (Figure 3-120).

Figure 3-119. South Tufa

The western portion of the South Tufa shoreline area had very little exposed beach due to the rise in lake level.

Figure 3-120. South Tufa, Eastern Extent

By fall, the extensive but narrow brackish pond was present throughout summer and fall.

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 a permanent brackish pond fed by the outflow of Pebble and Twin Warm Springs (referred to as “north pond”). These and other springs in the area support extensive wet meadow, alkali meadow, and marsh vegetation, primarily around the pond and springheads. The springs in the Warm Springs area are slightly to moderately brackish.

The north pond has been present at all lake elevations observed. Some expansion and contraction have occurred, with the pond at its largest extent in 2006. This pond is the only place in the Warm Springs subarea where waterfowl are consistently encountered. Due to the very gradual sloping shoreline in this area, small changes in lake elevation result in large differences in the amount of exposed playa on shore. Longshore action has also shaped this shoreline as evidenced by the prominent littoral bars creating the north pond and ponds downgradient. During periods of declining lake elevation, seepage of water from the north pond through the loose sandy soil results in the development of ephemeral brackish ponds downgradient of the north pond as was noted in 2010 (LADWP 2018). Due in part to their ephemeral nature, vegetation development was not observed in these nearshore brackish ponds. In the summer of 2014, shoreline subsidence of approximately one foot was seen in the vicinity of the north pond. From 2014-2016, several new springs appeared in the expanse of exposed playa that developed in response to a significant drop in lake level. Since 2014, some drying of the wetlands has been noted.

In 2019, extensive flooding and numerous brackish ponds existed in the Warm Springs area (Figure 3-121). The north pond (Figure 3-122) retains open water and has not experienced vegetation encroachment as has been observed in the fresh water marshes at Mono Lake. In summer, adult brine fly appeared to be very abundant along the shoreline of Warm Springs. Additionally, brine fly were present in high numbers on the water surface of Mono Lake in summer. A wild horse herd of approximately 300 individuals with colts was present in early June at Warm Springs, and again in fall. Well-developed livestock trails now exists in the area, with feeding concentrated near springs.

Figure 3-121. Overview of Warm Springs

The outflow channel of Pebble Spring in the foreground feeds a permanent brackish pond nearshore.

Figure 3-122. Warm Springs, North Pond, Looking West.

West Shore (WESH)

The majority of the West Shore subarea (WESH) is located immediately east of Highway 395, along a steep fault scarp. While some shallow gradient areas exist along the southern boundary, the majority of the area is steeply sloping lakeward. Several fractured rock gravity springs (LADWP 1987) and two small drainages, Log Cabin Creek and Andy Thom Creek provide fresh water resources along the length of this shoreline subarea, although ponds are lacking. A very narrow beach exists along much of the length and becomes inundated at higher lake elevations. Significant changes have not been noted in the configuration of this shoreline subarea with lake elevation changes. The lake level increase since 2017 has reduced barren playa in the area (Figure 3-123).

Figure 3-123. Overview of the West Shore, Looking North/Northwest

Wilson Creek (WICR)

Wilson Creek is along the northwest shore. Wilson Creek supports a large expanse of wet meadow, multiple fresh water springs, and mudflats. The Wilson Creek subarea has the second highest median spring flow of the monitored springs. Due to the shoreline configuration and presence of large tufa towers, this subarea has two protected bays. Submerged pumice blocks are present throughout the shallows of the eastern portion of the subarea. The bathymetry indicates a very gentle sloping topography throughout the protected bays and all along the shoreline. Due to the shelter, spring flow, and shallow waters near shore, the hypopycnal layer may be extensive in this area. The spring flow and shallow waters also lend toward the formation of mudflats, which have been present at most lake elevations observed. At the lowest elevation observed (2016), the retreat of shoreline resulted in some loss of the protection of the bays, however, mudflats were still prominent due to the high spring flow. The extreme low lake elevation observed in 2016 allowed an opportunity to visualize the near shore topography and the significance of spring flow to Wilson Creek bay (LADWP 2018). The topography is very gently sloping throughout the entire bay, extending out beyond the mouth of the bay and east of Tufa Mound spring. The high spring flow in this area combined with the sheltered nature of the bay is conducive to creating hypopycnal conditions. Even at higher lake elevations, such as in 2012, hypopycnal conditions would likely occur across the bay except under windy conditions, due to the high spring flow and contribution from Wilson Creek to the west in 2012. The shallow areas in the bay would make food more accessible to waterfowl. The high spring flow conditions combined with the sheltering of the bay and shallow waters support ideal feeding and loafing conditions for waterfowl at Mono Lake.

In 2019, mudflat areas were limited in the bay due to the increase in lake elevation since 2017 (Figure 3-124). A sheltered pond created by the outflow of Wilson Creek was present near the western border of the shoreline subarea (Figure 3-125).

Figure 3-124. Wilson Creek Bay, as Viewed From the Northeast

The outflow of two springs, Black Point Seep and Scoria Tufa enter the bay from the northeast. Limited mudflats were present in 2019.

Figure 3-125. Wilson Creek Bay, as Viewed From the West

Wilson Creek flows created a large nearshore pond along the western portion of the shoreline area.

Bridgeport Reservoir Shoreline

All three shoreline segments at Bridgeport Reservoir: North Arm, West Bay, and East Shore are shown in Figure 3-126. The North Arm seen at the far end of the photo is in the narrowest part of the reservoir and includes primarily sandy beaches bordered by upland vegetation. 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 water level in the reservoir is higher. The West Bay also receives extensive seepage and runoff from the adjacent irrigated pastures. 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. In 2019, elevated reservoir levels resulted in the creation of extensive shallow feeding areas near the deltas of the East Walker River, Robinson and Buckeye Creeks.

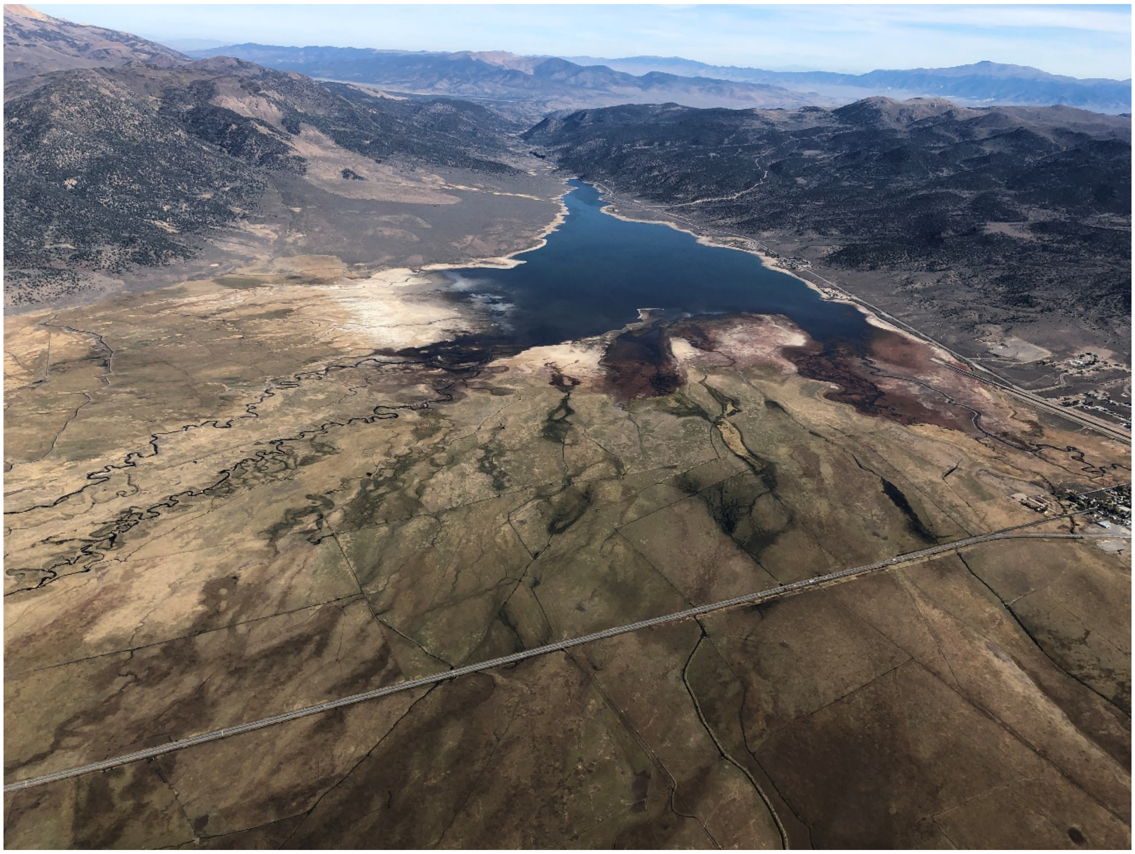


Figure 3-126. Bridgeport Reservoir, Looking North

Crowley Reservoir Shoreline Subareas

The major source of fresh water input to Crowley Reservoir is the Owens River. Other fresh water input includes flows from McGee and Convict Creeks, Layton Springs, and subsurface flow from other springs along the west shore. Vegetation communities immediately surrounding Crowley Reservoir include irrigated pasture, wet meadow, Great Basin scrub, alkali meadow, and mudflats.

Chalk Cliffs (CHCL)

The Chalk Cliffs subarea lacks fresh water inflow areas and wetland habitats, and is dominated by sandy beaches adjacent to steep, sagebrush-covered slopes (Figure 3-127). In the October 2019 photo of the Chalk Cliffs area, a heavy growth of algae is visible.

Figure 3-127. Chalk Cliffs

Hilton Bay (HIBA)

Hilton Bay includes Big Hilton Bay to the north and Little Hilton Bay to the south (Figure 3-128). The Hilton Bay area, surrounded by meadow and sagebrush habitat, receives small amounts of fresh water input from Hilton Creek, Whiskey Creek, and area springs.

Figure 3-128. Hilton Bay

Layton Springs (LASP)

The Layton Springs shoreline area is bordered by upland vegetation and a sandy beach. Layton Springs provides fresh water input at the southern border of this lakeshore segment. In the October 2019 photo of the Chalk Cliffs area (Figure 3-129), a heavy growth of algae is visible.

Figure 3-129. Layton Springs

McGee Bay (MCBA)

The McGee Bay shoreline area supports mudflat areas immediately adjacent to wet meadow habitats. McGee Creek and Convict Creek are tributaries to Crowley Reservoir in this shoreline area (Figure 3-130). Vast mudflats often occur along the west shore of Crowley Reservoir, as this areas receives inflow from springs and subsurface flow from up-gradient irrigation. In 2019, the increased reservoir level resulted in an inundation of much of the mudflat area in McGee Bay (Figure 3-130, Figure 3-131).

Figure 3-130. McGee Bay shoreline south of McGee and Convict Creek outflow

Figure 3-131. Mudflat Habitat in the McGee Creek Shoreline Area

North Landing (NOLA)

The North Landing area is influenced by subsurface flows and supports meadow, wet meadow and mudflat habitats (Figure 3-132). In the October 2019 photo of the North Landing area, a heavy growth of algae is visible.

Figure 3-132. North Landing

Sandy Point (SAPO)

Most of the length of Sandy Point area 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. In the October 2019 photo of the Sandy Point area (Figure 3-133) a heavy growth of algae is visible.

Figure 3-133. Sandy Point

Upper Owens River (UPOW)

The Upper Owens River receives direct flow from the Owens River, the largest source of fresh water to Crowley Reservoir. This subarea includes large areas of exposed mudflats and reservoir bottom (Figure 3-134). Heavy algal growth was observed in this area of the lake in October.

Figure 3-134. Upper Owens Delta

3.3.4 Lake-fringing Wetland Condition Discussion

The increase in level of Mono Lake in 2019 resulted in somewhat predictable shoreline changes. At Mono Lake, the acreage of lake-fringing ponds has been a function of lake elevation (LADWP 2018, LADWP unpublished data). Shoreline ponds were present in multiple shoreline subareas in 2019. Shoreline ponds develop more readily along the south and east shores, which corresponds to South Tufa, South Shore Lagoons, Simon's Spring and Warm Springs, and the presence and formation of these ponds are influenced by lake level, wind and wave action. Increases in lake level also restore the connectivity of existing ponds with the water line and spring outflow areas of Mono Lake. In areas of continuous fresh water flow such as DeChambeau Creek and Simon's Spring, wetland vegetation expands lakeward with declining lake levels, and mudflats form. Lake level recovery then often inundates the newly colonized wetland vegetation and submerges mudflats, but rarely do extensive ponds form. Inundated wetland vegetation in these areas may support large numbers of alkali flies, and create shallow foraging areas with cover for waterbirds. Increased pond acreage and connectivity of shoreline ponds with the shoreline and spring outflow areas results in improved habitat quality for waterfowl.

Elevated reservoir level at Bridgeport Creek resulted in the creation of extensive shallow feeding areas near the deltas of the East Walker River, Robinson and Buckeye Creeks.

The level of Crowley Reservoir was also somewhat elevated, inundating preferred waterfowl loafing areas along the west shoreline in the McGee Bay area. A heavy algal growth at the reservoir persisted into October.

3.4 Waterfowl Population Surveys

Overview of Waterfowl Population Surveys

LADWP has conducted waterfowl population monitoring annually from 2002-2019 at three sites in Mono County: Mono Lake, Bridgeport Reservoir, and Crowley Reservoir (Figure 3-135). Mono Lake is almost centrally located in Mono County and lies just east of the town of Lee Vining. Bridgeport Reservoir is approximately 22 miles northwest of Mono Lake near the town of Bridgeport. Crowley Reservoir is approximately 31 miles southeast of Mono Lake, and 12 miles southeast of the town of Mammoth Lakes. These sites are the main areas of waterfowl concentration in Mono County, and combined, support the overwhelming majority of waterfowl numbers in the county.

Waterfowl population monitoring in Mono County under the Plan includes summer ground counts and fall aerial surveys. Of the three survey areas, waterfowl population monitoring has been most intensive at Mono Lake, and has included summer ground surveys for breeding waterfowl as well as fall aerial surveys. Fall aerial surveys are conducted Bridgeport and Crowley Reservoirs as well as at Mono Lake. The Plan intended waterfowl population monitoring at Mono Lake to continue until the targeted lake elevation of 6,392 foot elevation had been reached and the lake experienced one complete wet/dry cycle afterward. Based on the lake level prediction model available when the Plan was developed, LADWP anticipated monitoring waterfowl annually until 2014 (LADWP 1996a). As of 2019, the target lake level has yet to be reached. Decision 1631 required a hearing in Mono Lake did not reach 6,391 feet by September 28, 2014, however the Settlement Agreement Regarding Continuing Implementation of Water Rights Orders 98-05 and 98-07 (SWRCB 2013) and proposed license amendments postponed any potential hearing until September 28, 2020. Waterfowl population monitoring has thus continued, although potential modifications to the program were presented in the Periodic Overview Report (LADWP 2018).

Summer Ground Surveys

Summer ground surveys are conducted in the Mono Basin along the shoreline of Mono Lake and at the DeChambeau and County Pond complexes. Although the summer use of Mono Lake by waterfowl is small as compared to use by fall migrants, limited historical information was available during Plan development. The Plan provided no specific guidance regarding the objectives of summer monitoring, however Drewien et al. (1996) recommended summer counts to record numbers and species composition of waterfowl and other waterbirds. The implied intent of summer surveys was to fill in gaps in knowledge regarding summer use by waterfowl.

Fall Aerial Surveys

Fall aerial waterfowl surveys are conducted at Mono Lake, Bridgeport Reservoir and Crowley Reservoir. Mono Lake is a migratory stopover location for waterfowl, and use by waterfowl is expected to be highest during the fall migratory period. The response of fall waterfowl populations to restoration will be evaluated using aerial survey data. Waterfowl population response will be evaluated relative to conditions at Mono Lake, but also on a regional scale using waterfowl survey data from Bridgeport and Crowley Reservoirs.

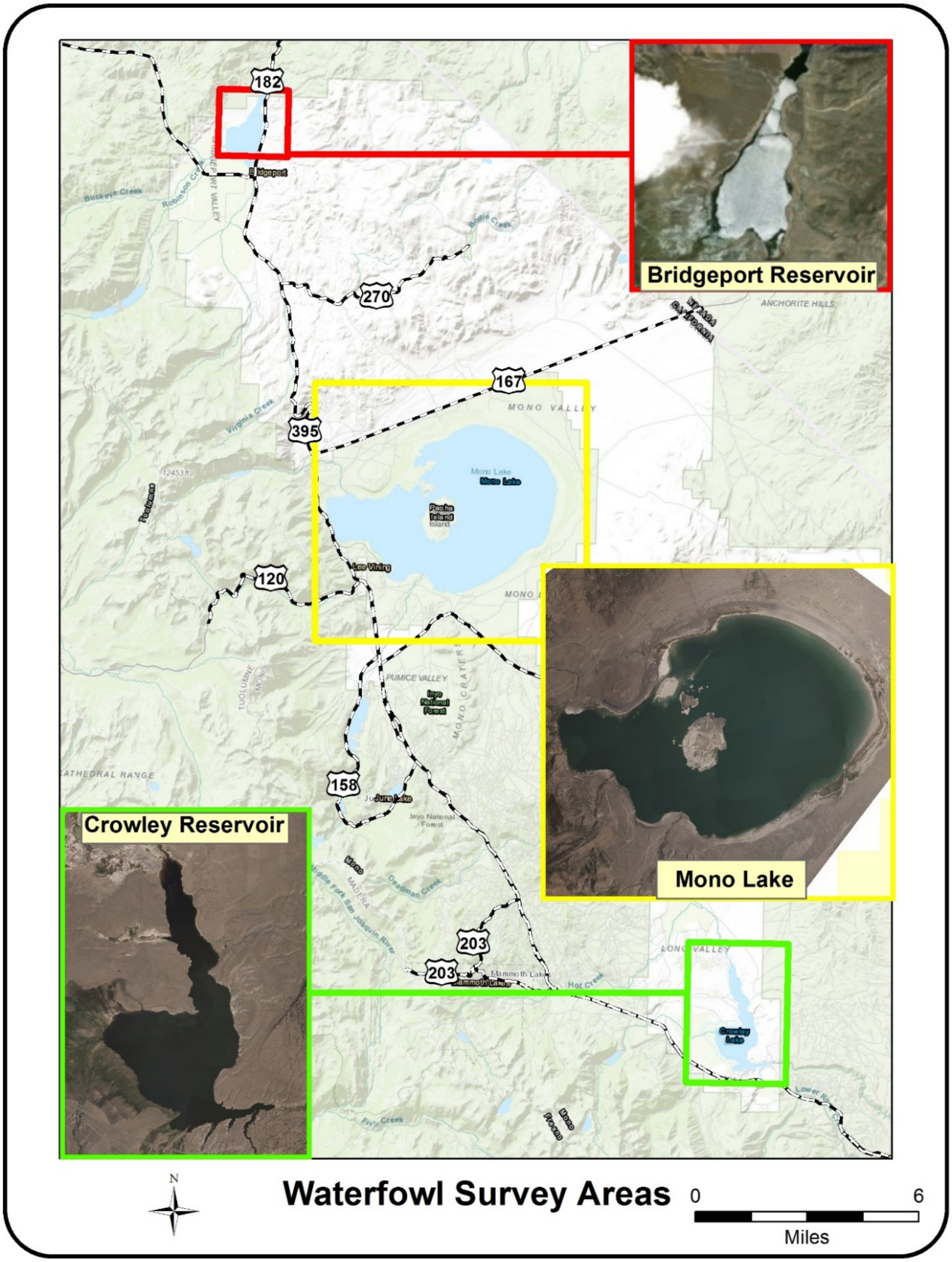


Figure 3-135. Overview of Waterfowl Survey Areas

3.4.1 Waterfowl Population Monitoring Methodologies

Summer Ground Surveys

Mono Lake Shoreline Surveys

Summer ground counts along the shoreline of Mono Lake determine summer waterfowl population size and species composition, document broods, record waterfowl habitat use and habitat conditions. Summer ground counts have been conducted annually since 2002. Summer survey areas include nine shoreline subareas totaling approximately 14 miles of shoreline (Figure 3-136). The shoreline subareas are as follows: DeChambeau Creek (DECR), lower Lee Vining Creek and delta (LVCR), Mill Creek (MICR), lower Rush Creek and Rush Creek Delta (RUCR), Sammons Spring (a.k.a "Simons") (SASP), South Tufa (SOTU), South Shore Lagoons (SSLA), Warm Springs (WASP), and Wilson Creek (WICR). In 2019, all surveys were conducted by Deborah House. Additional observers were Erin Nordin and Bill Deane, LADWP Watershed Resources Specialists.

Each shoreline subarea was visited three times in 2019 with surveys occurring at three-week intervals beginning in early June (Table 3-25). Surveys were conducted by walking at an average rate of approximately 1 mile/hr., depending on conditions, and recording waterfowl species as they were encountered. Surveys started within one hour of sunrise, and all shoreline areas were surveyed over a 4-5 day period. Shoreline subarea visitation was varied in order to minimize the effect of time-of-day on survey results. For each waterfowl observation, the following was recorded: time of the observation; species, total number, sex, and habitat use. Habitat use was recorded by documenting both behavior and landtype the waterfowl were occupying. Behavior types recorded include resting, foraging, flying over, nesting, brooding, sleeping, swimming, or calling. In addition to the landtypes used for mapping, 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.

Table 3-25. 2019 Summer Waterfowl Survey Number and Dates by Subarea

	2019 Survey Number and Date		
Subarea	**Survey 1**	**Survey 2**	**Survey 3**
DECR	5-Jun	25-Jun	15-Jul
LVCR	5-Jun	25-Jun	15-Jul
MICR	5-Jun	25-Jun	17-Jul
RUCR	3-Jun	27-Jun	15-Jul
SASP	6-Jun	26-Jun	18-Jul
SOTU	5-Jun	24-Jun	16-Jul
SSLA	4-Jun	24-Jun	16-Jul
WASP	3-Jun	27-Jun	17-Jul
WICR	5-Jun	25-Jun	17-Jul
COPO	5-Jun	25-Jun	15-Jul
DEPO	5-Jun	25-Jun	15-Jul

Waterfowl broods were actively searched for while conducting summer ground counts at Mono Lake. Because waterfowl flush readily in response to disturbance, and females with broods are especially wary, observers frequently scanned the shoreline ahead in order to increase brood detection. Brooding females at Mono Lake generally respond in one of two ways to disturbance. Gadwall typically take their young out onto the open water of Mono Lake, where they can be more difficult to age. Other species will retreat to cover onshore, where are difficult to observe. Careful scanning of the shoreline and planned approaches to waterfowl use areas has been needed to consistently find broods. The following is recorded for each brood: species, brood 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 allows for a determination of the minimum number of “unique broods” using the Mono Lake wetland and shoreline habitats.

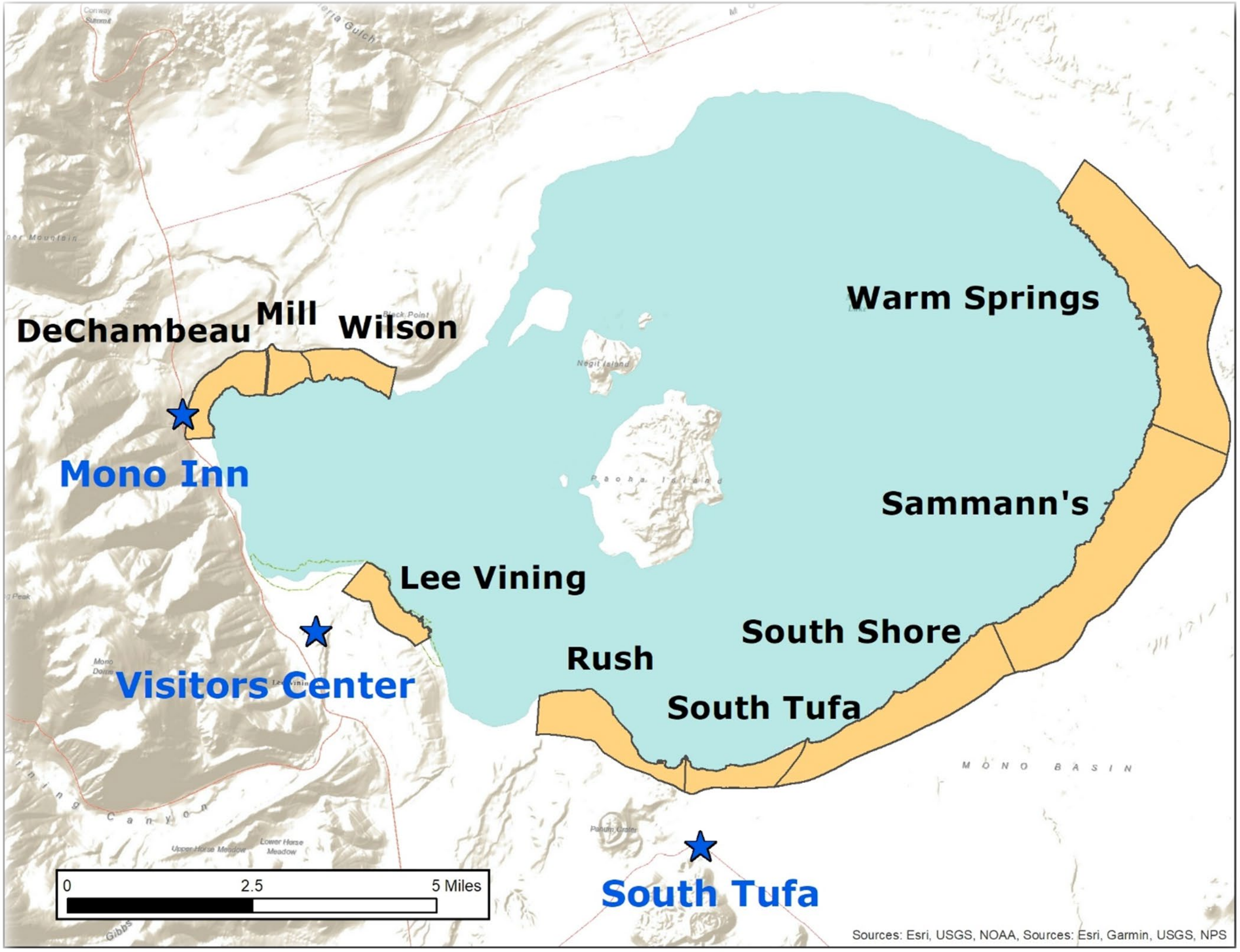


Figure 3-136. Summer Ground Count Shoreline Subareas - 2002-2019

Salinity measurements of lake-fringing ponds were taken using an Extech EC400 Conductivity/TDS/Salinity probe in order to aid in the 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 ppt (the maximum range of the probe) lacking vegetation and subsurface or surface freshwater inflow were classified as hypersaline.

Restoration Ponds

From 2002-2019 summer ground counts were also conducted at the DeChambeau and County Pond complexes north of the lake.

The DeChambeau Ponds are a complex of five artificial ponds of varying size (Figure 3-137). There are two water sources currently supplying water to the DeChambeau Ponds. The primary water source is Wilson Creek. Delivery of water from Wilson Creek to the DeChambeau ponds is via an underground pipe, and has averaged 1-2 cfs in recent years (N. Carle, pers. com.). The underground piping moves water from pond 1 to pond 5. The second source is water from a hot spring adjacent to DEPO_4. The hot spring water is typically delivered to each of the five ponds through piping, however a leak developed around 2008 or 2009 in the pipe supplying the ponds (N. Carle, pers. com.). Since the development of the leak, hot spring water can only be delivered to DEPO_4. In summer of 2019, water was present in ponds 2, 3 and 4, however the water level in DEPO_4 was low.

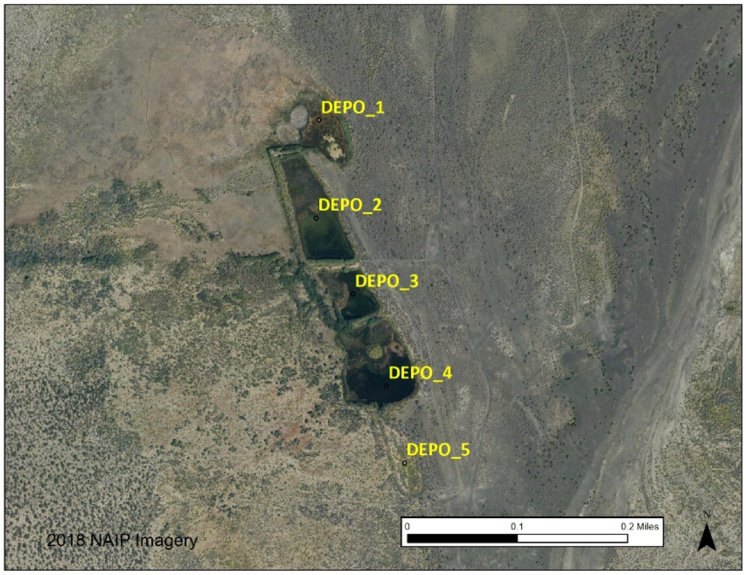


Figure 3-137. DeChambeau Ponds

2018 Imagery courtesy of National Agriculture Imagery Program (NAIP).

The two County Ponds lie in a natural basin and former lagoon that experienced drying as the lake level dropped below 6,405 feet in the 1950’s. The County Pond complex consists of two ponds – County Pond East (COPO_E) and County Pond West (COPO_W) (Figure 3-138). Water is delivered to the County Ponds via a pipe from the DeChambeau Ponds. A diversion box exists at the County Ponds to allow some control over water releases to the individual ponds. According to the U.S. Forest Service, County Pond West has been difficult to dry out, and has been subject to cattail overgrowth. In 2019, County Pond West was a solid monoculture of dead cattails and dry. Although water delivery had been restored to COPO_E in 2019, emergent vegetation now covers approximately 75% of the pond area.

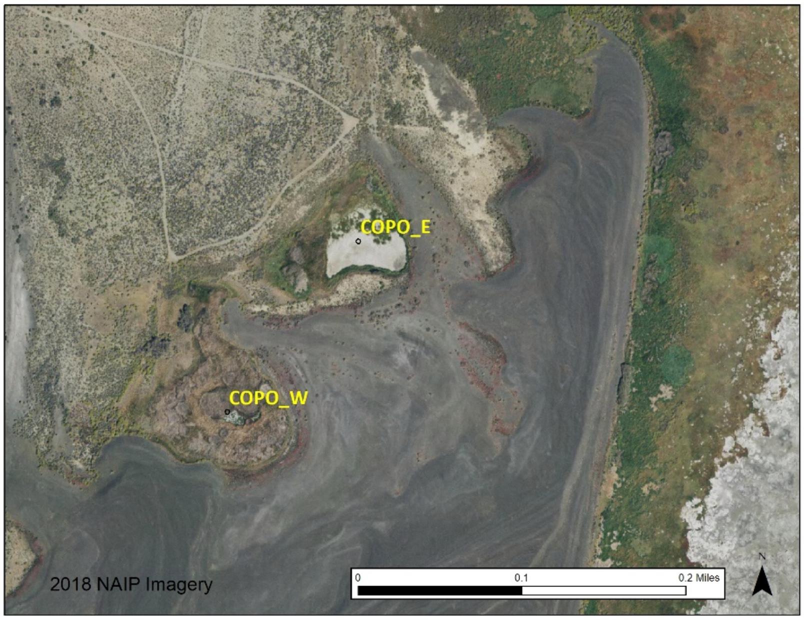


Figure 3-138. County Ponds

2018 Imagery courtesy of National Agriculture Imagery Program (NAIP).

Fall Aerial Surveys

Since 2002, aerial surveys have been conducted annually during the fall waterfowl migratory period at three lakes in Mono County: Mono Lake, Bridgeport Reservoir, and Crowley Reservoir. Each year, six surveys were conducted biweekly, with the first survey conducted the first week of September, and the final survey occurring in the mid-November. In all cases, surveys of all three waterbodies were completed during a single flight by 1200 hours (local time) on the day of the survey. Survey dates for 2019 are provided as Table 3-26. Each of the three study sites were divided into shoreline and/or open-water segment areas in order to document the spatial distribution of waterfowl.

Table 3-26. Fall 2019 Aerial Survey Dates

Survey Number	Date
Survey 1	6-Sep
Survey 2	17-Sep
Survey 3	26-Sep
Survey 4	16-Oct
Survey 5	31-Oct
Survey 6	13-Nov

Aerial surveys were conducted using a high-winged four-passenger aircraft at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Two observers other than the pilot were present on all six flights. In 2019, waterfowl surveys were conducted by the Mono Basin Waterfowl Program Director and LADWP Watershed Resources staff. The primary observers were Deborah House and Chris Allen, and the secondary observer was Erin Nordin.

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, followed by a count of the number of individuals of each species present.

Mono Lake

Aerial surveys were conducted at Mono Lake in order to effectively and efficiently survey both the shoreline and open water areas. The areas surveyed at Mono Lake were the shoreline and off-shore open water areas of Mono Lake. At Mono Lake, most dabbling ducks and geese occur in close proximity to the shoreline. Ruddy Duck, which is one of the two most abundant species, however, can occur in large numbers well offshore.

All areas were surveyed during each flight. Completing the surveys within this short of a time period limits the chance of double-counting birds due to local movements, and effectively records the total birds present on a single day. The shoreline was divided into 15 shoreline segments. Shoreline segment boundaries for Mono Lake followed those established in Jehl (2002), except for minor adjustments made in order to provide the observer with obvious landmarks that are easily seen during aerial surveys. A sampling grid is used to survey open-water areas of Mono Lake during aerial flights. The grid consists of eight parallel transects spaced at one-minute (1/60th of a degree, approximately one nautical mile) intervals further divided into a total of 25 sub-segments of approximately equal length (LADWP 2018) (Figure 3-139).

Perimeter surveys were conducted over water while maintaining a distance of approximately 500-800 feet from the shoreline. When conducting aerial surveys, the perimeter flight was conducted first, and in a counterclockwise direction, starting in the Ranch Cove area.

Cross-lake transects were flown immediately afterward, starting with the southernmost transect and working northwards. When conducting cross-lake transect counts, observers sat on opposite sides of the plane and counted Ruddy Ducks, other waterfowl, and phalaropes occurring on the open water. In order to increase detection of waterfowl on the open water, observers sat on opposite sides of the aircraft during cross-lake transect surveys. 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 opposite headings 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.

During aerial surveys, the beginning and ending points for each subsection were determined using both landscape features and the mobile mapping program Avenza®.

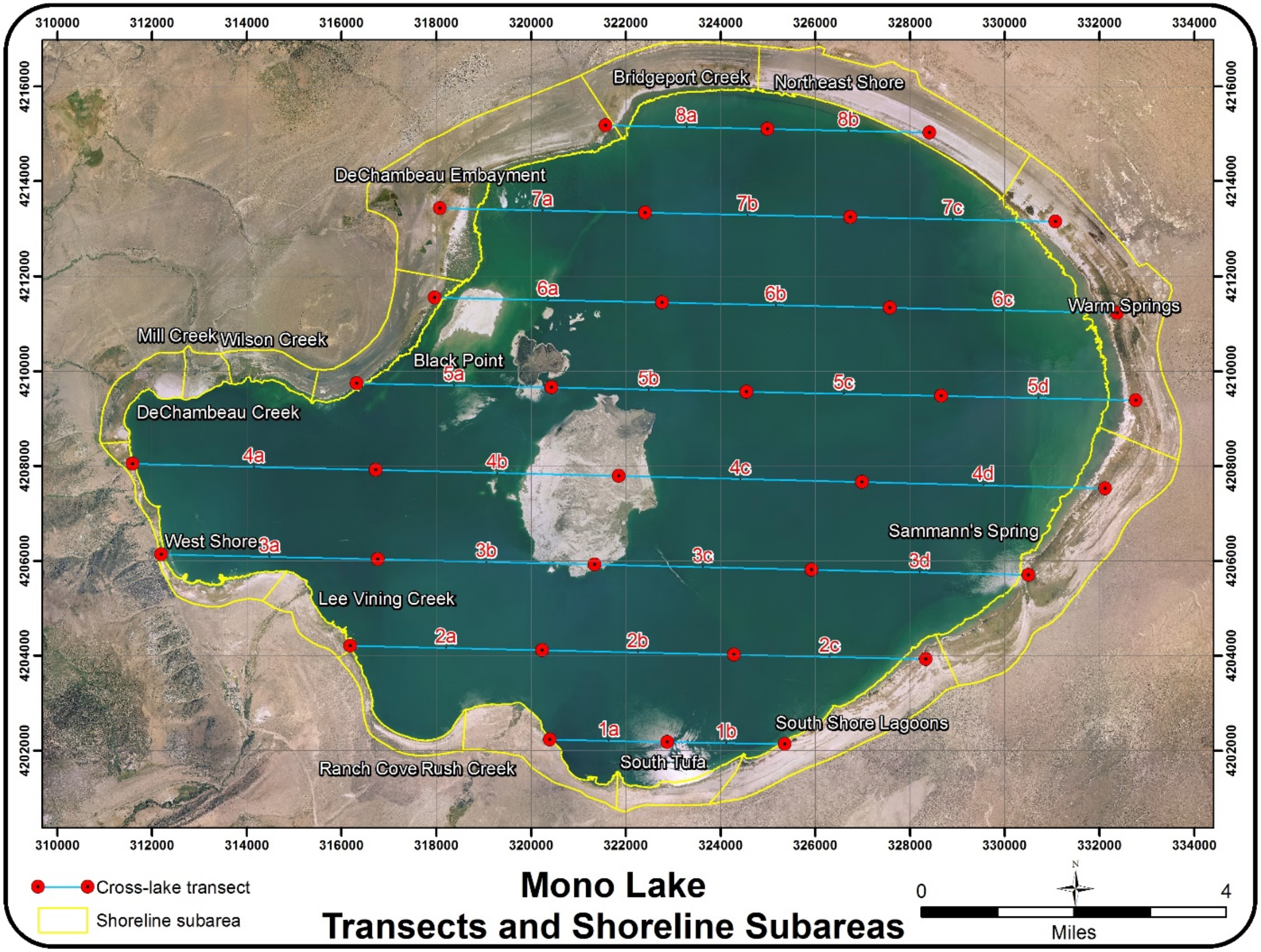


Figure 3-139. Mono Lake Shoreline Subareas and Cross-lake Transects

Restoration Ponds

DeChambeau and County Restoration Pond complexes were also surveyed during the aerial flights. Waterfowl observations were recorded by pond.

Bridgeport Reservoir

Bridgeport Reservoir is located in Bridgeport Valley in northern Mono County, California, at an elevation of 6,460 feet. Bridgeport Valley has an arid continental climate (Zellmer 1977) and experiences relatively cool, mild summers and cold, snowy winters. The average July temperate is 63°F (17C), and the maximum July temperature is in the low 90's. Winters are cold as the average minimum January temperature is 9.1°F, and the average maximum is 42.5°F. Precipitation averages 10 inches (25 cm), most in the form of snow, and Bridgeport averages 65 frost-free days a year. Bridgeport Reservoir typically freezes over in the winter for varying lengths of time. The mid-November flights are generally ice-free, however in some years, a thin layer of ice has been present in some areas of the reservoir.

Bridgeport is part of the hydrologically closed Walker River Basin, which spans the California/Nevada border. Bridgeport Reservoir, completed in 1923, provides irrigation water to Smith and Mason Valleys in Nevada (Sharpe et al. 2007). Numerous creeks originating from the east slope of the Sierra Nevada drain toward Bridgeport Reservoir. These tributaries are used for upslope irrigation of Bridgeport Valley to support the primary land use of cattle grazing. The creeks directly tributary to the reservoir are the East Walker River, Robinson Creek and Buckeye Creek. Downstream of Bridgeport Reservoir Dam, the East Walker River continues flowing into Nevada, joining the West Walker River, ultimately discharging into the terminal Walker Lake, Nevada. In Nevada, the Walker River system supports extensive agricultural operations.

Bridgeport Reservoir is a small reservoir with a surface area of approximately 7.4 square miles and a storage capacity of 42,600 acre-feet. The reservoir is rather shallow with a mean depth of 15 feet and a maximum depth of 43 feet (Horne 2003). Irrigated pastures border the south and southwestern portion of the reservoir, while Great Basin scrub is dominant along the north arm and east shore.

Bridgeport Reservoir is eutrophic and experiences summer blooms of blue-green algae. Four colonial forms of cyanobacteria have been found to be common: Aphanizomenon, Anabaena, Microcystis, and Gloeotrichia (Horne 2003). In shallow areas near the deltas, submergent aquatic vegetation is abundant.

In September 2019, Bridgeport Reservoir held 17,752 acre-feet (http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=BDP&d=today). The September 2019 level was 18% higher than September of 2018.

Although Bridgeport is a small reservoir, ground access to areas where waterfowl concentrate is limited. At Bridgeport Reservoir, all shoreline areas were surveyed during aerial flights, with additional passes over open water areas as needed, based on waterfowl distribution.

Crowley Reservoir

Crowley Reservoir is located in Long Valley, at an elevation of 6,780 feet. Created by the construction of the Long Valley Dam in 1941, Crowley Reservoir is the second largest lake in Mono County, and the largest reservoir in the county, averaging 13.2 square miles. The major source of fresh water input to Crowley Reservoir is the Owens River. Other fresh water input includes flows from McGee and Convict Creeks, Layton Springs, and subsurface flow from other springs along the west shore. Crowley is much deeper than Bridgeport Reservoir, with a mean depth of 35 feet and a maximum depth of 125 feet (Corvallis Environmental Research Laboratory and Environmental Monitoring Support Laboratory 1978). The storage capacity of Crowley Reservoir is 183,465 acre-feet. In September 2019, Crowley Reservoir held 141,221 acre-feet (http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=crw&d=today). The September 2019 level was 17% higher than September of 2018.

Crowley Reservoir is eutrophic and experiences summer blooms of the nitrogen fixing cyanobacteria *Gloeotrichia* in summer, and late-summer and fall season blooms of the cynaobacteria *Aphanizomenon* (Jellison et al. 2003). In shallow areas near the deltas, submergent aquatic vegetation is abundant. Crowley Reservoir is known for supporting a healthy population of midges (Chironomidae).

At Crowley Reservoir, all seven shoreline areas were surveyed during each flight with additional passes over open water areas as needed, based on waterfowl distribution. Ground access is good at most locations of Crowley, but limited in the area of highest waterfowl use in the McGee Bay area.

3.4.2 Waterfowl Data Summary and Analysis

Summer Ground Surveys

Summer Waterfowl Community

The summer waterfowl community data summary includes all waterfowl breeding, migrant, and non-breeding/oversummering species observed in 2019. Waterfowl species were classified as breeding or nonbreeding based on whether a territorial pair, nest, or brood had been observed over the length of the study. The 2019 summer waterfowl community data were summarized by survey number.

Breeding Population Size and Composition

The Mono Lake breeding waterfowl population size was determined by calculating the annual mean and standard error of all breeding species combined. The breeding waterfowl community composition was evaluated by calculating the 2002-2019 mean plus standard error for each breeding species. The 2019 totals were compared to the long-term 2002-2019 mean.

Brood totals for shoreline surveys will be used as an estimate of waterfowl breeding productivity. Annual brood number totals were determined by eliminating broods potentially double-counted over the season. Brood species, age, size and location were used to determine which broods to eliminate from the total. The calculation of brood parameters included all nesting species except Canada Goose. Canada Goose initiates nesting earlier than the other waterfowl species and family groups can be difficult to approach closely on foot except in areas where they have become habituated to humans. These factors combined with the tendency of this species to be highly mobile has made ageing broods accurately and determining the minimum number of broods difficult.

The spatial distribution of breeding waterfowl was evaluated by calculating the total number of broods observed for each shoreline area in 2019. The total broods observed per shoreline subarea was compared with the long-term averages by shoreline subarea.

Lake Level and Breeding Waterfowl Populations

Breeding waterfowl populations were evaluated to determine the responsiveness to lake level changes. Simple linear regression was used to evaluate the relationship between breeding waterfowl population size (2002-2019) and the elevation of Mono Lake each year in June. This analysis was conducted for annual lakewide totals of breeding species, and by species. Ruddy Duck was not analyzed due to low numbers, and Canada Goose was excluded due to potential double-counting issues, as discussed above. The influence of lake level in June on annual waterfowl productivity was also examined using regression analysis.

Habitat Use

Habitat use data were summarized for each breeding species by both modeled and mapped vegetation types (LADWP 2018).

Restoration Ponds

Waterfowl numbers for each pond were summed. The 2019 waterfowl use and total brood results were compared to the long-term mean from the period 2002-2019.

Fall Surveys

Fall Waterfowl Population Size and Species Composition

Fall waterfowl population size was evaluated using three separate indices: total annual waterfowl, peak seasonal count, and an estimate of the minimum population size. Total annual waterfowl is the sum of all waterfowl over the six yearly surveys. The total waterfowl counts can be interpreted as an index of the number of waterfowl using each survey area, assuming a short turnover time (< the average time between surveys, or ~14 days), and that new individuals are encountered during each survey. This method is likely to overestimate total seasonal use, but is a simple index in the absence of information regarding stopover periods. The peak seasonal count within any one year was also compiled to represent the maximum number of waterfowl that might be expected on any one day and to allow for comparison to early waterfowl data. Thirdly, a population estimator was used to provide a conservative estimate of the minimum total number of waterfowl using each survey area each year (LADWP 2018).

Species totals per survey area were summarized by survey. The results of 2019 aerial surveys were compared to the long-term 2002-2019 average.

Spatial distribution

The number of waterfowl detected during the shoreline perimeter flights and the cross-lake transects were summed. The annual and total mean proportion of waterfowl detected in each of the shoreline subareas was calculated.

Comparison with Reference Data

Surveys of Bridgeport Reservoir and Crowley Reservoir are being conducted to provide a set of reference data with which to evaluate trends observed at Mono Lake. In order to evaluate the relative use of these three areas as a fall waterfowl site, annual mean waterfowl populations from 2003-2019 were compared.

Restoration Ponds

Waterfowl were summed by species across the three annual surveys. Mean annual waterfowl use was calculated for 2002-2019.

3.4.3 Waterfowl Population Survey Results

3.4.3.1 Summer Ground Counts - Mono Lake Shoreline

Summer waterfowl community

In 2019, 922 waterfowl and 10 waterfowl species were observed over the three summer shoreline surveys (Table 3-27). Summer waterfowl numbers were highest in early June, and lowest on the last survey in mid-July. Gadwall, Mallard and Canada Goose, are the most abundant summer waterfowl species, comprising 94% of all waterfowl at Mono Lake in 2019. All three are regular breeding species, along with Green-winged Teal. Cinnamon Teal was present all summer, however no broods were seen. Northern Pintail and Ruddy Duck have nested along the Mono Lake shoreline, but in 2019 these species along with Blue-winged Teal, Northern Shoveler, and Red-breasted Merganser occurred as non-breeding migrants or oversummering individuals.

Table 3-27. Summer Ground Count Waterfowl Detections in 2019.

Mono Lake breeding waterfowl species are in bold type.

Species	Survey 1	Survey 2	Survey 3	Total Detections
	June 3-6	June 24-27	July 15-18	
Blue-winged Teal	1			1
Canada Goose	92	61	132	285
Cinnamon Teal	6	7	2	15
Gadwall	108	213	114	435
Green-winged Teal	22	3	4	29
Mallard	118	15	16	149
Northern Pintail	4			4
Northern Shoveler	1			1
Red-breasted Merganser		1	1	2
Ruddy Duck			1	1
Total waterfowl by survey	352	300	270	922

Breeding population size and composition

The breeding waterfowl population at Mono Lake in 2019 was 306, or approximately 153 pairs. The 2019 breeding population was comparable in size to the long-term mean of 304.8 +/- 20.7 SE. Breeding was confirmed for Canada Goose, Gadwall, Green-winged Teal and Mallard. Canada Goose numbers were well above average in 2019. With the exception of Mallard, numbers of all other breeding species were slightly below their respective long-term means (Figure 3-140).

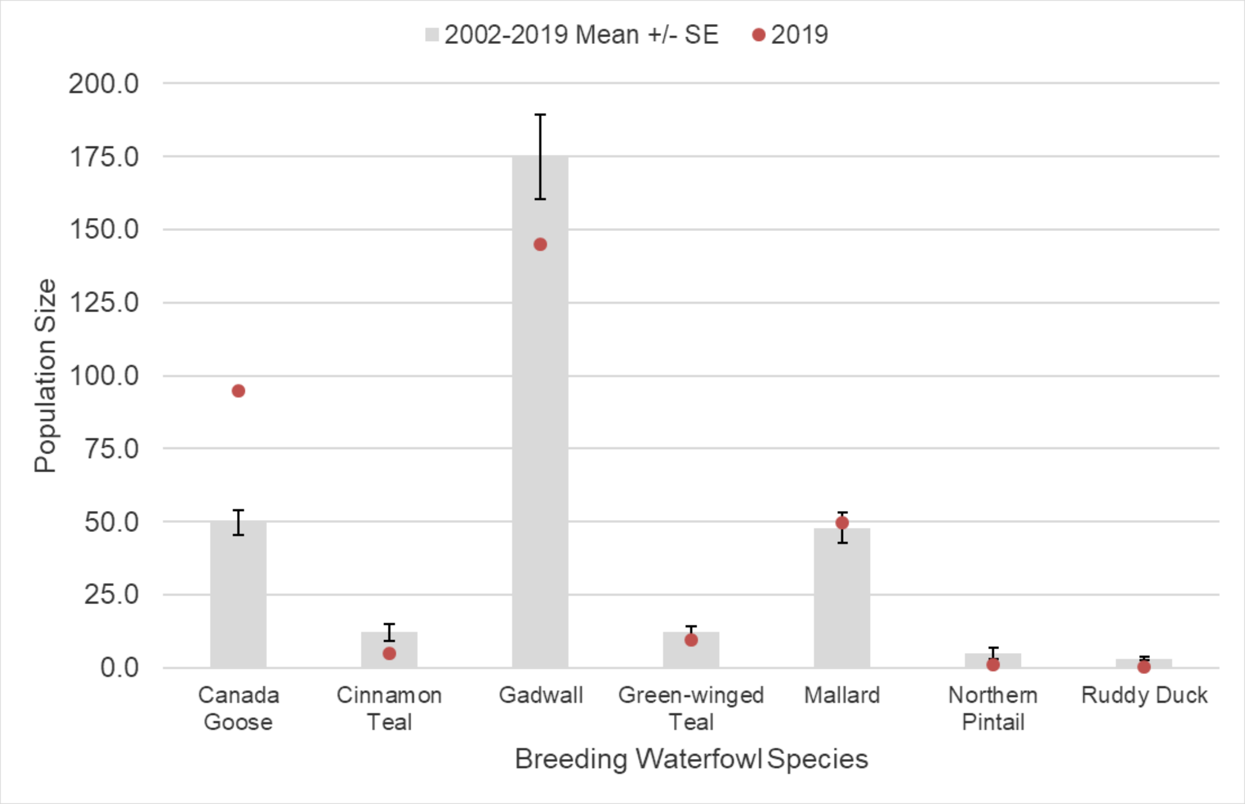


Figure 3-140. Breeding Waterfowl Species Composition, Long-term Means and 2019 Breeding Population Size

At total of 76 waterfowl broods were seen in 2019, including seven broods of Canada Geese and 69 dabbling duck broods. Dabbling duck production (69 broods) was well above the long-term average of 46.9 +/- 3.9 SE (Figure 3-141). Gadwall broods were most numerous, comprising 84% of all dabbling duck broods (58/69). In 2019, no broods were found for Cinnamon Teal, Northern Pintail or Ruddy Duck. As many as seven Canada Goose broods were seen, although this number may be an overestimate as this species is highly mobile, increasing the chance of double-counting family groups.

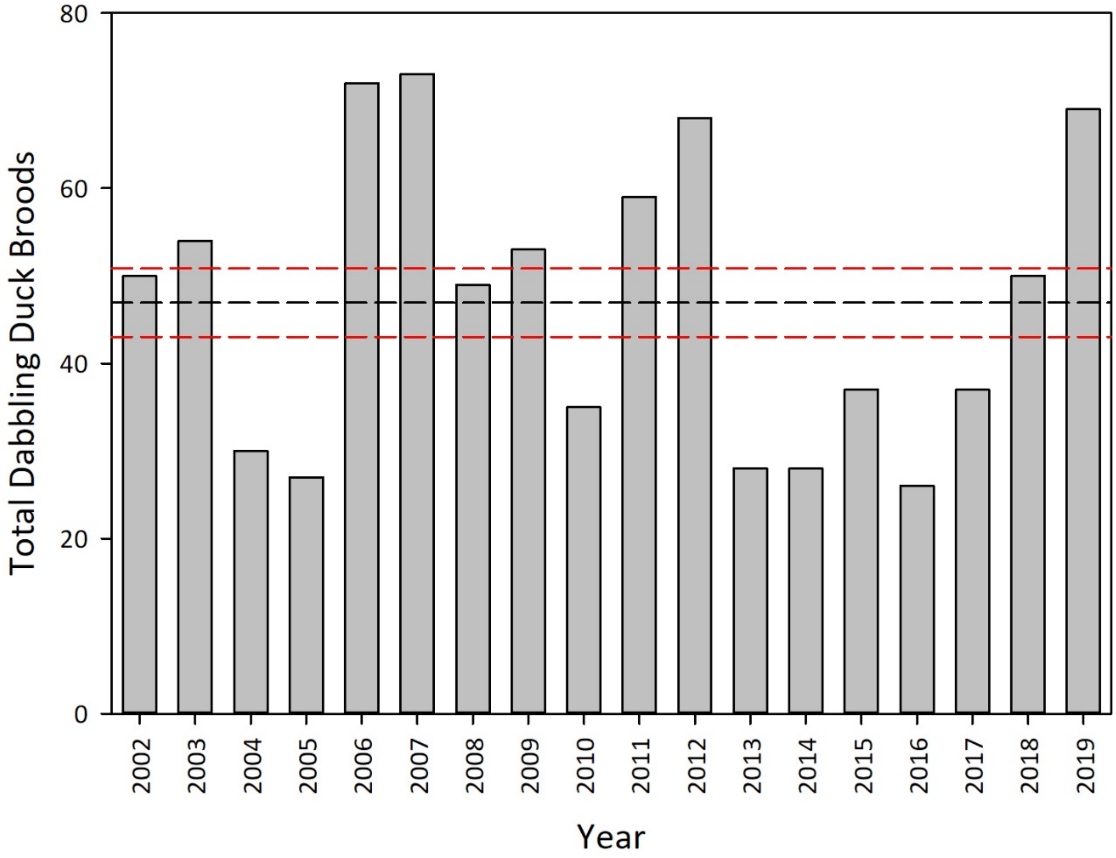


Figure 3-141. Total Annual Waterfowl Broods (Excluding Canada Goose) 2002-2019

The dashed reference lines indicate the long-term mean (black) and +/- standard error (SE) (red).

Table 3-28. Waterfowl Broods by Shoreline Area, 2019

Breeding Waterfowl Species	DECR	LVCR	MICR	RUCR	SASP	SOTU	SSLA	WASP	WICR	Total 2019 Broods
Canada Goose	1		2				3		1	**7**
Cinnamon Teal										**0**
Gadwall	1	1		4	9	1	35		7	**58**
Green-winged Teal		1		2					1	**4**
Mallard		1		2	1		3			**7**
Northern Pintail										**0**
Ruddy Duck										**0**
Total broods per shoreline area	**2**	**3**	**2**	**8**	**10**	**1**	**41**	**0**	**9**	**76**

In 2019, breeding activity was concentrated along the south shoreline, including the South Shore Lagoons and Simon's Spring shoreline areas. Breeding was particularly concentrated in the South Shore Lagoons subarea where more than half of all waterfowl broods were found in 2019 (Table 3-28, Figure 3-142). In the northwest shore areas of DeChambeau Creek, Mill Creek and Wilson Creek, breeding activity was notably below average. No broods were detected in Mill Creek in 2019, an area typically supporting up to 13% of lakewide broods. Since 2002, Wilson Creek has supported an average of over 20% of all broods, second only to South Shore Lagoons. In 2019, only 11.6% of all broods were in Wilson Creek. Only one brood was observed at DeChambeau Creek.

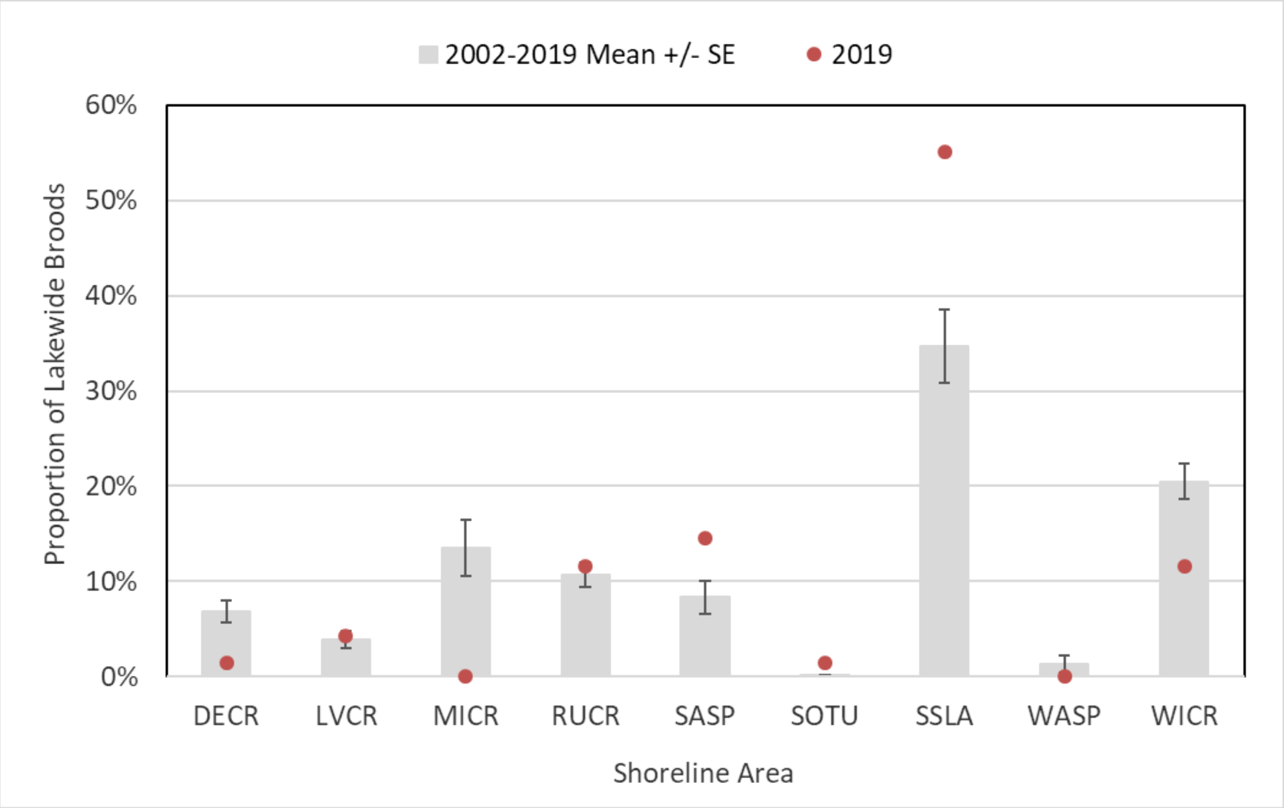


Figure 3-142. Proportion of Lakewide Broods by Shoreline Subarea

The 2019 results are shown relative to the 2002-2019 mean +/- standard error (SE).

Lake Level and Breeding Waterfowl Populations

Total annual breeding waterfowl numbers have been positively correlated with lake level (r^2_{adj}=0.47, p=0.09) (Figure 3-143). The largest waterfowl breeding population at Mono Lake (1,666 total detections) was in 2007 when the lake was also at the highest elevation observed of 6,384.5 feet. Breeding populations were at their lowest in 2016 and 2017 when 513 and 434

total breeding waterfowl were observed, respectively. Of the breeding species examined, all except Green-winged Teal has shown a positive response to lake level increase (
Table **3-29**).

The populations of Cinnamon Teal, Gadwall, Mallard and Northern Pintail are larger at higher lake levels, leading to more diverse waterfowl communities.

Table 3-29. The correlation between breeding waterfowl species and Mono Lake elevation in June of each year

Breeding Species	r^2_{adj}	p value
Cinnamon Teal	0.237	0.023*
Gadwall	0.519	0.0005*
Green-winged Teal	0.074	0.140
Mallard	0.444	0.0015*
Northern Pintail	0.195	0.0381*

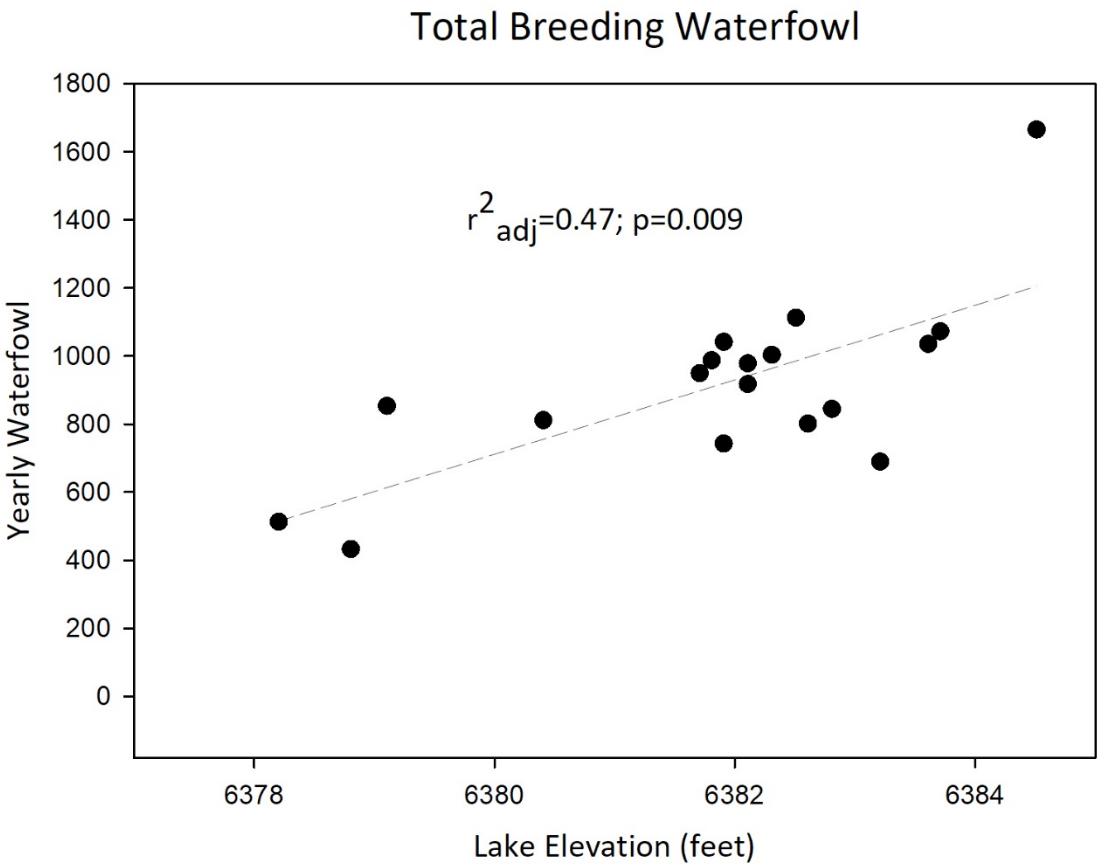


Figure 3-143. The relationship between total breeding waterfowl along Mono Lake shoreline and the lake elevation in June of each year.

Brood production at Mono Lake has shown a nonlinear response to lake level changes (Figure 3-144). At lake elevations below 6,382 feet, the total number of broods has remained below 40, varying from 27 to 37. With lake level increases above 6,382 feet, total brood numbers increase significantly, with a high of 73 in 2007.

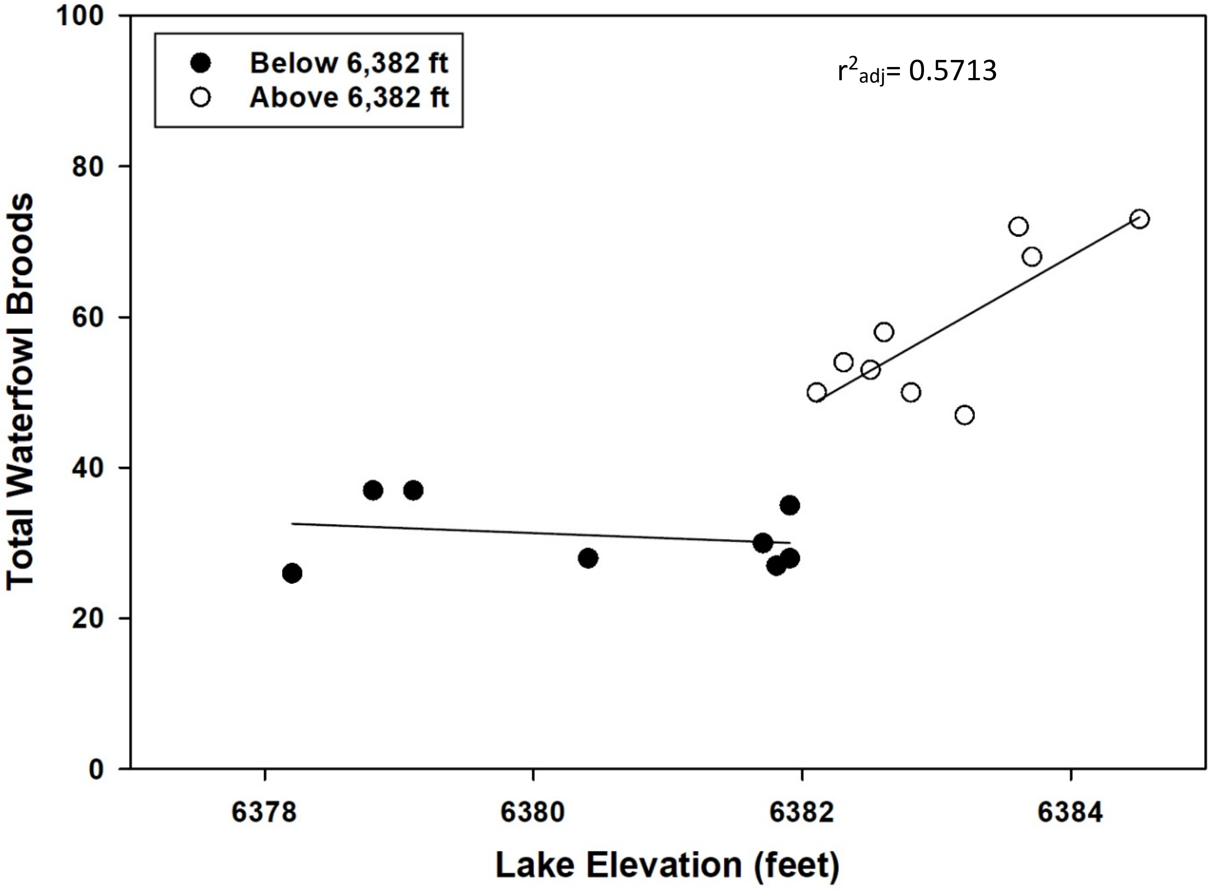


Figure 3-144. The relationship between total broods along Mono Lake shoreline and the lake elevation in June of each year.

3.4.3.2 Habitat Use

Most dabbling duck activity is concentrated around nearshore water features, while Canada Goose is the only species that regularly uses meadow/marsh habitat (Table 3-30). In 2019, Canada Goose were observed most frequently feeding in alkaline wet meadow areas, often with broods. On-shore water features were the landtype most heavily used by dabbling ducks, with freshwater and brackish ponds receiving the most use. Both freshwater and brackish ponds were used by ducks for feeding, brooding and resting. Ria areas were primarily used by Gadwall for feeding.

Table 3-30. Proportional Habitat use by Breeding Waterfowl Species, 2019

Landtypes		Breeding Waterfowl Species				
Modeled	Mapped	Canada Goose	Cinnamon Teal	Gadwall	Green-winged Teal	Mallard
Meadow Marsh		71%	0%	1%	7%	1%
	Marsh	*0%*	*0%*	*0%*	*0%*	*0%*
	Wet Meadow	*0%*	*0%*	*0%*	*7%*	*0%*
	Alkaline Wet Meadow	*71%*	*0%*	*1%*	*0%*	*1%*
	Dry Meadow/Forb	*0%*	*0%*	*0%*	*0%*	*0%*
Water		18%	100%	41%	66%	92%
	Freshwater Stream	*0%*	*0%*	*0%*	*10%*	*3%*
	Freshwater Pond	*2%*	*40%*	*7%*	*10%*	*26%*
	Brackish Pond	*16%*	*60%*	*34%*	*45%*	*63%*
	Hypersaline Pond	*0%*	*0%*	*0%*	*0%*	*0%*
	Mudflat	*0%*	*0%*	*0%*	*0%*	*0%*
Upland		0%	0%	0%	0%	1%
Ria		11%	0%	52%	21%	5%
Riparian		0%	0%	0%	0%	1%
Barren Lake Bed		0%	0%	2%	7%	0%
Open Water		0%	0%	4%	0%	1%

Summer Ground Counts - Restoration Ponds

In 2019, the number of waterfowl averaged over the three summer visits to the Restoration Ponds was 10.7, which is well below the long-term average off 18.4. Waterfowl use was highest in DEPO_04 (13 birds over three visits) and COPO_E (8 birds). A total of nine broods were seen at the Restoration Ponds including seven Gadwall, one Northern Pintail and one Ruddy Duck brood. DEPO_4 supported five broods while four were found at COPO_E. The total number of broods at the Restoration Ponds was within the long-term mean (Figure 3-145).

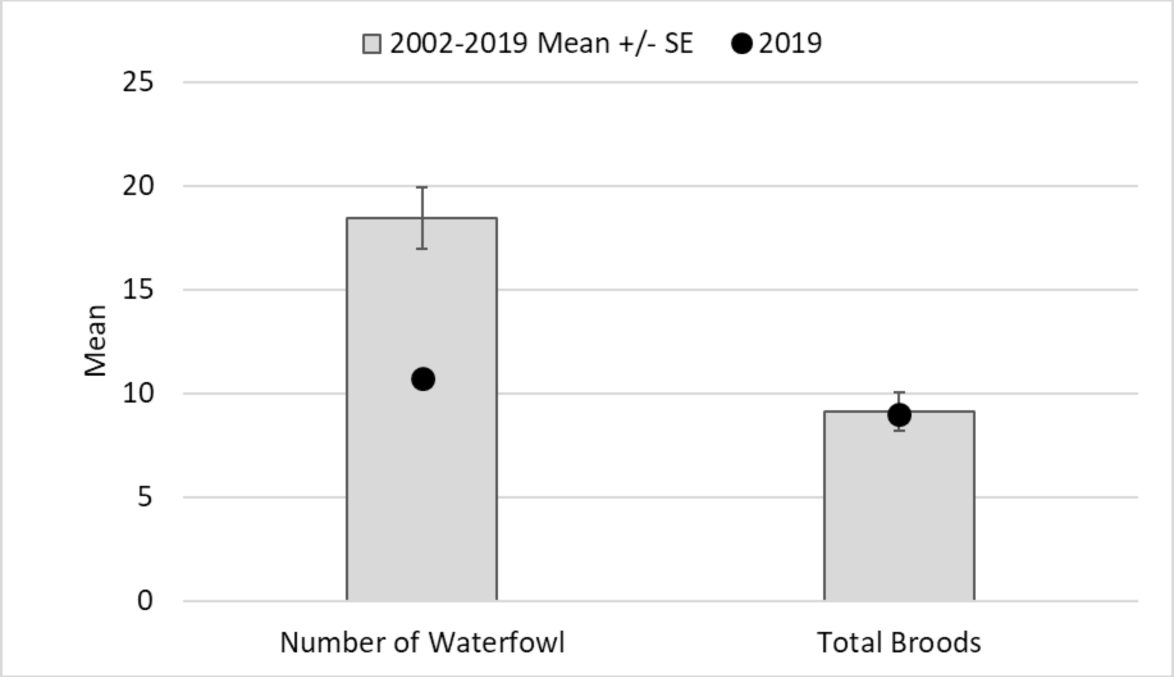


Figure 3-145. Mean Waterfowl and Total Broods at the Restoration Ponds, 2019

The 2002-2019 Long-term mean +/- standard error (SE) is shown for reference.

3.4.3.3 Mono Lake Fall Aerial Surveys

Fall Waterfowl Population Size and Species Composition

In 2019, 13,333 waterfowl were tallied during fall aerial surveys. The peak count of the season was 3,195 and the 2019 population estimate for 2019 is a conservative 3,415 (Table 3-31). The yearly total number of waterfowl at Mono Lake has averaged 24,762 +/-2,809 SE. The lowest total count of 8,732 was in 2018, and the highest total count of 51,377 in 2004. Peak numbers have averaged 7,941, ranging from a low of 1,826 in 2018 to the highest single day count of 17,844 at the end of September in 2004. The long-term estimated annual fall waterfowl population of Mono Lake, is 8,888 +/- 1,097 SE. Yearly population estimates have ranged from a low of 2,148 in 2018 to a high of 18,590 in 2004.

Table 3-31. Mono Lake Yearly Waterfowl Population Indices

Year	Total	Peak	Population Estimate
2002	25,410	7,751	7,571
2003	43,240	9,920	12,868
2004	51,377	10,797	18,590
2005	22,189	7,942	8,263
2006	22,157	6,605	6,943
2007	23,668	9,926	10,080
2008	38,252	13,914	14,017
2009	27,861	7,920	10,906
2010	11,856	3,293	4,760
2011	21,897	5,248	5,635
2012	43,108	17,400	17,400
2013	23,712	8,213	8,557
2014	21,898	8,171	11,075
2015	16,882	8,437	8,654
2016	15,275	4,297	5,644
2017	14,874	3,350	3,460
2018	8,732	1,826	2,148
2019	13,333	3,195	3,415
Mean	**24,762**	**7,678**	**8,888**
Std Err	**2,809**	**931**	**1,097**

Total waterfowl use varies temporally, with numbers highest during the month of September. This early season peak is largely due to the abundance of Northern Shovelers in September. After the end of September, waterfowl numbers at Mono Lake usually decline substantially. Waterfowl numbers in 2019 were well below the long-term mean on all surveys, except mid-November when the total was within the average range (Figure 3-146).

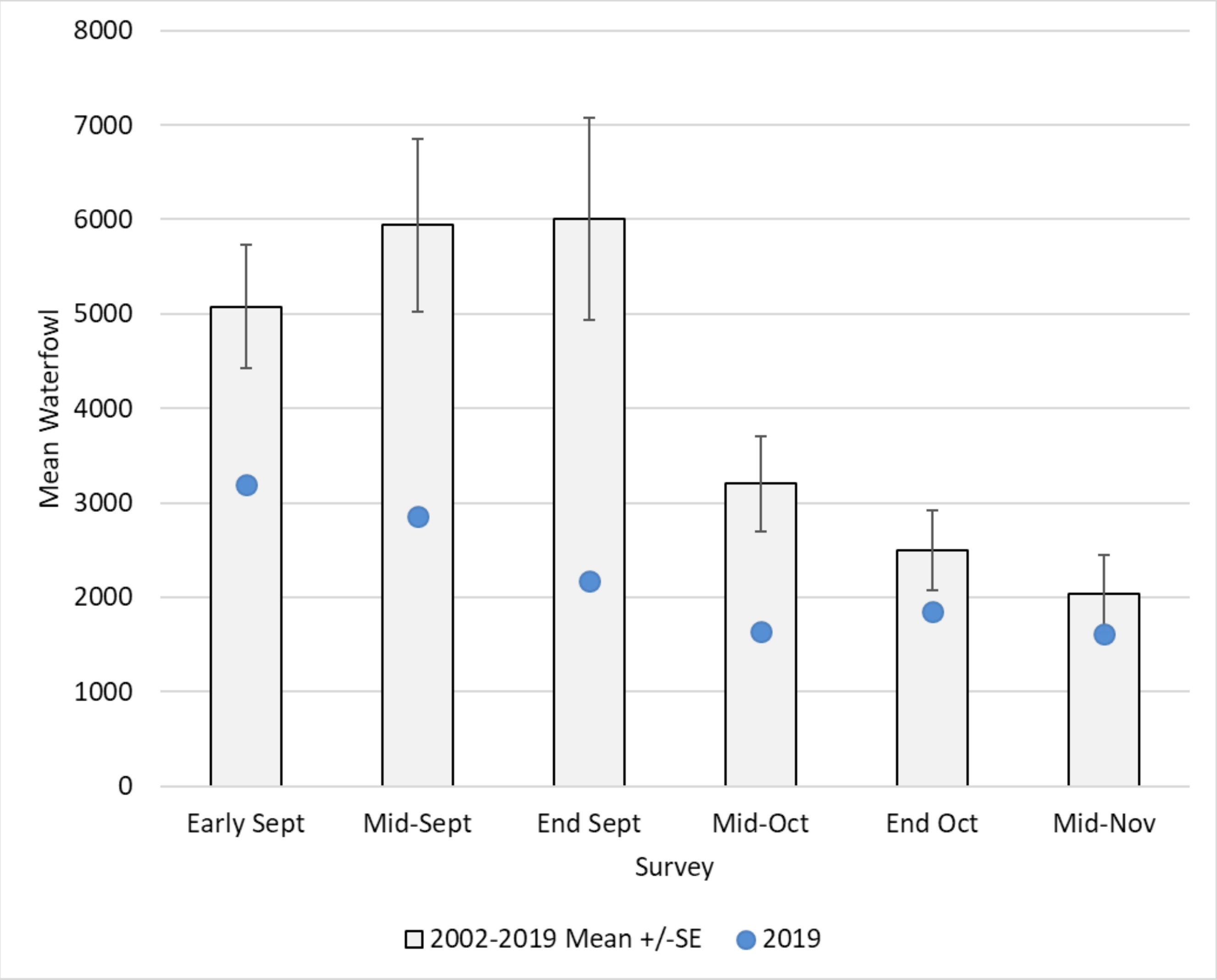


Figure 3-146. 2019 Mono Fall Waterfowl Survey Totals and 2002-2019 Means

A total 13 waterfowl species were detected on Mono Lake aerial surveys in fall of 2019 (Table 3-32). Northern Shoveler and Ruddy Duck were the most abundant species with Northern Shoveler comprising 60% (7,967/13,333) and Ruddy Duck 24% (3,152/13,333) of all waterfowl in 2019. The total number of Northern Shoveler and Ruddy Duck recorded at Mono Lake in 2019 was well below the long-term 2002-2019 average (Figure 3-147). Use by most other species was comparable to the long-term mean with the exception of reduced numbers of Mallard (Figure 3-148).

Table 3-32. Species Totals, 2019 Mono Lake Fall Waterfowl Surveys

Species	**Early Sept**	**Mid-Sept**	**End Sept**	**Mid-Oct**	**End Oct**	**Mid-Nov**	**Species Totals**
Snow Goose	0	0	0	0	2	6	8
Greater White-fronted Goose	0	0	0	7	0	0	7
Canada Goose	2	0	33	17	62	80	194
Northern Shoveler	2951	2395	1602	372	356	291	7967
Gadwall	116	51	22	10	1	0	200
American Wigeon	0	0	0	0	0	9	9
Mallard	53	83	53	179	50	33	451
Northern Pintail	6	1	25	174	161	130	497
Green-winged Teal	10	9	80	109	230	235	673
Unidentified Teal	0	0	0	100	50	3	153
Redhead	0	0	0	8	0	0	8
Ring-necked Duck	0	0	0	2	0	0	2
Bufflehead	0	0	0	0	1	4	5
Ruddy Duck	56	321	363	647	938	827	3152
Unidentified Diving Duck	1	0	0	6	0	0	7
Total	**3195**	**2860**	**2178**	**1631**	**1851**	**1618**	**13333**

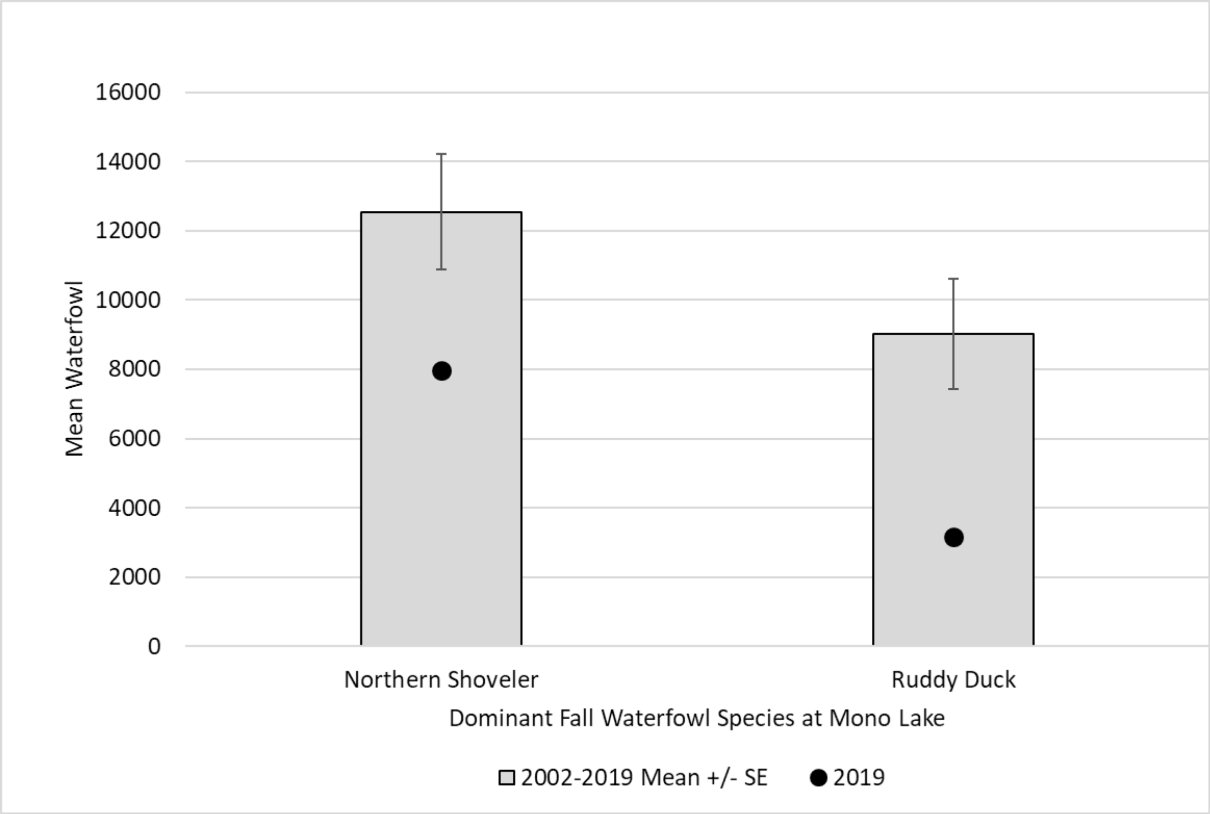


Figure 3-147. Mono Lake Total Northern Shoveler and Ruddy Duck and 2002-2019 Means

The total Northern Shoveler and Ruddy Ducks at Mono Lake in fall 2019 are shown as compared to the long-term mean.

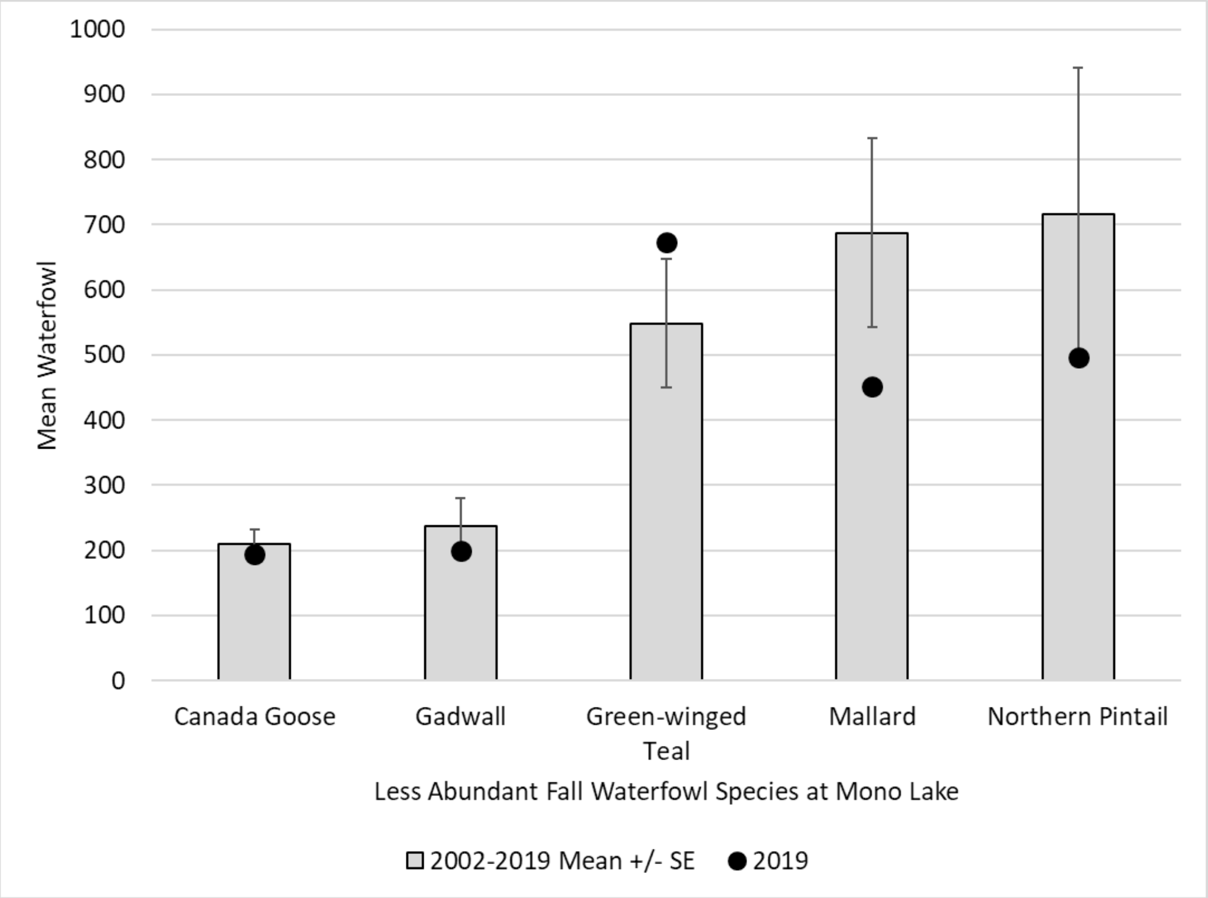


Figure 3-148. Mono Lake Waterfowl Species Totals and 2002-2019 Means

Totals for the less abundant, but common fall waterfowl species at Mono Lake in fall 2019 are shown as compared to the long-term mean.

Lake Level and Fall Waterfowl Populations

The annual lake level in September has not directly influenced the total number of waterfowl using Mono Lake over the fall survey period (r^2_{adj}= -0.038, p=0.54) (Figure 3-149).

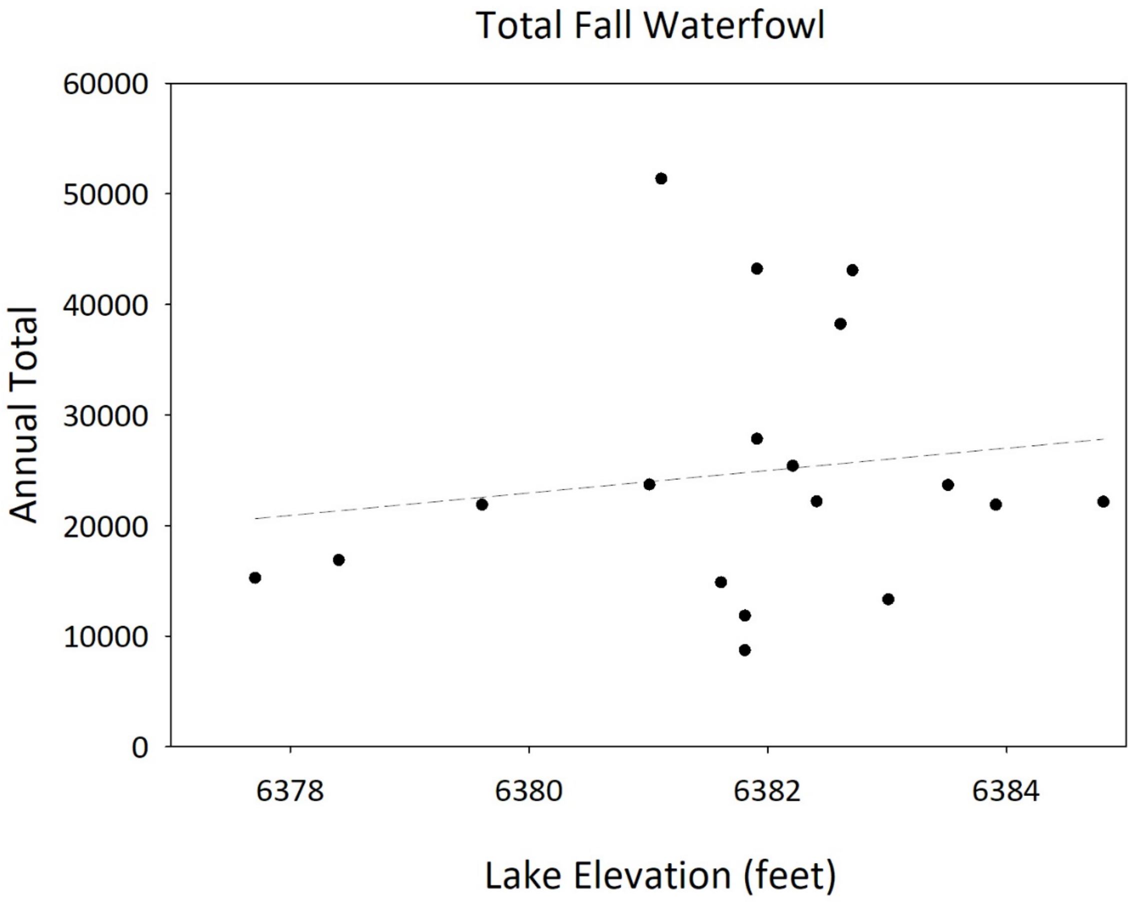


Figure 3-149. The relationship between total annual fall waterfowl populations and Mono Lake elevation in September of each year.

3.4.3.4 Bridgeport Reservoir

Fall Waterfowl Population Size

From 2003-2019, the yearly total number of waterfowl at Bridgeport Reservoir has averaged 33,106 +/-4,050 SE (Figure 3-150, Table 3-33). In 2019, 24,827 waterfowl were tallied and this value was below the long-term mean. The greatest use of Bridgeport Reservoir was in 2005 when 83,186 waterfowl were counted over the six surveys. The lowest total use occurred in fall of 2014 with a seasonal total of 13,119. Peak single survey fall counts have averaged 10,474, +/- 1,349 ranging from a low of 2,583 in 2014 to the highest single day count of 23,150 in 2005. The estimated minimum annual fall waterfowl population of Bridgeport Reservoir is 11,094 +/- 1,367 SE. Population estimates have ranged from a low of 2,691 in 2014 to a high of 23,150 in 2005.

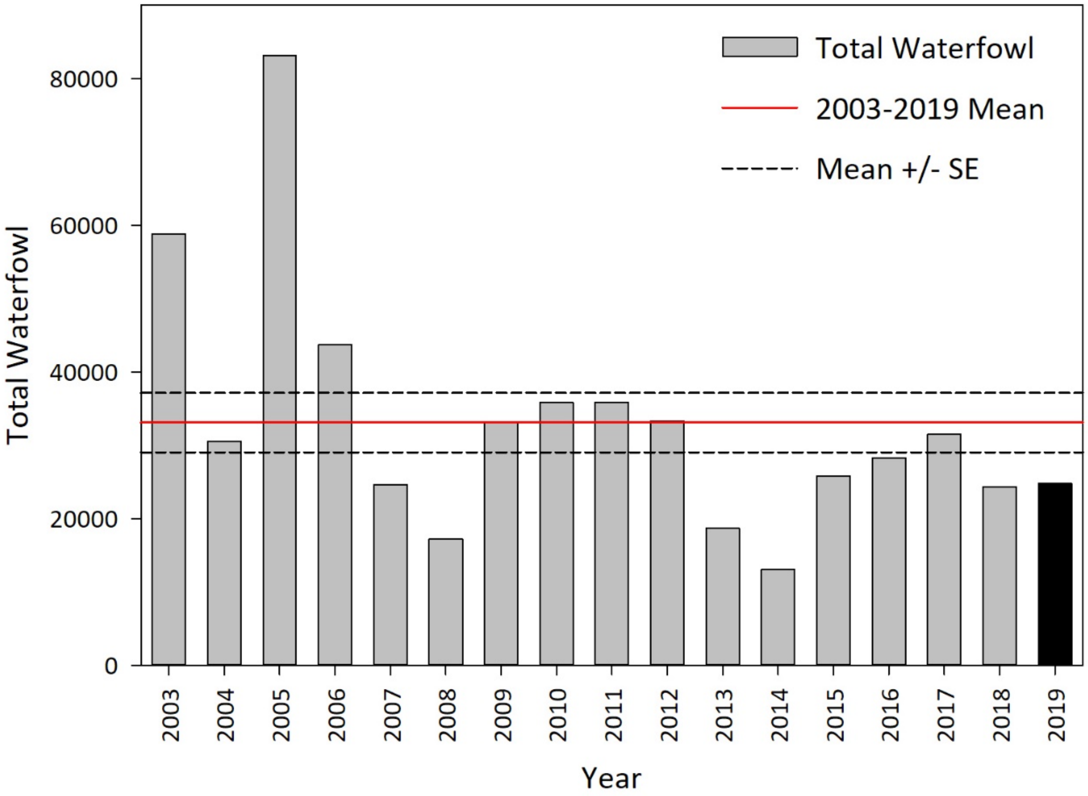


Figure 3-150 Annual Total Waterfowl at Bridgeport Reservoir, 2003-2019

The long-term mean and standard error are shown for reference.

Table 3-33. Bridgeport Reservoir Yearly Waterfowl Population Indices

Year	Total	Peak	Population Estimate
2003	58,821	20,941	22,922
2004	30,547	11,860	13,378
2005	83,186	23,150	23,150
2006	43,705	15,238	15,238
2007	24,632	11,957	12,910
2008	17,184	5,486	5,486
2009	33,226	11,270	11,270
2010	35,828	8,140	9,768
2011	35,865	9,770	10,847
2012	33,328	15,582	14,639
2013	18,657	7,430	8,842
2014	13,119	2,583	2,691
2015	25,817	5,434	5,434
2016	28,279	7,993	9,736
2017	31,474	6,709	7,534
2018	24,307	8,427	8,427
2019	24,827	6,098	6,331
Mean	**33,106**	**10,474**	**11,094**
Std Err	**4,050**	**1,349**	**1,367**

Species Composition

A total of 18 waterfowl species were detected at Bridgeport Reservoir during fall 2019 aerial surveys (Table 3-34). Geese and swans comprised approximately 5% of all waterfowl, and only Canada Goose was common. The six dabbling duck species totaled 83% of all waterfowl, of the dabbling duck species, Northern Shoveler, Gadwall, Mallard, Northern Pintail, Green-winged Teal, were most abundant. The most species-rich group was diving ducks, and although nine species were observed, diving ducks as a whole only comprised 12% of all waterfowl. Ruddy Duck and Bufflehead were the most abundant diving waterfowl species. Species richness was lowest in Early to Mid-September prior to the arrival of typical later migrant species including diving ducks, Tundra Swan and Snow Goose. Yearly totals were significantly below the long-term mean for Northern Shoveler, Gadwall, and Northern Pintail. Green-winged Teal and Ruddy Duck numbers were significantly above the long-term mean (Figure 3-151).

Table 3-34. Species Totals, 2019 Bridgeport Reservoir Fall Waterfowl Surveys

Species	**Early Sept**	**Mid-Sept**	**End Sept**	**Mid-Oct**	**End Oct**	**Mid-Nov**	**Species Totals**
Snow Goose	-	-	-	-	-	2	2
Canada Goose	450	336	250	10	120	40	1,206
Tundra Swan	-	-	-	-	25	-	25
Cinnamon Teal	80	-	-	-	-	-	80
Northern Shoveler	411	900	817	120	735	200	3,183
Gadwall	1,110	1,611	1,750	305	58	-	4,834
Mallard	70	100	155	1,550	990	450	3,315
Northern Pintail	100	400	1,014	950	485	400	3,349
Green-winged Teal	100	800	1,832	978	1,500	640	5,850
Canvasback	-	-	-	-	-	1	1
Redhead	-	-	50	-	2	-	52
Ring-necked Duck	-	-	60	5	-	-	65
Lesser Scaup	-	-	-	60	-	-	60
Bufflehead	-	-	1	36	95	810	942
Common Goldeneye	-	-	-	2	1	32	35
Hooded Merganser	-	-	-	-	10	-	10
Common Merganser	28	33	19	9	17	12	118
Ruddy Duck	-	80	150	150	370	950	1,700
Total	2,349	4,260	6,098	4,175	4,408	3,537	24,827

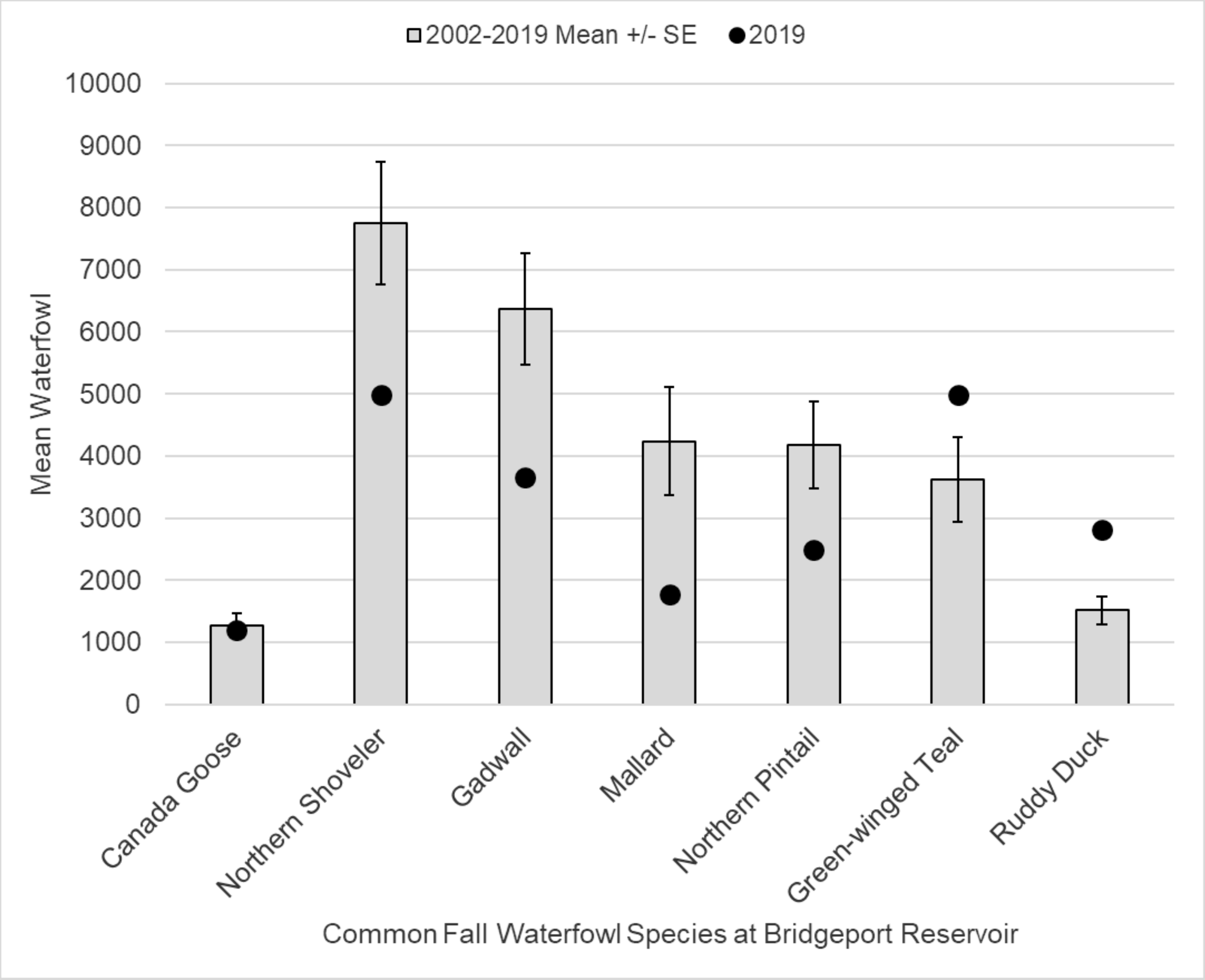


Figure 3-151. Abundance of the Dominant Waterfowl Species at Bridgeport Reservoir

This graph shows the 2019 results relative the long-term 2003-2019 mean.

Spatial distribution

Of the three subareas at Bridgeport Reservoir, waterfowl use was highest in the West Bay throughout the season (Table 3-35). Waterfowl are found throughout the West Bay and among the several deltas and inlets created where Buckeye Creek, Robinson Creek, and the East Walker River enter the West Bay. Geese are often found out on the meadows in this area away from the water's edge. Waterfowl use in the East shore subarea occurs primarily in the southern half of this segment area, in proximity to inflow from the East Walker River and shallow water feeding areas and mudflats. In the North Arm, waterfowl tend to be few in number and scattered along the immediate shoreline area.

Table 3-35. Bridgeport Reservoir, Spatial Distribution by Survey, 2019

Survey	EASH	NOAR	WEBA
Early September	170	29	2,150
Mid-September	71	33	4,156
End of September	472	65	5,561
Mid-October	1,150	20	3,005
End of October	782	221	3,405
Mid-November	848	96	2,593
Total waterfowl by shoreline segment	**3,493**	**464**	**20,870**

3.4.3.5 Crowley Reservoir

Fall Waterfowl Population Size

From 2003-2019, the yearly total number of waterfowl at Crowley Reservoir has averaged 47,172 +/-4,636 SE (Table 3-36). In 2019, 39,019 waterfowl were tallied and this value was slightly below the long-term mean plus standard error. The greatest use of Crowley Reservoir was in 2014 when 82,006 waterfowl were counted over the six surveys. The lowest total use occurred in fall of 2007 with a seasonal total only 17,995. Peak single survey fall counts have averaged 11,874, +/- 1,008 ranging from a low of 3,791 in 2007 to the highest single day count of 18,219 in 2005. The estimated minimum annual fall waterfowl population of Crowley Reservoir is 12,760 +/- 1,097 SE. Population estimates have ranged from a low of 6,035 in 2008 to a high of 20,021 in 2014.

Table 3-36. Crowley Reservoir Yearly Waterfowl Population Indices

Year	Total	Peak	Population Estimate
2003	74,107	15,555	19,058
2004	65,581	15,002	16,171
2005	57,449	18,219	18,219
2006	25,474	7,878	8,139
2007	17,955	3,791	6,099
2008	29,442	6,035	6,035
2009	36,441	11,695	12,268
2010	47,558	9,802	9,802
2011	29,670	11,290	11,290
2012	33,463	10,464	10,745
2013	62,362	16,089	16,089
2014	82,006	17,657	20,021
2015	65,133	16,117	17,134
2016	64,986	13,204	16,024
2017	33,341	7,819	8,596
2018	37,849	10,723	10,723
2019	39,019	10,518	10,518
Mean	**47,172**	**11,874**	**12,760**
Std Err	**4,636**	**1,008**	**1,097**

Species Composition

Sixteen waterfowl species were detected at Crowley Reservoir during fall 2019 aerial surveys. (Table 3-37). Northern Shoveler and Mallard were the most numerous species at Crowley Reservoir in 2019, totaling 11,937 and 8,087 respectively. Other common species include Gadwall, Northern Pintail, Green-winged Teal, and Ruddy Duck - all of which were somewhat equally abundant. Northern Shoveler numbers were significantly above the long-term mean at Crowley Reservoir. Gadwall, Green-winged Teal, Northern Pintail, and Ruddy Duck totals were below the long-term mean (Figure 3-152).

Species	**Early Sept**	**Mid-Sept**	**End Sept**	**Mid-Oct**	**End Oct**	**Mid-Nov**	**Species Totals**
Canada Goose	-	36	140	127	273	179	755
Tundra Swan	-	-	-	-	4	47	51
Cinnamon Teal	80	20	15	-	-	2	117
Northern Shoveler	1,445	1,617	4,502	2,506	1,840	27	11,937
Gadwall	492	638	1,170	814	145	80	3,339
American Wigeon	-	-	60	250	40	130	480
Mallard	282	122	50	1,850	3,550	2,224	8,078
Northern Pintail	61	260	300	1,720	1,010	572	3,923
Green-winged Teal	110	420	730	416	1,150	340	3,166
Unidentified Teal	-	-	15	-	1,510	-	1,525
Canvasback	-	-	-	6	-	26	32
Redhead	-	-	50	140	5	60	255
Ring-necked Duck	-	-	30	120	4	79	233
Lesser Scaup	20	-	-	-	32	101	153
Bufflehead	-	-	5	53	235	420	713
Common Merganser	12	2	4	-	-	2	20
Ruddy Duck	60	210	143	1,074	720	2,035	4,242
Total	2,562	3,325	7,214	9,076	10,518	6,324	37,849

Table 3-37. Species Totals, 2019 Crowley Reservoir Fall Waterfowl Survey

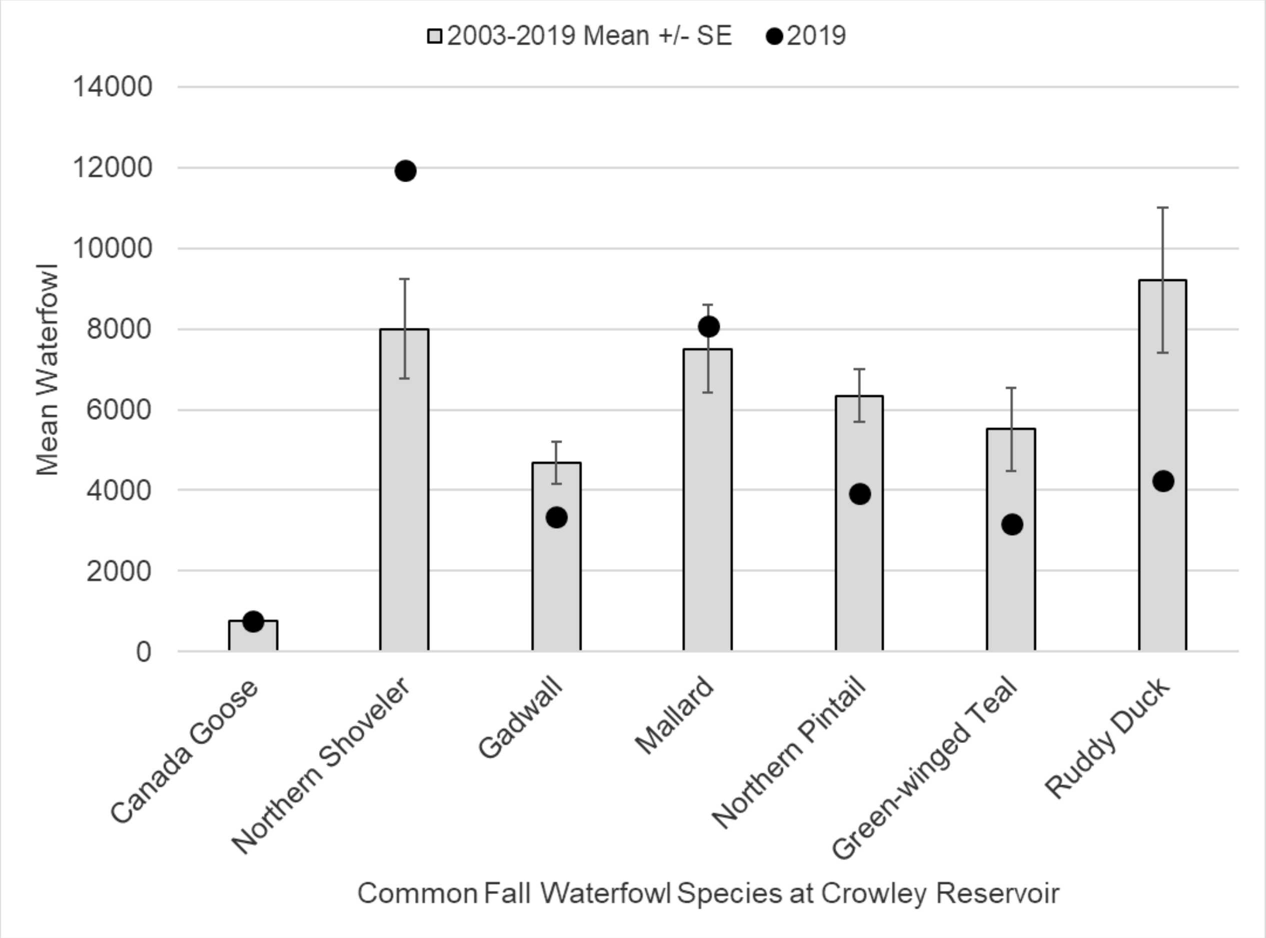


Figure 3-152. Crowley Reservoir Waterfowl Species Totals, 2019

Spatial Distribution

During the 2019 surveys, waterfowl at Crowley Reservoir were found concentrated primarily in two main areas – McGee Bay and the Upper Owens River delta (Table 3-38). Waterfowl in McGee Bay were found all along the length of this shoreline subarea. The McGee Bay subarea receives inflow from Convict and McGee Creeks, and spring flow and subsurface flows from irrigation upgradient. Wetland vegetation often extends to the shoreline, with small areas of mudflats present at all except the highest reservoir levels. During the later fall surveys in October, diving ducks can be numerous with large flocks of Ruddy Ducks and other diving species just off shore and on the open water. The other area of waterfowl concentration is the Upper Owens River delta where flows from the Owens River enter the reservoir. Except at very high reservoir levels, this area has extensive mudflats for loafing, shallow feeding areas, and quiet backwater bays. During early season surveys, waterfowl generally avoid the Chalk Cliffs area as there are limited feeding opportunities due the deep water and lack of fresh water inflow. Waterfowl continued to show a pattern, however of late-season use only of the Chalk

Cliffs area when significant numbers of dabbling ducks are then seen offshore or loafing along the narrow, dry beach. Yearly, increased use of Chalk Cliffs area has coincided with the opening of waterfowl hunting season, and waterfowl may be seeking refuge in this area of more difficult access. Hilton Bay has good waterfowl habitat with adjacent meadows, some fresh water inflow, and shallow waters, but the area is small in size, and supports fewer numbers of waterfowl than areas of comparable quality. Waterfowl use of the Layton Spring subarea is usually concentrated near the spring inflow. Birds may also be scattered in smaller numbers along the mudflats or nearshore throughout the remainder of the subarea which is primarily sandy beach. North Landing is another shoreline area with no direct fresh water inflow, and limited shallow water areas near shore and typically supports lower waterfowl use. The Sandy Point subarea is also an area of limited use by waterfowl due to a lack of freshwater input and limited shallow feeding areas.

Table 3-38. Crowley Reservoir, Spatial Distribution by Survey, 2019

Survey	CHCL	HIBA	LASP	MCBA	NOLA	SAPO	UPOW
Early September	-	150	160	722	156	34	1,340
Mid-September	-	226	-	1,450	32	15	1,602
End of September	4	190	152	3,065	21	7	3,775
Mid-October	109	201	182	4,470	51	67	3,996
End of October	496	823	565	4,541	393	600	3,100
Mid-November	1,078	344	356	2,975	153	122	1,296
Total waterfowl by shoreline segment	1,687	1,934	1,415	17,223	806	845	15,109

Comparison to Reference Sites

Annual waterfowl counts for all survey areas combined has averaged 105,010 +/- 7,556 SE for the period 2003-2019. Mono Lake has supported an average of 24,762 +/- 2,809, or approximately 24% of the total. Bridgeport Reservoir's annual mean of 33,106 +/-4,050 has accounted for 32% of the population, while Crowley has averaged 47,173 +/- 4,636 or approximately 45% of all waterfowl. Compared to Bridgeport and Crowley Reservoirs, the waterfowl population at Mono Lake is significantly lower (Figure 3-153).

Total waterfowl use in 2019 was below the long-term means for all three survey areas, however the difference was greatest at Mono Lake. The species composition of the waterfowl community at Mono Lake also differs notably from the other two survey areas in that it is composed primarily of the few species typically associated with saline lakes. In contrast, the waterfowl communities of Bridgeport and Crowley Reservoirs are more diverse, and have numerous codominant species as is typical of fresh water systems.

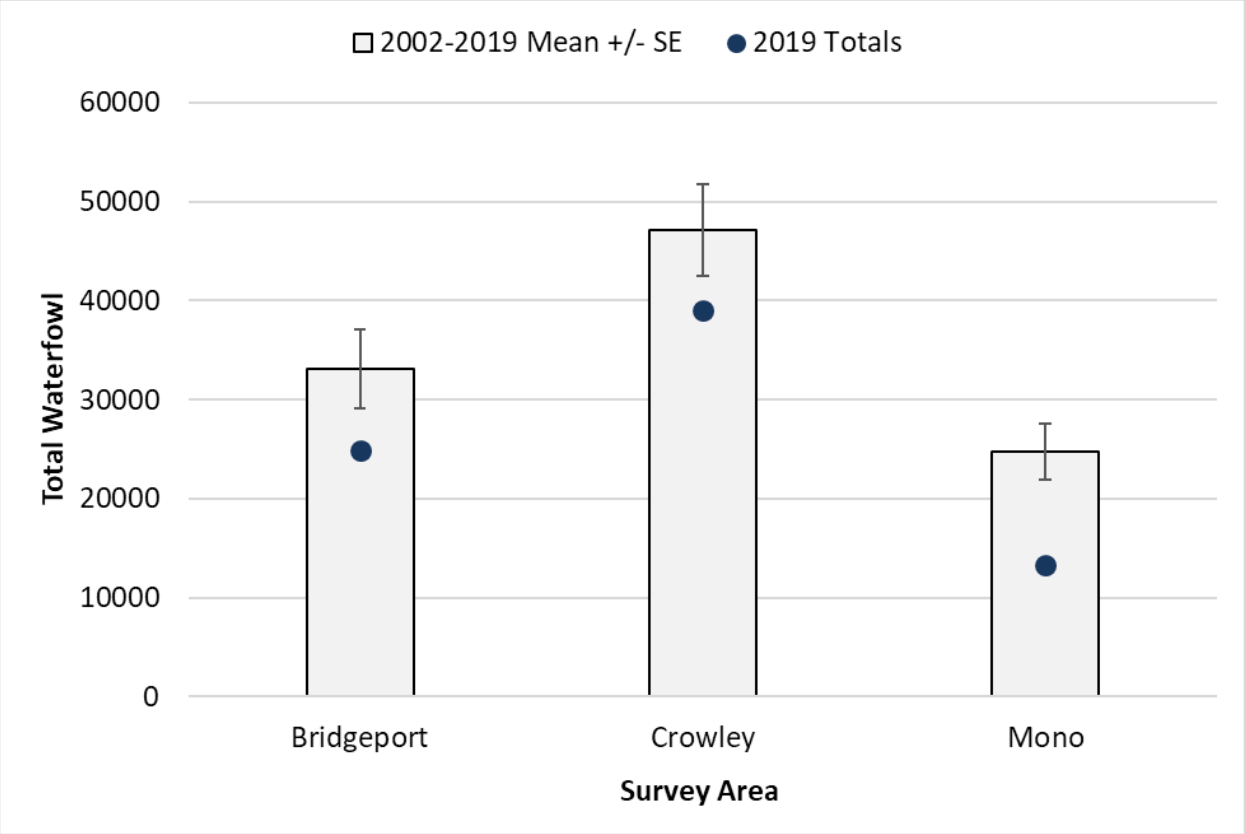


Figure 3-153. Comparison of Mean Fall Waterfowl at each of the Three Surveys Areas, 2003-2019

3.4.4 Waterfowl Survey Discussion

3.4.4.1 Summer Ground Surveys – Mono Lake Shoreline

Breeding Population Size and Composition

The elevation of Mono Lake influences waterfowl breeding population size, species composition, and brood production. Although the mid-June lake elevation in 2019 was the same as 2018, the overall breeding waterfowl population was not different from the long-term average, but was slightly less than in 2018. Over the next month, the lake level increased another 0.6 feet, and brood production ended up being well above normal, despite a slight reduction in overall population size as compared to 2018 and an average population size. While local conditions in June 2019 may not have supported an increase in the breeding population, or attracted more birds to settle, the increase in lake level by July may have improved nest survival or brood-rearing habitat, resulting in an overall increase in brood production over 2018, and numbers well above average.

The productivity of waterfowl breeding populations has been positively correlated with wetland productivity (Cox et al. 1998, Pietz et al. 2003, Kaminski and Prince 1981, Krapu et al. 1983). Breeding waterfowl populations are limited not only by the availability of open water wetlands but the capacity of those wetlands to support high densities of aquatic invertebrates (Cox et al. 1998, Pietz et al. 2003, Kaminski and Prince 1981, Krapu et al. 1983, Sjoberg et al. 2000). Waterfowl breeding habitat has shown improvement at Mono Lake at the higher lake levels observed due to increases in the number and extent of lake fringing ponds. The effect of lake level on pond availability is most pronounced along the south shore. Significant declines in the elevation of Mono Lake result in shoreline changes, particularly along the south shore including a drying of ponds, a draining of ponds due to berm erosion, or vegetation encroachment.

One mechanism by which increased lake elevation improves habitat is by restoring or maintaining connectivity between important waterfowl feeding areas at the outflow of springs or creeks, and the onshore breeding and brooding areas of freshwater ponds and wetland vegetation. Lake elevation may also be affecting breeding populations indirectly by influencing brood survival. One process by which this may occur is increased predation exposure and risk. As the lake level decreases, the distance between nesting areas with vegetation and high quality feeding areas, such as spring outflow sites, increases. Increases in lake elevation however, place breeding ponds closer to favorable feeding areas at the outflow of creeks and springs where densities of *Artemia* may be higher (Dana and Herbst 1977). Lake elevation may decrease the exposure of ducklings by reducing the distance over which they have to travel across open playa areas to move between feeding areas and cover.

The increased distance between feeding areas and cover will result in an increase in energy expenditure, and increase the exposure of young broods to predation. Ducklings are flightless for approximately the first seven weeks of life, and suffer the highest mortality in the first two weeks of life (Ball et al. 1975, Cox et al. 1998). Predation and adverse weather have been cited as major causes of duckling mortality (Cox et al. 1998). Predators of young ducks include coyote (*Canis latrans*), California Gull (Gates 1962), raccoon (*Procyon lotor*) and mink. Reduced energy expenditures will support higher growth rates of ducklings, providing some protection against adverse weather and predation (Cox et al. 1998). Factors affecting brood survival may ultimately influence the breeding population because of the tendency of waterfowl to return to their natal area to breed (Doherty et al. 2002).

Spatial distribution

Waterfowl breeding populations are concentrated into highly localized areas around the shoreline of Mono Lake, where fresh water resources occur for young ducklings. Although breeding waterfowl use all subareas to some extent, long-term data indicate use has been concentrated in three subareas: Wilson Creek, Mill Creek and South Shore Lagoons. Even within those subareas, breeding waterfowl use has been concentrated in areas of appropriate nesting or feeding habitat. South Shore Lagoons and Wilson Creek and Mill Creek have supported a similar proportion of the overall breeding waterfowl community. The South Shore Lagoons has produced more broods, with most breeding activity in the Goose Springs area.

In 2019, breeding activity was concentrated along the south shoreline, including the South Shore Lagoons and Simon's Spring shoreline areas. Breeding was particularly concentrated in the South Shore Lagoons subarea where more than half of all waterfowl broods were found in 2019. Whereas Mill Creek and Wilson Creek are generally high use areas, use in these areas was below the long-term mean and no broods were seen in Mill Creek. Wilson Creek below the Pumice Mine Road was periodically dewatered in 2019 (K. Bellomo, pers. comm.), and the effect this may have had on waterfowl use of this area is not clear. Over the last few years, flows in Wilson Creek have created a pond in the Wilson Creek delta, and waterfowl have used this pond heavily. Decreased inflow into the pond would raise the salinity, as the pond is open to Mono Lake waters. As was the case in 2018, the Goose Springs area of South Shore Lagoons absorbed most of the increased breeding activity observed in 2019. In 2018, multiple shoreline ponds were present in close proximity to one another on shore at Goose Springs including the freshwater ponds at the spring heads, a large open freshwater pond downstream, and a large brackish pond immediately on shore. These conditions were favorable nesting, breeding, feeding and escape. It is uncertain why use declined in Mill Creek, however field observations indicate that the high creek flows experienced in the summer of 2017 and 2018 created a deep channel at the mouth of the creek, effectively eliminating the shallow feeding areas where the majority of waterfowl feeding and brooding have been observed to take place.

Habitat Use

Ground surveys allow an opportunity to record specific habitat and microhabitat types used by waterfowl. Shoreline features including the deltas of freshwater streams, freshwater ponds, brackish ponds, and mudflats are the main habitats used by dabbling duck species.

The only species that regularly uses meadow/marsh habitat and feeds with broods in alkaline wet meadow habitats near or on shore is Canada Goose. Canada Goose was also regularly observed swimming in open water areas offshore, frequently in response to disturbance. On-shore water features were the landtype most heavily used by dabbling ducks, with freshwater and brackish ponds receiving the most use. Both freshwater and brackish ponds were used by ducks for feeding and resting. Ria areas were used almost exclusively for feeding and were used primarily by Gadwall and Green-winged Teal. Mallard showed the highest proportional use of on shore water features such as fresh and brackish ponds, with relatively less use of ria.

3.4.4.2 Summer Ground Surveys - Restoration Ponds

Waterfowl habitat at the Restoration Ponds continues to be impacted by ageing infrastructure and water delivery problems. Waterfowl use was below the long-term mean and confined primarily to two ponds – DEPO_4 and COPO_E. The release of water to COPO_E following repairs to the infrastructure helped to maintain overall brood production rates for the Restoration Ponds, however the significant increase in cattail cover at these ponds may impact waterfowl habitat quality, especially if the trend continues.

3.4.4.3 Fall Aerial Counts

Mono Lake - Population size and species composition

Waterfowl use at Mono Lake in fall 2019 showed an increase from the extreme low observed in 2018, but was still well below the long-term average. The causative factors influencing annual fall waterfowl numbers at Mono Lake have not been clearly identified. *Artemia* cyst production may partly explain the annual variation in waterfowl populations at Mono Lake (LADWP 2018). In open saline waters of Great Salt Lake, Northern Shoveler and Green-winged Teal were found to consume largely *Artemia* cysts and adults. In that study, cysts comprised a larger component of the diet than adult brine shrimp, making up 52% of the biomass of the diet of the shoveler, and 80% of Green-winged Teal diets (Roberts 2013). While some waterfowl species, such as Mallard and geese are typically seen in shoreline ponds or mudflats, other fall migrants including Northern Shoveler, Green-winged Teal and Northern Pintail, congregate near shore at creek deltas. *Artemia* are likely to be the most abundant prey item in these areas, however other potential dietary items may be present.

A time budget study has not been conducted of waterfowl use of shoreline areas during fall migration, thus the importance of the different shoreline subareas for feeding, drinking, roosting, or bathing is not known. An understanding of how waterfowl use each subarea would provide a greater understanding of the specific resources available for waterfowl around the lake, and how they are being used.

Reduced use by the dominant waterfowl species at Mono Lake - the dabbling duck Northern Shoveler and the diver Ruddy Duck, was observed in 2019. Multiple factors may influence these migrating populations including productivity on breeding grounds, flyway habitat conditions, weather, and disease. The reasons for the decrease in fall waterfowl numbers at Mono Lake in 2019 is not known although preliminary analysis to date suggests regional drought condition may result in increased use of Mono Lake as a stopover. Similar decreases in waterfowl populations were observed at both Bridgeport and Crowley Reservoir in 2019, however the decrease in use of Mono Lake was more substantial.

The differences in the characteristics between individual saline lakes with regard to parameters such as salinity, fresh water inputs, and water depth, can influence the quality of the habitat for waterfowl and therefore species composition and abundance. Salinity and water depth influence not only the types and abundance of food items, but also accessibility. Mono Lake is deep, highly saline, with limited shallow shoreline areas. These features limit the habitat quality for waterfowl and may ultimately limit recovery of waterfowl populations. In order for waterfowl to meet their energetic demands, food resources need to be accessible, abundant, and of sufficient quality.

The food resources at individual saline lakes can vary widely, depending on salinity and fresh water inputs. Closed lake systems can vary from brackish (1-3 gm/L) to highly saline (e.g. Mono Lake 80-90 gm/L). At moderate salinity levels aquatic invertebrate communities are more diverse than at higher salinities. Few invertebrate species are tolerant of high salinities, thus highly saline lakes such as Mono Lake have low invertebrate diversity, however, can support large number of some species. Depending on salinity, the invertebrate community of closed lake systems may include *Artemia*, Dipterans (alkali fly, midges), Corixids, water fleas (Daphnia), beetles (Coleptera). The highly saline water of Mono Lake currently only support *Artemia* and *Ephydra*, however other species may have occurred historically when the lake was no more than 50 gm/L salinity. For example, experimental studies have shown that at the prediversion salinity of 50 gm/L, twice the diatom diversity would have been supported and greater biomass and diversity of benthic algae (Herbst and Blinn 1998). The highly saline water also limits the availability of vegetable food sources to isolated fresh water and brackish ponds as the salinity of the lake is above the tolerance of wetland plants.

Birds inhabiting saline environments encounter additional energetic costs associated with osmoregulation. Osmoregulation in waterbirds occurs through physiological, behavioral, or mechanistic adaptations. In some species, ingesting salts while feeding and drinking in saline environments cause large changes in the organs responsible for osmotic regulation including the kidneys, small intestine, and hindgut. Salt glands are the most efficient organ by which waterbirds cope with excess salt. Birds in marine environments have more well-developed salt glands than non-marine species (Gutiérrez 2014). In high salinity environments, the intestines of some birds increase in mass, so that the salt holding capacity, increases and more salt can be routed to the salt glands (Gutiérrez 2014). Salt glands hypertrophy when birds switch from fresh to saline habitats in order to maintain water and electrolyte balance (El-Gohary et al. 2013, Gutiérrez 2014). Waterfowl using Mono Lake may be different “subpopulations” using saline habitats along the flyway, and thus populations will not be closely tied to those of Bridgeport or Reservoir. In addition maintaining large, functioning salt glands is physiologically demanding. Birds may also osmoregulate through behavioral or mechanistic actions. Behaviorally, birds may avoid saline habitats, or by feeding on prey with lower salt loads, or visit fresh water sources near feeding grounds. Other birds may use mechanical means of decreasing the intake of saline water such as using surface tension to deliver prey to the mouth or using the tongue to compress water off of prey (Rubega 1997, Mahoney and Jehl 1985). Waterfowl populations at Mono Lake may be small compared to Bridgeport and Crowley due not only to limited shallow water feeding areas at Mono Lake, but due to avoidance of the saline waters because of the physiological demands of salt stress.

Waterfowl using Mono Lake must balance the energetic costs of migration and molt and with food intake. The two most abundant and widespread secondary producers are brine shrimp and alkali flies. Other food resources are available at lake-fringing brackish and freshwater ponds, however these are localized at particular shoreline areas, and their presence and availability ephemeral.

Waterfowl diets vary according to the feeding environment and available food resources. Food items reported as being important to Northern Shovelers feeding in saline habitats include water boatmen (Corixidae) (Euliss and Jarvis 1991), copepods and rotifers (Euliss 1989), brine shrimp cysts (Roberts 2013, Boula 1986, Vest 2013) and alkali fly larvae (Roberts 2013. Boula 1986) and pupae (Boula 1986). Brine shrimp adults are not as digestible and have lower caloric density as compared to other food sources, and may not be selected for when other food is available. The diet of Northern Shovelers at Mono Lake has not been studied; therefore the extent to which they use the various life stages of brine shrimp or alkali fly at Mono Lake is unknown. Although many dabbling duck species consume both vegetable and animal foods, many studies have found a preponderance of animal matter in the diet of Northern Shoveler. In saline lakes that lack aquatic vegetation and have limited vegetative food resources such as Mono Lake, waterfowl species whose diet is composed largely of animal manner can still find resources. Northern Shoveler also has a specialized bill morphology including very closely spaced lamellae, allowing for the effective filtering of small aquatic invertebrates (Gurd 2007). Northern Shoveler may be able to feed more efficiently at Mono Lake than other species, despite saline conditions because of their bill structure.

Although Northern Shoveler may be abundant at saline lakes, they do not have the physiological adaptation of well-developed salt glands for osmoregulation (Roberts 2013). Like most nonmarine waterfowl, Northern Shoveler need access to fresh water daily. Northern Shoveler can forage efficiently at saline sites however supporting only small aquatic invertebrates such as those found at Mono Lake, and osmoregulate through behavioral means by visiting fresh water resources.

Despite the productivity of Mono Lake, access of these food resources to dabbling duck species like Northern Shoveler is somewhat limited. The topography and bathymetry is such that shallow-water feeding areas, especially those near springs, are widespread and not extensive. The range of water depths for optimal foraging by dabbling ducks is 2-10 inches. Prey will generally be less accessible in water depths greater than about 10 inches, and thus foraging efficiency will decrease. At Mono Lake, dabbling ducks have been observed to feed almost exclusively near shore, and more specifically, where the bathymetry data suggests a greater extent of shallow water than areas where waterfowl use is lower or absent.

The spatial distribution of waterfowl at shoreline sites in fall suggests that waterfowl habitat at Mono Lake is highly localized. Although the Wilson Creek area makes up <2% of the entire shoreline area, it has supported 45% of all dabbling ducks. The combination of abundant spring flow, extensive wet meadow habitat upgradient, and shallow offshore gradient in the Wilson Creek bay likely contribute to creating a favorable shallow water feeding and loafing area for fall migrant waterfowl.

The data suggest that waterfowl populations at Mono Lake are responding more to conditions at the lake itself, and have poor correlation to numbers and trends at the nearby freshwater lakes used as comparison sites.

4.0 SUMMARY AND RECOMMENDATIONS

The Mono Basin Waterfowl Habitat Restoration Program was developed to evaluate the effect of changes in the Mono Lake area relative to the restoration objectives, and to provide information to guide future restoration activities. The program has included a number of restoration projects, objectives, and monitoring projects. Restoration has included establishing a target lake elevation, reestablishing perennial flow in tributaries, channel openings, providing financial assistance for the restoration of waterfowl habitat, and exotic species control.

The implementation of Decision 1631 appears to have resulted in the lake level stabilization, although Mono Lake is still well below the target lake level 26 years later. Climatic factors may be influencing Mono Lake and its recovery. Current trends indicate seasonal increases in salinity and water temperature, a finding aligned with regional climatic trends. Based on our analysis, a lack of sustained high freshwater input will not be able to reverse the trend of increasing salinity, and future limnological conditions of Mono Lake will largely depend on runoff conditions.

Within the range of lake elevations observed since 2002, shoreline waterfowl habitat in general shows improvement at higher lake level. These improvements include increased shoreline pond acreage and increased connectivity of shoreline ponds with the shoreline and spring outflow areas. Breeding waterfowl have been very responsive to lake level increases, however fall migratory populations have not.

Mono Lake is deep, highly saline, with limited shallow shoreline areas. These features limit the habitat quality for waterfowl and may ultimately limit recovery of waterfowl populations. In order for waterfowl to meet their energetic demands, food resources need to be accessible, abundant, and of sufficient quality. The current trends seen in the data with regard to salinity and water temperature, if continued, will influence waterfowl habitat conditions at Mono Lake.

Order 98-05 provided for funds to be set aside for waterfowl habitat restoration in the Mono Basin. The Restoration Ponds represent a potential location in the Mono Basin for waterfowl habitat enhancement. Waterfowl habitat at the Restoration Ponds would benefit from upgrades to the existing water delivery system to allow for more flexibility in water delivery to individual ponds. The system is also in need of repair, as recent failures in the water delivery infrastructure have affected pond habitat. We also recommend that Restoration Ponds managers consider implementing a system of rotational seasonal flooding of the ponds to improve pond productivity and waterfowl use. Seasonal flooding is a waterfowl habitat management technique used at most waterfowl management areas and wildlife refuges in

California to manage waterfowl habitat. Continuous inundation of wetlands will lead to decreased productivity of waterfowl forage plants and invertebrates supported by them. Seasonal flooding programs can also be used to control emergent vegetation and maintain open water habitats. The overgrowth of cattails has greatly reduced waterfowl habitat quality at the County Ponds due to continual inundation during the growing season. Seasonal manipulation of water delivery should be considered as a tool to aid in long-term management of emergent vegetative growth impacting waterfowl habitat at the Restoration Ponds. Thus moving away from continual year-round inundation of ponds to seasonal flooding is encouraged and recommended. We encourage parties interested in using these funds to repair and upgrade the ageing infrastructure of the Restoration Ponds for the improvement of waterfowl habitat to contact the Mono Basin Waterfowl Director for guidance or further recommendations as needed.

1) **Waterfowl time budget study -** Order 98-05 required a time budget study to be conducted during each of the first two fall migration periods after the plan was approved, and again when Mono Lake reaches its target lake elevation. A single time budget study of Ruddy Ducks was completed in fall of 2000 by Jehl. We recommend the Mono Basin Waterfowl Program Director develop a study plan for the second required time budget study focusing on shoreline use by waterfowl. The objective will be to implement the study during the fall migratory period of 2020. A time budget study allows for the determination of the relative importance of different shoreline sites for migratory waterfowl, and would provide insight into the importance of hypopycnal areas for feeding, resting, or drinking.

2) **Restoration Pond Management** - We recommend interested parties work with the Mono Basin Waterfowl Program Director in evaluating the feasibility of implementing a seasonal flooding program of the DeChambeau and County Restoration Ponds. In order to implement seasonal flooding, repairs and upgrades to the existing system may be required. A first step would be to discuss objectives, potential benefits, and potential costs to determine the feasibility of management change. Although the established fund is set aside by LADWP, the U.S. Forest Service would be responsible for project initiation and environmental documentation.

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