

Mono Basin
Annual Monitoring Reports

May 2026

*Prepared for State Water Resources Control Board
In Accordance with the Terms and Conditions of Amended
License Nos. 10191 and 10192*

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Section I. Mono Basin Fisheries Monitoring Report
Rush, Lee Vining, and Walker Creeks 2025

Prepared by Ross Taylor and Associates

**Mono Basin Fisheries Monitoring Report
Rush, Lee Vining, and Walker Creeks
2025**



Prepared by Ross Taylor and Associates for

The State Water Resources Control Board, the Los Angeles Department of Water and Power,
and the Mono Basin Monitoring Administration Team

April 20, 2026

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Executive Summary

The 2025 fisheries sampling was the fourth of ten years of biological monitoring of the Stream Ecosystem Flows (SEF), with oversight from the recently formed Mono Basin Monitoring Administration Team (MAT) as directed by the California State Water Resource Control Board's (SWRCB) amended Licenses 10191 and 10192. This monitoring continues a 25-year history of monitoring ordered by the SWRCB under Orders 98-05 and 98-07. Five of the six reaches sampled in 2025 were similar in length to those sampled between 2009 and 2024. A sixth site, the Rush Creek 8-Channel was sampled for the third year in a row. Sample site selection has evolved over time, with more sites annually sampled in 1999 through 2008 as the Fisheries Team investigated potential differences in fish production based on proximity to the Grant Lake Reservoir (GLR) dam and varying channel slopes and confinement. For example, in Rush Creek, the Mono Gate One Return Ditch (MGORD) was selected because of its tailwater condition below the dam and its propensity to support older and larger Brown Trout. Upper Rush was selected for its moderately-sloped channel and its location just downstream of a confined, gorge-like section. Finally, the Bottomlands section was selected for its location in a low-gradient area that has more potential for the formation of meanders, deeply scoured pools, and side-channels.

The 2025 Runoff Year (RY) was 69% of normal and classified as a Dry-Normal-1 RY type, as measured on April 1st. The range of runoff that defines a Dry-Normal-1 RY is 60%-80% exceedance. The preceding 13 years included a Normal RY of 103% in 2024, a record Extreme-Wet RY of 226% in 2023, a Dry RY of 60% in 2022, Dry RY of 58% in 2021, Dry-Normal-1 RY of 71% in 2020, a Wet RY of 140% in 2019, a Normal RY of 85% in 2018, an Extreme-wet RY of 206% in 2017 and five consecutive below "Normal" RYs (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).

Based on the 2013 terms of settlement and the recently amended licenses, in odd years the fisheries' monitoring effort was reduced to single-pass electrofishing. Thus in 2025, single-pass electrofishing was conducted at the usual annually sampled sites: the MGORD, Upper Rush and the Bottomlands in Rush Creek, the Lee Vining Creek main channel, and in Walker Creek. In addition, single-pass electrofishing was conducted at 8-Channel section in lower Rush Creek.

Odd-year Monitoring Metrics

For single-pass electrofishing in odd years, the monitoring metrics included condition factors, growth rates (in length and weight) from recaptures of previously PIT tagged trout, and relative stock densities (RSD) for three size classes of catchable trout (Table 1). Generating statistically valid population estimates, density estimates and standing crop estimates were infeasible with single-pass data and these metrics will only be generated in even-years.

Table 1 provides a concise view of comparisons of the 2025 monitoring metrics versus 2024 results. The Results section provides more detail regarding the percentages of decreases and increases of all monitoring metrics (Table 1).

PIT Tagging – New Tags and Recaptures

In 2025, a total of 592 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks. In addition, two recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 594 PIT tags were implanted during the 2025 fisheries sampling. Of the 594 trout tagged, 480 were age-0 Brown Trout and 80 were age-1 and older Brown Trout. For Rainbow Trout, 30 age-0 fish were tagged and four age-1 and older were tagged. Seventy-eight of the Brown Trout tagged in the MGORD section were up to 225 mm in total length and were presumed to be age-1 fish. In addition, 53 age-0 Brown Trout were tagged in the MGORD.

In September of 2025, a total of 71 previously tagged trout (69 Brown Trout and two Rainbow Trout) were recaptured in the Rush Creek watershed. Three of the recaptures occurred in the Bottomlands section, followed by three recaptures in the 8-Channel section, 20 recaptures in the Upper Rush section (including two Rainbow Trout), six recaptures in Walker Creek, and 39 recaptures in the MGORD. In September of 2025, a total of 12 previously tagged Brown Trout (that retained their tags) were recaptured in the Lee Vining Creek main channel section. Growth rates of all PIT-tagged recaptured age-1 Brown Trout decreased from 2024 to 2025 (Table 1).

Summer Water Temperatures in Rush Creek

In 2025, the Dry-Normal-1 RY included an 18-day-long GLR spill and relatively high GLR storage levels during the summer months. This resulted in favorable summer thermal conditions in the MGORD with progressively degrading thermal metrics in a downstream direction. Water temperature metrics at all monitoring locations downstream of the MGORD include daily peaks exceeding 70°F on 12 to 32 days of the 92-day summer period and maximum diurnal fluctuations of 14.7°F to 17.9°F.

Proposed Fisheries Sampling for 2026 Season

We intend to conduct population estimate sampling in the fall of 2026 at the following locations: MGORD Rush, Upper Rush, Bottomlands Rush, Lee Vining Creek main channel, and Walker Creek. In addition to conducting population estimate sampling at the annually sampled locations, the Fisheries Stream Scientist proposes to conduct single-pass sampling at the 8-Channel section of Rush Creek. The Fisheries Stream Scientist also proposes to conduct benthic macroinvertebrate (BMI) sampling in 2026, using both traditional kick-net sampling and eDNA. A detailed scope and budget for an appropriate level of BMI sampling to make the transition from kick-net sampling to eDNA was provided to the MAT by the Fisheries Stream Scientist on 3/26/26. The Fisheries Stream Scientist has also submitted an amendment request to CDFW to allow BMI sampling in Mono Basin streams under their Scientific Collector's Permit (SCP).

Table 1. Summary of Mono Basin Brown Trout annual monitoring metrics; changes between sampling years 2024 and 2025. N/A = not applicable or not available. For applicable metrics, the increases/decreases between 2024 and 2025 are provided in parentheses. For growth rates, increases/decreases between 2024 and 2025 are provided in millimeters or grams. Because single-pass electrofishing was conducted in 2025, no comparisons of population estimates, densities, standing crops and apparent survival rates were possible.

Annual Monitoring Metrics	Rush Creek - MGORD	Rush Creek - Upper	Rush Creek - Bottomlands	Walker Creek	Lee Vining Creek
Condition Factor	Decrease	No Change	Decrease	Decrease	Decrease
Growth Rate (mm) of Age-1 Recaptures	Decrease (6 mm)	Decrease (39 mm)	Decrease (12 mm)	Decrease (20 mm)	Decrease (4 mm)
Growth Rate (g) of Age-1 Recaptures	Decrease (7 g)	Decrease (21 g)	Decrease (12 g)	Decrease (8 g)	Decrease (5 g)
Growth Rate (mm) of Age-2 Recaptures	N/A	N/A	N/A	N/A	N/A
Growth Rate (g) of Age-2 Recaptures	N/A	N/A	N/A	N/A	N/A
RSD-225	Increase	Decrease	Decrease	N/A	Decrease
RSD-300	Increase	Decrease	Decrease	N/A	Increase
RSD-375	Increase	N/A	N/A	N/A	N/A

Introduction

Study Area

The 2025 fisheries sampling was the fourth of ten years of biological monitoring of the Stream Ecosystem Flows (SEF), with oversight from the recently formed Mono Basin Monitoring Administration Team (MAT) as directed by the California State Water Resource Control Board's (SWRCB) amended Licenses 10191 and 10192. This monitoring continues a 25-year history of monitoring ordered by the SWRCB under Orders 98-05 and 98-07. Five of the six reaches sampled in 2025 were similar in length to those sampled between 2009 and 2024. A sixth site, the Rush Creek 8-Channel was sampled for the third year in a row. Sample site selection has evolved over time, with more sites annually sampled in 1999 through 2008 as the Fisheries Team investigated potential differences in fish production based on proximity to the Grant Lake Reservoir (GLR) dam and varying channel slopes and confinement. For example, in Rush Creek, the Mono Gate One Return Ditch (MGORD) was selected because of its tailwater condition below the dam and its propensity to support older and larger Brown Trout. Upper Rush was selected for its moderately-sloped channel and its location just downstream of a confined, gorge-like section. Finally, the Bottomlands section was selected for its location in a low-gradient area that has more potential for the formation of meanders, deeply scoured pools, and side-channels.

Hydrology

The 2025 Runoff Year (RY) was 69% of normal and classified as a Dry-Normal-1 RY type, as measured on April 1st. The range of runoff that defines a Dry-Normal-1 RY is 60%-80% exceedance. The preceding 13 years included a Normal RY of 103% in 2024, an Extreme-Wet RY of 226% in 2023, a Dry RY of 60% in 2022, Dry RY of 58% in 2021, Dry-Normal-1 RY of 71% in 2020, a Wet RY of 140% in 2019, a Normal RY of 85% in 2018, a record Extreme-wet RY of 206% in 2017 and five consecutive below "Normal" RYs (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).

Following the flow regimes developed for Los Angeles Department of Water and Power's (LADWP) State Water Board Order WR-2021-0086, in Dry-Normal-1 runoff years, SEFs in Rush Creek were defined in Table 2-9 of the Synthesis Report (Table 2). For the actual 2025 Rush Creek hydrograph, the red line in Figure 1 depicts both snowmelt runoff and Southern Cal Edison (SCE) ramping in Rush Creek upstream of GLR. The purple line depicts the SEF releases by LADWP into the top end of the MGORD (Figure 1). The blue vertical bars depict the 18-day spill over the dam spillway; the peak spill rate was 81 cfs for four days on 6/13-16/25 (Figure 1). The light-tan dotted line in Figure 1 depicts the combined flows below GLR of the SEF release plus the spill. The dashed blue line in Figure 1 depicts flows in lower Rush Creek with unregulated accretions from Parker and Walker Creeks. The brown dashed line depicts storage

elevations in GLR (Figure 1). The daily average peak flow in Rush Creek below Parker and Walker Creeks was 195 cfs on 6/13/25 (Figure 1). The purple line of the 2025 Rush Creek Dry-Normal-1 SEF releases from the MGORD closely followed the benches, ascensions, snowmelt peak, and recession limb as prescribed in Table 2.

For RY 2025 in Lee Vining Creek, LADWP followed the diversion rate table (when diverting) and fall/winter baseflows consistent with the SEF regime defined in WR-2021-0086 (Figure 2). In 2025, several peaks occurred in Lee Vining Creek above the intake (on 5/11/25, 5/25/25, 6/2/25, and 6/11/25), with the highest peak of 250 cfs on 6/2/25 (Figure 2). The differences in flow between the Above and Below hydrographs are the diversions consistent with the Synthesis Report's diversion rate table (Figure 2). What was lost in the daily average flows reported in Figure 2 were the variable up-and-down ramping that occurred in Lee Vining Creek by Southern Cal Edison (SCE), when hydropeaking was conducted for power generation during periods of higher demand, which were passed downstream by LADWP to lower Lee Vining Creek. The Fisheries Team observed this ramping on Lee Vining Creek while planning for their 9/18/25 electrofishing event. SCE was ramping flows in the afternoon and then dropping flows at night, with these erratic flows passed downstream, below LADWP's diversion. Flows variations within a 24-hour period were between low 20s to >60 cfs. On 9/18/25, while electrofishing we observed the highwater mark from the previous day's peak ramping flow (Figure 3).

Table 2. Rush Creek SEFs for Dry-Normal-1 runoff year type as defined in the Synthesis Report.

Table 2-9. Rush Creek recommended SEFs for DRY-NORMAL I runoff year types.

DRY-NORMAL I RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 13	40-70	13	5%
Spring Bench					
Snowmelt Ascension					
Snowmelt Bench	May 14	July 3	80	51	
Snowmelt Flood					
Snowmelt Peak (release)					
Snowmelt Peak (spill)					
Fast Recession					
Medium Recession (Node)	July 4	July 9	70-45	6	6%
Slow Recession	July 10	July 27	45-27	18	3%
Summer Baseflow	July 28	September 30	27	65	
Fall Baseflow	October 1	November 30	27	61	
Winter Baseflow	December 1	March 31	27	121	

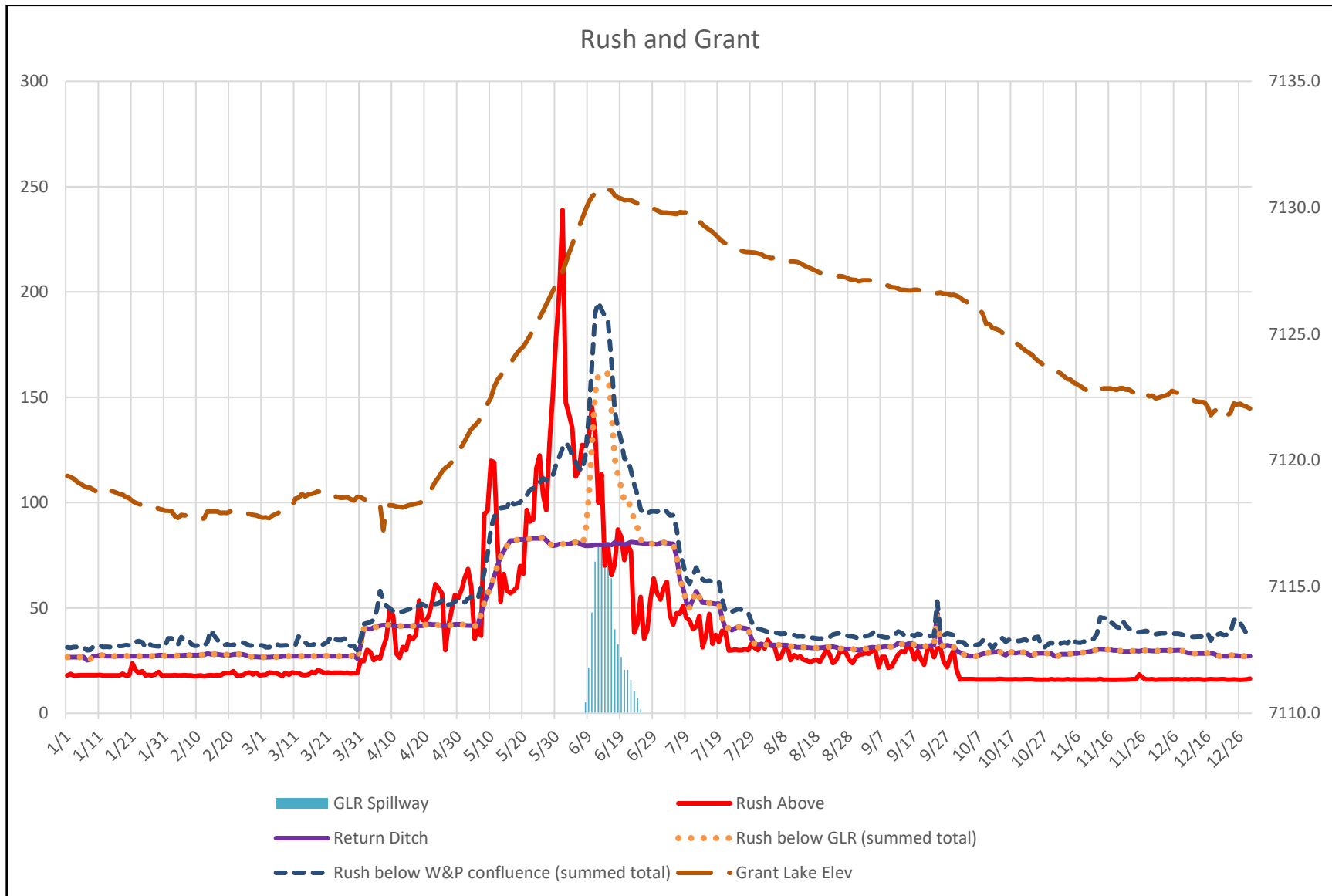


Figure 1. Rush Creek hydrographs between January 1st and December 31st of 2025.

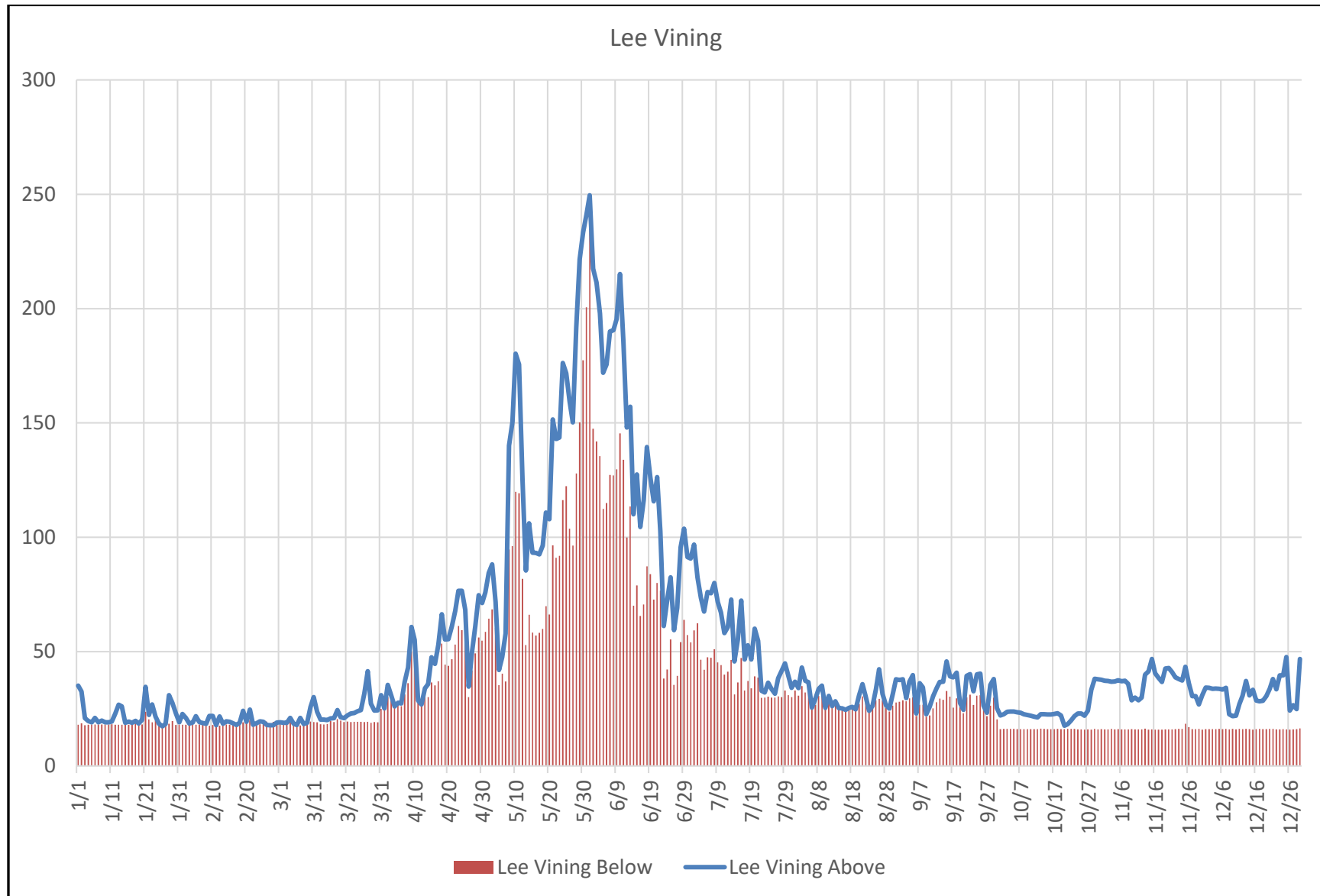


Figure 2. Lee Vining Creek hydrograph between January 1st and December 31st of 2025.



Figure 3. Lee Vining Creek on 9/18/25 with left-bank bar still showing signs of previous day's peak flow level from SCE's hydropeaking event (yellow arrows pointing at high water lines).

Grant Lake Reservoir (GLR)

In 2025, storage elevation levels in GLR fluctuated from 7,119.3 ft on January 1st to the peak of an 18-day spill on 6/13-16/25, when 81 cfs was flowing over the dam's spillway for four days (Figure 1). After the spill, GLR's elevation slowly dropped for the remainder of the year to an elevation of 7,122.1 ft on December 31st (Figure 1).

During the summer months of RY 2025, 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) (McB&T and RTA 2010). From July through September 2025, GLR was 26.6 ft to 29.9 ft above the 7,100 ft elevation (Figure 1). However, the 2025 summer water temperature monitoring data, at lower Rush Creek monitoring locations, documented some unfavorable water temperatures with relatively large diurnal fluctuations and daily peaks >70°F, leading to less than favorable thermal conditions for Brown Trout growth and survival. It's possible that in 2025 hotter summer weather and air temperatures were over-riding the thermal benefits usually provided by a fuller GLR.

Methods

The annual fisheries monitoring was conducted between September 16th – 22nd of 2025. The sampling was conducted by Ross Taylor of Ross Taylor and Associates (RTA), Lawrance Vernallis (RTA employee), Olivia Vosburg (RTA employee), Sam Pasewark (RTA employee), Ty Seay (RTA employee), and two sub-consultants: Beth Long and Dylan Keel (RES). Single-pass electrofishing was used in 2025 to capture fish in the regularly sampled sections and one relatively new Rush Creek section. To avoid pushing fish out of sections, block fences or nets were installed at the lower end of each Rush Creek and Lee Vining section, except for the MGORD section. The block 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 hardware 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 was then secured to the rope with sections of baling wire. A lower block fence was installed in the morning of sampling a particular section and was removed at the completion of sampling. To prevent failure, all fences were periodically cleaned of leaves and twigs during the day's sampling.

The bottom of the Walker Creek section was blocked with a 1/4-inch-mesh nylon seine net. Rocks were placed on the lead line to prevent trout from swimming underneath the seine net. A long T-post was laid across the channel, on top of the banks, and then the cork line of the seine net was zip-tied to the T-post. Both ends of the seine net were weighed with rocks to hold it in place. As with the block fences, the seine net was periodically cleaned of leaves and twigs during the day's sampling.

Equipment used to conduct electrofishing on the MGORD, Upper, Bottomlands, and 8-Channel sections of Rush Creek included a seven-foot plastic barge that contained the Smith-Root® 2.5 GPP electrofishing system, a generator, an insulated cooler, and battery powered aerators. The Smith-Root® 2.5 GPP electrofishing system included a 5.5 horsepower 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.

Sampling runs on the Upper, Bottomlands, and 8-Channel sections of Rush Creek consisted of a single downstream pass starting at the upper end of the section and ending at the lower block fence. In 2025, the field crew consisted of a barge operator, two anode operators, and four netters: two for each anode. The barge operator's job consisted of carefully maneuvering the barge down the creek and ensuring the overall safety of the entire crew. The anode operators' job was to safely shock and hold trout until they were netted. The netters' job was to net and transfer fish to the insulated cooler and monitor trout for signs of stress. Once the cooler was full of fish, electrofishing was temporarily stopped to process the trout. The trout were then transferred from the cooler to net pens and placed back in the creek. The trout were then

processed in small batches and returned to a recovery net pen 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 single-pass electrofishing on the Lee Vining Creek main channel consisted of an upstream pass starting at the lower block fence to the top of the section, 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-20B and Model-12 POW backpack electrofishers, four netters, and one bucket carrier who transported the captured trout. As needed, the bucket carrier transferred fish into one of three net pens stationed along the channel when the bucket was full of trout.

Due to the depth of the MGORD, all electrofishing and netting was done from inside a fiberglass 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 secured to the upstream side of the drift boat, and a single throw anode was used. A single netter used a 12-foot-long handle dipnet to net the stunned trout, which were then placed in an insulated cooler equipped with aerators. A safety officer sat at the stern of the drift boat whose job was to monitor the trout in the cooler, the electrofishing equipment, the electrofishing crew, and shut off the power should the need arise. Once the cooler was full, the trout were moved to a net pen and placed back in the creek for the shore-based crew to process before continuing the electrofishing effort. Any time the electrofishing crew unloaded fish into a net pen ahead of the processing crew, the net pen's location was marked with bright-colored survey flagging at the edge of the MGORD road.

For the Walker Creek section, a single pass was considered an upstream pass from the lower seine net to the top of the section, followed by a downstream pass back to the lower seine net. One member of the electrofishing crew operated a Smith-Root® LR-20B electrofisher; another member was the primary netter, and a third member was the backup netter/bucket carrier. As needed, the bucket carrier transferred fish into a net pen when the bucket was full of trout.

To process trout, small batches of fish from the net pen 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 in total length (TL), and weighed to the nearest gram on an electronic balance. 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 net pen 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 net pens back into the sub-sections they had been captured in.

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 in 2014 and continued annually through the 2025 field season. Starting in 2017, PIT tags implanted in trout caught in the MGORD were focused primarily on fish up to 225 mm in TL, with the intent being to tag only age-0 and presumed age-1 trout.

All data collected in the field were written on hardcopy data sheets and also entered into Excel spreadsheets using an electronic tablet. Hardcopy data were used to provide a crucial back-up in case of in-field technical issues with the tablet. The hardcopy data sheets were also used to proof the Excel spreadsheets prior to analyses.

Channel Dimensions

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. Channel lengths were only measured if the start or end points differed, or if noticeable changes occurred to the channel reach, such as the cutting-off of a meander bend. Channel dimensions are typically measured in even years only, for the purpose of generating biomass and density estimates.

Mortalities

During single-pass electrofishing, we kept track of all fish mortalities for project SCP reporting purposes. PIT tags were removed from all mortalities with previously implanted tags. The PIT tag database was updated to confirm these mortalities and “tag pulled” was noted in the comments column because these tags were typically reused.

Length-Weight Relationships

Length-weight regressions (Cone 1989 as cited in Taylor and Knudson 2012) 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 the demarcation between poor and average condition (Reimers 1963; Barnham and Baxter 1998; Blackwell et al. 2000). The literature considers a trout condition factor of <1.00 as poor, a condition factor of 1.00-1.19 as average, and a condition factor ≥ 1.20 as good (Barnham and Baxter 1998).

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). A primary purpose of generating RSD values is to describe the structure of a fish population in terms of recreational fishing satisfaction. For Rush and Lee Vining Creeks this would be a descriptor of an eastern Sierra trout stream; as in, out of the estimated numbers of catchable trout (≥ 150 mm or ≈ 6 inches) what proportion are “stock” length (≥ 225 mm or ≈ 9 inches), “memorable” length (≥ 300 mm or ≈ 12 inches), or “trophy” length (≥ 375 mm or ≈ 15 inches). These three RSD values are calculated by:

RSD-225 = $[(\# \text{ of Brown Trout } \geq 225 \text{ mm}) \div (\# \text{ of Brown Trout } \geq 150 \text{ mm})] \times 100$

RSD-300 = $[(\# \text{ of Brown Trout } \geq 300 \text{ mm}) \div (\# \text{ of Brown Trout } \geq 150 \text{ mm})] \times 100$

RSD-375 = $[(\# \text{ of Brown Trout } \geq 375 \text{ mm}) \div (\# \text{ of Brown Trout } \geq 150 \text{ mm})] \times 100$

Water Temperature Monitoring

Water temperatures were recorded (in °F) at various locations within Rush and Lee Vining Creeks. Data loggers were deployed by Robbie Di Paolo of the Mono Lake Committee (MLC) 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 for this report were deployed at the following locations in 2025:

1. Rush Creek – upstream of GLR.
2. Rush Creek - top of MGORD.
3. Rush Creek - bottom of MGORD.
4. Rush Creek - at Upper Rush/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 2025 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°F.
5. Number of hours with temperatures exceeding 66.2°F.
6. Number of good/fair/poor potential growth days, based on daily average temperatures.
7. Number of bad thermal days based on daily average temperatures.
8. Maximum diurnal fluctuations.
9. Average maximum diurnal fluctuations for a consecutive 21-day period.

Results

Trout Capture Summaries

Upper - Rush Creek Section

In 2025, a total of 493 Brown Trout ranging in size from 55 mm to 354 mm were captured on a single electrofishing pass in the Upper Rush section (Figure 4). For comparison, in 2024 a total of 477 Brown Trout were caught on the mark-run. In 2025, age-0 Brown Trout (<125 mm in total length) comprised 70% of the total catch (compared to 63% in 2024 and 35% in 2023).

In 2025, the 98 Brown Trout captured in the 125-199 mm size class comprised 20% of the total catch in the Upper Rush section (compared to 18% in 2024 and 6% in 2023).

The 48 Brown Trout ≥ 200 mm in length caught in 2025 comprised 10% of the Upper Rush total Brown Trout catch (compared to 19% in 2024 and 59% in 2023). In 2025, five Brown Trout >300 mm in length were captured in the Upper Rush section.

A total of 69 Rainbow Trout were captured in the Upper Rush section comprising 12% of the section's total trout catch in 2025; Rainbow Trout comprised 15% of the total catch in 2024 and 12% of the total catch in 2023. The 69 Rainbow Trout ranged in length from 53 mm to 321 mm and 56 of these fish were in the <125 mm size class (Figure 5).

Bottomlands - Rush Creek Section

In 2025, a total of 321 Brown Trout ranging in size from 54 mm to 276 mm were captured on a single electrofishing pass in the Bottomlands section of Rush Creek (Figure 6). For comparison, in 2024 a total of 402 Brown Trout were caught on the mark-run. Brown Trout <125 mm in length comprised 78% of the total catch in 2025 versus 82% of the total catch in 2024.

Brown Trout 125-199 mm in length comprised 20% of the total catch in the Bottomlands section in 2025 versus 3% of the total catch in 2024. The very low numbers of likely age-1 fish in 2024 were due to the poor recruitment of age-0 fish in 2023, the record runoff year.

Brown Trout ≥ 200 mm in length comprised 2% of the total catch in the Bottomlands section in 2025 (versus 15% in 2024) with no fish >300 mm in total length (Figure 6).

MGORD - Rush Creek Section

Within the MGORD section of Rush Creek a total of 554 Brown Trout were captured on a single electrofishing pass in 2025 (Figure 7). For comparison, 341 Brown Trout were caught on the mark run in 2024. In 2025, Brown Trout caught in the MGORD ranged in size from 73 mm to 622 mm in length (Figure 7). In 2025, age-0 Brown Trout included seven fish between 125-132 mm in length, and the length-frequency distribution shows a distinct break between age-0 and age-1 classes, at 132 mm and 160 mm (Figure 7). A total of 70 age-0 Brown Trout (73-132 mm

in length) were captured in 2025, which comprised 13% of the total catch of Brown Trout (age-0 fish comprised 11% of the catch in 2024).

In 2025, a total of 50 Brown Trout in the 125-199 mm size class were caught during the single electrofishing pass in the MGORD section, which comprised 9% of the total Brown Trout catch. For comparison, in 2024, the 125-199 mm size class comprised 13% of the Brown Trout catch.

In 2025, the catch of 434 Brown Trout ≥ 200 mm in length comprised 78% of the total Brown Trout catch in the MGORD section versus 75% in 2024. Of these 434 Brown Trout ≥ 200 mm, 126 fish were ≥ 300 mm, compared to 124 fish ≥ 300 mm in 2024 and 28 fish ≥ 300 mm in 2023. Sixteen Brown Trout ≥ 375 mm in TL were captured in 2025 (compared to 14 fish in 2024, nine fish in 2023 and six fish in 2022). In 2025, nine of these Brown Trout were >400 mm in TL (Figure 7).

In 2025, 24 Rainbow Trout were captured in the MGORD section (Figure 8), compared to 56 captured in 2024. In the previous 12 years, the Rainbow Trout catch in the MGORD has ranged from zero to 56 fish. Most of the Rainbow Trout captured in 2025 appeared to be of natural origin, with several larger fish exhibiting signs of hatchery origin, primarily eroded fins.

For the past 20 sampling years, electrofishing passes through the MGORD have produced a wide range of total catch values (all size classes of Brown and Rainbow Trout), ranging from a low of 121 fish in 2016 to a high of 685 fish in 2007. The 2025 total catch of 578 trout was the highest catch in the past 14 years, and the 4th highest catch overall.

- 2025 – Single pass = 578 trout.
- 2024 – Mark run = 362 trout. Recapture run = 345 trout. Two pass average = 353.5 fish.
- 2023 – Single pass = 135 trout.
- 2022 – Mark run = 100 trout. Recapture run = 148 trout. Two pass average = 124 fish.
- 2021 – Mark run = 273 trout. Recapture run = 387 trout. Two pass average = 330 fish.
- 2020 – Single pass = 457 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.

The 8-Channel - Rush Creek Section

In 2025, a total of 313 Brown Trout ranging in size from 64 mm to 298 mm and six Rainbow Trout between 72 mm and 179 mm were captured on a single electrofishing pass in the 8-Channel section of Rush Creek (Figure 9). A total of 237 Brown Trout <125 mm in length were caught, which comprised 76% of the Brown Trout catch. This was the third consecutive year that the 8-Channel was sampled, with the initial sampling occurring in 2023 when the 8-Channel was part of a three-way channel split created by a series of beaver dams. However, for the past two years, 2024 and 2025, all of Rush Creek's flow has been in the 8-Channel.

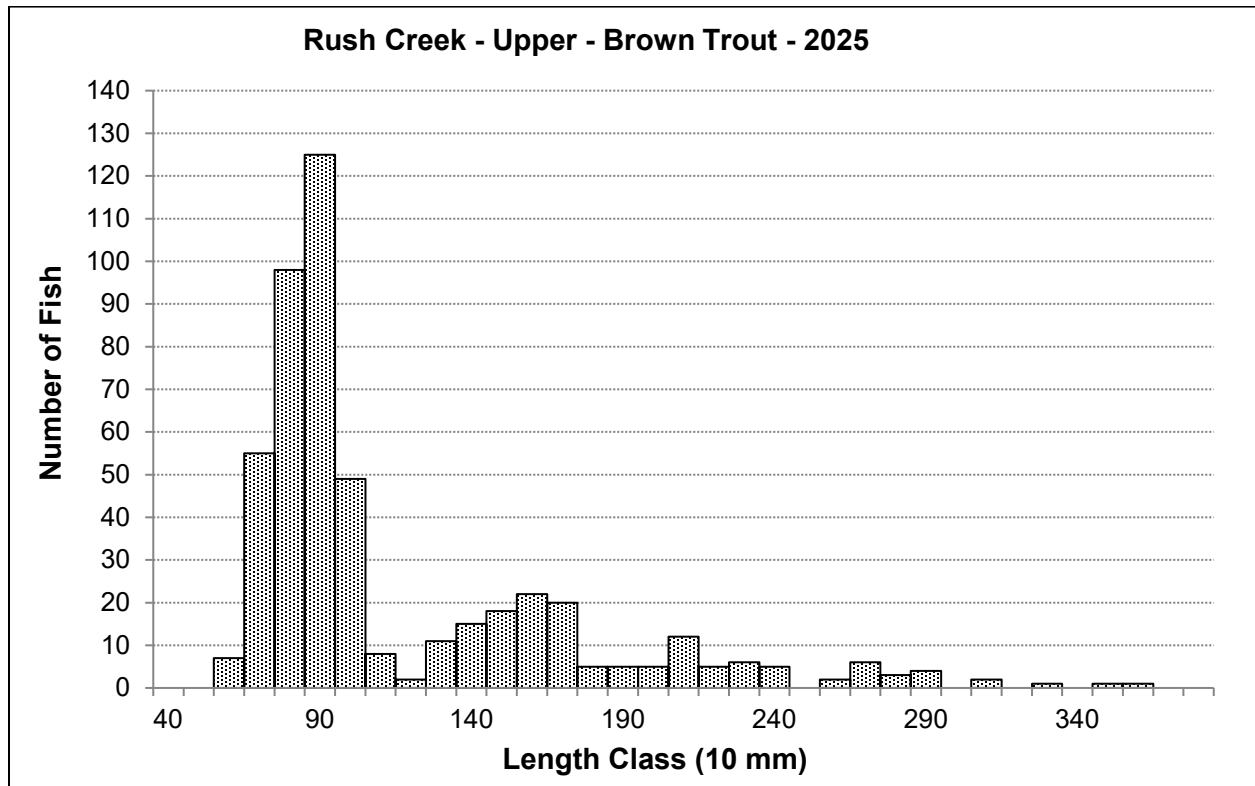


Figure 4. Length-frequency histogram of Brown Trout captured in Upper Rush on 9/16/2025.

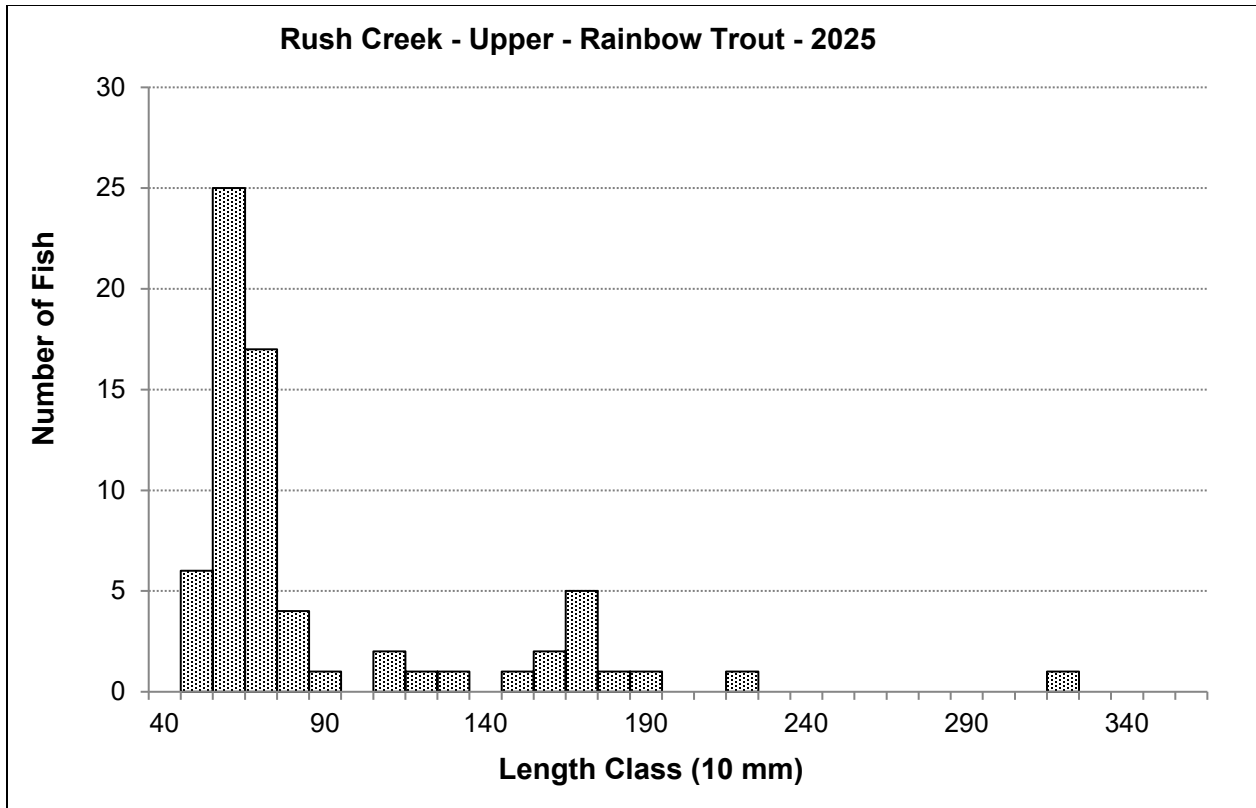


Figure 5. Length-frequency histogram of Rainbow Trout captured in Upper Rush on 9/16/2025.

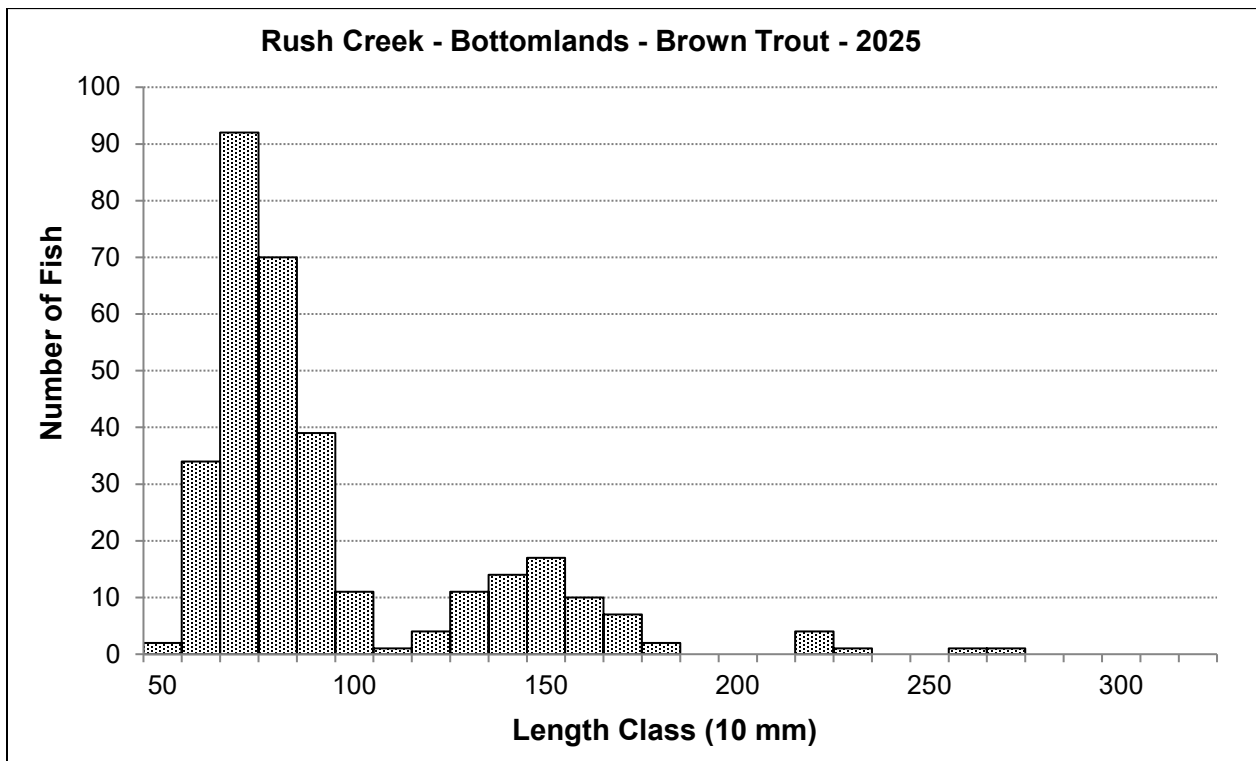


Figure 6. Length-frequency histogram of Brown Trout captured in the Bottomlands section of Rush Creek on 9/17/2025.

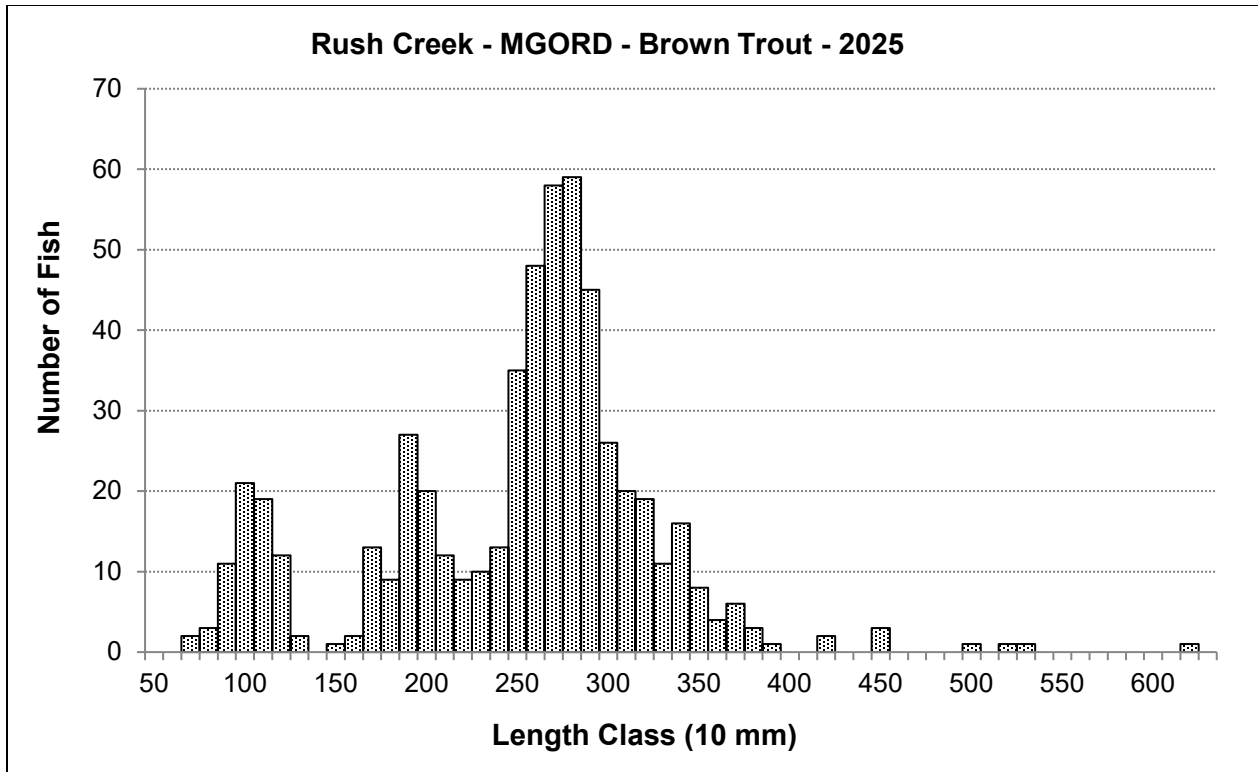


Figure 7. Length-frequency histogram of Brown Trout captured in the MGORD section of Rush Creek on 9/22/2025.

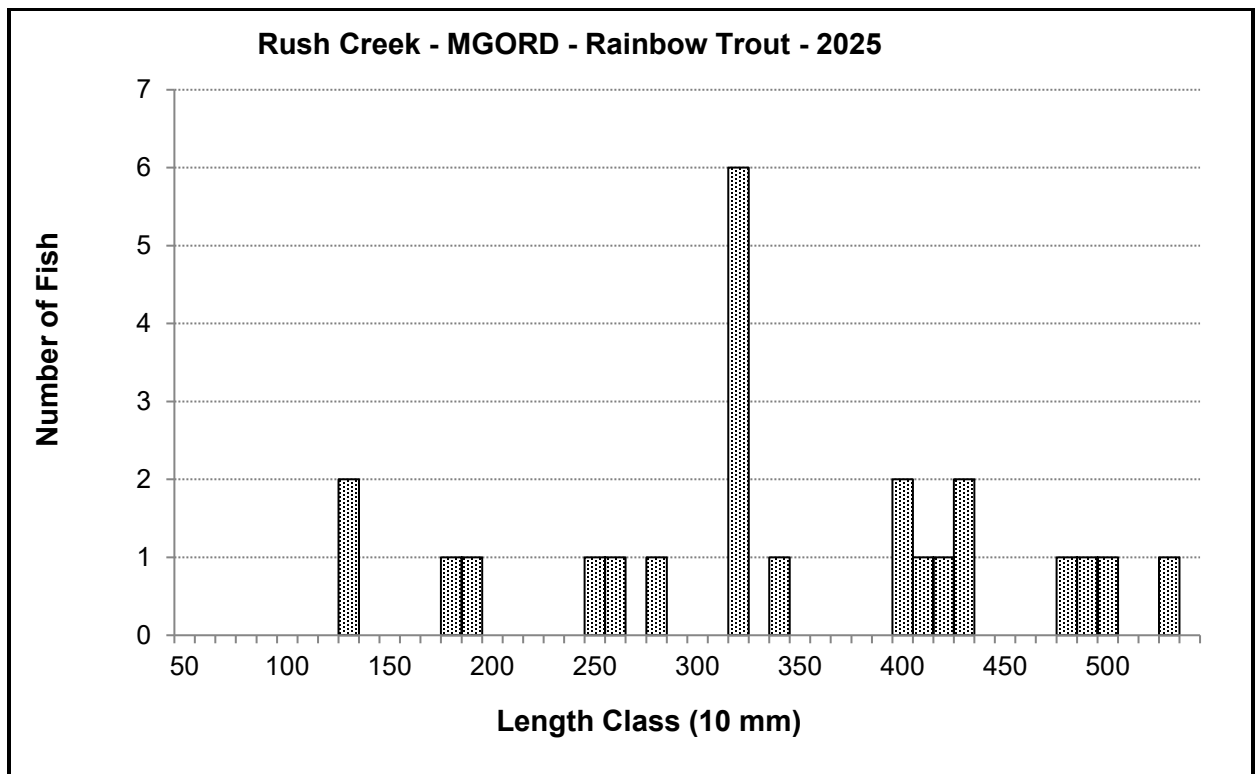


Figure 8. Length-frequency histogram of Rainbow Trout captured in the MGORD section of Rush Creek on 9/22/2025.

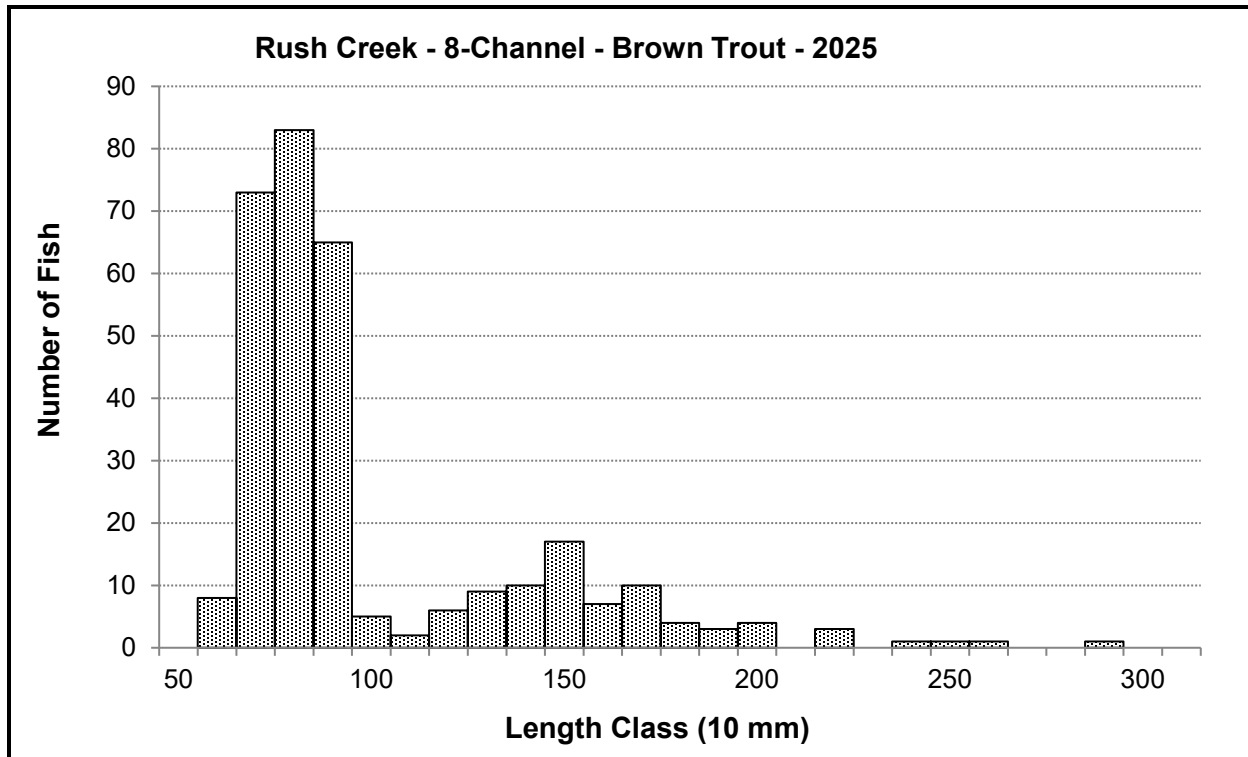


Figure 9. Length-frequency histogram of Brown Trout captured in the 8-Channel section of Rush Creek on 9/19/2025.

Lee Vining Creek

In 2025, a total of 209 Brown Trout and 19 Rainbow Trout were captured on the single electrofishing pass made in the Lee Vining Creek main channel section. In 2025, Brown Trout ranged in size from 67 mm to 347 mm in TL (Figure 10). In 2025, a total of 142 Brown Trout <125 mm in length were captured and this age-class comprised 68% of the Brown Trout catch. Just two years prior, in 2023, no Brown Trout <125 mm in length were caught in Lee Vining Creek.

In 2025, the 38 Brown Trout caught in the 125-199 mm size class comprised 18% of the total Brown Trout catch in Lee Vining Creek (Figure 10).

In 2025, a total of 29 Brown Trout ≥ 200 mm were captured in Lee Vining Creek (Figure 12). Ten Brown Trout captured in 2025 were >300 mm in TL; the highest number of fish >300 mm ever caught in Lee Vining Creek for 25 years of available data (Figure 10).

Of the 19 Rainbow Trout caught in Lee Vining Creek in 2025, 18 of these fish were in the <125 mm size class.

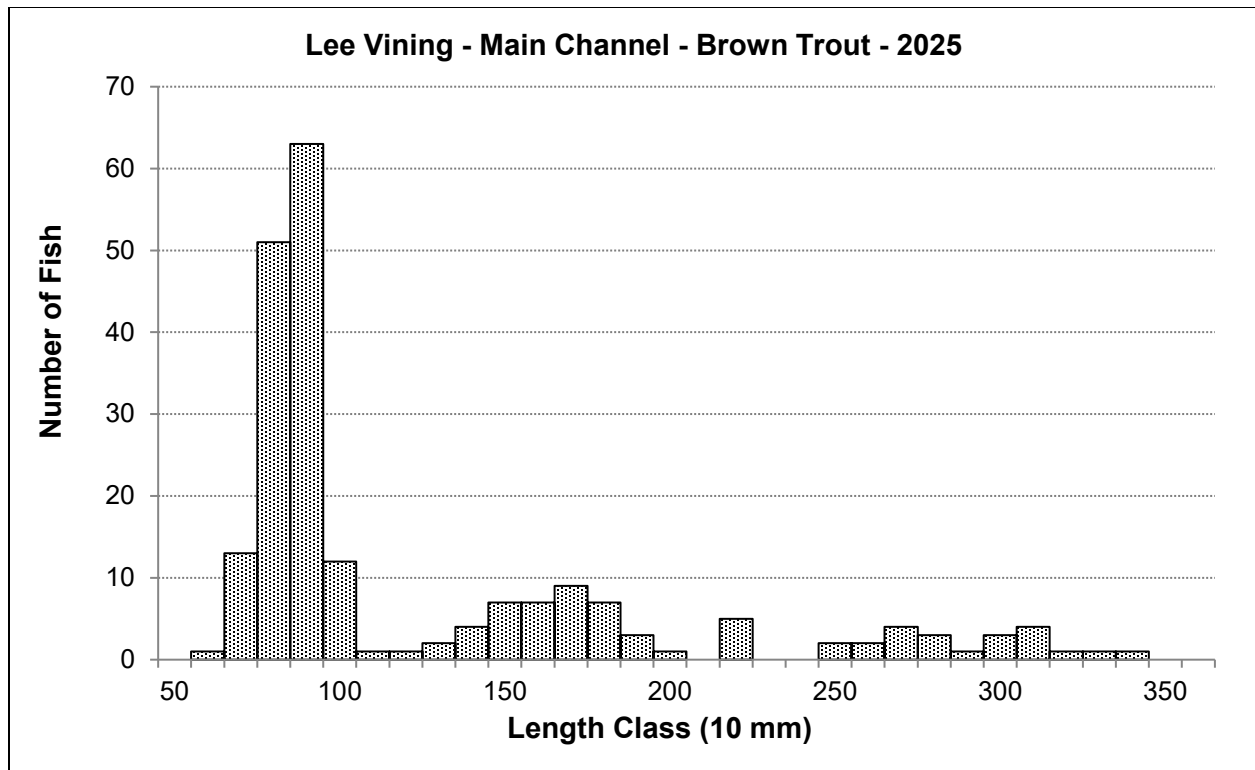


Figure 10. Length-frequency histogram of Brown Trout captured in the main channel section of Lee Vining Creek on 9/18/2025.

Walker Creek

In 2025, 132 Brown Trout were captured in one electrofishing pass in the Walker Creek section, versus 70 fish caught during two depletion passes in 2024. In 2025, a total of 80 Brown Trout <125 mm were caught versus 23 fish <125 mm caught on two depletion passes in 2024 (Figure 11). Age-0 Brown Trout comprised 61% of the catch in 2025 (Figure 11).

Brown Trout in the 125-199 mm size class (29 fish) accounted for 22% of Walker Creek's total catch in 2025 versus 4% of the catch in 2024.

Brown Trout ≥200 mm in length accounted for 17% of the total catch in 2025 (23 fish caught) versus 63% of the total catch in 2024. The largest Brown Trout captured in Walker Creek in 2025 was 256 mm in length (Figure 11).

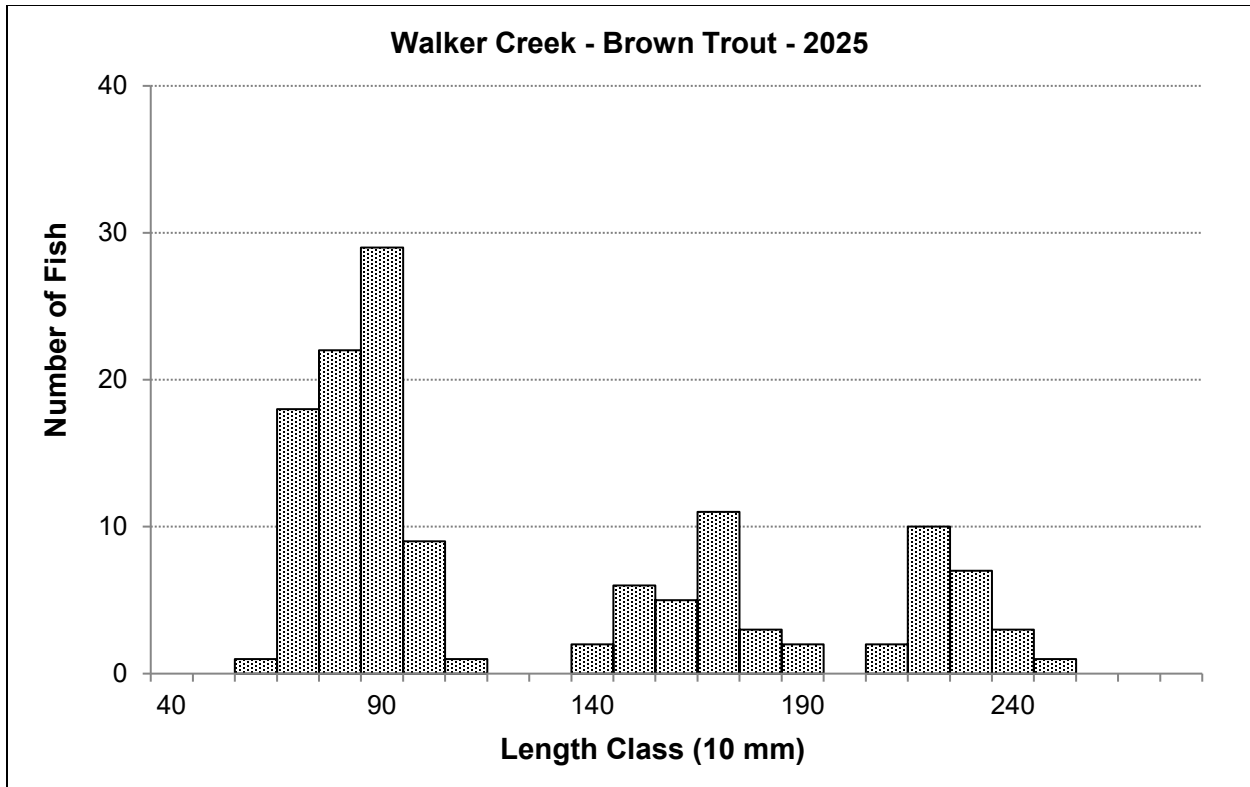


Figure 11. Length-frequency histogram of Brown Trout captured in Walker Creek on 9/20/2025.

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, and were reasonable (Table 4).

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 2025 regression equations are in ***bold*** type.

Section	Year	N	Equation	r^2	P
Bottomlands	2025	86	$\log_{10}(\text{WT}) = 2.9063 * \log_{10}(\text{L}) - 4.8409$	0.99	<0.01
	2024	131	$\log_{10}(\text{WT}) = 2.9939 * \log_{10}(\text{L}) - 5.0233$	0.99	<0.01
	2023	62	$\log_{10}(\text{WT}) = 3.1294 * \log_{10}(\text{L}) - 5.3820$	0.98	<0.01
	2022	253	$\log_{10}(\text{WT}) = 3.1013 * \log_{10}(\text{L}) - 5.2251$	0.98	<0.01
	2021	205	$\log_{10}(\text{WT}) = 3.0091 * \log_{10}(\text{L}) - 5.0526$	0.98	<0.01
	2020	223	$\log_{10}(\text{WT}) = 2.9792 * \log_{10}(\text{L}) - 4.9754$	0.98	<0.01
	2019	310	$\log_{10}(\text{WT}) = 2.9631 * \log_{10}(\text{L}) - 4.9409$	0.99	<0.01
	2018	226	$\log_{10}(\text{WT}) = 2.9019 * \log_{10}(\text{L}) - 4.8059$	0.99	<0.01
	2017	160	$\log_{10}(\text{WT}) = 3.0398 * \log_{10}(\text{L}) - 5.0998$	0.99	<0.01
	2016	132	$\log_{10}(\text{WT}) = 3.0831 * \log_{10}(\text{L}) - 5.2137$	0.99	<0.01
	2015	301	$\log_{10}(\text{WT}) = 3.0748 * \log_{10}(\text{L}) - 5.1916$	0.99	<0.01
	2014	238	$\log_{10}(\text{WT}) = 3.0072 * \log_{10}(\text{L}) - 5.0334$	0.98	<0.01
	2013	247	$\log_{10}(\text{WT}) = 2.7997 * \log_{10}(\text{L}) - 4.5910$	0.98	<0.01
	2012	495	$\log_{10}(\text{WT}) = 2.8149 * \log_{10}(\text{L}) - 4.6206$	0.98	<0.01
	2011	361	$\log_{10}(\text{WT}) = 2.926 * \log_{10}(\text{L}) - 4.8580$	0.99	<0.01
	2010	425	$\log_{10}(\text{WT}) = 2.999 * \log_{10}(\text{L}) - 5.0050$	0.99	<0.01
	2009	511	$\log_{10}(\text{WT}) = 2.920 * \log_{10}(\text{L}) - 4.8210$	0.99	<0.01
	2008	611	$\log_{10}(\text{WT}) = 2.773 * \log_{10}(\text{L}) - 4.5240$	0.99	<0.01
Upper Rush	2025	160	$\log_{10}(\text{WT}) = 2.9689 * \log_{10}(\text{L}) - 4.9538$	0.99	<0.01
	2024	198	$\log_{10}(\text{WT}) = 2.9982 * \log_{10}(\text{L}) - 5.0095$	0.99	<0.01
	2023	131	$\log_{10}(\text{WT}) = 3.044 * \log_{10}(\text{L}) - 5.0950$	0.99	<0.01
	2022	392	$\log_{10}(\text{WT}) = 2.9632 * \log_{10}(\text{L}) - 4.9305$	0.99	<0.01
	2021	441	$\log_{10}(\text{WT}) = 2.9851 * \log_{10}(\text{L}) - 4.9837$	0.98	<0.01
	2020	426	$\log_{10}(\text{WT}) = 2.9187 * \log_{10}(\text{L}) - 4.8382$	0.99	<0.01
	2019	686	$\log_{10}(\text{WT}) = 2.9667 * \log_{10}(\text{L}) - 4.9298$	0.99	<0.01

Table 4 (continued).

Section	Year	N	Equation	r ²	P
Upper Rush	2018	391	$\text{Log}_{10}(\text{WT}) = 2.9173 * \text{Log}_{10}(\text{L}) - 4.8237$	0.99	<0.01
	2017	309	$\text{Log}_{10}(\text{WT}) = 3.0592 * \text{Log}_{10}(\text{L}) - 5.1198$	0.99	<0.01
	2016	176	$\text{Log}_{10}(\text{WT}) = 3.0702 * \text{Log}_{10}(\text{L}) - 5.1608$	0.99	<0.01
	2015	643	$\text{Log}_{10}(\text{WT}) = 2.9444 * \text{Log}_{10}(\text{L}) - 4.8844$	0.99	<0.01
	2014	613	$\text{Log}_{10}(\text{WT}) = 2.9399 * \text{Log}_{10}(\text{L}) - 4.8705$	0.99	<0.01
	2013	522	$\text{Log}_{10}(\text{WT}) = 2.9114 * \text{Log}_{10}(\text{L}) - 4.8160$	0.99	<0.01
	2012	554	$\text{Log}_{10}(\text{WT}) = 2.8693 * \text{Log}_{10}(\text{L}) - 4.7210$	0.99	<0.01
	2011	547	$\text{Log}_{10}(\text{WT}) = 3.006 * \text{Log}_{10}(\text{L}) - 5.0140$	0.99	<0.01
	2010	420	$\text{Log}_{10}(\text{WT}) = 2.995 * \text{Log}_{10}(\text{L}) - 4.9941$	0.99	<0.01
	2009	612	$\text{Log}_{10}(\text{WT}) = 2.941 * \text{Log}_{10}(\text{L}) - 4.8550$	0.99	<0.01
	2008	594	$\text{Log}_{10}(\text{WT}) = 2.967 * \text{Log}_{10}(\text{L}) - 4.9372$	0.99	<0.01
	2007	436	$\text{Log}_{10}(\text{WT}) = 2.867 * \text{Log}_{10}(\text{L}) - 4.7150$	0.99	<0.01
	2006	485	$\text{Log}_{10}(\text{WT}) = 2.99 * \text{Log}_{10}(\text{L}) - 4.9802$	0.99	<0.01
	2005	261	$\text{Log}_{10}(\text{WT}) = 3.02 * \text{Log}_{10}(\text{L}) - 5.0203$	0.99	<0.01
	2004	400	$\text{Log}_{10}(\text{WT}) = 2.97 * \text{Log}_{10}(\text{L}) - 4.9430$	0.99	<0.01
	2003	569	$\text{Log}_{10}(\text{WT}) = 2.96 * \text{Log}_{10}(\text{L}) - 4.8920$	0.99	<0.01
	2002	373	$\text{Log}_{10}(\text{WT}) = 2.94 * \text{Log}_{10}(\text{L}) - 4.8670$	0.99	< 0.01
	2001	335	$\text{Log}_{10}(\text{WT}) = 2.99 * \text{Log}_{10}(\text{L}) - 4.9630$	0.99	< 0.01
	2000	309	$\text{Log}_{10}(\text{WT}) = 3.00 * \text{Log}_{10}(\text{L}) - 4.9610$	0.98	< 0.01
	1999	317	$\text{Log}_{10}(\text{WT}) = 2.93 * \text{Log}_{10}(\text{L}) - 4.8482$	0.98	< 0.01
MGORD	2025	538	$\text{Log}_{10}(\text{WT}) = 2.8979 * \text{Log}_{10}(\text{L}) - 4.7640$	0.98	<0.01
	2024	626	$\text{Log}_{10}(\text{WT}) = 2.9152 * \text{Log}_{10}(\text{L}) - 4.8039$	0.98	<0.01
	2023	108	$\text{Log}_{10}(\text{WT}) = 3.0180 * \text{Log}_{10}(\text{L}) - 4.9965$	0.99	<0.01
	2022	229	$\text{Log}_{10}(\text{WT}) = 3.1344 * \text{Log}_{10}(\text{L}) - 5.3145$	0.99	<0.01
	2021	498	$\text{Log}_{10}(\text{WT}) = 2.9447 * \text{Log}_{10}(\text{L}) - 4.8871$	0.99	<0.01
	2020	383	$\text{Log}_{10}(\text{WT}) = 3.0144 * \text{Log}_{10}(\text{L}) - 5.0575$	0.98	<0.01
	2019	314	$\text{Log}_{10}(\text{WT}) = 2.9774 * \text{Log}_{10}(\text{L}) - 4.9282$	0.98	<0.01
	2018	350	$\text{Log}_{10}(\text{WT}) = 3.0023 * \text{Log}_{10}(\text{L}) - 5.0046$	0.98	<0.01
	2017	159	$\text{Log}_{10}(\text{WT}) = 3.0052 * \text{Log}_{10}(\text{L}) - 5.0205$	0.99	<0.01
	2016	183	$\text{Log}_{10}(\text{WT}) = 3.0031 * \text{Log}_{10}(\text{L}) - 5.3093$	0.99	<0.01
	2015	172	$\text{Log}_{10}(\text{WT}) = 3.131 * \text{Log}_{10}(\text{L}) - 5.0115$	0.99	<0.01
	2014	399	$\text{Log}_{10}(\text{WT}) = 2.9805 * \text{Log}_{10}(\text{L}) - 4.9827$	0.98	<0.01

Table 4 (continued).

Section	Year	N	Equation	r ²	P
MGORD	2013	431	$\text{Log}_{10}(\text{WT}) = 2.8567 * \text{Log}_{10}(\text{L}) - 4.6920$	0.98	<0.01
	2012	795	$\text{Log}_{10}(\text{WT}) = 2.9048 * \text{Log}_{10}(\text{L}) - 4.8081$	0.99	<0.01
	2011	218	$\text{Log}_{10}(\text{WT}) = 2.917 * \text{Log}_{10}(\text{L}) - 4.8230$	0.98	<0.01
	2010	694	$\text{Log}_{10}(\text{WT}) = 2.892 * \text{Log}_{10}(\text{L}) - 4.7563$	0.98	<0.01
	2009	689	$\text{Log}_{10}(\text{WT}) = 2.974 * \text{Log}_{10}(\text{L}) - 4.9330$	0.99	<0.01
	2008	862	$\text{Log}_{10}(\text{WT}) = 2.827 * \text{Log}_{10}(\text{L}) - 4.6020$	0.98	<0.01
	2007	643	$\text{Log}_{10}(\text{WT}) = 2.914 * \text{Log}_{10}(\text{L}) - 4.8254$	0.98	<0.01
	2006	593	$\text{Log}_{10}(\text{WT}) = 2.956 * \text{Log}_{10}(\text{L}) - 4.8722$	0.98	<0.01
	2004	449	$\text{Log}_{10}(\text{WT}) = 2.984 * \text{Log}_{10}(\text{L}) - 4.9731$	0.99	<0.01
	2001	769	$\text{Log}_{10}(\text{WT}) = 2.873 * \text{Log}_{10}(\text{L}) - 4.7190$	0.99	<0.01

Condition factors of Brown Trout >150 mm in length in 2025 decreased from 2024 values in the Bottomlands section of Rush Creek, the MGORD and in Walker Creek (Figure 12). Between 2024 and 2025, condition factor of Brown Trout >150 mm in length remained the same in the Upper Rush section (Figure 12). Between 2024 and 2025, condition factors of Brown Trout and Rainbow Trout >150 mm in length decreased in the Lee Vining Creek main channel (Figure 13).

Brown Trout in the Upper Rush section had a condition factor of 0.94 in 2025, the same is in 2024 and a decrease from 1.02 in 2023 (Figure 12). The Upper Rush section has had Brown Trout condition factors ≥ 1.00 in 12 of 26 sampling seasons (Figure 12).

Brown Trout in the Bottomlands section of Rush Creek had a condition factor of 0.90 in 2025, a decrease from 0.97 in 2024 (Figure 12). In 18 years of sampling in the Bottomlands section, 2022 was the only sampling year that the Brown Trout condition factor was ≥ 1.00 (Figure 12).

The MGORD's 2025 Brown Trout condition factor equaled 0.98, a slight decrease from 0.99 in 2024 (Figure 12). In 2025, condition factors for larger Brown Trout in the MGORD were also computed: fish ≥ 300 mm had a condition factor of 0.99 (0.97 in 2024) and fish ≥ 375 mm had a condition factor of 1.09 (0.92 in 2024).

In 2025, the condition factor for Brown Trout in Lee Vining Creek was 0.95, a small decrease from 0.97 in 2024 (Figure 13). The Lee Vining Creek main channel section has had Brown Trout condition factors ≥ 1.00 in 15 of 25 sampling seasons. In 2025, the Rainbow Trout condition factor for the Lee Vining Creek main channel was 0.99, a slight decrease from 1.01 in 2024.

In Walker Creek, Brown Trout had a condition factor of 0.90 in 2025, a decrease from 0.98 in 2024 (Figure 12). Brown Trout condition factors in Walker Creek have been ≥ 1.00 in 12 of the

26 sampling years; however, in the past 11 years only the 2018 sampling year had a condition factor ≥ 1.00 (Figure 12).

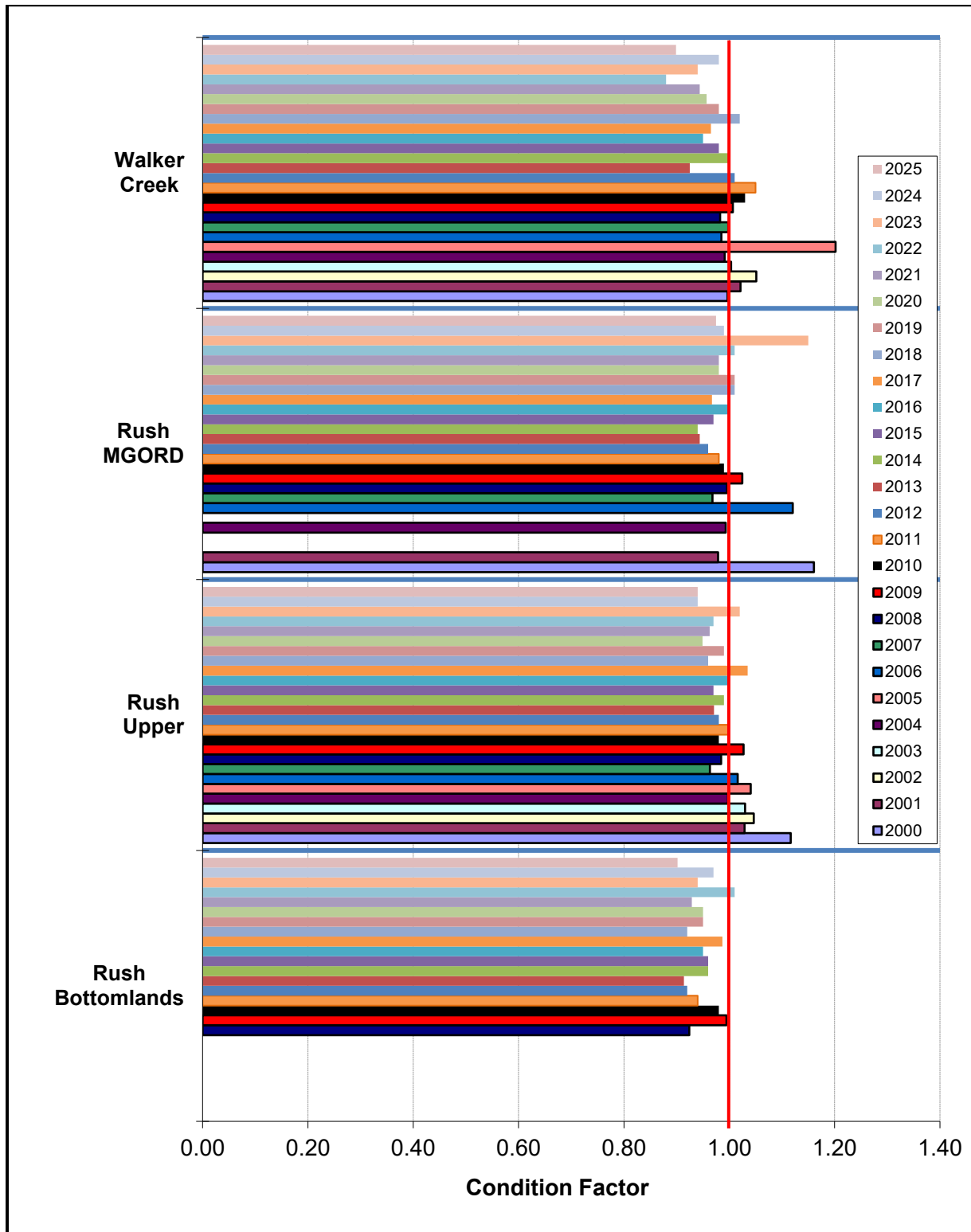


Figure 12. Condition factors for Brown Trout ≥ 150 mm in length from sample sections of Rush Creek and Walker Creek from 2000 to 2025.

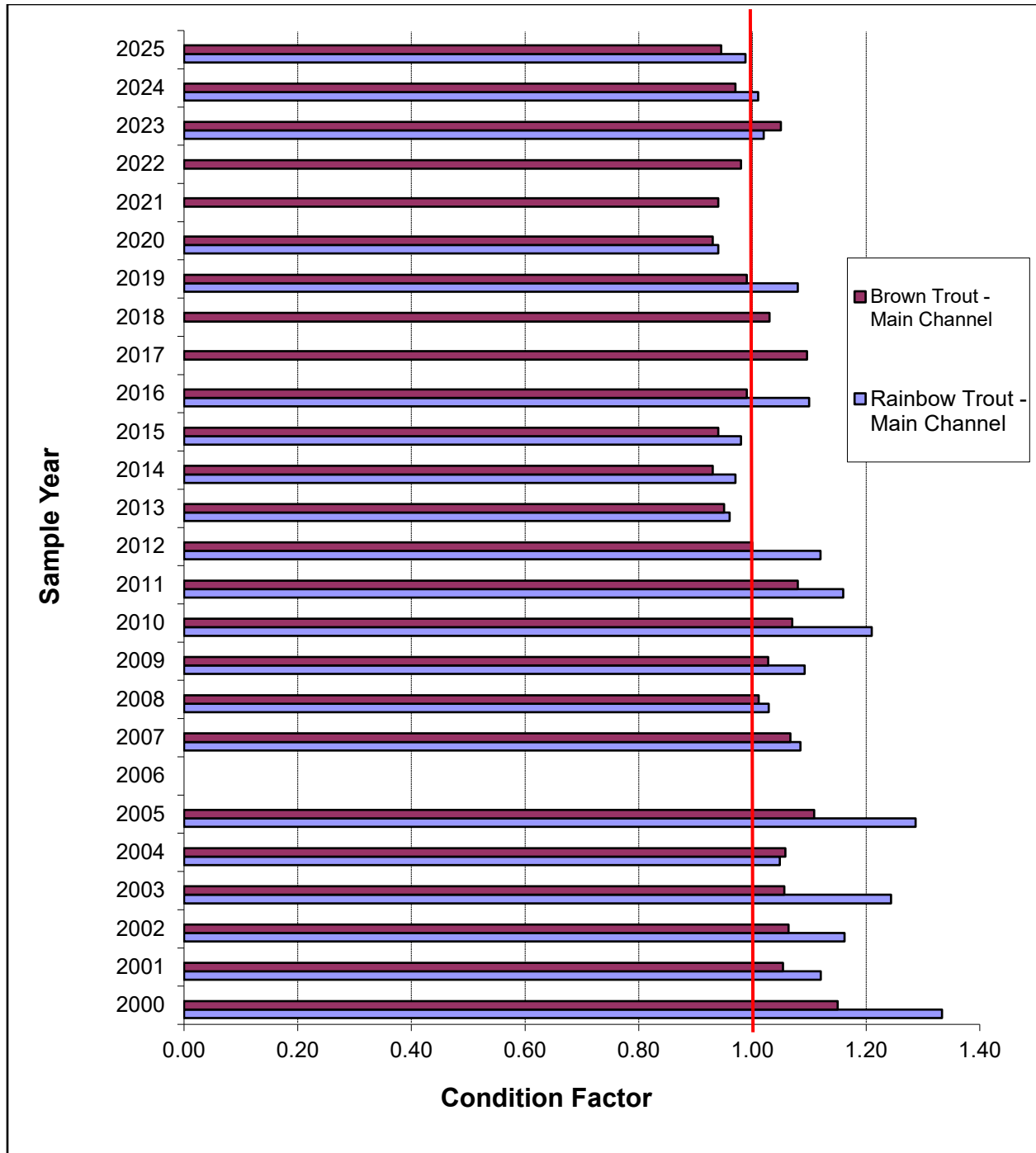


Figure 13. Condition factors for Rainbow Trout and Brown Trout ≥ 150 mm in length from the main channel section of Lee Vining Creek from 2000 to 2025. Main channel was not sampled in 2006 due to high flows.

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

In the Upper Rush section, the RSD-225 equaled 25 for 2025, down from the RSD-225 of 45 in 2024 and 58 in 2023 (Table 5). The 2025 RSD-225 value was influenced by higher numbers of fish in the 150 to 224 mm size class than in the ≥ 225 mm size class (Table 5). The RSD-300 value was 5 in 2025, the second highest RSD-300 value over the past seven sampling seasons (Table 5). Over 26 sampling years, a total of 174 Brown Trout ≥ 300 mm were captured in the Upper Rush Creek section, an average of 6.7 fish ≥ 300 mm per year (Table 5).

In the Bottomlands section of Rush Creek, the RSD-225 dropped drastically from 72 in 2024 to 9 in 2025 (Table 5). The Bottomlands 2025 RSD-225 value was most likely influenced by a large decrease in the numbers of fish ≥ 225 mm (age-2 fish), which was likely related to the very low age-0 recruitment in 2023 during the record snowmelt runoff (Table 5). The RSD-300 value was 0 in 2025, because no Brown Trout ≥ 300 mm were captured in the Bottomlands section (Table 5). Over the 18 sampling years, a total of 32 Brown Trout ≥ 300 mm were captured in the Bottomlands section, an average of 1.8 fish ≥ 300 mm per year (Table 5).

In the MGORD, the RSD-225 value increased from 61 in 2024 to 82 in 2025 (Table 5). In 2025, the RSD-300 value was 26, the highest RSD-300 value since 2017 (Table 5). The RSD-375 value increased slightly from 2 in 2024 to 3 in 2025 (Table 5). Even though the RSD-375 value was only 3, a total of 16 fish ≥ 375 mm were caught in a single electrofishing pass, the highest number of big fish captured since 2016 (Table 5). The 2025 single-pass electrofishing in the MGORD included 126 fish ≥ 300 mm in TL (Table 5). Sample years 2024 and 2025 were the first consecutive years where more than 100 Brown Trout ≥ 300 mm in TL were caught in the MGORD since 2009 and 2010 (Table 5). For sampling conducted between 2001 and 2012, the annual average catch of Brown Trout ≥ 300 mm equaled 180 fish/year; then for the past 13 sampling years the annual average catch of Brown Trout ≥ 300 mm equaled 51 fish/year (Table 5). Previous annual reports speculated on factors possibly influencing the reduced numbers of older and larger Brown Trout in the MGORD (Taylor 2025). However, for 2024 and 2025, the annual average catch of Brown Trout ≥ 300 mm equaled 125 fish/year, a possible sign of a rebound in the numbers of older and larger Brown Trout residing in the MGORD (Table 5).

RSD values were computed for the 8-Channel in 2023, 2024 and 2025. For the 8-Channel, the RSD-225 equaled 66 in 2023, 37 in 2024, and 13 in 2025. The RSD-300 also steadily dropped from 6 in 2023 to 2 in 2024 and to 0 in 2025. In 2024 and 2025, larger proportions of the fish ≥ 150 mm were in the 150 to 224 mm size class, thus lowering the RSD-225 values. The number of Brown Trout ≥ 300 mm in length also dropped from five fish to two fish to zero fish, thus lowering RSD-300 values for each of the three years of available data. The loss of lower velocity pool habitat in 2024 and 2025 may have resulted in fewer larger trout occupying the 8-Channel.

The RSD-225 value for Lee Vining Creek dropped from 71 in 2024 to 44 in 2025 due to a higher proportion fish in the 150-224 mm size class (Table 6). However, in 2025, ten Brown Trout greater than 300 mm in length were captured in Lee Vining Creek, thus the RSD-300 value was 16, the highest value for the 26 years of data (Table 6).

Table 5. RSD values for Brown Trout in Rush Creek sections from 2000 to 2025.

Sampling Location on 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	2025	108	81	22	5	0	25	5	0
Upper Rush	2024	176	97	68	11	0	45	6	0
Upper Rush	2023	104	44	57	2	1	58	3	1
Upper Rush	2022	235	196	37	2	0	17	1	0
Upper Rush	2021	274	257	13	4	0	6	1	0
Upper Rush	2020	148	129	18	1	0	13	1	0
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	0
Upper Rush	2013	336	288	45	3	0	14	1	0
Upper Rush	2012	354	284	66	3	1	20	1	0
Upper Rush	2011	498	381	110	6	1	23	1	0
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	0
Upper Rush	2007	282	210	61	9	2	26	4	1
Upper Rush	2006	233	154	69	10	0	34	4	0
Upper Rush	2005	202	139	56	5	2	31	3	1
Upper Rush	2004	179	112	64	2	1	37	2	1
Upper Rush	2003	264	216	45	2	1	18	1	0
Upper Rush	2002	220	181	35	1	2	18	2	1
Upper Rush	2001	223	190	27	6	0	15	3	0
Upper Rush	2000	182	158	22	2	0	13	1	0
Bottomlands	2025	44	40	4	0	0	9	0	0
Bottomlands	2024	71	20	47	4	0	72	6	0
Bottomlands	2023	55	39	15	0	1	29	2	2
Bottomlands	2022	145	123	22	0	0	15	0	0
Bottomlands	2021	121	110	10	1	0	9	1	0
Bottomlands	2020	128	117	11	0	0	9	0	0
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

Table 5 (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
Bottomlands	2013	128	123	5	0	0	4	0	0
Bottomlands	2012	325	290	34	1	0	11	0	0
Bottomlands	2011	267	218	46	3	0	18	1	0
Bottomlands	2010	307	225	81	1	0	27	0	0
Bottomlands	2009	379	321	56	1	1	15	1	0
Bottomlands	2008	160	141	19	0	0	12	0	0
MGORD	2025	484	89	269	110	16	82	26	3
MGORD	2024	578	226	228	110	14	61	21	2
MGORD	2023	91	6	62	14	9	93	25	10
MGORD	2022	198	56	114	22	6	72	14	3
MGORD	2021	431	204	180	35	12	53	11	3
MGORD	2020	322	167	112	37	6	48	13	2
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
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
8-Channel	2025	52	45	7	0	0	13	0	0
8-Channel	2024	59	37	21	1	0	37	2	0
8-Channel	2023	86	29	52	5	0	66	6	0

Table 6. RSD values for Brown Trout in the Lee Vining Creek main channel section from 2000-2025.

Sampling Location	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
LV Main	2025	61	34	17	10	0	44	16
LV Main	2024	80	23	49	8	0	71	10
LV Main	2023	76	32	41	3	0	58	4
LV Main	2022	129	105	24	0	0	19	0
LV Main	2021	175	169	6	0	0	3	0
LV Main	2020	80	69	11	0	0	14	0
LV Main	2019	131	107	22	2	0	18	2
LV Main	2018	51	39	10	2	0	24	4
LV Main	2017	23	17	5	1	0	26	4
LV Main	2016	169	145	24	0	0	14	0
LV Main	2015	210	192	18	0	0	9	0
LV Main	2014	200	173	27	0	0	14	0
LV Main	2013	325	308	16	1	0	5	0
LV Main	2012	111	72	37	2	0	35	2
LV Main	2011	60	31	23	5	1	48	10
LV Main	2010	62	28	32	2	0	55	3
LV Main	2009	137	106	30	1	0	23	1
LV Main	2008	149	138	11	0	0	7	0
LV Main	2007	29	24	5	0	0	17	0
LV Main	2006	Not sampled in 2006 due to unsafe high flows						
LV Main	2005	60	37	20	2	1	38	5
LV Main	2004	70	60	8	2	0	14	3
LV Main	2003	52	27	23	2	0	48	4
LV Main	2002	100	74	23	3	0	26	3
LV Main	2001	90	71	16	3	0	21	3
LV Main	2000	51	32	18	1	0	37	2

PIT Tag Recaptures

PIT Tags Implanted between 2009 and 2025

Between 2009 and 2025, a total of 12,973 PIT tags were implanted in Brown Trout and Rainbow Trout within the annually sampled sections of Rush, Lee Vining and Walker Creeks. 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 for 2009 through 2024 tabulated in Appendix B.

In 2025, a total of 592 trout received PIT tags and adipose fin clips in Rush, Lee Vining, and Walker Creeks (Table 7). In addition, two recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 594 PIT tags were implanted during the 2025 fisheries sampling (Table 7). Of the 594 tagged trout, 480 were age-0 Brown Trout and 80 were age-1 and older Brown Trout (Table 7). For Rainbow Trout, 30 age-0 fish were tagged and four age-1 and older were tagged (Table 7). Seventy-eight of the Brown Trout tagged in the MGORD section were between 167-225 mm in TL and were presumed to be age-1 fish (Table 7). In addition, 53 age-0 Brown Trout were tagged in the MGORD (Table 7). Tagged and recaptured fish provided empirical information to estimate annual fish growth rates, tag retention, and fish movements.

Table 7. Total numbers of trout implanted with PIT tags during the 2025 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	175	1*	13	0	189 Trout
	Bottomlands	109	1*	0	0	110 Trout
	MGORD	53**	78***	0	4	135 Trout
	8-Channel	50	0	0	0	50 Trout
LV Creek	Main Channel	53	0	17	0	70 Trout
Walker Creek	Above Old 395	40	0	0	0	40 Trout
Species/Age Class Sub-totals:		480	80	30	4	Total Trout: 594

*shed tag/new tag implanted

**up to 132 mm

***167 mm to 225 mm in total length

In September of 2025, a total of 71 previously tagged trout (that retained their tags) were recaptured in the Rush Creek watershed (Appendix C). Three of the recaptures occurred in the Bottomlands section, followed by three recaptures in the 8-Channel section, 20 recaptures in the Upper Rush section (including two Rainbow Trout), six recaptures in Walker Creek, and 39 recaptures in the MGORD (Appendix C). In September of 2025, a total of 12 previously tagged

Brown Trout (that retained their tags) were recaptured in the Lee Vining Creek main channel section (Appendix C). During the 2025 sampling, only two previously tagged Rainbow Trout were recaptured, thus very limited growth rate information was available for Rainbow Trout in Rush Creek and Lee Vining Creek.

In the following text, growth between 2024 and 2025 is referred to as 2025 growth rates. A 2025 trout refers to a fish recaptured in September of 2025. The age of a PIT tagged trout reflects its age during the sampling year. For instance, an age-1 trout in 2025 indicates a trout that was tagged in September 2024 at age-0, and its length and weight were remeasured in September 2025 when it was recaptured.

Also note there is a separate results section for reporting growth rates of recaptures from the MGORD section of Rush Creek, primarily because most of these fish were tagged at presumed age-1 (based on total lengths up to 225 mm), instead of at a known age-0. However, when captured in the MGORD, age-0 trout were also implanted with PIT tags.

Growth of Age-1 Brown Trout Between 2024 and 2025

In 2025, a total of 29 known age-1 Brown Trout were recaptured that were tagged as age-0 fish in 2024, for an overall recapture rate of 4.0% (29 recaps/742 age-0 fish tagged in 2024). Nineteen of the age-1 recaptures were from Rush Creek sections, one recapture in Walker Creek, and nine recaptures in Lee Vining Creek.

In the Upper Rush section, 14 age-1 Brown Trout were recaptured in 2025, and the average growth rates of these 14 trout were 62 mm and 28 g (Table 8). Compared to 2024 rates, the average growth rates of the 14 age-1 Brown Trout were lower by 26 mm and 21 g (Table 8). The 2025 growth rates of age-1 Brown Trout in Upper Rush when combined with the 2020 and 2021 average growth rates were the three lowest rates recorded for the 16 years of available data (Table 8). The 2025 growth rates of age-1 Brown Trout in the Upper Rush section were the third lowest rates for the 16 years of available data (Table 8).

In the Bottomlands section of Rush Creek, two age-1 Brown Trout were recaptured in 2025, and the average growth rates of these trout were 65 mm and 28 g (Table 8). Compared to 2024 rates, the growth rates of the two age-1 Brown Trout were lower by 12 mm and by 12 g (Table 8). The 2025 growth rates of age-1 Brown Trout in the Bottomlands were the lowest rates since 2020 and 2021 (Table 8).

In Walker Creek, one age-1 Brown Trout was recaptured in 2025, and the average growth rates of this trout were 47 mm and 22 g (Table 8). There were no 2024 growth rates for comparison with the 2025 growth rates (Table 8). When compared to the 2023 data, the 2025 growth rates were 20 mm less in length and 8 g less in growth (Table 8).

In Lee Vining Creek, nine age-1 Brown Trout were recaptured in 2025, and the average growth rates of these nine trout were 67 mm and 34 g (Table 8). There were no 2024 growth rates for

comparison with the 2025 growth rates (Table 8). When compared to the 2023 data, the 2025 growth rates were 4 mm less in length and 5 g less in growth (Table 8).

In the 8-Channel section of Rush Creek, two age-1 Brown Trout were recaptured in 2025, and the average growth rates of these trout were 60 mm and 26 g. These growth rates for age-1 Brown Trout in the 8-Channel were similar to growth rates in the Bottomlands, which makes sense because of the proximity of these two sample sections.

Growth of Age-2 Brown Trout Between 2024 and 2025

In 2025, a total of two known age-2 Brown Trout were recaptured that were tagged as age-0 fish in 2023, for a recapture rate of 1.4% (two recaps/141 age-0 fish tagged in 2023). One of these fish was recaptured in Upper Rush and the other fish was recaptured in the Bottomlands section of Rush Creek. Relatively few age-0 fish were PIT tagged in 2023 due to the very low age-0 recruitment that year during the record runoff.

The one age-2 fish recaptured in Upper Rush had growth rates of 22 mm and 38 g between age-1 and age-2 (Table 8). The 2025 age-2 growth rates were the lowest ever recorded in the Upper Rush section for the 13 years of available data (Table 8).

The one age-2 fish recaptured in the Bottomlands section of Rush Creek had growth rates of 42 mm and 38 g between age-1 and age-2 (Table 8). Over the past seven years, recaptures of age-2 Brown Trout have occurred in three of those years, and each time it was a single fish per year (Table 8).

Growth of Age-3 Brown Trout Between 2024 and 2025

In 2025, five known age-3 Brown Trout were recaptured that were tagged as age-0 fish in 2022; two fish were recaptured in Upper Rush, two were recaptured in Walker Creek, and one was recaptured in Lee Vining Creek. In Upper Rush, between age-2 and age-3, the average growth rates of the two Brown Trout were 10 mm and 8 g (Table 8). In Walker Creek, between age-2 and age-3, the average growth rates of the two Brown Trout were 18 mm and 18 g (Table 8). In Lee Vining Creek, between age-2 and age-3, the one Brown Trout experienced growth rates of 59 mm and 116 g (Table 8).

Growth of Age-4 Brown Trout Between 2024 and 2025

In 2025, two known age-4 Brown Trout were recaptured in Walker Creek that were tagged as age-0 fish in 2021. Between age-3 and age-4, the average growth rates of these two Brown Trout were 7 mm and 4 g (Table 8). One of these fish had lost 16 g and one had gained 8 g. At age-4, these two fish were 229 and 246 mm in TL. One of these fish had been recaptured every year since being tagged in 2021.

Growth of MGORD Brown Trout Between 2024 and 2025

Based on past years' length-frequency histograms and lengths of known age-1 fish (from recaptures of previously tagged age-0 fish), a conservative cut-off of 225 mm in TL was used to

define the probable 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 fish in which their ages are known or accurately presumed. During the single electrofishing pass of the MGORD on 9/22/25, a total of 39 Brown Trout were recaptured with PIT tags, by far the highest number of PIT tag recaptures made in this annually sampled section of Rush Creek.

In 2025, two age-1 Brown Trout were recaptured in the MGORD that were tagged at age-0 in the MGORD; for a recapture rate of 3.4% (two recaps/58 age-0 fish tagged in 2024). Between 2024 and 2025, the average growth rates of these two fish were 112 mm and 93 g, compared to average growth rates of 118 mm and 86 g in 2024. At age-1, these two Brown Trout were 206 mm and 208 mm in TL. Compared to the Upper Rush section, average growth rates of age-1 Brown Trout in the MGORD were 50 mm greater for length and 65 g greater for weight (more than three-fold greater in weight growth).

In 2025, 26 age-2 Brown Trout were recaptured in the MGORD that were PIT tagged in the MGORD as presumed age-1 fish in 2024; for a recapture rate of 14.4% (26 recaps/180 age-1 fish tagged in 2024). To date, this is the highest number of age-2 recaptures made in the MGORD. Between 2024 and 2025, the average growth rates of these 26 fish were 64 mm and 97 g. This growth of 97 g in weight was more than two-fold greater than the age-2 fish recaptured in Upper Rush.

In 2025, nine previously tagged Brown Trout were caught in the MGORD as non-sequential recaptures. Three of these Brown Trout were tagged as age-0 fish in the Upper Rush section and were recaptured in the MGORD at age-3. Between age-0 and age-3, these three fish had average growth rates of 231 mm and 368 g. These age-3 Brown Trout averaged 326 mm in total length, with a range of 317 mm to 333 mm. Another non-sequential age-3 recapture in the MGORD was a Brown Trout tagged at age-0 in the Bottomlands sections. Between age-0 and age-3 this fish had grown by 239 mm and 353 g and was 352 mm in TL. Three more of the non-sequential recaptures were tagged in the MGORD at age-0 and recaptured at age-2. Between age-0 and age-2, these three fish had average growth rates of 180 mm and 202 g. These three known age-2 Brown Trout were 269 mm, 271 mm, and 291 mm in TL. The next non-sequential recapture was a Brown Trout tagged at age-1 in 2021 that was recaptured at age-5 in 2025; this fish was 202 mm and 75 g at age-1 and was 455 mm and 1,172 g at age-5.

The ninth non-sequential Brown Trout recaptured in the MGORD in 2025 was a large fish tagged at age-1 in 2016 (213 mm TL). This fish was recaptured at age-2 in 2017 (304 mm TL) and at age-3 in 2018 (345 mm TL). This fish was 521 mm in TL and 2,426 g at age-10 when caught on 9/22/25 (Figure 14). In the seven years between its 2018 recapture and its 2025 recapture, this large male Brown Trout grew an average of 25 mm and 288 g per year.

Movement of PIT Tagged Trout Between Sections

Previous annual fisheries reports have summarized movements of PIT tagged fish between the sample sections, with most movements occurring from the Upper Rush section upstream into the MGORD (Taylor 2021). Movements between the Upper Rush section and the MGORD were initially documented during the radio telemetry study when approximately 50% of the radio-tagged fish left the MGORD during both of the fall/early winter spawning periods that occurred during the two-year study period (Taylor et al. 2009). As described in the previous section, in 2025, three of the PIT tagged Brown Trout recaptured in the MGORD had moved upstream from the Upper Rush section, sometime between age-0 and age-3, and a fourth Brown Trout had moved from the Bottomlands up into the MGORD between age-0 and age-3. These movements of fish into the MGORD from other sections continue to support the importance of the MGORD to Rush Creek's Brown Trout population and the ability of both adult and juvenile Brown Trout to migrate to more favorable habitats for both spawning and rearing. The radio telemetry study also showed that adult Brown Trout had relatively tight home ranges in the MGORD for most of the year, made farther-ranging movements during spawning season, and then frequently returned to their established home territory (Taylor et al. 2009).

PIT Tag Shed Rate of Trout Recaptured in 2025

In 2025, a total of 73 trout with adipose fin clips were recaptured and two of these fish failed to produce a PIT tag number when scanned with the tag reader (one from Upper Rush and one from Bottomlands). Assuming that all these fish were previously PIT tagged, the 2025 calculated shed rate was 2.7% (2 shed tags/73 clipped fish recaptured) versus shed rates of 12.5% in 2024, 4.7% in 2023, 3.8% in 2022, 2.3% in 2021 and 6.8% in 2020. 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 been linked to tagger's experience and crew turnover rates, with less experienced taggers resulting in higher shed rates (Dare 2003). Starting in 2022, RTA's fisheries crew was comprised of mostly new individuals and some with minimal tagging experience, which may explain some of the higher shed rates, yet as the crew has gained more experience, it is possible that the low rate of 2.7% reflects this increased experience.



Figure 14. MGORD Brown Trout (521 mm TL) that was recaptured on 9/22/25.

Table 8a. Average growth (length/weight) of Brown Trout recaptured from 2009 through 2016 by age. Note: *denotes only one PIT tagged fish recaptured.

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

Table 8b. Average growth (length/weight) of Brown Trout recaptured from 2017 through 2025 by age. Note: *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)								
		2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025
Upper Rush Creek	Age 1	132/129	83/56	77/43	55/21	66/27	81/41	120/98	88/49	62/28
	Age 2	108/239	39/66	48/71	44/55	54/42	68/67*			22/38*
	Age 3		11/40*	15/27*	41/49*					10/8
	Age 4					38/144*				
	Age-5						15/-49*			
Rush Creek Bottom-lands	Age 1	118/96	72/42	74/38	64/29	67/26	80/41	104/68	77/40	65/28
	Age 2		39/55	36/44*		35/33*	81/84*			42/38*
	Age 3				21/20*					
	Age 4									
	Age-5									
LV Main Channel Brown Trout	Age 1	110/92*	103/77	71/41	72/29	63/27	73/33	71/39		67/34
	Age 2	77/128*		60/91*	70/81	46/47	55/54	57/64*	71/73	
	Age 3					30/48				59/116
	Age 4						31/67*			
	Age-5									
LV Main Channel RB Trout	Age 1			80/43*				105/71*		
	Age 2									
	Age 3									
	Age 4									
	Age-5									
Walker Creek Above Old 395	Age 1	66/33		55/28	54/24	47/18	53/18	67/30		47/22*
	Age 2	37/37	42/52		36/30	25/19	37/23	52/42	63/62	
	Age 3	42/59*	25/37	25/37		12/19	22/18	39/51	40/47	18/18
	Age 4		27/37*		8/-5		13/-5	103/212*	29/44*	7/4
	Age-5							22/36*		

Comparison of Length-at Age Amongst Sample Sections

During September 2025 sampling, five known age-classes of PIT tagged Brown Trout were recaptured within four fisheries monitoring sections of Rush, Walker, and Lee Vining Creeks (Tables 9 and 10). Along with providing age-specific length information for each section, these data allowed comparisons of length-at-age between sample sections and between the years 2013-2025 (Tables 9 and 10).

In Upper Rush, the average length-at-age-1 in 2025 was 154 mm, 37 mm less than the average length-at-age-1 in 2024 (Table 9). In 2025, age-1 Brown Trout in Upper Rush were, on average, 2 mm longer than age-1 fish in the Bottomlands section (Table 9). In the Bottomlands section, the average length-at-age-1 in 2025 was 152 mm, 25 mm less than the 2024 average length-at-age-1, and the lowest value for 11 years of available data (Table 9).

In Upper Rush, the average length-at-age-2 in 2025 was 208 mm, 65 mm less than the average length-at-age-2 in 2024 and the second lowest value for 11 years of available data (Table 9). In the Bottomlands section, the average length-at-age-2 equaled 227 mm in 2025, 17 mm less than the average length-at-age-2 in 2024 (Table 9).

In 2025, one PIT-tagged age-3 Brown Trout was recaptured in the Upper Rush section, and this fish was 264 mm in TL (Table 9). Since 2013, only one age-3 recaptured in the Upper Rush section has exceeded 300 mm in TL (Table 9). No age-3 Brown Trout has been recaptured in Bottomlands section of Rush Creek since 2021 (Table 9). Also, no PIT-tagged age-4 or age-5 Brown Trout were recaptured in either of these sections in 2025 (Table 9).

For Walker Creek in 2025, one age-1 Brown Trout was recaptured, and this fish was 161 mm in TL (Table 9). In 2025, no PIT tagged age-2 Brown Trout were recaptured in Walker Creek (Table 9). In 2025, two PIT tagged age-3 Brown Trout were recaptured in Walker Creek and the average length-at-age-3 equaled 234 mm, 12 mm longer than the 2024 average (Table 9). In 2025, three PIT tagged age-4 Brown Trout were recaptured in Walker Creek and the average length-at-age-4 equaled 236 mm, 14 mm less than the 2024 average (Table 9). No age-5 Brown Trout were recaptured in Walker Creek during the 2025 fisheries sampling.

For the Lee Vining Creek main channel in 2025, nine age-1 Brown Trout were recaptured, and the average length-at-age-1 equaled 163 mm (Table 10). In 2025, no previously tagged age-2 Brown Trout were recaptured. In 2025, two age-3 Brown Trout were recaptured in Lee Vining Creek, and the average length-at-age-3 equaled 280 mm.

As in past years, in 2025, the length-at-age of Brown Trout in the MGORD was far greater when compared to Upper Rush, the Bottomlands, and Walker Creek (Table 11). The average length at age-2 in the MGORD was longer than an age-3 fish in Upper Rush and longer than age-3 and age-4 fish in Walker Creek (Table 11). In 2025, a PIT tagged recaptured age-5 Brown Trout in the MGORD was 455 mm in TL.

These findings of average lengths by age-class continue to support previous conclusions by the Stream Scientist that very few Brown Trout reach age-4 or older in Rush Creek or Lee Vining Creek (Taylor 2022). Outside of the MGORD, we have never recaptured a PIT tagged Brown Trout older than age-5. The MGORD continues to be the only section where Brown Trout lengths consistently approach or exceed 300 mm by age-2 or age-3, and by age-4 are meeting or exceeding lengths of 325-350 mm (~13-14 inches), a standard frequently cited as a common fish size pre-1941 and at the start of LADWP's diversions out of the Mono Basin (Table 11) (Sims and Sims 1990; SWRCB 1994).

Table 9. Size range of PIT tagged recaptures in 2013-2025 by age class for Brown Trout at three electrofishing sections on Rush and Walker Creeks. NOTE: years omitted if no tagged fish were recaptured.

Section	Cohort	Size Range (mm)	Average Length (mm)
Upper Rush	Age-1	2025 = 121-180 2024 = 180-203 2023 = 193-258 2022 = 151-189 2021 = 126-185 2020 = 124-167 2019 = 128-202 2018 = 158-232 2017 = 224-264 2016 = 192-237 2015 = 169-203	2025 = 154 2024 = 191 2023 = 222 2022 = 169 2021 = 154 2020 = 145 2019 = 173 2018 = 193 2017 = 243 2016 = 208 2015 = 187
	Age-2	2025 = 197-225 2024 = 257-287 2023 = 267-285 2022 = 217-237 2021 = 174-233 2020 = 209-235 2019 = 203-251 2018 = 236-305 2017 = 284-337 2016 = 289* 2015 = 205-242	2025 = 208 2024 = 273 2023 = 276 2022 = 228 2021 = 198 2020 = 221 2019 = 237 2018 = 274 2017 = 313 2016 = 289* 2015 = 217
	Age-3	2025 = 264 2024 = 304 2021 = 220 2020 = 287 2019 = 251 2018 = 295 2014 = 226-236 2013 = 227-263	2025 = 264 2024 = 304 2021 = 220 2020 = 287 2019 = 251 2018 = 295 2014 = 231 2013 = 245
	Age-4	2021 = 325 2014 = 288 2013 = 252-255	2021 = 325 2014 = 288 2013 = 254
	Age-5	2022 = 340 2014 = 298	2022 = 340 2014 = 298
Bottomlands	Age-1	2025 = 150-153 2024 = 168-185 2023 = 177-222 2022 = 142-204 2021 = 155 2020 = 141-187 2019 = 133-196 2018 = 166-199 2017 = 189-246 2016 = 172-217 2015 = 150-181	2025 = 152 2024 = 177 2023 = 202 2022 = 166 2021 = 155 2020 = 155 2019 = 168 2018 = 181 2017 = 221 2016 = 197 2015 = 169
	Age-2	2025 = 227 2024 = 235-259 2022 = 202-236 2021 = 186 2019 = 219 2018 = 251-287 2015 = 197-239 2014 = 192 2013 = 156-196	2025 = 227 2024 = 244 2022 = 219 2021 = 186 2019 = 219 2018 = 267 2015 = 219 2014 = 192 2013 = 178
	Age-3	2021 = 214-248 2020 = 240 2014 = 194 2013 = 194-227	2021 = 231 2020 = 240 2014 = 194 2013 = 204
	Age-4	2014 = 215-219	2014 = 216
	Age-5	2016 = 318	2016 = 318

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

Table 9 (continued).

Section	Cohort	Size Range (mm)	Average Length (mm)
Walker Creek	Age-1	2025 = 161 2023 = 131-187 2022 = 114-169 2021 = 121-154 2020 = 132-170 2019 = 141-168 2017 = 151-179 2016 = 145-187 2015 = 133-177	2025 = 161 2023 = 159 2022 = 140 2021 = 138 2020 = 151 2019 = 159 2017 = 166 2016 = 167 2015 = 154
	Age-2	2024 = 210-225 2023 = 167-220 2022 = 151-205 2021 = 155-187 2020 = 190-196 2018 = 191-221 2017 = 180-224 2016 = 180-226 2014 = 168-200 2013 = 181-208	2024 = 217 2023 = 191 2022 = 175 2021 = 175 2020 = 194 2018 = 210 2017 = 202 2016 = 201 2014 = 186 2013 = 197
	Age-3	2025 = 232-239 2024 = 205-236 2023 = 209-221 2022 = 180-215 2021 = 200-212 2019 = 215-235 2018 = 204-245 2017 = 238 2015 = 211-231 2014 = 207-222 2013 = 219-221	2025 = 234 2024 = 222 2023 = 214 2022 = 199 2021 = 205 2019 = 220 2018 = 228 2017 = 238 2015 = 219 2014 = 217 2013 = 220
	Age-4	2025 = 229-246 2024 = 250 2023 = 240-299 2022 = 205-221 2020 = 224-243 2018 = 265 2015 = 249 2014 = 211 2013 = 219	2025 = 236 2024 = 250 2023 = 270 2022 = 213 2020 = 234 2018 = 265 2015 = 249 2014 = 211 2013 = 219
	Age-5	2024 = 257 2023 = 227 2014 = 220	2024 = 257 2023 = 227 2014 = 220

Table 10. Size range of PIT tagged fish recaptured in 2013-2025 by age class for Brown Trout and Rainbow Trout on Lee Vining Creek. NOTE: years omitted if no tagged fish were recaptured.

Section	Cohort	Size Range (mm)	Average Length (mm)
Brown Trout in Lee Vining Main Channel	Age-1	2025 = 139-190 2023 = 154-181 2022 = 145-169 2021 = 126-182 2020 = 125-185 2019 = 142-209 2018 = 170-194 2017 = 210 2016 = 147-186 2015 = 149-190	2025 = 163 2023 = 170 2022 = 161 2021 = 154 2020 = 155 2019 = 174 2018 = 183 2017 = 210 2016 = 171 2015 = 166
	Age-2	2024 = 218-233 2023 = 212-250 2022 = 183-230 2021 = 163-225 2020 = 212-270 2019 = 222-274 2017 = 247 2016 = 205-217 2015 = 176-214 2014 = 174-195 2013 = 206-225	2024 = 229 2023 = 225 2022 = 208 2021 = 195 2020 = 232 2019 = 247 2017 = 247 2016 = 211 2015 = 197 2014 = 188 2013 = 215
	Age-3	2025 = 268-291 2023 = 266 2022 = 226-246 2021 = 246 2017 = 280-305 2016 = 210-256 2015 = 188-228 2014 = 234-241 2013 = 238-271	2025 = 280 2022 = 236 2021 = 246 2017 = 293 2016 = 240 2015 = 215 2014 = 238 2013 = 253
	Age-4	2025 = 280 2022 = 277 2016 = 237	2025 = 280 2022 = 277 2016 = 237
	Age-5	None captured in past 12 years	
Rainbow Trout in Lee Vining Main Channel	Age-1	2023 = 202 2019 = 165 2015 = 140-177	2023 = 202 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 12 years. No age-5 fish in the past 12 years either.	

Table 11. Comparisons of average length-at-age by age class for Brown Trout in the Rush Creek watershed in 2025, including the MGORD.

Sample Section	Average Length at Age-1 (mm)	Average Length at Age-2 (mm)	Average Length at Age-3 (mm)	Average Length at Age-4 (mm)
MGORD	207	271	335	354
UPPER RUSH	154	208	264	N/A
BOTTOMLANDS	151	227	N/A	N/A
WALKER CK.	161	N/A	234	236

Summer Water Temperature

During the past 14 years, the Mono Basin has experienced a five-year drought (2012-2016), a near-record Extreme-wet RY (2017), a Normal RY with a full GLR (2018), a Wet RY (2019), a Dry-Normal-1 RY (2020), a Dry RY (2021), a Dry RY (2022), a record Extreme-wet RY (2023), and a Normal RY in 2024 with a full GLR. These RY types have resulted in a range of summer water temperatures in Rush Creek, from moderate-to-severe stressful conditions in drier RYs to thermal regimes mostly conducive to fair-to-good growth conditions in wetter RYs and/or in average RYs with a full/spilling GLR.

In 2025, the water temperature monitoring was again conducted by the MLC. The deployment of redundant data loggers at key locations and more frequent inspections of deployed units resulted in no gaps in the water temperature data sets.

In 2025, the Dry-Normal-1 RY occurred with a modest 18-day spill out of GLR and relatively high storage levels all summer long (within 4.5 feet of full). However, water temperature monitoring locations below the MGORD experienced some days with peaks $>70^{\circ}\text{F}$ and relatively large diurnal fluctuations (Table 12). At the four Rush Creek temperature monitoring locations below the MGORD, the maximum diurnal fluctuations were relatively large (14.1°F to 17.9°F), the second or third largest fluctuations experienced for the 13 years of available summer water temperature data (Table 12). Cooling at night was a factor, as well as some extremely warm air temperatures recorded in the Mono Basin (see air temperature data presented in the Discussion section).

Similar to the 2013-2024 annual reports, 2025 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 13). Development of these thermal-based growth criteria were fully described in previous annual reports (Taylor 2013 and 2014). Using these growth prediction metrics, good potential growth days in 2025 varied from 29 to 53 days in Rush Creek out of the 92-day period from July 1 to September 30 (Table 13). For all Rush Creek temperature monitoring locations downstream of GLR, the number of days classified as “fair” potential growth days in 2025 ranged from 39 to 63 days (Table 13). In 2025, zero to six days were classified as either poor potential growth days or bad thermal days at the temperature monitoring locations downstream of GLR (Table 13). Conversely, at the Above Damsite location, there were 12 poor potential growth days and three bad thermal days, which accounted for 16% of the 92-day summer period when water temperature data were evaluated (Table 13).

As was done with the 2013-2024 data, the diurnal temperature fluctuations for July, August and September 2025 were characterized by the one-day maximum fluctuation that occurred each month and by monthly averages (Table 14). Also, for each temperature monitoring location, the highest average diurnal fluctuations over consecutive 21-day durations were determined (Table 14). The diurnal fluctuations throughout the summer of 2025 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 14). Over the 21-day durations, these larger diurnal fluctuations were above the threshold of 12.6°F considered detrimental to trout growth (Werley et al. 2007) during the summer of 2025 as recorded at the Above Parker (13.7°F), Below Narrows (14.3°F), and County Road (16.0°F) temperature monitoring locations (Table 14). August into September were when these temperature monitoring locations experienced their highest 21-day diurnal fluctuations, including levels detrimental to trout growth (Werley et al. 2007). Diurnal fluctuations of 13.5°F and greater in lower Rush Creek were described as “common” by Cullen and Railsback (1993) in 1991 and 1992, and the authors commented that the historic springs below The Narrows “*moderated Rush Creek such that stream temperatures were not a problem to fish in the bottomlands.*”

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 2025. 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 15). The values from 2013-2024 were also included to better illustrate the variability that occurred at all the temperature monitoring locations (Table 15). The 2025 data show that all the temperature monitoring stations located downstream of GLR experienced relatively few hours in exceedance of the 66.2°F thermal threshold, with seasonal ranges of 0% to 17% of the 2,208-hour summer period (Table 15). The decrease in the number of hours in exceedance of the 66.2°F thermal threshold between the Above Parker and Below Narrows temperature monitoring locations shows the continued, small, yet positive influence that accretions from Parker and Walker Creeks have on lower Rush Creek summer water temperatures (Table 15).

Summer water temperatures in Lee Vining Creek were all within the range of fair-to-good growth potential during 2025. Regardless of RY type, excessively warm water has not been an issue in Lee Vining Creek, thus detailed analyses were not performed with the 2025 data.

Table 12. Summary of water temperature data during the summer of RY 2025 (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 2013-2024 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. Fluctuation
Rush Ck. – Above Damsite	2023 = 55.2 2024 = 60.4 2025 = 61.5	2023 = 53.0 2024 = 56.5 2025 = 57.1	2023 = 58.3 2024 = 65.6 2025 = 67.2	2023 = 0 2024 = 11 2025 = 33	2023 = 10.0 2024 = 14.9 2025 = 14.8	9/18/23 8/27/24 8/02/25
Rush Ck. – Top of MGORD	2013 = 63.1 2014 = 64.8 2015 = 64.4 2016 = 63.8 2017 = 57.0 2018 = 60.7 2019 = 58.5 2020 = 63.2 2021 = 65.9 2022 = 65.9 2023 = 54.0 2024 = 57.8 2025 = 60.9	2013 = 62.7 2014 = 64.6 2015 = 64.1 2016 = 63.0 2017 = 56.5 2018 = 59.6 2019 = 57.2 2020 = 62.1 2021 = 65.2 2022 = 65.0 2023 = 53.3 2024 = 56.5 2025 = 59.7	2013 = 63.7 2014 = 65.0 2015 = 64.8 2016 = 64.7 2017 = 58.1 2018 = 61.9 2019 = 59.9 2020 = 64.4 2021 = 66.8 2022 = 67.0 2023 = 55.0 2024 = 59.3 2025 = 62.3	2013 = 0 2014 = 0 2015 = 0 2016 = 0 2017 = 0 2018 = 0 2019 = 0 2020 = 0 2021 = 5 2022 = 3 2023 = 0 2024 = 0 2025 = 0	2013 = 3.4 2014 = 3.9 2015 = 2.1 2016 = 6.5 2017 = 5.4 2018 = 6.7 2019 = 8.2 2020 = 6.4 2021 = 6.5 2022 = 6.6 2023 = 8.2 2024 = 9.1 2025 = 6.8	7/09/13 8/13/14 7/03/15 7/07/16 9/07/17 8/20/18 8/10/19 7/02/20 7/13/21 7/12/22 8/31/23 8/20/24 8/05/25
Rush Ck. – Bottom of MGORD	2013 = 63.2 2014 = 64.8 2015 = 64.4 2016 = 63.8 2017 = 57.1 2018 = 61.0 2019 = 58.7 2020 = 63.2 2021 = 65.8 2022 = 65.9 2023 = N/A 2024 = 58.1 2025 = 61.5	2013 = 60.9 2014 = 62.9 2015 = 62.3 2016 = 61.8 2017 = 56.5 2018 = 58.9 2019 = 56.6 2020 = 60.5 2021 = 63.4 2022 = 63.7 2023 = N/A 2024 = 55.7 2025 = 58.8	2013 = 67.1 2014 = 68.5 2015 = 68.0 2016 = 66.9 2017 = 58.5 2018 = 63.9 2019 = 61.3 2020 = 67.5 2021 = 69.8 2022 = 69.5 2023 = N/A 2024 = 61.8 2025 = 65.6	2013 = 1 2014 = 20 2015 = 20 2016 = 1 2017 = 0 2018 = 0 2019 = 0 2020 = 17 2021 = 44 2022 = 50 2023 = N/A 2024 = 0 2025 = 0	2013 = 9.0 2014 = 8.3 2015 = 8.4 2016 = 8.0 2017 = 6.4 2018 = 8.7 2019 = 8.1 2020 = 10.0 2021 = 8.5 2022 = 8.7 2023 = N/A 2024 = 12.3 2025 = 10.4	7/09/13 7/13/14 7/06/15 7/04/16 9/07/17 7/05/18 8/10/19 8/03/20 7/24/21 7/29/22 2023 = N/A 8/18/24 8/06/25
Rush Ck. – Old Highway 395 Bridge/Upper Rush section	2013 = 62.6 2014 = 64.0 2015 = N/A 2016 = 63.5 2017 = 59.0 2018 = 60.9 2019 = 58.7 2020 = 62.6 2021 = 65.0 2022 = 64.7 2023 = 57.4 2024 = 58.2 2025 = 61.1	2013 = 58.8 2014 = 60.5 2015 = N/A 2016 = 60.1 2017 = 57.5 2018 = 58.0 2019 = 56.1 2020 = 58.5 2021 = 61.2 2022 = 60.4 2023 = 55.8 2024 = 54.8 2025 = 57.2	2013 = 68.7 2014 = 69.8 2015 = N/A 2016 = 68.8 2017 = 61.0 2018 = 65.3 2019 = 62.3 2020 = 68.4 2021 = 70.8 2022 = 70.6 2023 = 59.6 2024 = 63.3 2025 = 67.0	2013 = 40 2014 = 51 2015 = N/A 2016 = 47 2017 = 0 2018 = 0 2019 = 0 2020 = 30 2021 = 63 2022 = 55 2023 = 0 2024 = 0 2025 = 12	2013 = 13.5 2014 = 13.3 2015 = N/A 2016 = 12.5 2017 = 7.6 2018 = 10.9 2019 = 10.7 2020 = 14.0 2021 = 12.8 2022 = 15.2 2023 = 9.6 2024 = 13.2 2025 = 14.1	7/09/13 7/13/14 N/A 7/11/16 9/07/17 7/10/18 9/14/19 8/03/20 8/02/21 8/07/22 8/31/23 8/20/24 8/08/25

Table 12 (continued).

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. Fluctuation
Rush Ck. – Above Parker	2016 = 63.2 2017 = 59.0 2018 = 60.9 2019 = 58.4 2020 = 62.2 2021 = 64.4 2022 = 64.5 2023 = 57.5 2024 = N/A 2025 = 61.0	2016 = 58.8 2017 = 57.2 2018 = 57.2 2019 = 55.5 2020 = 57.1 2021 = 59.6 2022 = 59.4 2023 = 55.6 2024 = N/A 2025 = 56.3	2016 = 69.4 2017 = 61.9 2018 = 66.3 2019 = 62.3 2020 = 68.6 2021 = 70.8 2022 = 70.7 2023 = 60.4 2024 = N/A 2025 = 67.6	2016 = 55 2017 = 0 2018 = 0 2019 = 0 2020 = 40 2021 = 61 2022 = 59 2023 = 0 2024 = N/A 2025 = 16	2016 = 13.7 2017 = 8.6 2018 = 13.4 2019 = 11.8 2020 = 16.1 2021 = 14.4 2022 = 15.7 2023 = 10.7 2024 = N/A 2025 = 15.7	7/11/16 9/08/17 7/10/18 9/14/19 8/03/20 8/02/21 8/07/22 9/27/23 2024 = N/A 8/06/25
Rush Ck. – below Narrows	2013 = 61.2 2014 = 63.2 2015 = 62.3 2016 = 61.7 2017 = 58.4 2018 = 60.0 2019 = 57.8 2020 = 61.0 2021 = 63.2 2022 = 63.2 2023 = 57.3 2024 = 58.0 2025 = 60.2	2013 = 56.2 2014 = 57.1 2015 = 58.8 2016 = 56.9 2017 = 56.3 2018 = 56.0 2019 = 54.4 2020 = 55.5 2021 = 58.0 2022 = 58.0 2023 = 55.2 2024 = 53.6 2025 = 54.9	2013 = 67.6 2014 = 69.4 2015 = 66.1 2016 = 68.3 2017 = 61.3 2018 = 65.4 2019 = 62.2 2020 = 67.5 2021 = 69.7 2022 = 69.5 2023 = 60.3 2024 = 63.8 2025 = 66.8	2013 = 24 2014 = 46 2015 = 0 2016 = 34 2017 = 0 2018 = 0 2019 = 0 2020 = 16 2021 = 49 2022 = 52 2023 = 0 2024 = 0 2025 = 12	2013 = 16.3 2014 = 17.3 2015 = 11.5 2016 = 14.3 2017 = 8.2 2018 = 12.4 2019 = 12.7 2020 = 15.7 2021 = 14.9 2022 = 14.7 2023 = 8.9 2024 = 14.2 2025 = 15.9	7/19/13 7/26/14 9/23/15 7/13/16 9/07/17 7/10/18 9/22/19 8/03/20 8/12/21 7/29/22 8/31/23 8/16/24* 8/02/25
Rush Ck. – County Road	2013 = 61.4 2014 = 62.0 2015 = 62.1 2016 = 61.6 2017 = N/A 2018 = N/A 2019 = 58.2 2020 = 61.0 2021 = 63.1 2022 = 63.3 2023 = 61.4 2024 = 58.6 2025 = 60.7	2013 = 56.5 2014 = 56.7 2015 = 59.1 2016 = 56.0 2017 = N/A 2018 = N/A 2019 = 54.0 2020 = 54.5 2021 = 56.6 2022 = 57.5 2023 = 56.8 2024 = 53.1 2025 = 54.4	2013 = 66.6 2014 = 67.8 2015 = 65.5 2016 = 68.3 2017 = N/A 2018 = N/A 2019 = 63.6 2020 = 68.5 2021 = 70.7 2022 = 70.2 2023 = 63.6 2024 = 65.2 2025 = 68.0	2013 = 7 2014 = 24 2015 = 2 2016 = 32 2017 = N/A 2018 = N/A 2019 = 0 2020 = 42 2021 = 57 2022 = 55 2023 = 0 2024 = 1 2025 = 32	2013 = 14.7 2014 = 17.6 2015 = 9.2 2016 = 16.1 2017 = N/A 2018 = N/A 2019 = 13.5 2020 = 18.2 2021 = 17.4 2022 = 16.8 2023 = 12.6 2024 = 15.7 2025 = 17.9	8/02/13 7/26/14 7/28/15 7/11/16 N/A N/A 9/13/19 8/03/20 9/02/21 7/29/22 8/04/23 8/26/24 8/11/25

Table 13. Classification of 2013-2025 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 percentage (%) 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. – Above Damsite	2023 = 92 (100%) 2024 = 46 (50%) 2025 = 32 (35%)	2023 = 0 2024 = 35 (38%) 2025 = 45 (49%)	2023 = 0 2024 = 2 (2%) 2025 = 12 (13%)	2023 = 0 2024 = 9 (10%) 2025 = 3 (3%)
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%) 2020 = 6 (6%) 2021 = 0 2022 = 12 (13%) 2023 = 90 (98%) 2024 = 66 (72%) 2025 = 34 (37%)	2013 = 43 (47%) 2014 = 14 (15%) 2015 = 20 (22%) 2016 = 32 (35%) 2017 = 26 (29%) 2018 = 42 (46%) 2019 = 23 (25%) 2020 = 50 (54%) 2021 = 30 (33%) 2022 = 21 (23%) 2023 = 2 (2%) 2024 = 26 (28%) 2025 = 55 (60%)	2013 = 17 (18%) 2014 = 25 (27%) 2015 = 5 (5%) 2016 = 17 (18%) 2017 = 0 2018 = 3 (3%) 2019 = 4 (4%) 2020 = 12 (13%) 2021 = 8 (9%) 2022 = 5 (6%) 2023 = 0 2024 = 0 2025 = 3 (3%)	2013 = 18 (20%) 2014 = 48 (52%) 2015 = 60 (65%) 2016 = 33 (36%) 2017 = 0 2018 = 0 2019 = 0 2020 = 24 (26%) 2021 = 54 (59%) 2022 = 54 (59%) 2023 = 0 2024 = 0 2025 = 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%) 2020 = 4 (4%) 2021 = 14 (15%) 2022 = 23 (25%) 2023 = N/A 2024 = 68 (74%) 2025 = 29 (32%)	2013 = 38 (41%) 2014 = 11 (12%) 2015 = 20 (22%) 2016 = 31 (34%) 2017 = 25 (27%) 2018 = 42 (46%) 2019 = 28 (30%) 2020 = 50 (54%) 2021 = 30 (33%) 2022 = 14 (15%) 2023 = N/A 2024 = 24 (26%) 2025 = 57 (62%)	2013 = 20 (22%) 2014 = 21 (23%) 2015 = 5 (6%) 2016 = 16 (17%) 2017 = 0 2018 = 2 (2%) 2019 = 2 (2%) 2020 = 18 (20%) 2021 = 13 (14%) 2022 = 7 (8%) 2023 = N/A 2024 = 0 2025 = 6 (6%)	2013 = 23 (25%) 2014 = 54 (59%) 2015 = 59 (64%) 2016 = 36 (39%) 2017 = 0 2018 = 0 2019 = 0 2020 = 20 (22%) 2021 = 35 (38%) 2022 = 48 (52%) 2023 = N/A 2024 = 0 2025 = 0
Rush Ck. – Old Highway 395 Bridge/Upper Rush section	2013 = 14 (15%) 2014 = 7 (8%) 2015 = N/A 2016 = 16 (17%) 2017 = 75 (82%) 2018 = 36 (39%) 2019 = 64 (70%) 2020 = 17 (18%) 2021 = 24 (26%) 2022 = 29 (32%) 2023 = 77 (89%) 2024 = 78 (85%) 2025 = 30 (33%)	2013 = 41 (45%) 2014 = 25 (27%) 2015 = N/A 2016 = 24 (26%) 2017 = 17 (18%) 2018 = 56 (61%) 2019 = 28 (30%) 2020 = 48 (52%) 2021 = 30 (33%) 2022 = 17 (18%) 2023 = 10 (11%) 2024 = 14 (15%) 2025 = 62 (67%)	2013 = 33 (36%) 2014 = 27 (29%) 2015 = N/A 2016 = 19 (21%) 2017 = 0 2018 = 0 2019 = 0 2020 = 17 (18%) 2021 = 11 (12%) 2022 = 7 (8%) 2023 = 0 2024 = 0 2025 = 0	2013 = 4 (4%) 2014 = 33 (36%) 2015 = N/A 2016 = 33 (36%) 2017 = 0 2018 = 0 2019 = 0 2020 = 10 (11%) 2021 = 27 (29%) 2022 = 39 (42%) 2023 = 0 2024 = 0 2025 = 0

Table 13 (continued).

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. – Above Parker Ck.	2016 = 17 (18%) 2017 = 65 (71%) 2018 = 28 (30%) 2019 = 67 (73%) 2020 = 24 (26%) 2021 = 30 (33%) 2022 = 31 (34%) 2023 = 81 (88%) 2024 = N/A 2025 = 28 (30%)	2016 = 26 (28%) 2017 = 27 (29%) 2018 = 64 (70%) 2019 = 25 (27%) 2020 = 41 (45%) 2021 = 34 (37%) 2022 = 16 (17%) 2023 = 11 (12%) 2024 = N/A 2025 = 63 (69%)	2016 = 24 (26%) 2017 = 0 2018 = 0 2019 = 0 2020 = 21 (23%) 2021 = 10 (11%) 2022 = 7 (8%) 2023 = 0 2024 = N/A 2025 = 1 (1%)	2016 = 25 (27%) 2017 = 0 2018 = 0 2019 = 0 2020 = 10 (11%) 2021 = 18 (20%) 2022 = 38 (41%) 2023 = 0 2024 = N/A 2025 = 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%) 2020 = 36 (39%) 2021 = 26 (28%) 2022 = 33 (36%) 2023 = 75 (90%) 2024 = 92 (100%) 2025 = 53 (58%)	2013 = 69 (75%) 2014 = 58 (63%) 2015 = 44 (48%) 2016 = 52 (57%) 2017 = 17 (18%) 2018 = 46 (50%) 2019 = 18 (20%) 2020 = 53 (58%) 2021 = 39 (42%) 2022 = 22 (24%) 2023 = 8 (10%) 2024 = 0 2025 = 39 (42%)	2013 = 6 (7%) 2014 = 18 (20%) 2015 = 22 (24%) 2016 = 16 (17%) 2017 = 0 2018 = 0 2019 = 0 2020 = 2 (2%) 2021 = 10 (11%) 2022 = 27 (29%) 2023 = 0 2024 = 0 2025 = 0	2013 = 0 2014 = 3 (3%) 2015 = 2 (2%) 2016 = 2 (2%) 2017 = 0 2018 = 0 2019 = 0 2020 = 1 (1%) 2021 = 17 (18%) 2022 = 8 (9%) 2023 = 0 2024 = 0 2025 = 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%) 2020 = 31 (34%) 2021 = 26 (28%) 2022 = 33 (36%) 2023 = 24 (69%) 2024 = 49 (78%) 2025 = 40 (44%)	2013 = 64 (70%) 2014 = 59 (65%) 2015 = 39 (42%) 2016 = 50 (54%) 2017 = N/A 2018 = N/A 2019 = 21 (23%) 2020 = 50 (54%) 2021 = 31 (34%) 2022 = 15 (16%) 2023 = 11 (31%) 2024 = 14 (22%) 2025 = 51 (55%)	2013 = 8 (9%) 2014 = 14 (15%) 2015 = 23 (25%) 2016 = 13 (14%) 2017 = N/A 2018 = N/A 2019 = 0 2020 = 10 (11%) 2021 = 9 (10%) 2022 = 8 (9%) 2023 = 0 2024 = 0 2025 = 1 (1%)	2013 = 3 (3%) 2014 = 2 (2%) 2015 = 5 (6%) 2016 = 5 (6%) 2017 = N/A 2018 = N/A 2019 = 0 2020 = 1 (1%) 2021 = 26 (28%) 2022 = 36 (39%) 2023 = 0 2024 = 0 2025 = 0

Table 14. Diurnal temperature fluctuations in Rush Creek for 2025: 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: 2024 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. – Above Damsite	Max = 14.5°F (10.6) Ave = 10.4°F (6.1)	Max = 14.8°F (14.9) Ave = 11.3°F (11.6)	Max = 12.7°F (12.7) Ave = 8.6°F (12.2)	12.7°F (12.2) July 31 – Aug 20
Rush Ck. – Top of MGORD	Max = 5.9°F (5.3) Ave = 3.5°F (3.1)	Max = 6.8°F (9.1) Ave = 3.3°F (4.0)	Max = 2.3°F (3.7) Ave = 0.9°F (1.1)	3.8°F (5.4) Aug 2 – 22
Rush Ck. – End of MGORD	Max = 9.1°F (7.9) Ave = 6.9°F (4.1)	Max = 10.4°F (12.3) Ave = 8.0°F (7.7)	Max = 7.6°F (7.8) Ave = 5.6°F (6.5)	8.5°F (8.6) July 21 – Aug 10
Rush Ck. – Old Hwy 395 Bridge	Max = 12.9°F (4.3) Ave = 9.8°F (3.0)	Max = 14.1°F (9.6) Ave = 11.0°F (4.0)	Max = 10.8°F (7.8) Ave = 8.3°F (4.6)	12.0°F (11.3) July 21 – Aug 10
Rush Ck. – Above Parker	Max = 14.8°F (N/A) Ave = 11.5°F (N/A)	Max = 15.7°F (N/A) Ave = 12.6°F (N/A)	Max = 12.2°F (N/A) Ave = 9.7°F (N/A)	13.7°F (N/A) July 21 – Aug 10
Rush Ck. – below Narrows	Max = 14.7°F (10.6) Ave = 12.1°F (7.7)	Max = 15.9°F (14.2) Ave = 12.9°F (11.7)	Max = 12.8°F (13.4) Ave = 10.3°F (11.2)	14.3°F (12.2) July 31 – Aug 20
Rush Ck. – County Road	Max = 17.1°F (14.0) Ave = 14.5°F (10.3)	Max = 17.1°F (15.7) Ave = 14.5°F (14.7)	Max = 14.9°F (15.2) Ave = 11.8°F (12.8)	16.0°F (13.9) July 22 – Aug 11

Table 15. 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 - 2025. The total number of hours within each month is 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. – Above Damsite	2023 = 0 hrs 2024 = 34 hrs (5%) 2025 = 142 hrs (19%)	2023 = 0 hrs 2024 = 157 hrs (21%) 2025 = 196 hrs (26%)	2023 = 0 hrs 2024 = 21 hrs (3%) 2025 = 30 hrs (4%)	2023 = 0 hrs 2024 = 212 hrs (10%) 2025 = 368 hrs (17%)
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 2020 = 0 hrs 2021 = 488 hrs (66%) 2022 = 246 hrs (33%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 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 2020 = 71 hours (10%) 2021 = 588 hrs (79%) 2022 = 728 hrs (98%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 0 hrs	2013 = 0 hrs 2014 = 0 hrs 2015 = 0 hrs 2016 = 0 hrs 2017 = 0 hrs 2018 = 0 hrs 2019 = 13 hrs 2020 = 47 hrs (7%) 2021 = 35 hrs (5%) 2022 = 343 hrs (48%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 0 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%) 2020 = 118 hrs (5%) 2021 = 1,111 hrs (50%) 2022 = 1,317 hrs (60%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 0 hrs

Table 15 (continued).

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. – 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 2020 = 49 hrs (6%) 2021 = 444 hrs (60%) 2022 = 257 hrs (35%) 2023 = N/A 2024 = 0 hrs 2025 = 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 2020 = 234 hrs (31%) 2021 = 376 hrs (51%) 2022 = 535 hrs (72%) 2023 = N/A 2024 = 11 hrs (2%) 2025 = 110 hrs (15%)	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%) 2020 = 101 hrs (14%) 2021 = 125 hrs (17%) 2022 = 247 hrs (34%) 2023 = N/A 2024 = 14 hrs (2%) 2025 = 71 hrs (10%)	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%) 2020 = 335 hrs (15%) 2021 = 945 hrs (43%) 2022 = 1,039 hrs (47%) 2023 = N/A 2024 = 25 hrs (1%) 2025 = 181 hrs (8%)
Rush Ck. – Old 395 Bridge/Upper Rush	2013 = 181 hrs (24%) 2014 = 287 hrs (39%) 2016 = 216 hrs (29%) 2017 = 0 hrs 2018 = 17 hrs (2%) 2019 = 0 hrs 2020 = 113 hrs (15%) 2021 = 351 hrs (47%) 2022 = 252 hrs (34%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 38 hrs (5%)	2013 = 228 hrs (31%) 2014 = 248 hrs (33%) 2016 = 263 hrs (35%) 2017 = 0 hrs 2018 = 32 hrs (4%) 2019 = 4 hrs (0.5%) 2020 = 241 hrs (32%) 2021 = 328 hrs (44%) 2022 = 350 hrs (47%) 2023 = 0 hrs 2024 = 27 hrs (4%) 2025 = 157 hrs (21%)	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%) 2020 = 87 hrs (12%) 2021 = 127 hrs (18%) 2022 = 162 hrs (23%) 2023 = 0 hrs 2024 = 34 hrs (5%) 2025 = 74 hrs (10%)	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%) 2020 = 441 hrs (20%) 2021 = 806 hrs (37%) 2022 = 764 hrs (35%) 2023 = 0 hrs 2024 = 61 hrs (3%) 2025 = 269 hrs (12%)
Rush Ck. – Above Parker Creek	2016 = 240 hrs (32%) 2017 = 0 hrs 2018 = 70 hrs (9%) 2019 = 0 hrs 2020 = 146 hrs (20%) 2021 = 342 hrs (46%) 2022 = 276 hrs (37%) 2023 = 0 hrs 2024 = N/A 2025 = 78 hrs (11%)	2016 = 269 hrs (36%) 2017 = 0 hrs 2018 = 68 hrs (9%) 2019 = 11 hrs (2%) 2020 = 257 hrs (35%) 2021 = 316 hrs (42%) 2022 = 348 hrs (47%) 2023 = 0 hrs 2024 = N/A 2025 = 170 hrs (23%)	2016 = 65 hrs (9%) 2017 = 14 hrs (2%) 2018 = 44 hrs (6%) 2019 = 27 hrs (4%) 2020 = 73 hrs (10%) 2021 = 122 hrs (17%) 2022 = 157 hrs (22%) 2023 = 0 hrs 2024 = N/A 2025 = 79 hrs (11%)	2016 = 574 hrs (26%) 2017 = 14 hrs (0.6%) 2018 = 182 hrs (8%) 2019 = 38 hrs (2%) 2020 = 476 hrs (22%) 2021 = 780 hrs (35%) 2022 = 781 hrs (35%) 2023 = 0 hrs 2024 = N/A 2025 = 327 hrs (15%)
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 2020 = 109 (15%) 2021 = 273 hrs (37%) 2022 = 243 hrs (33%) 2023 = 0 hrs 2024 = 0 hrs 2025 = 79 hrs (11%)	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%) 2020 = 204 hrs (27%) 2021 = 267 hrs (36%) 2022 = 265 hrs (36%) 2023 = 0 hrs 2024 = 23 hrs (3%) 2025 = 143 hrs (19%)	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%) 2020 = 43 hrs (6%) 2021 = 104 hrs (14%) 2022 = 109 hrs (15%) 2023 = 0 hrs 2024 = 16 hrs (2%) 2025 = 37 hrs (5%)	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%) 2020 = 356 hrs (16%) 2021 = 644 hrs (29%) 2022 = 617 hrs (28%) 2023 = 0 hrs 2024 = 39 hrs (2%) 2025 = 259 hrs (12%)

Table 15 (continued).

Rush Ck. – County Road	2013 = 197 hrs (27%)	2013 = 172 hrs (23%)	2013 = 42 hrs (6%)	2013 = 411 hrs (19%)
	2014 = 222 hrs (30%)	2014 = 195 hrs (26%)	2014 = 79 hrs (11%)	2014 = 496 hrs (23%)
	2015 = 174 hrs (23%)	2015 = 119 hrs (16%)	2015 = 0 hrs (0%)	2015 = 293 hrs (13%)
	2016 = 212 hrs (28%)	2016 = 233 hrs (31%)	2016 = 42 hrs (6%)	2016 = 487 hrs (22%)
	2017 = N/A	2017 = N/A	2017 = N/A	2017 = N/A
	2018 = N/A	2018 = N/A	2018 = N/A	2018 = N/A
	2019 = 0 hrs	2019 = 76 hrs (10%)	2019 = 10 hrs (1%)	2019 = 86 hrs (4%)
	2020 = 195 hrs (26%)	2020 = 241 hrs (32%)	2020 = 41 hrs (6%)	2020 = 477 hrs (22%)
	2021 = 301 hrs (40%)	2021 = 278 hrs (37%)	2021 = 99 hrs (14%)	2021 = 678 hrs (31%)
	2022 = 290 hrs (39%)	2022 = 282 hrs (38%)	2022 = 107 hrs (15%)	2022 = 679 hrs (31%)
	2023 = 0 hrs	2023 = 2 hrs	2023 = N/A	2023 = N/A
	2024 = 10 hrs (2%)	2024 = 48 hrs (13%)	2024 = 38 hrs (5%)	2024 = 96 hrs (6%)
	2025 = 149 hrs (20%)	2025 = 181 hrs (24%)	2025 = 53 hrs (7%)	2025 = 383 hrs (17%)

Discussion

The 2025 sampling was the fourth year of fisheries monitoring under the recently issued WR-2021-0086, which amended LADWP's license and signaled the start of the 10-year post-settlement monitoring period. During this 10-year period, all watershed monitoring activities (fisheries, geomorphic/riparian, Mono Lake limnology, and waterfowl) will be conducted by consultants, with oversight from the MAT. The purpose of the post-settlement monitoring is to evaluate the effectiveness of the SEF flow regimes and as needed, make recommended changes to these flows (timing and magnitude), as long as the overall quantity of water released by LADWP is not increased from those defined in WR-2021-0086 for specific RY types.

The 2025 sampling year was also highlighted by a Dry-Normal-1 RY with a limited 18-day spill over GLR and relatively high storage levels within GLR during the summer months (within 4.5 feet of full). The spill and relatively high storage level in GLR still resulted in some less than favorable summer water temperatures in Rush Creek, downstream of the MGORD.

Finally, the 2025 sampling year occurred during LADWP's planning of several large projects on Rush Creek to better implement SEF peak flows and to replace aging and failing infrastructure. Preliminary plans to modify the spillway of GLR included the installation of Langman Gates to control spill, which were then changed to construction of a siphon structure to pass SEF peak flows out of GLR to Rush Creek in wetter RY types. The roto-valve which controls flows entering the top of the MGORD and LADWP's exports was damaged during the RY 2023 record snowmelt flows. The roto-valve is set within a circular concrete shaft that may also require repair and/or replacement. In late 2025, LADWP requested input from the Fisheries Stream Scientist in plans to repair the roto-valve and to conduct a diver inspection of the concrete shaft, in which both tasks required either short-term flow interruption in the MGORD (diver inspection) or potentially long-term dewatering of the MGORD (roto-valve replacement). As discussions occurred of actions that will negatively affect the aquatic ecosystem within MGORD, the fisheries monitoring in 2024 and 2025 documented encouraging increases of the MGORD's trout population, including substantial increases in larger and older Brown Trout.

Thus, this report's Discussion is focused on GLR storage levels as related to summer water temperatures and the importance of the MGORD to Rush Creek's Brown Trout population. The Discussion section concludes with a methods evaluation and proposed fisheries/aquatic biota monitoring activities for 2026.

Summer Water Temperatures Related to GLR Levels and Climate

Relatively recent efforts to monitor and model water temperatures in Rush Creek and GLR started in the early 1990s, including modeling of GLR storage levels and effects on water temperatures (Cullen and Railsback 1993). However, discussions of water temperatures in Rush Creek, thermal loading effects of reservoirs, and cooling effects of Parker and Walker Creeks and spring-flow go back as far as the 1930s, as described by CA Fish and Game fisheries biologist Elden Vestal in his 1990 deposition (Sims and Sims 1990). The effects of water temperature on Brown Trout growth, condition and survival are well studied, and the peer-

reviewed literature is exhaustive. The Fisheries Team has conducted studies concerning instream flows, GLR storage, and water temperatures in Rush Creek and its effects of growth and condition factors of Brown Trout (Hunter et al. 2009; Shepard et al. 2009; McB&T and RTA 2010). Results of these studies informed recommendations made in the Synthesis Report, including management of as high as possible storage levels in GLR going into the summer months to better moderate downstream water temperatures. Three GLR storage levels were recommended in the Synthesis Report, based on these studies and the best information available in 2009 regarding climate change and its likely effects on Mono Basin hydrology (McB&T and RTA 2010). A GLR storage threshold level of approximately 20,000 acre-feet or an elevation of 7,100 feet from July through September during all RY types was recommended to minimize negative thermal conditions in Rush Creek downstream of GLR. This threshold relied on the results and recommendations made by Cullen and Railsback (1993) and of the StreamTemp modeling (Shepard et al. 2009).

As previously presented, Rush Creek summer water temperatures in 2025 were mostly favorable for Brown Trout growth in the MGORD and data from the single electrofishing pass made on 9/22/25 reflected these favorable water temperature metrics. However, even within the MGORD, the metrics of daily average temperature, daily average peak temperature and maximum diurnal fluctuation increased from the Top of MGORD to Bottom of MGORD temperature monitoring locations (Table 12). Furthermore, in 2025, as in most years, the farther downstream from the MGORD, the more thermal conditions degraded for Brown Trout growth and condition factors. Again, the 2025 fisheries data supported this, as reflected by very low growth rates of Brown Trout PIT tag recaptures in Upper Rush and Bottomlands sections.

As previously presented, GLR storage levels were relatively high throughout 2025, including the summer months of July, August and September. The GLR storage elevation was 7,129.9 feet on July 1st, 7,128.2 feet on August 1st, and 7,127.1 feet on September 1st, and 7,126.6 feet on September 30th. These levels were 26.6 feet to 29.9 feet higher than the minimum storage threshold of 7,100 feet recommended in the Synthesis Report, yet there were still unfavorable water temperature metrics in Rush Creek below the MGORD, in the form of daily peaks >70°F, excessively high diurnal fluctuations, and number of hours where temperatures exceeded 66.2°F.

These results raise several questions regarding our analysis and Synthesis Report recommendations. Were our assumptions about the inflection point of GLR storage level and water temperature modeled in 1993 wrong, dated, or irrelevant? Has sediment infill of GLR thrown off assumptions about how much water is currently available and how it is affected by solar thermal inputs? Were analyses made in Section 5.10 of the Synthesis Report missing key inputs when predicting Brown Trout growth under varying RY types, GLR storage levels, and climate conditions? Has climate change and global warming proceeded at rates greater than what was predicted in the early 2000s with what was the best available data at that time? The following paragraphs attempt to address each of these questions.

Yes, our assumptions about the inflection point of GLR storage level and water temperature modeled in 1993 are dated and most likely irrelevant. It is now obvious that a storage elevation

of 7,100 feet in GLR would fail to provide suitable summer water temperatures to Rush Creek downstream of the MGORD as shown from recent data. Another year to examine is RY 2016 when GLR storage levels in July-September were 4.2 feet to 10.7 feet above the 7,100-foot elevation threshold, yet summer water temperature metrics were poor downstream of the MGORD. However, at the time of Synthesis Report development, the Cullen and Railsback (1993) paper was the best resource we had available. Cullen and Railsback (1993) raised the issue of GLR infill with sediment as a likely cause confounding their modeled results with actual reservoir water temperature data. This leads to the issue of how much sediment infill has occurred in the 85 years since GLR was constructed and how has this affected the true storage capacity of GLR and the accurate relationship between storage level elevations and water temperatures. The simple answer is, we don't know, because we don't have a current bathymetric survey of GLR.

Were analyses made in Section 5.10 of the Synthesis Report missing key inputs when predicting Brown Trout growth under varying RY types, GLR levels, and climate conditions? Yes, we lacked information regarding food availability in the form of benthic macroinvertebrates (BMI) and assumed unlimited rations were available yet recognized that actual growth would be lower (McB&T and RTA 2010). Conducting updated BMI collections with traditional kick-net and eDNA techniques may shed light on food availability in Rush Creek. Air temperature inputs regarding global warming scenarios and effects on Brown Trout growth in the Synthesis Report added 2°F to the 2008 air temperature data set, which in hindsight may have been too conservative as a proxy for future climate warming (McB&T and RTA 2010).

Yes, climate change is occurring and likely at rates faster than estimated 25-30 years ago. Berkeley Earth's long-term global temperature analyses concluded that, *"if we were to assume that global warming was continuing at the same rate as during the 50-year period 1970-2019, then the 2023 to 2025 excursion is by far the largest deviation from that trend, with less than a 1-in-100 chance of occurring solely due to natural variability (Figure 17). While 1-in-100 chance events do sometimes occur, we consider it more likely that the recent rate of global warming has been larger than expected, exceeding both the previous trend and what would be expected when considering only the observed pattern of greenhouse gas emissions."* The past 11 years have been the 11 warmest on record since 1850 and the Earth is currently at its warmest global average temperature for at least several thousand years (Berkeley Earth 2026).

In the Mono Basin, 36 years of air temperature data collected in Lee Vining documents increases from the 1990s to the 2020s in average maximum temperature, daily average temperature and number of days with temperatures greater than 90°F (Table 16). The number of days with air temperatures greater than 90°F experienced the largest increase, from 3.4 days a year on average for the 1990s to 18.7 days a year on average for the 2020s (Table 16).

The overarching theme for Rush Creek is that the Brown Trout population responds better to wetter runoff years than to average-to-drier runoff years and responds better in all years when GLR is full going into the months of July, August and September. The most practical and effective management recommendation for LADWP to provide the best possible summer water temperatures in Rush Creek is to have GLR at the highest level possible going into the summer

months. This was first recommended by Cullen and Railsback (1993), was re-recommended in the Synthesis Report in 2010, and remains the Fisheries Stream Scientist recommendation.

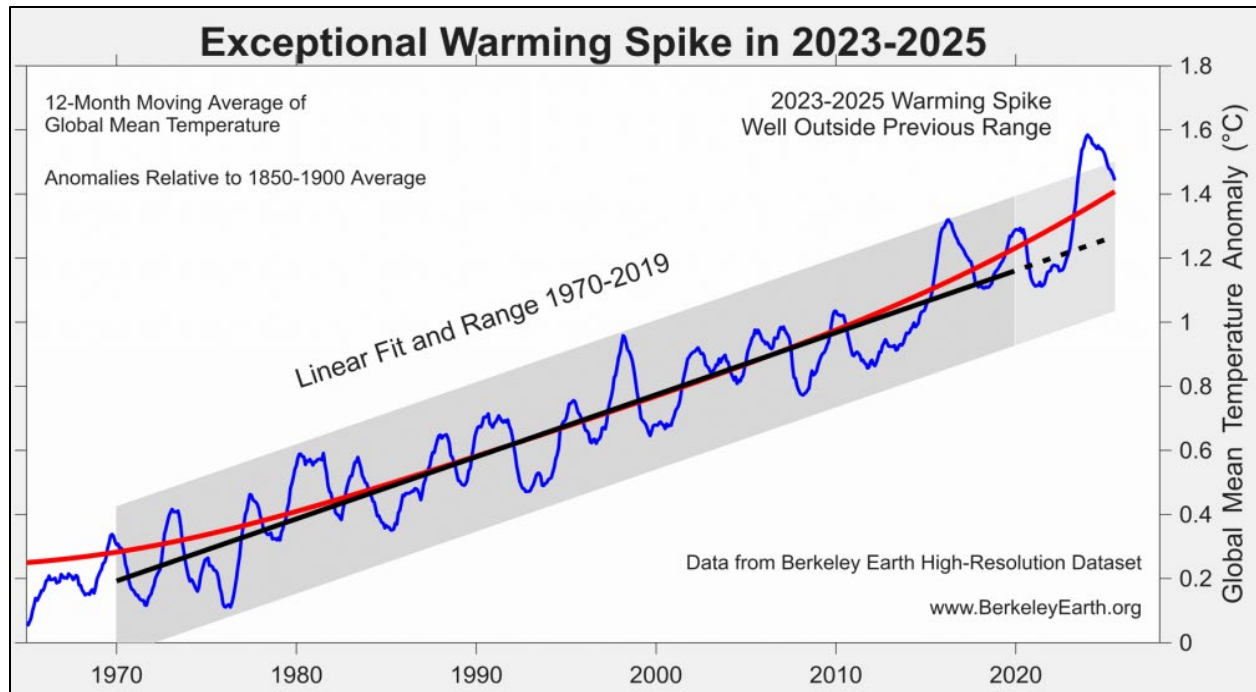


Figure 17. Plot of 12-month moving average of global mean temperatures and exceptional Warming spike of 2023-2025.

The Synthesis Report recommended threshold of a GLR 7,100-foot storage elevation in July-September should no longer be considered an adequate storage elevation that will effectively minimize negative thermal conditions in Rush Creek downstream of GLR.

The Synthesis Report recommendation to direct Lee Vining Creek diversion flows into the 5-siphons in Dry and Dry-Normal-1 RY types when GLR storage is below 25,000 acre-feet (by July 1st) should be maintained, even though having all the required circumstances lined-up for this to occur are infrequent and may only have a short-term thermal benefit to Rush Creek. The biggest limitation is having available water to divert from Lee Vining Creek in drier years after July 1st.

Changing climate and variable snowpack conditions in the eastern Sierra will most likely dictate the long-term fate and viability of Rush Creek's Brown Trout fishery. A shift towards less snowpack, more rain-on-snow events, and/or earlier snowmelt runoff may impact Rush Creek's trout populations along with other ecological and watershed processes. However, continued SEF releases, maturation of the riparian canopy, six more years of annual monitoring, and adaptive management may still push the restoration of the creeks and the trout fisheries in a positive direction.

Table 16. Thirty-six years of summer (July-September) air temperature data for Lee Vining, CA. Data are from Western Regional Climate Center and National Weather Service/Reno.

YEAR	Ave Max Temp (°F)	Ave Min Temp (°F)	Ave of Daily Ave Temp (°F)	Number of Days ≥90°F
1990	80.2	49.8	65.0	1
1991	81.3	51.3	66.3	4
1992	79.9	49.7	64.9	0
1993	N/A	N/A	N/A	N/A
1994	82.7	51.3	67.0	12
1995	80.8	49.9	65.3	0
1996	80.7	50.3	65.4	3
1997	79.1	49.1	64.2	0
1998	79.4	51.2	65.4	7
1999	79.4	49.6	64.5	4
1990's Averages	80.4	50.2	65.3	3.4
2000	80.6	49.4	65.0	2
2001	81.9	51.8	66.9	4
2002	81.9	51.1	66.5	14
2003	82.3	51.6	66.9	5
2004	80.6	48.3	64.5	1
2005	79.8	50.3	65.0	6
2006	80.6	50.3	65.4	7
2007	81.7	52.0	66.8	12
2008	83.3	51.5	67.4	6
2009	82.1	50.7	66.4	5
2000's Averages	81.5	50.7	66.1	6.2
2010	81.9	49.7	65.8	4
2011	81.7	51.8	66.8	1
2012	84.4	52.6	68.5	12
2013	81.3	50.4	65.9	8
2014	81.5	51.6	66.6	6
2015	80.9	50.9	65.9	5
2016	83.3	49.1	66.2	16
2017	81.4	51.3	66.4	10
2018	83.6	51.8	67.7	13
2019	81.4	50.2	65.8	2
2010's Averages	82.1	50.9	66.6	7.7

Table 16 (continued)

YEAR	Ave Max Temp (°F)	Ave Min Temp (°F)	Ave of Daily Ave Temp (°F)	Number of Days ≥90°F
2020	83.5	50.1	67.2	17
2021	90.7	45.1	63.7	24
2022	83.8	53.5	68.6	22
2023	81.8	51.0	66.4	9
2024	84.6	51.2	67.9	23
2025	82.1	50.8	66.4	17
2020's Averages	84.4	50.3	66.7	18.7

Mono Gate One Return Ditch (MGORD)

The MGORD is a unique section of Rush Creek, located immediately downstream of GLR. The MGORD is a trapezoidal canal that is approximately 1.2 miles in length, with widths around 25-30 feet at flows of 25 to 45 cfs. The channel is low gradient with laminar flow and deep pools interspersed with shallower runs. Cover habitat for trout is predominantly extensive beds of elodea with some boulder clusters and areas of overhanging willows. The Fisheries Team first sampled the MGORD in 2001 and since 2006 has sampled this section annually. The radio telemetry-movement study conducted between 2005 and 2007 included tagging and tracking 41 large Brown Trout (age-3 and older) from the MGORD.

The extensive data set amassed from 20+ years of sampling the MGORD has shown that this is the only section of Rush Creek downstream of GLR that consistently produces large Brown Trout, as defined by fish >300 mm in (≈12 inches) and fish >375 mm (≈15 inches), metrics frequently used to describe the pre-1941 Brown Trout fishery in Rush Creek (Sims and Sims 1990; SWRCB 1994). MGORD is the only section of Rush Creek where Brown Trout of age-5 and older are consistently captured, and Brown Trout of age-9 to age-11 have been documented from PIT tag recaptures (such as Figure 14). Brown Trout growth rates between age-0 and age-1, between age-1 and age-2, and between age-2 and age-3 in the MGORD are consistently higher than in any other Rush Creek sampling section.

The radio telemetry-movement study documented by monthly tracking that the 41 large Brown Trout tagged in the MGORD occupied small home territories for much of the year, except for the fall-early winter spawning season. During the spawning season, radio-tagged fish either made frequent movements within the MGORD or left the MGORD and were tracked as far as 24,500 feet downstream. Tagged female fish that left the MGORD which we were able to radio-track were found spawning approximately 6,000-7,000 feet downstream. The fixed antenna array installed at the lower end of the MGORD documented that female Brown Trout tended to return quickly to the MGORD, whereas large males sometimes didn't return to the MGORD until the following spring. For example, in 2005, a large female Brown Trout (Code 23) left the MGORD for 14 days and in that timespan travelled 6,200 ft downstream, spawned, and travelled 6,200 ft back up to the MGORD. On our November 16th relocation we made mobile receiver and visual contact with Code 23 in a lateral scour pool, just upstream of the Upper

Rush sampling section, that had several freshly constructed redds at the tail-out. The radio telemetry-movement study spanned two spawning seasons, and the fixed antenna array documented 54% of the tagged Brown Trout in 2005 and 45% of the tagged Brown Trout in 2006 leaving the MGORD in late-October through early-December. Taylor et al. (2009) summarized that *“based on movements of our tagged fish, a sizeable portion of the MGORD fish seasonally moves downstream into other reaches of Rush Creek. Because the fecundity of Brown Trout is related to body size, the contribution of age-0 recruitment from MGORD female Brown Trout to the downstream channel is probably substantial. Based on our ten years of annual sampling, the Upper Rush sampling section has consistently had the highest densities of age-0 fish (Hunter et al. 2009). We speculate that the relatively high densities of age-0 Brown Trout in the Upper Rush sampling section are influenced by the spawning of large female Brown Trout that reside for most of the year up in the MGORD.”*

The connectivity between the MGORD and lower sections of Rush Creek is also associated with the consistent recapture of PIT tagged Brown Trout in the MGORD that were initially tagged as age-0 fish in the Upper Rush sampling section. Conversely, we have yet to recapture a fish downstream of the MGORD that was PIT tagged at age-0 in the MGORD.

Why is the MGORD section of Rush Creek able to consistently produce older and larger Brown Trout, that at younger ages grow faster than trout in any other section of Rush Creek? Steadier flows that never peak higher than 350 cfs? More suitable low-velocity habitat and deeper pools? More overhead cover? More food resources? Are there summer water temperatures that are more conducive to growth, as characterized by lower daily maximum temperatures and smaller diurnal fluctuations? The answer is probably “yes” to all or some of these factors in any given year.

During the five-year drought of 2012 through 2016, the MGORD experienced less than favorable summer water temperatures due to low storage levels in GLR that heated up and delivered warm water into the MGORD. During the five-year drought, the catch of trout in the MGORD steadily dropped, as did the numbers of older and larger fish. The annual fisheries monitoring then documented the slow recovery of the large-fish segment of the MGORD’s Brown Trout population. Encouragingly, sample years 2024 and 2025 documented a resurgence of total trout numbers in the MGORD, as well as being the first consecutive years where more than 100 Brown Trout ≥ 300 mm were caught in the MGORD since 2009 and 2010.

This summary of information regarding the MGORD was provided for readers to better understand the unique conditions and trout population within the MGORD that would likely be jeopardized or lost if this reach was subjected to either short-term flow interruption in the MGORD (diver inspection) or long-term dewatering of the MGORD (roto-valve replacement). The Fisheries Stream Scientist suggests that options are explored to avoid dewatering the MGORD for a two-to-three-year period. Is it feasible to construct a new roto-valve and shaft adjacent to the existing structure and then make a quick switch-over from the existing infrastructure to the new? During the preliminary AOP meeting on 3/30/26, LADWP presented an option that may avoid long-term dewatering, but the presentation was brief and lacked detail. When available, a more detailed presentation by LADWP would be helpful to better understand the new valve construction and avoidance of impacts to the MGORD’s existing aquatic biota.

Methods Evaluation

In most years small variations in channel widths occur in Rush, Lee Vining, and Walker Creeks. Thus, we recommend that channel lengths and widths are re-measured in even years when population estimate sampling occurs to generate more accurate density and standing crop estimates.

In 2022 the MLC assumed sole responsibility for the water temperature monitoring in Mono Basin streams. It is recommended that the MLC continue to either place redundant data loggers at all Rush Creek water temperature monitoring locations or conduct periodic visits to the data loggers to ensure that complete data sets are collected during the months of July, August, and September to preserve the integrity of the summer water temperature monitoring program. The MLC has requested that RTA include the purchase of 12 water temperature data loggers in their 2026-2027 scope of work and budget to replace lost and older equipment (≈\$2,500.00).

The PIT tagging program allowed us to continue to document annual growth rates of trout, fish movement, calculate apparent survival rates, and assess the ability of fish to reach or exceed lengths of 300 mm. Continuation of the PIT tagging program is recommended during the post-settlement Fisheries Monitoring Program.

Trout size classes (<125, 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. However, we acknowledge that in Walker Creek, some age-1 Brown Trout are occasionally less than 125 mm in TL and in MGORD are bigger than 199 mm in TL. We also acknowledge that in the MGORD and occasionally in other Rush Creek sections age-0 fish may exceed 125 mm in TL, especially in high runoff years when cooler summer water temperatures result in higher growth rates.

To ensure that electrofishing sampling can be conducted safely and efficiently, flow in Rush Creek should not exceed **35 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 SWRCB WR-2021-0086.

Proposed Fisheries Sampling for 2026 Season

We intend to conduct population estimate sampling in the fall of 2026 at the following locations: MGORD Rush, Upper Rush, Bottomlands Rush, Lee Vining Creek main channel, and Walker Creek. In addition to conducting population estimate sampling at the annually sampled locations, the Fisheries Stream Scientist intends to conduct single-pass sampling in the recently established 8-Channel of Rush Creek. Summer water temperatures will also be collected within these specific sections by the MLC.

The Fisheries Stream Scientist recommends that benthic macro-invertebrate (BMI) monitoring is conducted in Rush Creek in 2026. A presentation of a BMI monitoring program that bridges traditional kick-net sampling with eDNA sampling was given to the MAT and interested parties

on 3/16/26. The Fisheries Stream Scientist then submitted a detailed proposal with a scope and budget to the MAT for consideration on 3/26/26 and responded to clarifications requested by CDFW's MAT representative on 4/1/26.

The Fisheries Stream Scientist continues to recommend that a bathymetric survey of GLR is conducted to assess the amount of sediment infill and to determine the actual storage capacity of GLR. Reduced storage likely negates assumptions about minimum storage levels for suitable summer water temperatures in Rush Creek, as well as affecting water availability for SEF releases and future exports. Bathymetric surveys are commonly used to assess rates of sedimentation in reservoirs, and the loss of storage capacity can depend on several factors (Iraddock and Bwanbale 2021). Globally the overall loss of reservoir storage capacity is estimated at 1 to 2% of total storage capacity per year (Iraddock and Bwanbale 2021). In 1991 and 1992, the GLR thermal characteristics study by Cullen and Railsback (1993) determined that their reservoir thermal model underpredicted water surface elevations, which corresponded to a storage volume error of approximately 1,000 acre-feet and that sedimentation may have caused this discrepancy in their depth-to-volume regression and modeled water temperatures.

Recommended changes to SEF's based on 2025 Fisheries Monitoring

The Fisheries Stream Scientist's primary recommendation on Rush Creek is to enter the spring and summer of 2026 with GLR as full as possible. A fuller GLR will provide better summer water temperatures in Rush Creek, especially with RY 2026 forecasted to a Dry-Normal-1.

The primary recommendation on Lee Vining Creek is for LADWP (if feasible) to better control the releases downstream of their point of diversion to minimize the near-hourly hydropeaking conducted by SCE and provide a steadier discharge to the lower channel. The hydropeaking we observed in September 2025 on lower Lee Vining Creek was dewatering and rewatering substantial portions of channel margins daily, especially in riffle areas that could potentially strand fish and impact BMI productivity (Figure 3). The daily average flows reported by LADWP for Lee Vining Creek below their point of diversion masked these likely detrimental and rapid ramping fluctuations caused by SCE's power generation operations. A systematic review of the impacts of hydropeaking summarizes the following: alteration of flow patterns and water quality (turbidity, temperature and dissolved oxygen); impacts to fish growth, survival, behavior, reproductive success, and migration; impacts to BMI community diversity and abundance; and bank erosion and loss of riparian vegetation (Bipa et al. 2024). Within the studies reviewed by Bipa et al. (2024) relating fish and hydropeaking, articles focusing on habitat almost unanimously agreed on its degradation (16 studies out of 20). The reviewed literature also agreed on the overall negative effect of hydropeaking on fish density (13 studies out of 14), stranding (10 studies out of 10), survival (8 studies out of 11), diversity (3 studies out of 4) and spawning (4 out of 4 studies) (Bipa et al. 2024).

The April 1, 2026, runoff forecast for the Mono Basin was 71% of normal (approximately 85,000 AF) and a Dry-Normal-1 RY type. The May 2026 runoff will set the final 2026 RY type. Depending on GLR storage levels going into May and June, released flows from GLR may translate into

cooler summer temperatures with a full reservoir or likely warmer, and unfavorable, water temperatures in Rush Creek with a moderate to low reservoir level.

The Fisheries Stream Scientist will review LADWP's draft AOP for 2026 and provide comments, as needed.

References Cited

- Armour, C.L. 1997. Evaluating temperature regimes for the protection of Brown Trout. U.S. Department of the Interior, National Biological Survey, Resource Publication #201. 26 p.
- Barnham, C. and A. Baxter. 1998. Condition factor, K, in salmonid fish. Fisheries Notes #FN0005 State of Victoria, Australia. 3 p.
- Bateman, D.S., R.E. Gresswell and A.M. Berger. 2009. Passive integrated tag retention rates in headwater populations of coastal cutthroat trout. North American Journal of Fisheries Management 29: 653-657.
- Bell, J.M. 2006. The assessment of thermal impacts on habitat selection, growth, reproduction, and mortality in Brown Trout (*Salmo trutta*): a review of the literature. Vermillion River EPA Grant #WS 97512701-1. 23p.
- Berkeley Earth. 2026. High resolution time series global temperature data.
www.berkeleyearth.org/data
- Bipa, N.J., and G. Stradiotti, M. Righetti, and G.R. Pisaturo. 2024, Impacts of hydropeaking: a systematic review. Science of the Total Environment, Volume 912: 169-251.
- Blackwell, B.G., M.L. Brown and D.W. Willis. 2000. Relative weight (W_r) status and current use in fisheries assessment and management. Reviews in Fisheries Science, 8(1): 1-44.
- Bouwes, N., N. Weber, C.E. Jordan, W.C. Saunders, and I.A. Tattam. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). Nature, Science Report #28581.
- Cone, R.S. 1989. The need to reconsider the use of condition indices in fishery science. Transactions of the American Fisheries Society 118: 510-514.
- Cullen, R.T. and S.F. Railsback. 1993. Summer thermal characteristics of Grant Lake, Mono County, California. Feasibility Study #2, Trihey and Associates, Concord, CA. 118 p.
- Dare, M.R. 2003. Mortality and long-term retention of passive integrated tags by spring Chinook salmon. North American Journal of Fisheries Management 23: 1015-1019.

- Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. *North American Journal of Fisheries Management* 4:273-285.
- Hunter, C., R. Taylor, K. Knudson and B. Shepard. 2007. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2006. Los Angeles Department of Water and Power. 74 p.
- Hunter, C., R. Taylor, K. Knudson and B. Shepard. 2008. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2007. Los Angeles Department of Water and Power. 49 p.
- Hunter, C., R. Taylor, B. Trush, D. Mierau, K. Knudson and B. Shepard. 2009. Instream flow study needs for Rush and Lee Vining Creeks. Los Angeles Department of Water and Power. 75 p.
- Iradukunda, P. and E. Bwambale. 2021. Reservoir sedimentation and its effect on storage capacity – a case study of Murera Reservoir, Kenya. *Cogent Engineering* 8: 14 p.
- McB&T and RTA. 2010. Synthesis of instream flow recommendations to the State Water Resources Control Board and the Los Angeles Department of Water and Power. 159 p.
- Reimers, N. 1963. Body condition and over-winter survival of hatchery-reared trout in Convict Creek, California. *Transactions of the American Fisheries Society* 92 (1): 39-46.
- Shepard, B., R. Taylor, K. Knudson and C. Hunter. 2009. Effects of flow, reservoir storage and water temperature on trout in Rush and Lee Vining Creeks, Mono County, California. Prepared for LADWP. 117 p.
- Sims and Sims. 1990. Deposition of Elden Vestal. Reported by Kathleen Soloaga of Sims and Sims, Certified Shorthand Reporter, Napa, California. 290 p.
- SWRCB. 1994. Mono Lake water right decision 1631. Decision and order amending water right licenses to establish fishery protection flows in streams tributary to Mono Lake and to protect public trust resources at Mono Lake and in the Mono Basin. 222 p.
- Taylor, R., K. Knudson, B. Shepard, and C. Hunter. 2009. Radio telemetry-movement study of Brown Trout in Rush Creek. Los Angeles Department of Water and Power. 55 p.
- Taylor, R. and K. Knudson. 2012. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2011. Los Angeles Department of Water and Power. 90 p.
- Taylor, R. 2013. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2012. Los Angeles Department of Water and Power. 100 p.
- Taylor, R. 2014. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2013. Los Angeles Department of Water and Power. 89 p.

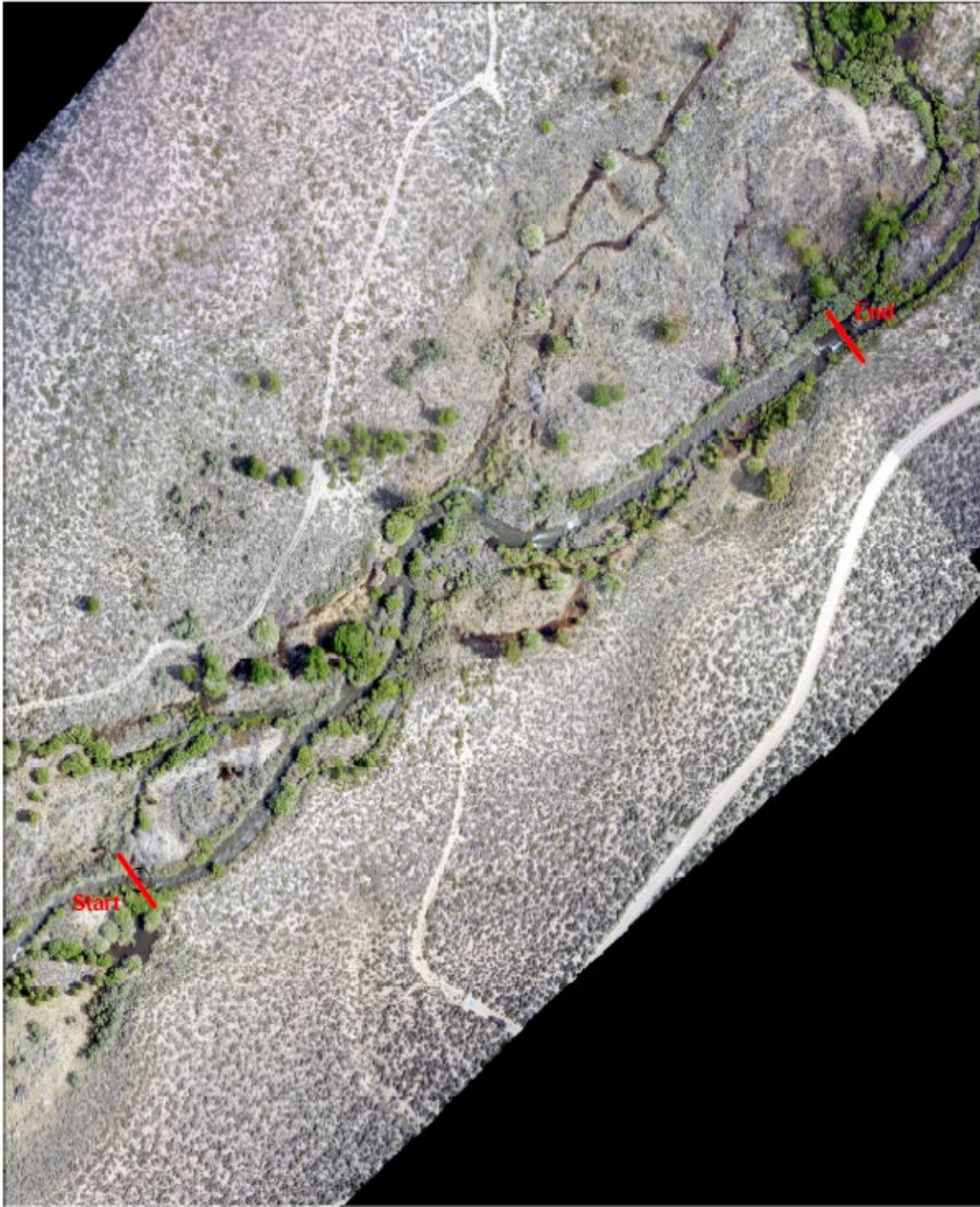
Taylor, R. 2021. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2020. Los Angeles Department of Water and Power. 97 p.

Taylor, R. 2022. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2021. Los Angeles Department of Water and Power. 97 p.

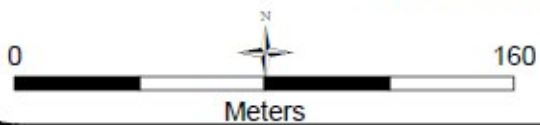
Taylor, R. 2025. Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker Creeks 2021. Los Angeles Department of Water and Power. 92 p.

Appendices for the 2025 Mono Basin Annual Fisheries Report

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



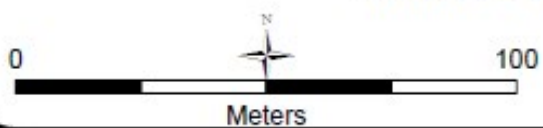
Upper Rush Creek



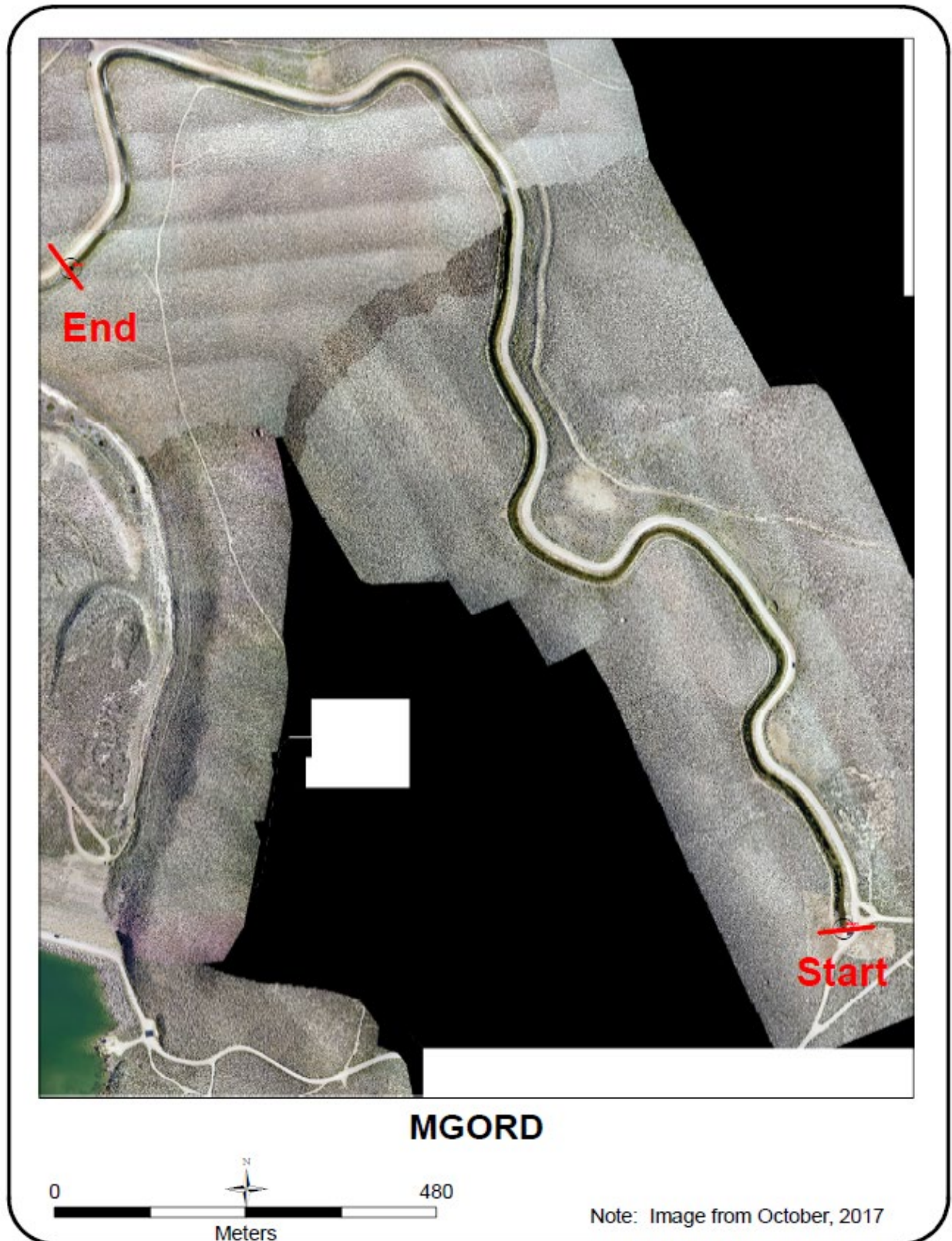
Note: Image from October, 2017



Rush Bottomlands

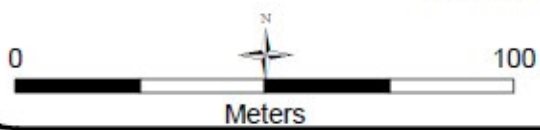


Note: Image from October, 2017

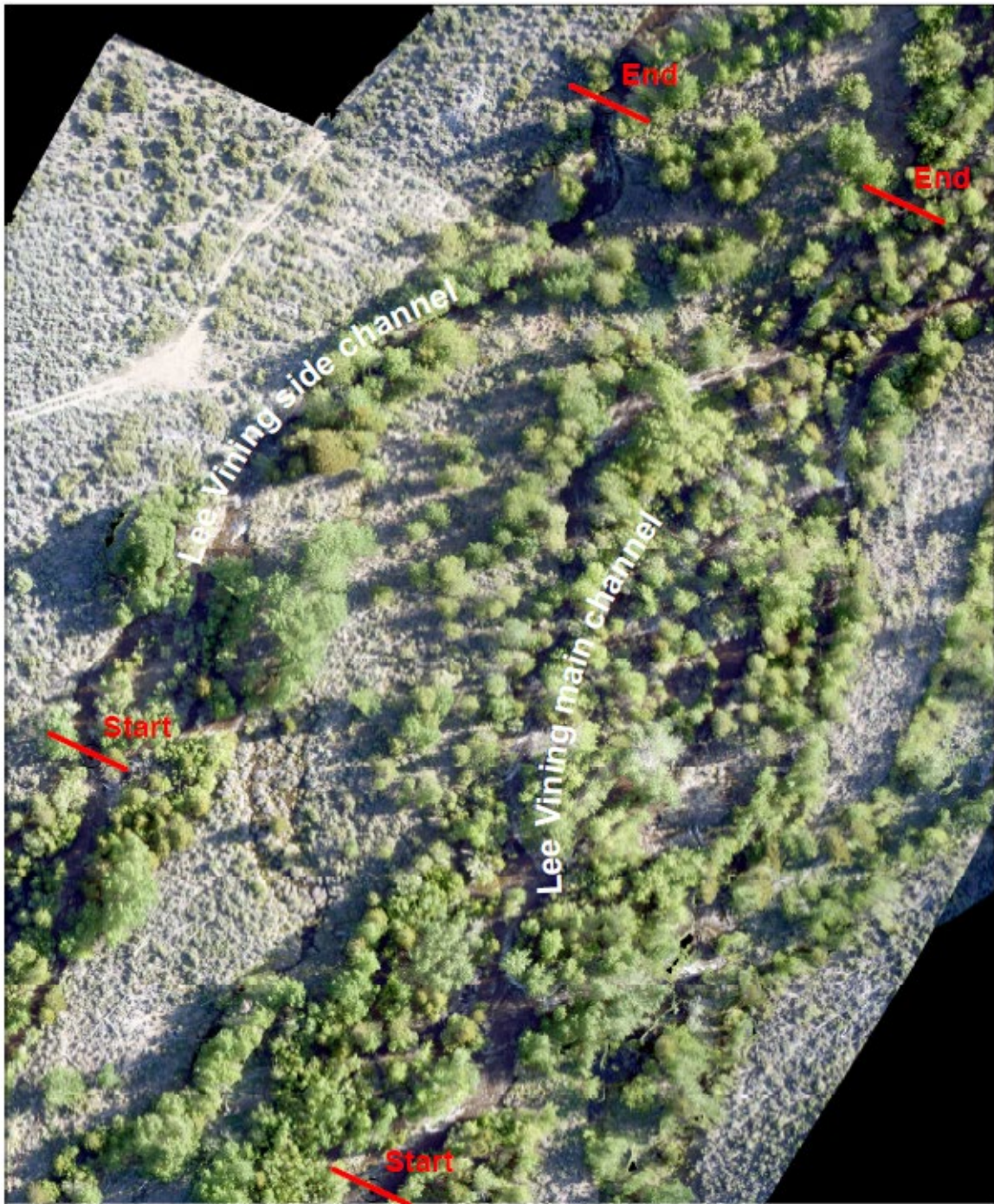




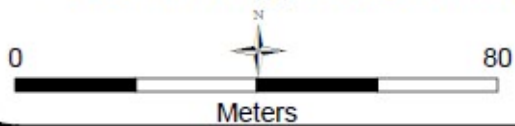
Walker Creek



Note: Image from October, 2017



Lee Vining Creek Main and B-1 Side Channels



Note: Image from October, 2017



Rush Creek 8-Channel section sampled in 2023 through 2025.

**Appendix B: Tables of Numbers of Brown Trout and
Rainbow Trout Implanted with PIT Tags (by sampling
section) between 2009 and 2022
(Note: no tags implanted in 2013)**

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

Table B-10. 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

Table B-11. Total numbers of trout implanted with PIT tags during the 2020 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	242	1*	27	0	270 Trout
	Bottomlands	65	0	0	0	65 Trout
	MGORD	80	132** 1*	2	7	222 Trout
Lee Vining Creek	Main Channel	102	1*	0	0	103 Trout
	Side Channel	0	0	0	0	0 Trout
Walker Creek	Above old 395	92	4*	0	0	96 Trout
Age Class Sub-totals:		581	139	29	7	Total Trout: 756

*shed tag/new tag implanted

**≤250 mm in total length

Table B-12. Total numbers of trout implanted with PIT tags during the 2021 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	148	1*	36	0	185 Trout
	Bottomlands	106	0	0	0	106 Trout
	MGORD	115	259** 1*	0	9	384 Trout
Lee Vining Creek	Main Channel	53	0	0	0	53 Trout
	Side Channel	17	0	0	0	17 Trout
Walker Creek	Above old 395	122	1*	0	0	123 Trout
Age Class Sub-totals:		561	262	36	9	Total Trout: 868

*shed tag/new tag implanted

**≤250 mm in total length

Table B-13. Total numbers of trout implanted with PIT tags during the 2022 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	225	4*	35	0	264 Trout
	Bottomlands	225	0	0	0	225 Trout
	MGORD	26	49**	1	1	77 Trout
Lee Vining Creek	Main Channel	30	1*	1	0	32 Trout
	Side Channel	0	0	0	0	0 Trout
Walker Creek	Above old 395	104	0	0	0	104 Trout
Age Class Sub-totals:		610	54	37	1	Total Trout: 702

*shed tag/new tag implanted

**up to 225 mm in total length

Table B-14. Total numbers of trout implanted with PIT tags during the 2023 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	53	2*	2	0	57 Trout
	Bottomlands	14	0	0	0	14 Trout
	MGORD	20	6**	8	0	34 Trout
Rush Creek – new sites	Caddis Channel	17	89***	0	11***	117 Trout
	Jeffrey Connector	29	14***	0	1***	44 Trout
	Old Main Ch.	7	28***	0	0	35 Trout
Lee Vining Creek	Main Channel	0	0	0	0	0 Trout
	Side Channel	0	0	0	0	0 Trout
Walker Creek	Above old 395	1	0	0	0	1 Trout
Species/Age Class Sub-totals:		141	139	10	12	Total Trout: 302

*shed tag/new tag implanted

**up to 225 mm in total length

***all fish tagged in new sample sections

Table B-15. Total numbers of trout implanted with PIT tags during the 2024 sampling season, by stream, sample section, age-class and species.

Creek Name	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	229	1*	35	0	265 Trout
	Bottomlands	197	0	1	0	198 Trout
	MGORD	58	180**	15	1	254 Trout
	Caddis or 8-Channel	85	0	0	0	85 Trout
LV Creek	Main Channel	150	0	5	0	155 Trout
Walker Creek	Above old 395	23	0	0	0	23 Trout
Species/Age Class Sub-totals:		742	181	56	1	Total Trout: 980

*shed tag/new tag implanted

**164 to 225 mm in total length

***all fish tagged in new sample sections

Appendix C: Table of PIT-tagged Fish Recaptured during September 2025 Sampling

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2023 Recapture	Location of Initial Capture and Tagging	Comments
9/16/2025	RBT	321	280	989001039661828	UpperRush	Upper Rush	
9/16/2025	BNT	264	163	989001042091116	UpperRush	Upper Rush	
9/16/2025	BNT	207	81	989001045526460	UpperRush	Upper Rush	
9/16/2025	BNT	225	102	989001045526507	UpperRush	Upper Rush	
9/16/2025	BNT	192	66	989001045526508	UpperRush	Upper Rush	
9/16/2025	BNT	174	48	989001045526729	UpperRush	Upper Rush	
9/16/2025	BNT	153	35	989001045526776	UpperRush	Upper Rush	
9/16/2025	BNT	155	35	989001045526785	UpperRush	Upper Rush	
9/16/2025	BNT	153	33	989001045526841	UpperRush	Upper Rush	
9/16/2025	BNT	166	40	989001045526845	UpperRush	Upper Rush	
9/16/2025	BNT	167	45	989001045526882	UpperRush	Upper Rush	
9/16/2025	BNT	151	31	989001045526889	UpperRush	Upper Rush	
9/16/2025	BNT	125	18	989002027387943	UpperRush	Upper Rush	
9/16/2025	BNT	151	35	989002027387954	UpperRush	Upper Rush	
9/16/2025	BNT	121	15	989002027387965	UpperRush	Upper Rush	
9/16/2025	BNT	153	32	989002027387985	UpperRush	Upper Rush	
9/16/2025	BNT	137	25	989002027388005	UpperRush	Upper Rush	
9/16/2025	BNT	173	45	989002027388007	UpperRush	Upper Rush	
9/16/2025	RBT	200	86	989002027388012	UpperRush	Upper Rush	
9/16/2025	BNT	180	59	989002027388020	UpperRush	Upper Rush	
9/16/2025	BNT	354	583	989002032248384	UpperRush	Upper Rush	Shed tag, new tag implanted
9/17/2025	BNT	227	95	989001045526425	Bottomlands	Bottomlands	
9/17/2025	BNT	150	32	989001045527073	Bottomlands	Bottomlands	
9/17/2025	BNT	153	35	989002027388104	Bottomlands	Bottomlands	

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2023 Recapture	Location of Initial Capture and Tagging	Comments
9/17/2025	BNT	151	30	989002032248201	Bottomlands	Bottomlands	Shed tag, new tag implanted
9/22/2025	BNT	521	2426	989001006110908	MGORD	MGORD	
9/22/2025	BNT	455	1172	989001039661593	MGORD	MGORD	
9/22/2025	BNT	328	365	989001039661788	MGORD	Upper Rush	
9/22/2025	BNT	317	350	989001039661821	MGORD	Upper Rush	
9/22/2025	BNT	333	414	989001039661839	MGORD	Upper Rush	
9/22/2025	BNT	314	312	989001042091220	MGORD	Upper Rush	
9/22/2025	BNT	368	502	989001042091257	MGORD	Upper Rush	
9/22/2025	BNT	352	368	989001042091316	MGORD	Bottomlands	
9/22/2025	BNT	269	181	989001045526422	MGORD	MGORD	
9/22/2025	BNT	271	213	989001045526428	MGORD	MGORD	
9/22/2025	BNT	291	243	989001045526491	MGORD	MGORD	
9/22/2025	BNT	294	244	989001045527039	MGORD	MGORD	
9/22/2025	BNT	297	254	989001045527048	MGORD	MGORD	
9/22/2025	BNT	260	152	989001045527059	MGORD	MGORD	
9/22/2025	BNT	290	214	989001045527077	MGORD	MGORD	
9/22/2025	BNT	208	104	989001045527100	MGORD	MGORD	
9/22/2025	BNT	261	155	989001045527114	MGORD	MGORD	
9/22/2025	BNT	268	159	989001045527119	MGORD	MGORD	
9/22/2025	BNT	271	158	989001045527122	MGORD	MGORD	
9/22/2025	BNT	260	152	989001045527123	MGORD	MGORD	
9/22/2025	BNT	257	166	989001045527132	MGORD	MGORD	
9/22/2025	BNT	284	238	989001045527141	MGORD	MGORD	
9/22/2025	BNT	276	195	989001045527148	MGORD	MGORD	

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2023 Recapture	Location of Initial Capture and Tagging	Comments
9/22/2025	BNT	296	223	989001045527156	MGORD	MGORD	
9/22/2025	BNT	259	158	989001045527161	MGORD	MGORD	
9/22/2025	BNT	257	146	989001045527194	MGORD	MGORD	
9/22/2025	BNT	289	227	989001045527195	MGORD	MGORD	
9/22/2025	BNT	255	150	989002027388135	MGORD	MGORD	
9/22/2025	BNT	248	126	989002027388144	MGORD	MGORD	
9/22/2025	BNT	206	97	989002027388147	MGORD	MGORD	
9/22/2025	BNT	269	171	989002027388151	MGORD	MGORD	
9/22/2025	BNT	287	222	989002027388156	MGORD	MGORD	
9/22/2025	BNT	297	285	989002027388168	MGORD	MGORD	
9/22/2025	BNT	256	187	989002027388170	MGORD	MGORD	
9/22/2025	BNT	264	159	989002027388185	MGORD	MGORD	
9/22/2025	BNT	275	186	989002027388192	MGORD	MGORD	
9/22/2025	BNT	275	230	989002027388202	MGORD	MGORD	
9/22/2025	BNT	257	162	989002027388205	MGORD	MGORD	
9/22/2025	BNT	240	139	989002027388219	MGORD	MGORD	
9/19/2025	BNT	298	242	989001045526536	8-Channel	8-Channel	
9/19/2025	BNT	136	23	989002027387864	8-Channel	8-Channel	
9/19/2025	BNT	151	31	989002027387869	8-Channel	8-Channel	
9/18/2025	BNT	280	213	989001038117103	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	268	190	989001039661720	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	291	236	989001042091084	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	163	39	989002027387726	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	151	30	989002027387751	Lee Vining Ck	Lee Vining Ck	

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2023 Recapture	Location of Initial Capture and Tagging	Comments
9/18/2025	BNT	190	62	989002027387785	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	151	35	989002027388028	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	143	24	989002027388037	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	183	56	989002027388074	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	139	25	989002027388090	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	170	46	989002027388094	Lee Vining Ck	Lee Vining Ck	
9/18/2025	BNT	181	65	989002027388121	Lee Vining Ck	Lee Vining Ck	
9/20/2025	BNT	229	95	989001039661174	Walker Ck	Walker Ck	
9/20/2025	BNT	246	125	989001039661217	Walker Ck	Walker Ck	
9/20/2025	BNT	234	110	989001039661323	Walker Ck	Walker Ck	
9/20/2025	BNT	232	119	989001039661760	Walker Ck	Walker Ck	
9/20/2025	BNT	239	113	989001042091484	Walker Ck	Walker Ck	
9/20/2025	BNT	161	36	989001045527090	Walker Ck	Walker Ck	

Section II. Annual Monitoring Report 2025 Results
of Geomorphic and Vegetation Monitoring
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Annual Monitoring Report 2025/2026

Results of Geomorphic and Vegetation Monitoring

Prepared by California Polytechnic University
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Definitions

Below are definitions used throughout this document.

- Aerial Photos - For our purposes, this refers to visual, infrared, and red edge aerial photographs obtained using a drone or other aerial vehicle.
- CHM - Canopy height model. A raster where each pixel contains the height of the canopy above the ground.
- DEM - Digital Elevation Model. A raster where each pixel contains the elevation of the ground.
- Drone - Unmanned / Unoccupied Aerial Vehicle, also known as a UAV.
- DTM - Digital Terrain Model. Another name for a DEM.
- DSM - Digital Surface Model. A raster where each pixel contains the elevation of the top-most feature on the landscape (i.e. top of trees, roofs of houses, ground if there is no cover).
- LADWP - Los Angeles Department of Water and Power.
- LiDAR - Light Detection and Ranging refers to using laser pulses to determine the distance to an object. For our purposes, this refers to scanning the surface of the earth from a drone to determine the height of objects and elevation of the ground.
- LWD - Large woody debris
- NAD83 - North American Datum, 1983. Used to reference geographic coordinates (a latitude and a longitude) to North America.
- NIR - Near Infrared. A band of the electromagnetic spectrum that represents heat and helps with the identification of plants.
- Orthophoto - An aerial image that has been processed to allow for accurate measurements.
- RCT - Riffle Crest Thalweg
- RCT-Q: Relationship between the riffle crest thalweg and stream flow typically presented as a chart with RCT on one axis and Q on the other.
- Red Edge (or RE) - A band of the electromagnetic spectrum between Red and NIR that helps with the identification of plants.
- RGB - Red, Green, Blue. Often used to identify visual spectrum images as opposed to images with data that is not visible to the human eye such as infrared.
- UAV - Unmanned / Unoccupied Aerial Vehicle, also known as a drone.
- WGS84 - World Geodetic System, 1984. Used to reference geographic coordinates (a latitude and a longitude) to the earth.

Executive Summary

This report focuses on the Geomorphic and Vegetation monitoring within the riparian areas of the tributaries that flow into Mono Lake. The goal of this phase of the project is to determine effective monitoring methods for the geomorphic and land cover (specifically vegetation) aspects of the riparian area. The project focuses on developing methods within the Rush Creek

riparian area from the Ford to the Narrows with the expectation that the area of study will expand to other riparian systems around the lake when the methods are refined.

The timeframe for this report is from July 2025 through April 2026. This included processing data from May of 2025 and modeling the land cover types within the study area. We planned to visit the site again in the fall but our field surveyor was injured and the trip had to be delayed. We plan to do field work in May and August of 2026 to survey the Rush Creek thalweg. Because we now feel that the methodology is producing the results we need, we plan to begin collecting data in other riparian corridors around Mono Lake.

The study presents results showing that land cover can be determined using drone based data including RGB and LiDAR. It also shows that the optimal resolution for the RGB data is about 1 meter which is significantly lower than expected and will aid in the speed of data acquisition and processing. This work was primarily from the thesis work completed by Jes Suoja.

Introduction

Riparian vegetation is considered a keystone habitat in desert riparian ecosystems, meaning that the loss of vegetation can have cascading effects on ecosystem services and functions (Johnson and Jones, 1977; Knight and Bottorff, 1984; Colvin et al., 2019). There is evidence that desert riparian ecosystems are sensitive to human alteration or disturbance (Johnson and Jones, 1977). To address the requirement of mapping riparian vegetation and land cover, we needed a method for classifying land use/land cover (LULC) throughout the study area.

Common LULC classification techniques include traditional pixel-based and object-based classifications, which use remotely sensed data to create detailed land cover prediction maps (Amalisana et al., 2017; Jin et al., 2018; Bertacchi et al., 2019; Uyeda et al., 2020). In addition, machine learning algorithms can be used with both classification techniques to improve accuracy, particularly with complex data (Zhi et al., 2018; Drobnjak et al., 2022). Pixel-based classification groups pixels based on spectral values into unique classes whereas object-based

classification involves identifying objects by shapes, textures, and spectral information and assigning objects to different classes through the process of segmentation and classification (Amalisana et al., 2017; Basheer et al., 2022). There are unsupervised and supervised classification methods as well. Supervised classification requires training data of known pixel values to be included for training the model (Amalisana et al., 2017; Basheer et al., 2017). Common remote sensing data includes visible spectrum imagery (RGB), near infrared imagery (NIR), and Light Detection and Ranging (LiDAR) data (Howland, 1980; Norman et al., 2014; Wang et al., 2024). LiDAR sensors send out laser pulses and detect how long it takes for the pulses to return to create point clouds that can be used to create detailed canopy height models, which can be helpful when classifying vegetation with different canopy heights (CHMs; Wang et al., 2024).

As remote sensing has continued to advance, many traditional pixel-based methods have lacked in performance compared to supervised machine learning classification techniques, including classification and regression trees (CART), support vector machines (SVMs), and random forests (RF), which have continued to grow in popularity (Yu et al., 2006; Weih and Riggan, 2010; Richards, 2022; Savitha and Talari, 2025). Studies have shown that utilizing traditional pixel-based methods as covariates within machine learning algorithms can help increase model accuracy, known as ensemble modeling (Du et al., 2012; Wen and Hughes, 2020).

The three main ensemble techniques are bagging, boosting, and stacking. Bagging, also known as bootstrap aggregation, is done by training the same algorithm many times using different training data subsets. Boosting is a process in which the first algorithm is trained using the entire training dataset and subsequent algorithms take into consideration the residuals of the previous algorithm (Wen and Hughes, 2020). Stacking is a multiple classifier system which uses classifiers as covariates within a machine learning algorithm (Du et al., 2012; Wen and Hughes, 2020). Common pixel-based traditional methods include maximum likelihood and minimum distance classifiers, but little research has been conducted utilizing these classifiers for a stacked machine learning ensemble model (Sathya and Deepa, 2017; Richards, 2022). Advances in UAV technology have led to increased availability of very high resolution (VHR) imagery, with a resolution of less than one meter (Benediktsson et al., 2012; Cubaynes et al., 2023). With the increase in VHR imagery, many complications have arisen, such as higher levels of required memory and processing power for computers (Benediktsson et al., 2012; He and Weng, 2018). In addition, increased pixel count in higher resolution imagery can lead to the salt and pepper phenomenon, where mixed pixels can occur due to the complex heterogeneity of the landscape (Benediktsson et al., 2012). Little research has been conducted regarding the effect of VHR imagery on model accuracy in machine learning LULC classification models, but some studies have found that complex landscapes may require higher resolution imagery (Ramezan et al., 2021; Li et al., 2023). However, most research focuses more on readily available imagery with resolutions greater than 1 meter, such as WorldView-2, Landsat 8, and Sentinel-2 (Murtaza and Romshoo, 2014; Mishra et al., 2016; Shirzadi et al., 2019; Basheer et al., 2022). Furthermore, there is a gap in knowledge regarding pinpointing the resolution that leads to the highest machine learning model accuracy.

Loss of habitats can decrease structural heterogeneity, which is important for the resilience of an ecosystem (Cardinale et al., 2006; Virah-Sawmy, 2009). Shifts or losses in riparian vegetation, and thus fish and waterfowl habitat, may have even larger-scale effects (Naiman et al., 2010; Kominoski et al., 2013). Classification of the vegetation and land cover types can provide insight into the biodiversity and heterogeneity of an ecosystem, both of which can be indicators of ecosystem health (Virah-Sawmy, 2009). In doing so, researchers can begin to determine the health of the ecosystem and isolate areas that need the most improvement.

Rush Creek is the largest of the tributary streams located on the lower southwest side of Mono Lake. The streambed of Rush Creek is “derived from granitic and metamorphic rock moved downstream from the Sierra Nevada by glaciation and bedload transport during high stream

flows” (LADWP, 1996). Riparian areas such as Rush Creek provide a favorable microclimate due its ability to moderate evapotranspiration along the riparian corridor. This area experiences large seasonal and annual variability in precipitation (National Research Council, 1987). The majority of precipitation comes in the form of snow in the winter. Annual precipitation varies greatly, from 100 mm per year to 1,000 mm per year (Taylor, 1982). This area also has prolonged periods of drought, as well as periods of heavy precipitation (National Research Council, 1987). The creek has a highly seasonal flow pattern, with flow being highest in the summer when snow melt occurs (Taylor, 1982; National Research Council, 1987). Historically, snowmelt floods were common, but water diversion by the Los Angeles Department of Water and Power (LADWP) has decreased the frequency of flooding (McBain & Trush, Inc. et al., 2010). Prior to restoration efforts the creek had dried up, resulting in near total loss of riparian vegetation, as well as fish and waterfowl habitat (State Water Resources Control Board, 1994).

Utilizing remote sensing techniques, particularly through unoccupied aerial vehicles (UAVs), can increase data collection efficiency and reduce the amount of disturbance to sensitive habitats (Cruzan et al., 2016). Because of this, the use of remote sensing for monitoring restoration has grown in popularity (Bertacchi et al., 2019; Huylenbroeck et al., 2020). In particular, this has been the case in desert riparian ecosystems (Norman et al., 2014; Song et al., 2024). Remote sensing can be used to produce high-resolution imagery for the purpose of classifying vegetation and land cover as part of riparian restoration and monitoring projects (Howland, 1980; Cruzan et al., 2016).

Aside from high-resolution visible spectrum (RGB) aerial imagery, UAVs can also be used with sensors to collect different types of data. One type of data that can be collected with UAVs for the purpose of monitoring changes in vegetation and land cover over time is Light detection and ranging (LiDAR). LiDAR is a product of laser technology and photodetection technology where a high frequency of laser pulses are sent out and the time it takes for the pulse to be reflected back is recorded (Wang et al., 2024). This can be used in restoration efforts to create extremely detailed models, such as digital surface and elevation models (DSM and DEM) as well as canopy height models (CHMs). Near infrared and red edge sensors can also be used with UAVs. Near infrared and red edge data can be used to calculate several vegetation indices, which are mathematical equations that calculate plant traits, such as plant vigor and stress, among others (Bannari et al., 1995). For example, the Normalized Difference Vegetation Index can be calculated using red and near infrared imagery to determine greenness (Wilson and Norman, 2018; Gomez-Sapiens et al., 2021). In addition, the Normalized Difference Red Edge Index can be used to isolate different types of vegetation based on changes in chlorophyll levels (Schuster et al., 2012). Research has shown that this can be an effective tool when determining vegetation change over time (Wilson and Norman, 2018; Gomez-Sapiens et al., 2021).

One monitoring team, the Stream Monitoring Team, was tasked with hydrology and geomorphic monitoring, assessing channel roughness, and mapping riparian vegetation and land cover. The main objective of the Stream Monitoring Team for 2025 was to determine effective monitoring methods in accordance with the licensing agreement including developing a protocol to increase monitoring efficiency, accuracy, and reproducibility.

Methods

Study Area

Mono Lake is located on the eastern edge of the eastern Sierra Mountains in California. The closest town is Lee Vining (Figure 1). There are a series of streams that flow into the lake including Lee Vining and Rush Creek.

The study site is Lower Rush Creek from what is known as “the Ford,” where Rush Creek Road crosses the creek, to “the Narrows” where Walker Creek joins Rush Creek (Figure 2; LADWP, 1996). The vegetation along Lower Rush Creek includes herbaceous and woody riparian vegetation, as well as desert shrub vegetation and some invasive, exotic vegetation (McBain & Trush, 2005). The primary vegetation is black cottonwood (*Populus balsamifera* subsp. *trichocarpa*), willow (*Salix* spp.), cattails (*Typha latifolia*), and various brush species (National Research Council, 1987; Stine, 1991).

Figure 3 provides the names of locations within the Rush Creek study area that are used in this report.



Figure 1. Map of California showing the location of Lee Vining, which neighbors Mono Lake.



Figure 2. Aerial Image showing the two main features that bound the study area, the ford and the narrows.

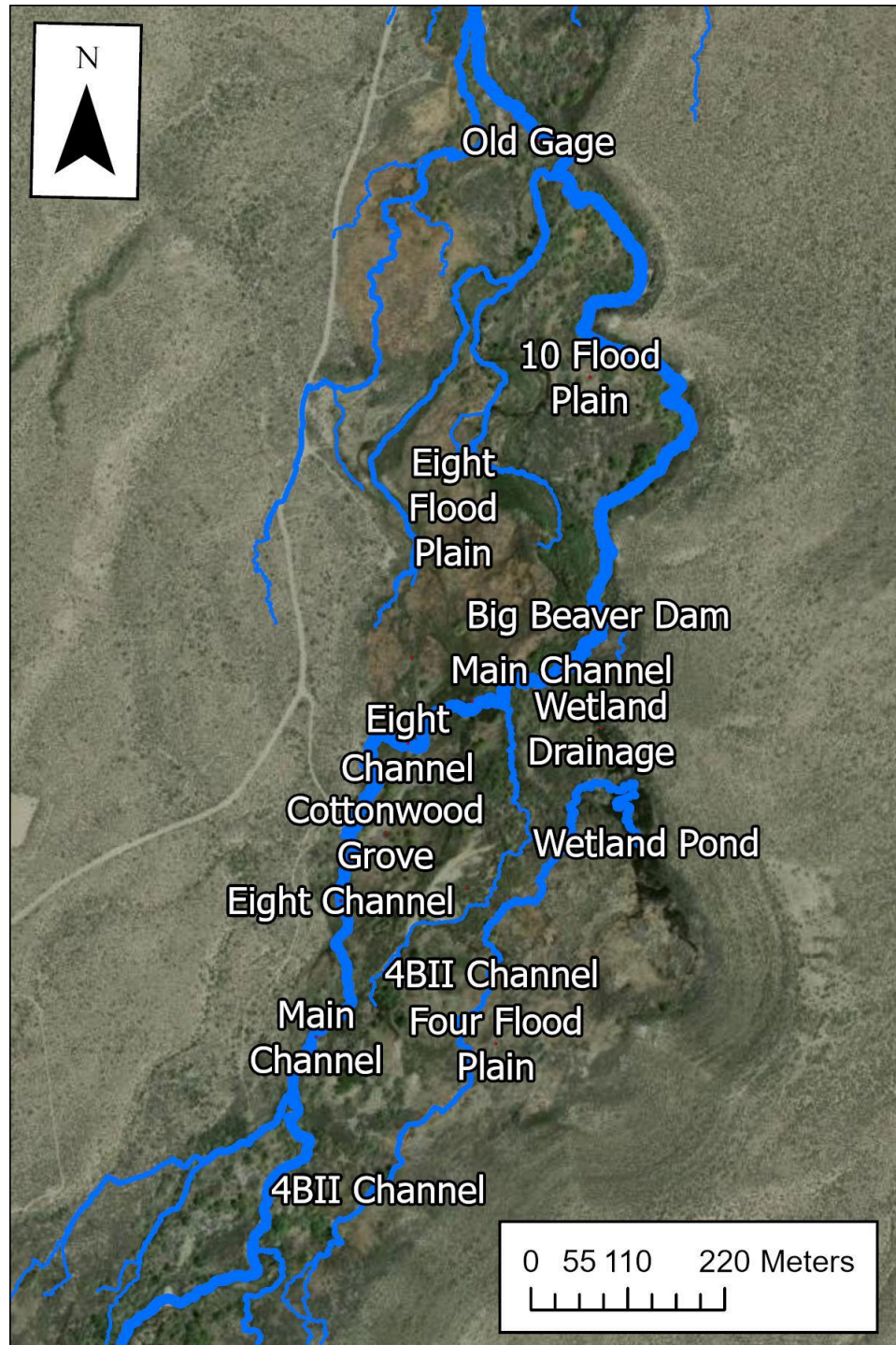


Figure 3. Map of the central area of the study area with labels for features that are mentioned in the text. The stream network is symbolized based on the reach level of the stream rather than actual flow.

Data Collection And Processing

Where possible, data was collected in the WGS 84 (World Geodetic System 1984) Universal Transverse Mercator, Zone 11 North (UTM Zone 11 North). Datasets in other spatial references were projected into WGS84, UTM Zone 11 North as soon as possible to keep all working data in the same spatial reference. Standard file formats were used through with LASer (LAS) files for point clouds from LiDAR flights, Shapefiles (shp) being used for vector data, and Tagged Image File Format (TIFF) files used for rasters.

Aerial Surveys

UAV visible spectrum (RGB) and LiDAR flights were conducted in summer of 2025 using a DJI Mavic 3M for RGB and a DJI Matrice 300 with a DJI Zenmuse L1 LiDAR sensor for LiDAR data collection. UAV flights were flown at 90-meter altitude with 80 percent front overlap, 70 percent side overlap, and a straight-down -90-degree gimbal tilt. Both drones were connected to a nearby permanent base station to ensure positioning accuracy. Structure from Motion was used to process the RGB drone flight data and create orthomosaics for analysis in Agisoft's Metashape software (Agisoft, 2024). CloudCompare and ArcGIS Pro were used to process the LiDAR data and generate a canopy height model (CHM; v2.13.2; CloudCompare, 2024; v3.4.0; ESRI, 2024).

The LiDAR data was cleaned to reduce outliers and noise using the Statistical Outlier Removal (SOR) Filter and the Noise Filter in CloudCompare (v2.13.2; CloudCompare, 2024). The Cloth Simulation Filter (CSF) was then used to separate out ground from non-ground points using a resolution of 0.5, 500 iterations, and a classification threshold of 0.02. The digital surface model (DSM) and digital terrain model (DTM) were then created using the kriging method for cells that did not contain LiDAR points. Kriging is the method of using spatial correlation to interpolate cell values from nearby cells when there are no LiDAR values within a particular cell (Minh et al., 2024). The CHM was created by subtracting a digital terrain model (DTM) from a digital surface model (DSM).

Ground Control Points

Five land cover classes: i.e., bare ground, herbaceous riparian, woody riparian, desert, and water, were adapted from the historical maps created by McBain and Trush (2005). Examples of the classes from ground photos and aerial imagery are shown in Figure 4. Thirty stratified random ground control points were generated in ArcGIS Pro using historical maps as strata (v3.4.0; ESRI, 2024). Locational coordinates of each ground control point were collected in the field using the post-processing kinematic method (PPK) with the Emlid Reach RS2 GNSS receiver, and subsequently sub-centimeter differential corrections were applied after field surveying in Emlid Studio (Figure 5, EMLID Tech Kft., 2019).

Thirty Regions of Interest (ROI) points were created for the minimum distance classifier (MDC) by visually identifying bare ground and vegetation classes in the RGB data. A manually digitized surface water layer was used as a mask within the MDC to ensure that water was not incorrectly

classified. The MDC was run using ENVI (v6.5; NV5, 2025). The final covariates that were included in the ensemble models were red, green, blue, the MDC bare ground and vegetation model output (BGV), and the CHM.



Figure 4. Examples of different land use/land cover classes. Top row is ground photography, and the bottom row is sections of aerial RGB imagery (photographs and RGB imagery by author). From left to right the classes are desert vegetation, herbaceous riparian vegetation, woody riparian vegetation, bare ground, and water.

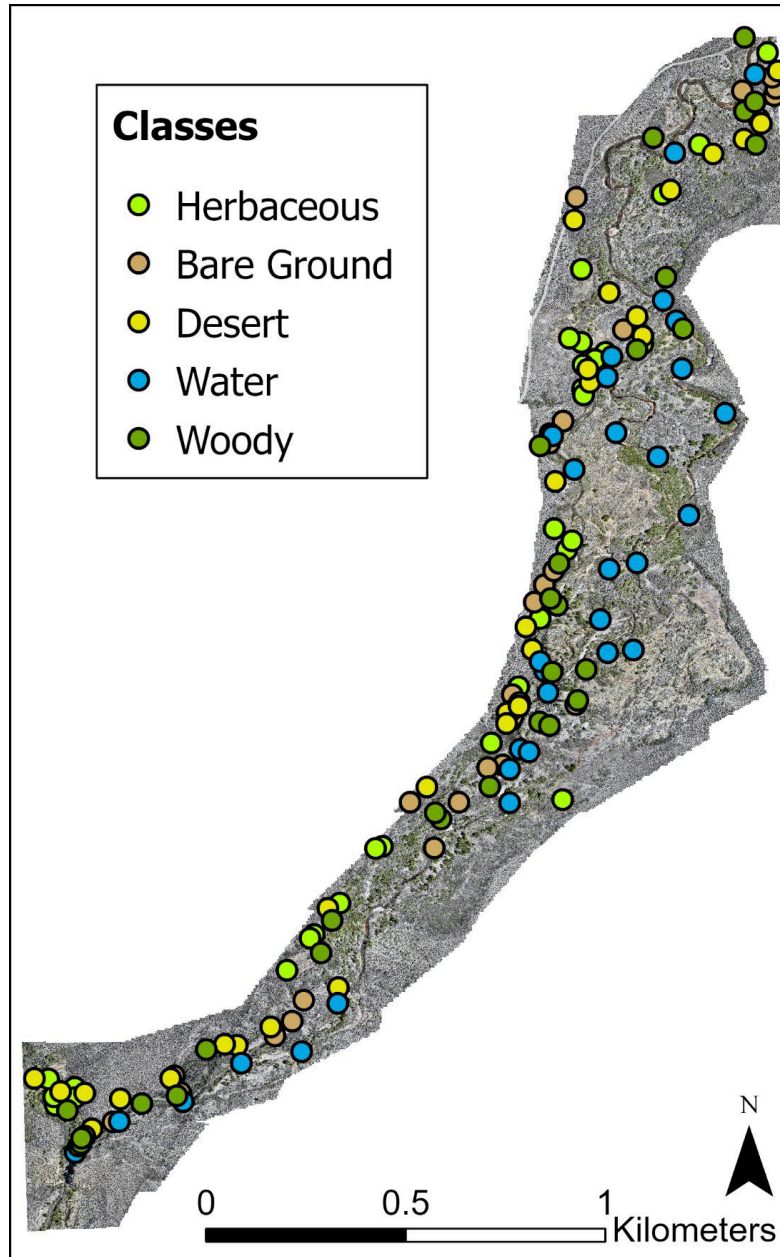


Figure 5. Thirty ground control points collected for each class in the study area for model training.

Resampling

All covariates were resampled from 15 centimeters to 50-centimeter, 75-centimeter, 1-meter, 1.125-meter, 1.25-meter, 1.375-meter, 1.5-meter, 2-meter, and 5-meter resolutions using cubic convolution resampling in ArcGIS Pro (v3.4.0; ESRI, 2024). Cubic convolution calculates a weighted average of the nearest sixteen pixels (Keys, 1981; Baboo and Devi, 2010). Covariate values were compiled into comma-separated values (CSV) files using BlueSpray (Beta 55; SchoonerTurtles, 2013).

Machine Learning Algorithms and Tuning Parameters

Minimum Distance Classifier for Stacking (MDC)

The MDC calculates class means using training data and then assigns pixels to the class of the closest mean (Richards, 2022). Training data was created by visually inspecting the RGB imagery and selecting 30 points each for bare ground and vegetation classes. The parameters that can be tuned in an MDC include the distance threshold and the standard deviation threshold (NV5, 2025; Richards, 2022). However, I achieved higher accuracy by not including thresholds in the final classification. The output map from this classifier assigned unique values to pixels of both classes, which were then included in the ensemble model data as a covariate.

Classification and Regression Trees (CART)

CART is a decision tree algorithm that separates decisions into nodes until it can no longer be split beyond what then becomes the terminal nodes (Basheer et al., 2022). Parameters were tuned by executing a manual grid search within the “rpart” function in RStudio (v2025.05; Posit, 2025). The two tuning parameters for the CART model are the complexity parameter (cp) and the minimum number of samples in a node, known as “minsplit” (Zhi et al., 2018). The cp attempts to prevent overfitting by defining the minimum improvement required at each split within the model (Zhi et al., 2018). The “minsplit” sets the minimum number of observations that are required for a further split to occur (Zhi et al., 2018). A cp of 0.01 and a “minsplit” of 4 were selected for best model performance.

Support Vector Machines (SVM)

SVM is a powerful machine learning algorithm that works by finding the optimal hyperplane that maximizes the margin between data classes (Ramezan et al., 2021; Basheer et al., 2022). We used the radial basis function kernel in this study which maps data points in a higher-dimensional space to find a hyperplane that separates points (Ramezan et al., 2021). The SVM model was built using the “train” function in RStudio.

The two tuning parameters for SVM are cost and sigma. Cost is the regularization parameter that determines the penalty for misclassifying points, whereas sigma dictates how much a single training example can influence the model (Ramezan et al., 2021; Yimer et al., 2024). A common cost value to start with is 1, which allows some violations of the margin and is beneficial when working with noisy or nonlinear data (Adugna et al., 2022). Parameters were tuned automatically within the “train” function, and a cost value of 1 and a sigma value of 1.39 were selected.

Random Forests (RF)

RF is a decision tree algorithm similar to CART, but instead of building one decision tree, the algorithm builds several decision trees using random subsets of the data (Ramezan et al., 2021; Basheer et al., 2022; Savitha and Talari, 2025). Because of the creation of several decision trees, RF has less susceptibility to overfitting compared to CART while also increasing

prediction accuracy (Kumari and Karthikeyan, 2025; Savitha and Talari, 2025). The RF model was built using the “train” function in RStudio, similar to the SVM. The key tuning parameter in the “train” function for RF is the number of variables randomly sampled at each split, known as “mtry” (Ramezan et al., 2021; Timer et al., 2024). A common “mtry” value is the square-root of the number of predictor variables (Yimer et al., 2024). A manual tuning grid search was performed and an “mtry” value of 2.24 was selected, which is close to the square-root of the number of predictor variables for this study.

Validation and Analysis

For all model algorithms, the data was split into training and testing datasets using a 70:30 split. For SVM and RF, a 10-fold cross-validation was performed with five repetitions. K-fold cross-validation is a resampling technique where the data is partitioned into multiple folds (Lyons et al., 2018). These folds are then used in an iterative manner where each fold is used as the test set and the remaining folds are used as the training set (Lyons et al., 2018). Model performance was evaluated using a confusion matrix, a table used to determine model performance by comparing the model’s prediction to the actual results (Yang and Berdine, 2024). Accuracy and Cohen’s kappa coefficient are outputs of the confusion matrix that are used to determine model performance. Cohen’s kappa coefficient is often used as a metric evaluating the effectiveness of the model, primarily because it removes random chance agreement (Sathyanarayanan and Roopashri Tantri, 2024). Following the creation of the prediction map in ArcGIS Pro using the prediction output from the model, data was visually checked for accuracy in ArcGIS Pro to check for extensive misclassified pixels, and to ensure that the performance metrics were not reporting misleading values. Any models that reported high accuracy but had extensive misclassified pixels across the study area were rejected. An analysis of variance (ANOVA) was conducted using the internal validation Cohen’s kappa coefficient values to determine significant differences between models using a p-value of 0.05 to show significance. A flowchart of methodology is shown in Figure 6.

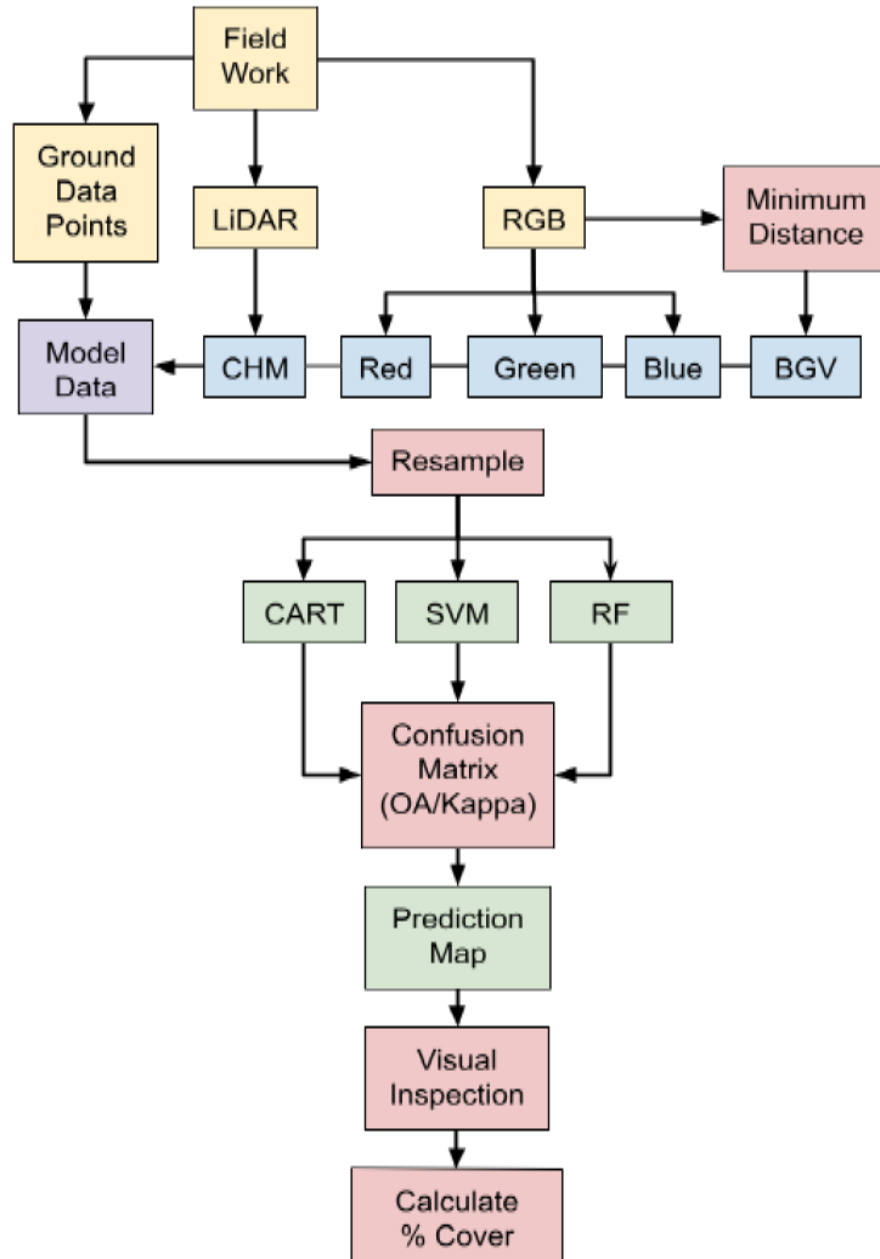


Figure 6. Methodological framework for the study.

Land Cover using LiDAR data

Using the LiDAR collected in May 2025, trees, shrubs and water were extracted from a small section of Rush Creek to test the effectiveness of the analysis. Part of Rush Creek's main channel was extracted using a relative elevation model (REM). A threshold value of -0.02 was utilized to extract the main stream after evaluating the effectiveness of values between 0 and -1. A new CHM was made to extract values higher than 5 meters for trees and values lower than 5

meters but higher than 0.5 meters for shrubs using Rstudio with the lidR package rather than the CloudCompare model that was mentioned earlier.

Historical Maps

Historical maps were acquired from McBain and Trush (2005) to be used for the analysis of class composition change over time. These historical maps were developed for the years 1929, 1999, and 2004 (Figure 7). All maps needed to be manually digitized in ArcGIS Pro to allow quantification of class composition for each year.

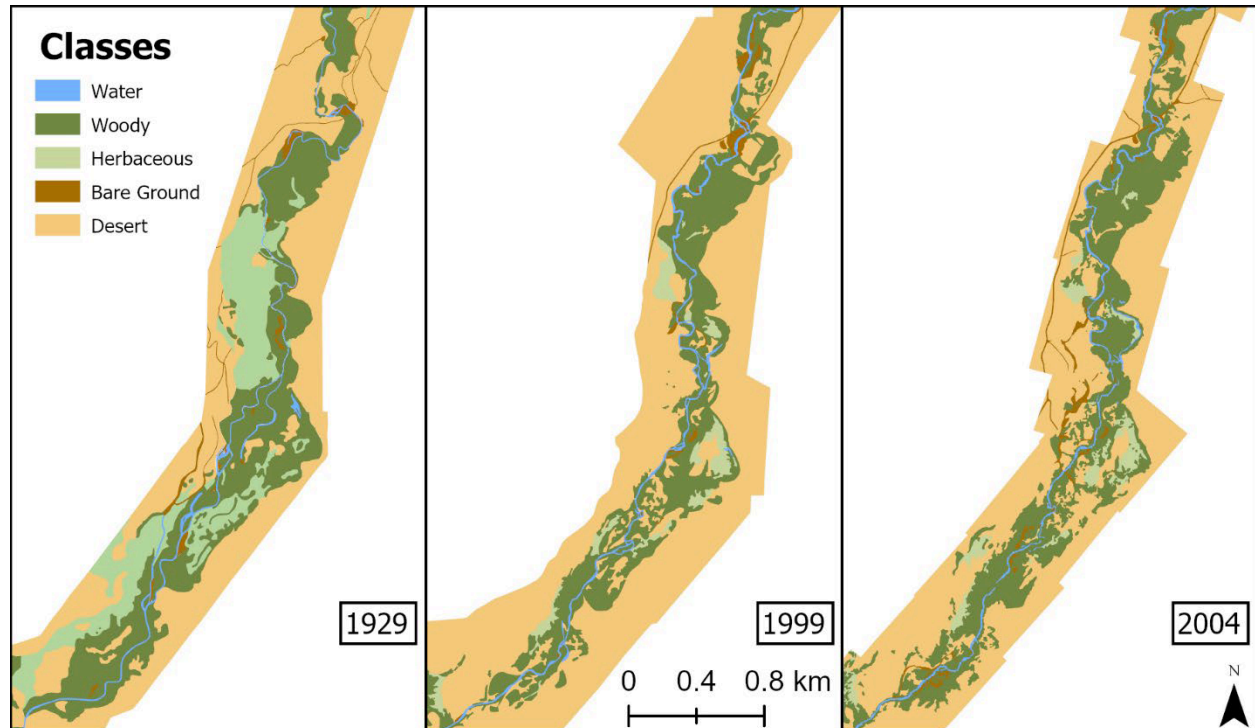


Figure 7. Compilation of the digitized historical maps from McBain and Trush depicting the five LCLU classes (2005).

Composition Change

Percent composition by class for each historical map year and the current land cover prediction map was calculated using ArcGIS Pro by dividing the total area of a class by the total area of the study area. The calculations were then loaded into Microsoft Excel within the Microsoft 365 suite for further analysis (v2511; Microsoft, 2025).

Ground Photography

Historical photos are being collected for the region and additional photos taken. When possible, photos of the area are taken at the same location as historical photos to be able to identify changes over time.

Results

Land Cover

SVM and RF achieved the highest accuracy at 1.25 and 1.5 meters, respectively, with an accuracy of 95% and a Cohen's kappa of 0.943, respectively (Table 1; Figures 8 and 9). The ANOVA results from the internal validation kappa values found no significant difference between the best SVM model and the best RF model ($p = 0.55$). A box and whisker plot showing the range of kappa values is shown in figure 10. The highest accuracy achieved by the CART model was 93% with a Cohen's kappa of 0.914 at 1.375 meters (Table 1; Figures 8 and 9). All 5-meter models achieved the lowest accuracy and Cohen's kappa for that model type (Table 1). The highest percent composition for any class was desert vegetation in the 1.25-meter SVM model, comprising 43% of all pixels (Figure 11). The desert vegetation class from the best performing RF and CART models was 31% and 29%, respectively (Figure 11). The RF and CART models reported the highest percent composition to be in the bare ground class at 35% and 36%, respectively (Figure 11). The lowest percent composition class for any model was water (Figure 11).

The composition of water increased by one percent across each map year (Figure 12). Woody riparian vegetation increased dramatically from 1929 to 2004 and then increased in the 2025 map (Figure 12). Herbaceous riparian vegetation decreased dramatically from 1929 to 1999 and then steadily increased across 2004 and 2025 (Figure 12). Bare ground and desert vegetation increased dramatically in 2025 (Figure 12).

Table 1. Accuracy (%) and Cohen's kappa coefficient results by resolution and model run. Areas marked with a hyphen (-) were excluded from the results during the visual inspection phase due to extensive errors not reflected in the accuracy and Cohen's kappa values.

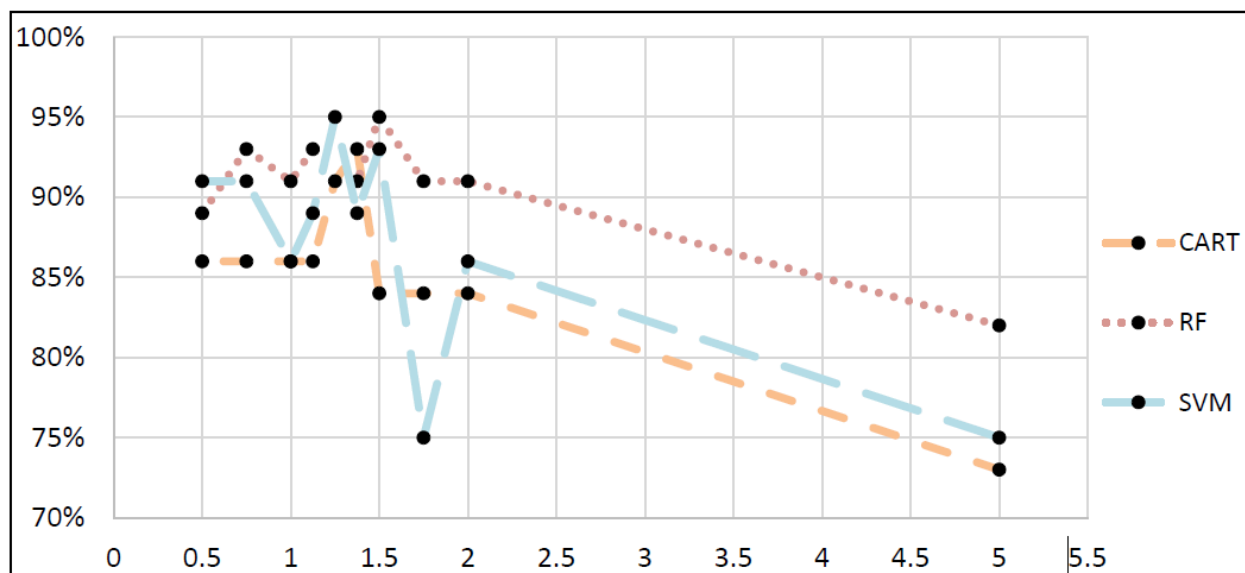


Figure 8. Graph of model performance for all resolutions.

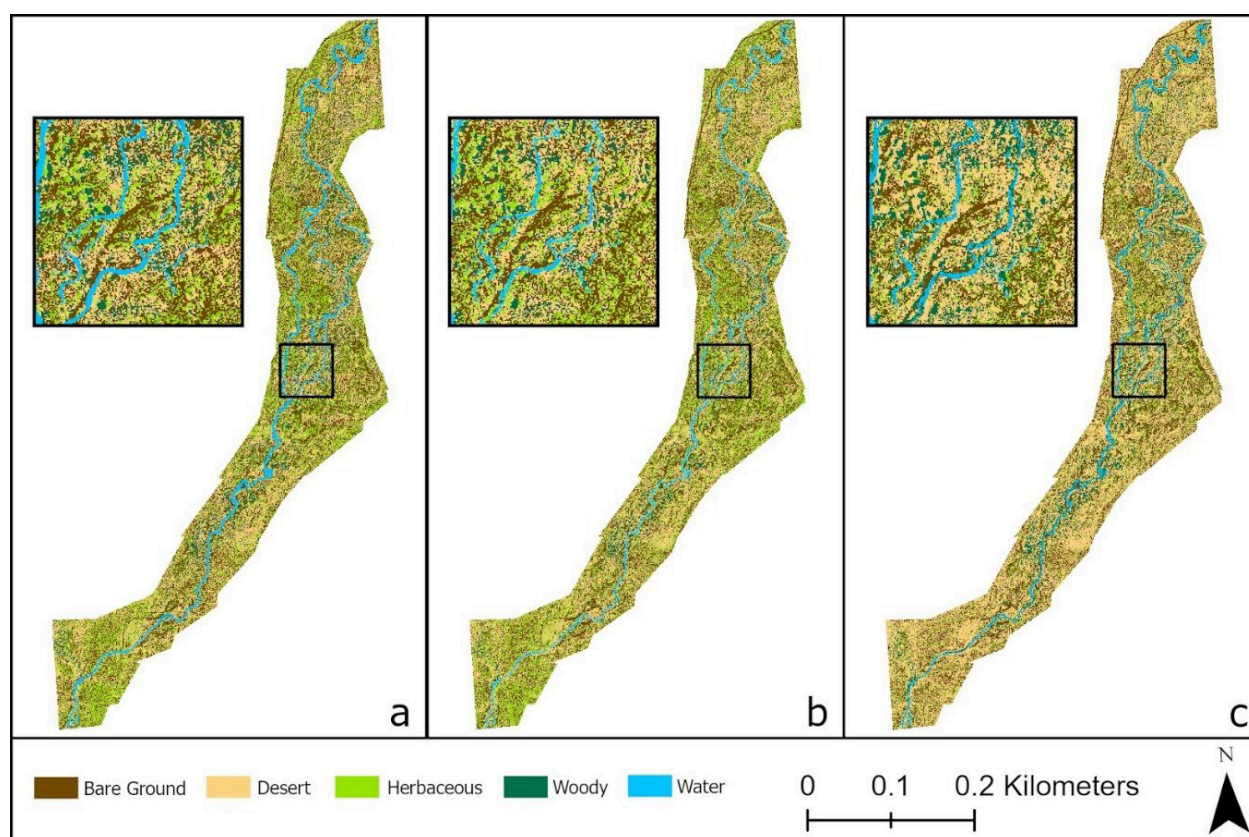


Figure 9. Maps of the best performing model by model type: CART model at 1.375-meter resolution on the left (a), RF model at 1.5-meter resolution (b), and SVM model at 1.25-meter resolution (c) with enlarged areas to show differences.

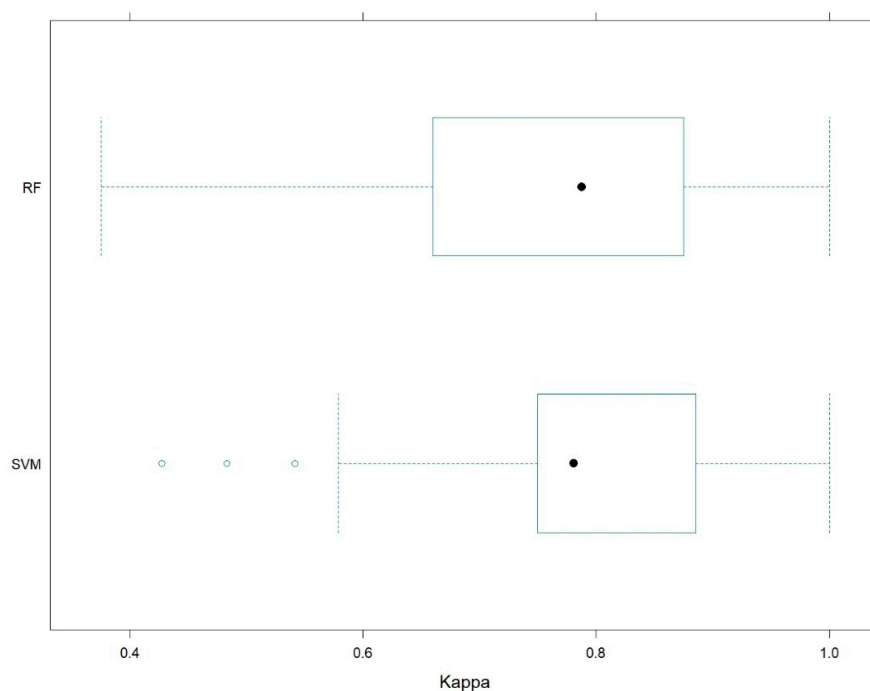


Figure 10. Box and whisker plot showing the range of internal validation kappa values for RF and SVM that were used for the ANOVA.

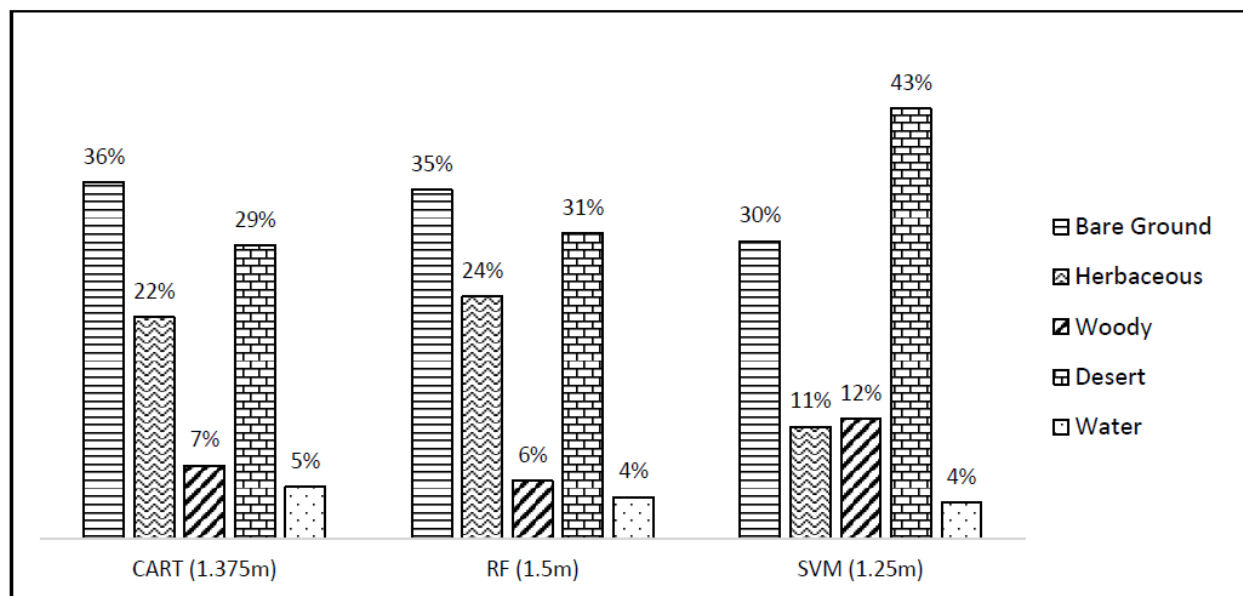


Figure 11. Percent composition by class for the best performing model of each model type.

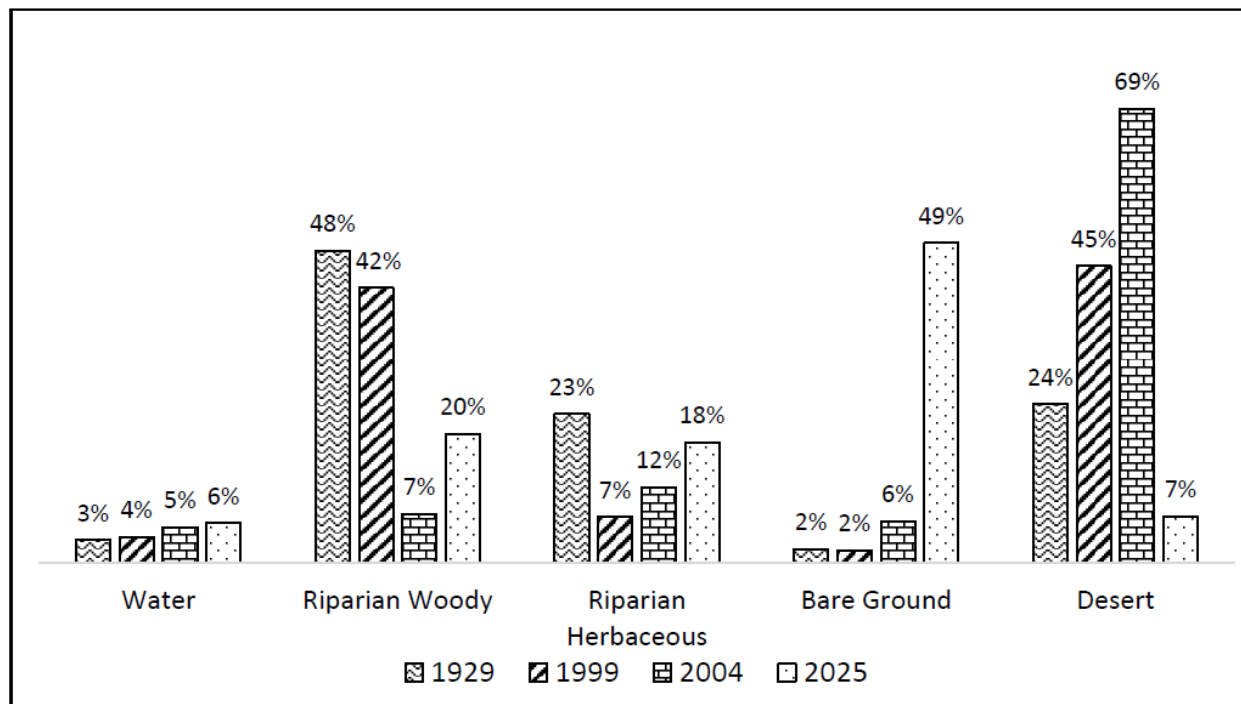


Figure 12. Percent composition by class for 1929, 1999, 2004, and 2025.

Land Cover Using LiDAR Data

The shrubs extracted from the CHM using Rstudio covered 31.6% of the portion of the Rush Creek study area (Figure 13). 13.7% of the area was categorized as trees that are greater than 5 meters (Figure 13). Water was identified to be 6.4% of the study area (Figure 14). The uncategorized land which includes other land covers such as bare ground was 48.3%.

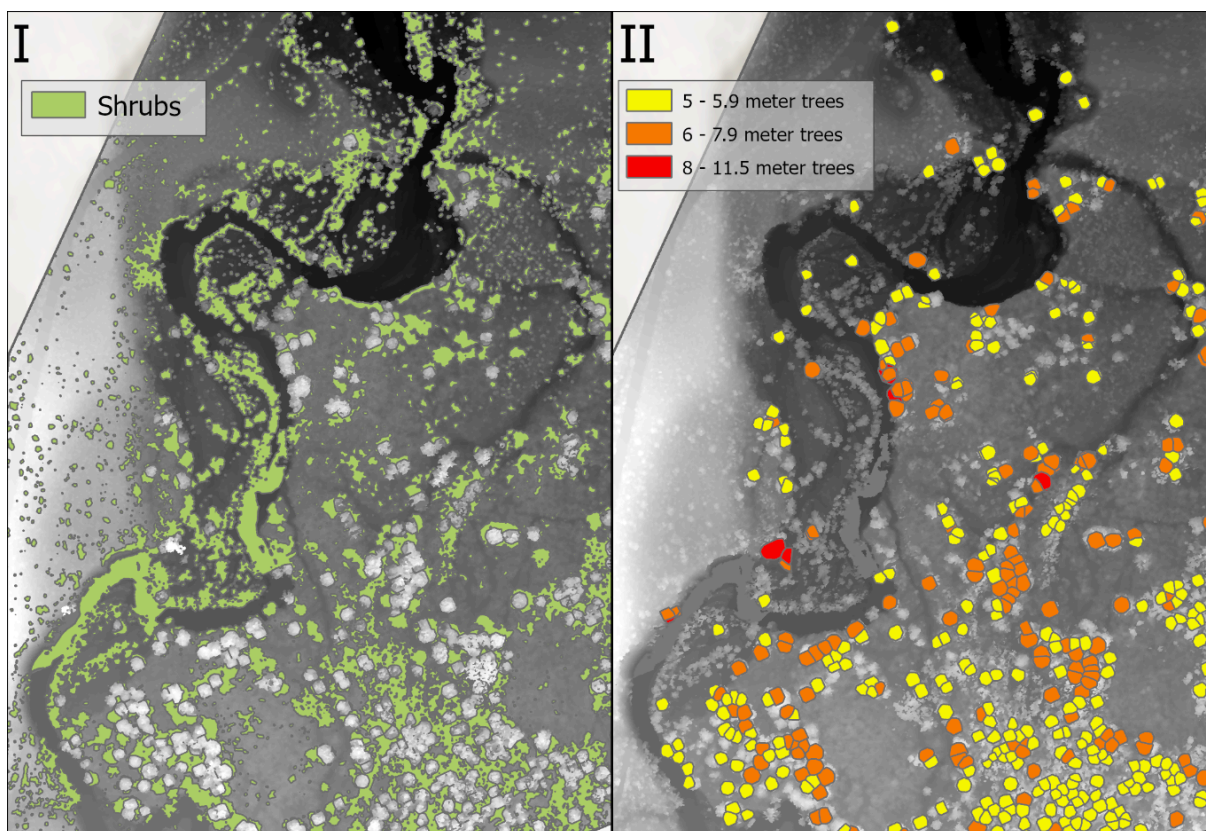


Figure 13. Land cover maps of a small section of Rush Creek showing shrubs and trees.

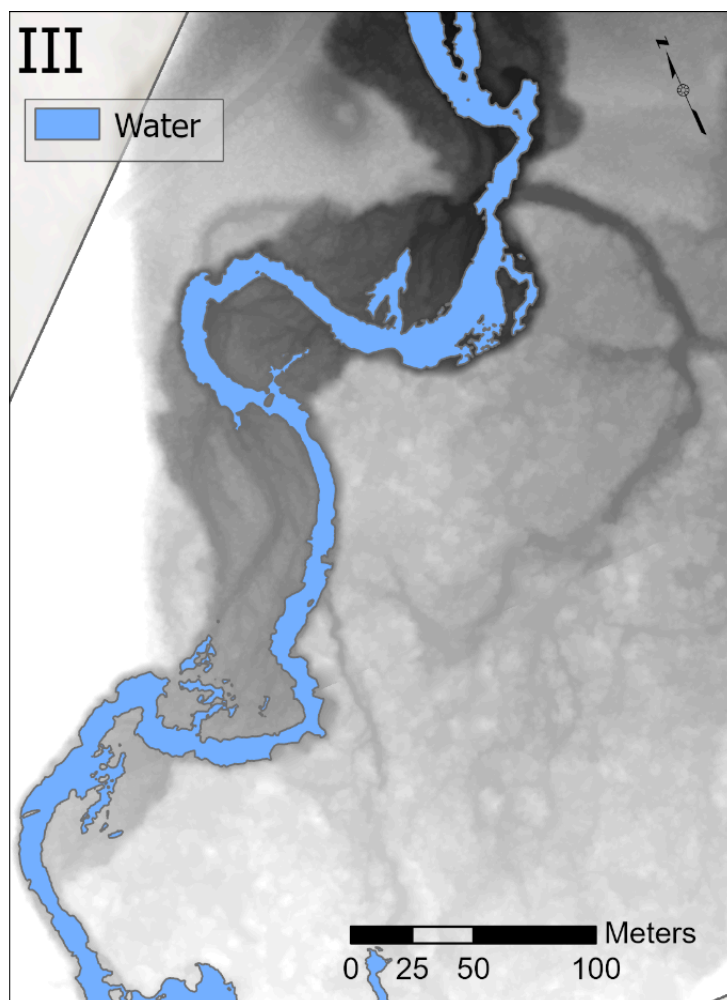


Figure 14. Land cover maps of a small section of Rush Creek showing water from the LiDAR data.

Ground Photography

Historical photographs were compiled in 2024/2025 season and new photographs were taken in May 2025 (Figures 15 through 17). Take note of the mountain in the background of the photos.



Figure 15. Photo of Rush Creek taken in 1920 (Stine et al., 1984).



Figure 16. Photo of Rush Creek taken in 1980 in the same location as the 1920 photo (Stine et al., 1984).



Figure 17. Photo of Rush Creek taken May 2025 in the same location as the 1920 and 1980 photos.

Discussion

From the confusion matrix outputs, Random Forest performed the best at 1.25 meters. However, upon visual inspection of the prediction map, this test was discarded due to extensive incorrectly classified water pixels that were predicted across the study area beyond the riparian area. This is likely due to the model selecting a decision tree with branches that satisfied the training data points but did not satisfy the rest of the study area. Additional covariates or more generalizable ground control points could fix this issue, but more research would need to be conducted to test this hypothesis. satisfy the rest of the study area. Additional covariates or more generalizable ground control points could fix this issue, but more research would need to be conducted to test this hypothesis.

Exclusion of the 1.25-meter Random Forest model run results in the SVM model at 1.25 meters and the Random Forest at 1.5 meters having the best performance. Overall, all models had adequate excellent results between 0.5 meters and 2 meters. The best performing models were between 1.25 and 1.5 meters, suggesting that VHR imagery is not necessary for highly accurate

LCLU classification models in the Mono Lake desert riparian ecosystem. Utilizing imagery that is slightly lower resolution than 1 meter could decrease the processing time and necessary processing power to achieve results.

The wide range of kappa coefficient values suggests that the models may be sensitive to specific train/test splits and future research may need to utilize more ground truthing points to achieve conclusive results. The ANOVA showed that there were no significant differences between the 1.5-meter RF model and the 1.25-meter SVM model. However, the SVM model class compositions most closely fit the actual compositions of the study area based on our experience of the study area when collecting ground truthing control points. When observing the SVM prediction map, the map had a more visually appealing generalized appearance due to the smoother clumping of pixels and decreased salt-and-pepper phenomenon. Other studies have found that pixel-based SVM can have this effect when compared to decision-tree models, such as CART and RF (Duro et al., 2012). Object-based analysis tends to have more accurate results in complex landscapes, but this analysis type requires more processing time (Duro et al., 2012). Our research findings suggest managers may want to utilize the pixel-based SVM model due to its visual appeal and more realistic portrayal of classes without the need for longer processing times.

Based on team observations on the ground in the study area, we determined the CART and RF models overpredicted herbaceous vegetation when compared to the SVM model. The ability for SVM to use hyperplanes may give the model an advantage when utilizing complex, heterogeneous, and possibly overlapping classes to create accurate prediction maps. However, more research is needed to determine the exact reason for these differences, but some studies suggest this may be due to the error within model training (Yimer et al., 2024).

There are a few possibilities as to why the RF model at 1.25 meters had extensive misclassified water pixels. Most of the models primarily utilized the bare ground vegetation model when predicting water pixels rather than utilizing the canopy height model for predicting water pixels. It is likely that the RF model had the highest accuracy because the model selected a decision tree that utilized the canopy height model to correctly classify many of the ground control points across classes, leading canopy height values of 0 or less to be classified as water regardless of where they occurred in the study area, rather than bare ground or herbaceous vegetation. This created extensive individual water pixels across the study area. However, this would need to be verified in future research. More fine tuning of the number of trees allowed in the model, referred to as the “ntree” parameter, to determine if a lower value provides more accurate results could be helpful in future studies. However, this would require more programming of the R script and increase the time necessary to run the model.

The dramatic increase in the bare ground class and decrease in the desert vegetation class in 2025 is likely due to the estimation and simplification methods of the bare ground and desert vegetation classes in the historical maps. The historical maps may have only included the bare ground class in areas that reached a certain threshold and then combined very small patches of bare ground with the desert vegetation class, but this was not reported in the Riparian Atlas

where the historical maps were acquired (McBain and Trush, 2005). Utilizing a map that does not combine bare ground patches into desert vegetation may yield a more accurate representation of the study area in future analyses.

Research into additional covariates that can accurately predict water to avoid manually digitizing the surface water could help improve accuracy in the future. Some studies have shown the possibility for the Automated Water Extraction Index (AWEI) to identify water by utilizing green, near infrared, and two shortwave infrared bands (Celik et al., 2019). Future annual surveys could utilize Worldview-3 superspectral imagery for AWEI and could incorporate other sensitive vegetation indices using the various multispectral bands the imagery contains as well. Further tuning of the cost parameter for the SVM model would be beneficial in future research as well. The current SVM model used a default value of 1 for the cost parameter which could potentially lead to underfitting, suggesting that the SVM model could have been more accurate had this parameter been tuned prior to running the models (Lin et al., 2005; Tharwat, 2019). Nonetheless, the SVM model performed well in the 0.5-meter to 2-meter range without the need for parameter tuning, suggesting that this model may be ideal for restoration managers due to less time needed to achieve results.

Resampling the 15-centimeter imagery to all the test resolutions could have led to possible incorrectly classified pixels that may not have been present in imagery that utilized its original resolution, such as resampling to 30-meter resolution versus acquiring Landsat imagery that is originally created at 30 meters. However, more research is needed to determine if resampling rather than acquiring data at original resolutions influences model accuracy. The inclusion of vegetation indices has improved model performance in other studies, but the similarities in pixel values across classes in the study area led us to not include vegetation indices in our final model. Utilization of hyperspectral data could allow us to home in on more sensitive vegetation indices, but this type of data can be extremely expensive (Roberts et al., 2018). Research into what vegetation indices could be effective in a desert riparian ecosystem could help improve model accuracy in the future.

Conclusion

This research was conducted as part of a long-term monitoring and restoration project that seeks to improve the fish and wildlife habitat of an iconic and important ecosystem by restoring wetlands along the study area (LADWP, 1996). Our 1.25-meter SVM model could be used to assist in the long-term monitoring of the study area by comparing the change in land cover over time. With the model performance being highest using a resolution above 1-meter, high computational power is unnecessary. In addition, UAV flights could occur at higher altitudes which would reduce time spent on each flight. However, it is recommended that land managers add more code to the R script to tune the cost parameter to improve performance. Furthermore, research into additional covariates using LiDAR or vegetation indices could also improve model performance. Through annual aerial surveys and ground control point data collection, land managers could effectively identify areas of concern, such as the decreasing percentage of important land cover types, before it becomes an extensive issue.

The two riparian vegetation classes have shown increases, suggesting they are shifting back towards the levels in the 1929 historical map. Restoration which increases these class types could help return these classes to previous composition. One obvious solution is to increase the flow rate by decreasing water diversions for human use. However, this has been a lengthy legal battle over the last half of a century (SWRCB, 1994; LADWP, 1996; SWRCB, 2017). Another possible solution would be to increase habitat for beavers due to their ability to increase wetland area in ecosystems through the creation of dams (Law et al., 2017). Further research needs to be conducted to determine the best method for increasing riparian vegetation in the study area.

Plans for the 2025/2026 Season

The next season will focus on:

- Obtaining complete datasets (LiDAR, RGB, and field surveys) for key areas.
- The field surveys will focus on those datasets that cannot be obtained through remote sensing, primarily the thalweg elevation and residual pools. This will include surveying the riffle crest thalwegs.
- As beavers have been identified in the area, we plan to survey the area of beaver sign and deploy wildlife cameras on a long term basis to capture beaver activity.

The areas will include:

- Mainstem Rush Creek from the Narrows downstream to Test Station Road culvert.
- Mainstem Lee Vining Creek from Route 395 crossing to Mono Lake.
- Parker and Walker creeks below their respective diversion dams.

We will then use similar processing techniques to identify land cover, topography, and wetted surface. Future datasets will then allow us to monitor land cover changes over time and changes in the topography of the riparian areas.

Data Management

All data collected is maintained by the Institute for Spatial Analysis, Modeling and Monitoring at Cal Poly Humboldt (<http://gis.humboldt.edu/isamm/>). Dr. Jim Graham is the director of the institute. The data is stored on a secure Google Drive shared drive.

A website is in development to allow visualization of the spatial data at:

<http://gis.humboldt.edu/websites/monolake/>

Archives of the data are made periodically and backups are maintained by Cal Poly Humboldt's Information and Technology Services department.

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References

- Adujna, T., Xu, W., & Fan, J. (2022). Comparison of Random Forest and Support Vector Machine Classifiers for Regional Land Cover Mapping Using Coarse Resolution FY-3C Images. *Remote Sensing*, 14(3), 574. <https://doi.org/10.3390/rs14030574>
- Agisoft. (2024). Metashape (Version 2.1.3) [Computer Software]. Agisoft.
- Amalisana, B., Rokhmatullah, & Hernina, R. (2017). Land Cover Analysis by Using Pixel-Based and Object-Based Image Classification Method in Bogor. *IOP Conference Series: Earth and Environmental Science*, 98(1), 012005. <https://doi.org/10.1088/1755-1315/98/1/012005>
- Baboo, D. S. S., & Devi, M. R. (2010). An Analysis of Different Resampling Methods in Coimbatore, District. *Global Journal of Computer Science and Technology*, 10(5).
- Basheer, S., Wang, X., Farooque, A. A., Nawaz, R. A., Liu, K., Adekanmbi, T., & Liu, S. (2022). Comparison of Land Use Land Cover Classifiers Using Different Satellite Imagery and Machine Learning Techniques. *Remote Sensing*, 14(19), 4978. <https://doi.org/10.3390/rs14194978>
- Benediktsson, J. A., Chanussot, J., & Moon, W. M. (2012). Very High-Resolution Remote Sensing: Challenges and Opportunities. *Proceedings of the IEEE*, 100(6), 1907–1910. <https://doi.org/10.1109/JPROC.2012.2190811>
- Bertacchi, A., Giannini, V., Di Franco, C., & Silvestri, N. (2019). Using unmanned aerial vehicles for vegetation mapping and identification of botanical species in wetlands. *Landscape and Ecological Engineering*, 15(2), 231–240. <https://doi.org/10.1007/s11355-018-00368-1>
- Cardinale, B. J., Srivastava, D. S., Emmett Duffy, J., Wright, J. P., Downing, A. L., Sankaran, M., & Jouseau, C. (2006). Effects of biodiversity on the functioning of trophic groups and ecosystems. *Nature*, 443(7114), 989–992. <https://doi.org/10.1038/nature05202>
- Celik, B., Kaya, S., Ugur, A., & Seker, D. (2019). Assessment of the relationship between land use/cover changes and land surface temperatures: A case study of thermal remote sensing. *Fresenius Environmental Bulletin*, 28.

- Chen, Y., Zhou, Y., Ge, Y., An, R., & Chen, Y. (2018). Enhancing Land Cover Mapping through Integration of Pixel-Based and Object-Based Classifications from Remotely Sensed Imagery. *Remote Sensing*, 10(1), 77. <https://doi.org/10.3390/rs10010077>
- CloudCompare. (2024) CloudCompare (Version 2.13.2) [Computer Software]. CloudCompare.
- Colvin, S. A. R., Sullivan, S. M. P., Shirey, P. D., Colvin, R. W., Winemiller, K. O., Hughes, R. M., Fausch, K. D., Infante, D. M., Olden, J. D., Bestgen, K. R., Danehy, R. J., & Eby, L. (2019). Headwater Streams and Wetlands are Critical for Sustaining Fish, Fisheries, and Ecosystem Services. *Fisheries*, 44(2), 73–91. <https://doi.org/10.1002/fsh.10229>
- Cruzan, M. B., Weinstein, B. G., Grasty, M. R., Kohrn, B. F., Hendrickson, E. C., Arredondo, T. M., & Thompson, P. G. (2016). Small unmanned aerial vehicles (micro-UAVs, drones) in plant ecology. *Applications in Plant Sciences*, 4(9), 1600041. <https://doi.org/10.3732/apps.1600041>
- Cubaynes, H. C., Clarke, P. J., Goetz, K. T., Aldrich, T., Fretwell, P. T., Leonard, K. E., & Khan, C. B. (2023). Annotating very high-resolution satellite imagery: A whale case study. *MethodsX*, 10, 102040. <https://doi.org/10.1016/j.mex.2023.102040>
- Drobnjak, S., Stojanović, M., Djordjević, D., Bakrač, S., Jovanović, J., & Djordjević, A. (2022). Testing a New Ensemble Vegetation Classification Method Based on Deep Learning and Machine Learning Methods Using Aerial Photogrammetric Images. *Frontiers in Environmental Science*, 10. <https://doi.org/10.3389/fenvs.2022.896158>
- Duro, D., Franklin, S., & Dube, M. (2012). A comparison of pixel-based and object-based image analysis with selected machine learning algorithms for the classification of agricultural landscapes using SPOT-5 HRG imagery. *Remote Sensing of Environment*, 118, 259–272. <https://doi.org/10.1016/j.rse.2011.11.020>
- ESRI. (2024). ArcGIS Pro (Version 3.4.0) [Computer Software]. ESRI.
- He, Y., & Weng, Q. (2018). *High Spatial Resolution Remote Sensing: Data, Analysis, and Applications*. CRC Press.
- Huylenbroeck, L., Laslier, M., Dufour, S., Georges, B., Lejeune, P., & Michez, A. (2020). Using remote sensing to characterize riparian vegetation: A review of available tools and perspectives for managers. *Journal of Environmental Management*, 267, 110652. <https://doi.org/10.1016/j.jenvman.2020.110652>
- Jin, S., Su, Y., Gao, S., Hu, T., Liu, J., & Guo, Q. (2018). The Transferability of Random Forest in Canopy Height Estimation from Multi-Source Remote Sensing Data. *Remote Sensing*, 10(8), Article 8. <https://doi.org/10.3390/rs10081183>
- Johnson, R. R., & Jones, D. A. (1977). Importance, preservation and management of riparian habitat: A symposium; Tucson, Arizona; July 9, 1977 (General Technical Report RM-43). USDA Forest Service.
- Keys, R. (1981). Cubic convolution interpolation for digital image processing. *IEEE Transactions on Acoustics, Speech, and Signal Processing*, 29(6), 1153–1160. <https://doi.org/10.1109/TASSP.1981.1163711>
- Knight, A. W., & Bottorff, R. L. (1984). The Importance of Riparian Vegetation to Stream Ecosystems. In R. E. Warner & K. M. Hendrix (Eds.), *California Riparian Systems* (pp. 160–167). University of California Press. <https://doi.org/10.2307/jj.8501409.25>
- Kumari, A., & Karthikeyan, S. (2025). A Comparative Analysis for Forty Years of Land Use Land Cover Change (1991–2021) Using Cart and Random Forest Classifiers for Varanasi

- District (India). *SN Computer Science*, 6(5), 521.
<https://doi.org/10.1007/s42979-025-04061-7>
- Law, A., Gaywood, M. J., Jones, K. C., Ramsay, P., & Willby, N. J. (2017). Using ecosystem engineers as tools in habitat restoration and rewilding: Beaver and wetlands. *Science of The Total Environment*, 605–606, 1021–1030.
<https://doi.org/10.1016/j.scitotenv.2017.06.173>
- Li, R., Gao, X., Shi, F., & Zhang, H. (2023). Scale Effect of Land Cover Classification from Multi-Resolution Satellite Remote Sensing Data. *Sensors*, 23(13), 6136.
<https://doi.org/10.3390/s23136136>
- Lin, P.-T., Su, S.-F., & Lee, T.-T. (2005). Support vector regression performance analysis and systematic parameter selection. *Proceedings. 2005 IEEE International Joint Conference on Neural Networks*, 2005., 2, 877–882 vol. 2.
<https://doi.org/10.1109/IJCNN.2005.1555968>
- Los Angeles Department of Water and Power. (1996). Mono Basin Stream & Stream Channel Restoration Plan. <https://www.monobasinresearch.org/legal/1996streamplan.pdf>
- Lyons, M. B., Keith, D. A., Phinn, S. R., Mason, T. J., & Elith, J. (2018). A comparison of resampling methods for remote sensing classification and accuracy assessment. *Remote Sensing of Environment*, 208, 145–153.
<https://doi.org/10.1016/j.rse.2018.02.026>
- McBain & Trush, Inc. (2005). 2005 Riparian Atlas.
- Microsoft. (2025). Microsoft 365. (Version 2511) [Computer Software]. Microsoft.
- Minh, N. Q., Huong, N. T. T., Khanh, P. Q., Hien, L. P., & Bui, D. T. (2024). Impacts of Resampling and Downscaling Digital Elevation Model and Its Morphometric Factors: A Comparison of Hopfield Neural Network, Bilinear, Bicubic, and Kriging Interpolations. *Remote Sensing*, 16(5), 819. <https://doi.org/10.3390/rs16050819>
- Mishra, V. N., Rai, P. K., Kumar, P., & Prasad, R. (2016). Evaluation of land use/land cover classification accuracy using multi-resolution remote sensing images. *Forum Geographic*, XV(1), 45–53. <https://doi.org/10.5775/fg.2016.137.i>
- Mono Basin Research Group. (1977). Ecological Study of Mono Lake. Institute of Ecology, 12. <https://monobasinresearch.org/online-reports/1976study/ecologicalstudyofmonolake.pdf>
- Mount, J. F. (2023). *California Rivers and Streams: The Conflict Between Fluvial Process and Land Use*. University of California Press.
- Moyle, P. B., & Randall, P. J. (1998). Evaluating the Biotic Integrity of Watersheds in the Sierra Nevada, California. *Conservation Biology*, 12(6), 1318–1326.
- Murtaza, K. O., & Romshoo, S. A. (2014). Assessing the Impact of Spatial Resolution on the Accuracy of Land Cover Classification. *Sustainable Development*.
- National Research Council. (1987). *The Mono Basin Ecosystem: Effects of Changing Lake Level* (p. 1007). National Academies Press. <https://doi.org/10.17226/1007>
- Norman, L., Villarreal, M., Pulliam, H. R., Minckley, R., Gass, L., Tolle, C., & Coe, M. (2014). Remote sensing analysis of riparian vegetation response to desert marsh restoration in the Mexican Highlands. *Ecological Engineering*, 70, 241–254.
<https://doi.org/10.1016/j.ecoleng.2014.05.012>
- NV5. (2025). ENVI (Version 6.5) [Computer Software]. NV5.
- Posit (2025). RStudio (Version 2025.05) [Computer Software]. Posit.

- Qian, Y., Zhou, W., Yan, J., Li, W., & Han, L. (2015). Comparing Machine Learning Classifiers for Object-Based Land Cover Classification Using Very High Resolution Imagery. *Remote Sensing*, 7(1), 153–168. <https://doi.org/10.3390/rs70100153>
- Ramezan, C. A., Warner, T. A., Maxwell, A. E., & Price, B. S. (2021). Effects of Training Set Size on Supervised Machine-Learning Land-Cover Classification of Large-Area High-Resolution Remotely Sensed Data. *Remote Sensing*, 13(3), 368. <https://doi.org/10.3390/rs13030368>
- Richards, J. A. (2022). Supervised Classification Techniques. In J. A. Richards (Ed.), *Remote Sensing Digital Image Analysis* (pp. 263–367). Springer International Publishing. https://doi.org/10.1007/978-3-030-82327-6_8
- Roberts, D. A., Roth, K. L., Wetherley, E. B., Meerdink, S. K., & Perroy, R. L. (2018). Hyperspectral Vegetation Indices. In *Hyperspectral Indices and Image Classifications for Agriculture and Vegetation* (2nd ed.). CRC Press.
- Sathyanarayanan, S. (2024). Confusion Matrix-Based Performance Evaluation Metrics. *African Journal of Biomedical Research*, 4023–4031. <https://doi.org/10.53555/AJBR.v27i4S.4345>
- Savitha, C., & Talari, R. (2025). Evaluating the performance of random forest, support vector machine, gradient tree boost, and CART for improved crop-type monitoring using greenest pixel composite in Google Earth Engine. *Environmental Monitoring and Assessment*, 197(4), 437. <https://doi.org/10.1007/s10661-025-13880-3>
- Shirzadi, A., Solaimani, K., Roshan, M. H., Kaviani, A., Chapi, K., Shahabi, H., Keesstra, S., Ahmad, B. B., & Bui, D. T. (2019). Uncertainties of prediction accuracy in shallow landslide modeling: Sample size and raster resolution. *CATENA*, 178, 172–188. <https://doi.org/10.1016/j.catena.2019.03.017>
- Smith, S. D., Wellington, A. B., Nachlinger, J. L., & Fox, C. A. (1991). Functional Responses of Riparian Vegetation to Streamflow Diversion in the Eastern Sierra Nevada. *Ecological Applications*, 1(1), 89–97. <https://doi.org/10.2307/1941850>
- Song, F., Zhang, W., Yuan, T., Ji, Z., Cao, Z., Xu, B., Lu, L., & Zou, S. (2024). UAV Quantitative Remote Sensing of Riparian Zone Vegetation for River and Lake Health Assessment: A Review. *Remote Sensing*, 16(19), 3560. <https://doi.org/10.3390/rs16193560>
- Stine, S. (1991). Extent of riparian vegetation on streams tributary to Mono Lake, 1930 -1940: An assessment of the streamside woodlands and wetlands, and the environmental conditions that supported them. Mono Basin Water Rights EIR. <https://www.monobasinresearch.org/images/mbeir/auxreports/01-riparian.pdf>
- Stine, S., Gaines, D., & Vorster, P. (1984). Destruction of Riparian Systems Due to Water Development in the Mono Lake Watershed. In R. E. Warner & K. M. Hendrix (Eds.), *California Riparian Systems* (DGO-Digital original, 1, pp. 528–533). University of California Press. <https://doi.org/10.2307/jj.8501409.73>
- Tharwat, A. (2019). Parameter investigation of support vector machine classifier with kernel functions. *Knowledge and Information Systems*, 61(3), 1269–1302. <https://doi.org/10.1007/s10115-019-01335-4>
- Ullah, S., Shafique, M., Farooq, M., Zeeshan, M., & Dees, M. (2017). Evaluating the impact of classification algorithms and spatial resolution on the accuracy of land cover mapping in

- a mountain environment in Pakistan. *Arabian Journal of Geosciences*, 10(3), 67.
<https://doi.org/10.1007/s12517-017-2859-6>
- Uyeda, K. A., Warkentin, K. K., Stow, D. A., O'Leary, J. F., Snaveley, R. A., Lambert, J., Bolick, L. A., O'Connor, K., Munson, B., Loerch, A. C., & Schmidtlein, S. (2020). Vegetation mapping using hierarchical object-based image analysis applied to aerial imagery and lidar data. *Applied Vegetation Science*, 23(1), 80–93. <https://doi.org/10.1111/avsc.12467>
- Virah-Sawmy, M., Gillson, L., & Willis, K. J. (2009). How does spatial heterogeneity influence resilience to climatic changes? *Ecological dynamics in southeast Madagascar*. *Ecological Monographs*, 79(4), 557–574. <https://doi.org/10.1890/08-1210.1>
- Weih, R. C., & Riggan, N. D. (2009). Object-based Classification vs. Pixel-based Classification: Comparative Importance of Multi-resolution Imagery. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 38(4).
- Wen, L., & Hughes, M. (2020). Coastal Wetland Mapping Using Ensemble Learning Algorithms: A Comparative Study of Bagging, Boosting and Stacking Techniques. *Remote Sensing*, 12(10), 1683. <https://doi.org/10.3390/rs12101683>
- Worstell, B. B., Poppenga, S. K., Evans, G. A., & Prince, S. (2014). Lidar point density analysis: Implications for identifying water bodies. In *Scientific Investigations Report* (Nos. 2014–5191). U.S. Geological Survey. <https://doi.org/10.3133/sir20145191>
- Yang, S., & Berdine, G. (2024). Confusion matrix. *The Southwest Respiratory and Critical Care Chronicles*, 12(53), 75–79. <https://doi.org/10.12746/swrccc.v12i53.1391>
- Yimer, S. M., Bouanani, A., Kumar, N., Tischbein, B., & Borgemeister, C. (2024). Comparison of different machine-learning algorithms for land use land cover mapping in a heterogenous landscape over the Eastern Nile river basin, Ethiopia. *Advances in Space Research*, 74(5), 2180–2199. <https://doi.org/10.1016/j.asr.2024.06.010>
- Yu, Q., Gong, P., Clinton, N., Biging, G., Kelly, M., & Schirokauer, D. (2006). Object-based Detailed Vegetation Classification with Airborne High Spatial Resolution Remote Sensing Imagery. *Photogrammetric Engineering & Remote Sensing*, 72(7), 799–811. <https://doi.org/10.14358/PERS.72.7.799>
- Zhi, J., Zhang, G., Yang, R., Yang, F., Jin, C., Liu, F., Song, X., Zhao, Y., & Li, D. (2018). An Insight into Machine Learning Algorithms to Map the Occurrence of the Soil Mattic Horizon in the Northeastern Qinghai-Tibetan Plateau. *Pedosphere*, 28(5), 739–750. [https://doi.org/10.1016/S1002-0160\(17\)60481-8](https://doi.org/10.1016/S1002-0160(17)60481-8)

Section III. Mono Lake Limnological
Monitoring 2025 Annual Report

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2025 Annual Report

Mono Lake Limnological Monitoring

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CHAPTER 1

INTRODUCTION

Saline lakes are widely recognized as productive aquatic habitats that harbor distinctive assemblages of species and often support large populations of resident or migratory birds. Saline lakes throughout the world are threatened by decreasing size and increasing salinity due to climate change and diversions of freshwater inflows for irrigation and other human uses. At Mono Lake, California, diversions of freshwater streams out of the basin beginning in 1941 led to a decline in surface elevation and an increase in the lake's salinity. In 1994, the State Water Resources Control Board (SWRCB) of California issued a decision to amend Los Angeles' water rights (Decision 1631) by restricting water diversions until the surface elevation of the lake reached 1,948 m (6392 ft).

Long-term monitoring of the plankton and their physical, chemical, and biological environment is essential to understanding the effects of changing lake levels and salinities and has been mandated by the SWRCB. Measurements of the vertical distribution of temperature, dissolved oxygen, conductivity, and nutrients are requisite for interpreting how variations in these variables affect plankton populations. The limnological monitoring program at Mono Lake includes the collection and interpretation of limnological data.

This report fulfills the requirements for limnological monitoring of Mono Lake set forth in State Water Resources Control Board Order Nos. 98-05 and 98-07. The limnological monitoring program consists of four components: meteorological, physical and chemical, phytoplankton, and brine shrimp (*Artemia*) populations. Meteorological data are collected with sensors on Paoha Island, while the other three components are assessed during monthly surveys (except when the lake is inaccessible in winter). The methodology employed is detailed in Chapter 2, and results obtained during 2025 are presented in Chapter 3. In Chapter 4 we use measurements made with sensors suspended in Mono Lake to provide further analyses of stratification and mixing, and related variations in dissolved oxygen. We also present results from a series of experiments done to develop a method for estimating primary production by phytoplankton using changes in dissolved oxygen. In addition, measurements of particulate

carbon and nitrogen are used to examine seasonal variations in particulate matter and to evaluate relationships with chlorophyll concentrations.

This work was supported by a contract from the National Fish and Wildlife Foundation with funds from the Los Angeles Department of Water and Power (LADWP) to J. M. Melack at the Earth Research Institute, University of California, Santa Barbara. Laboratory work was performed at the Sierra Nevada Aquatic Research Laboratory, University of California. We thank Everett Phillipps, Juyung Yoo, and Max Grensted for field assistance, and Sally MacIntyre for analysis of the moored sensor data.

CHAPTER 2

METHODS

Meteorology

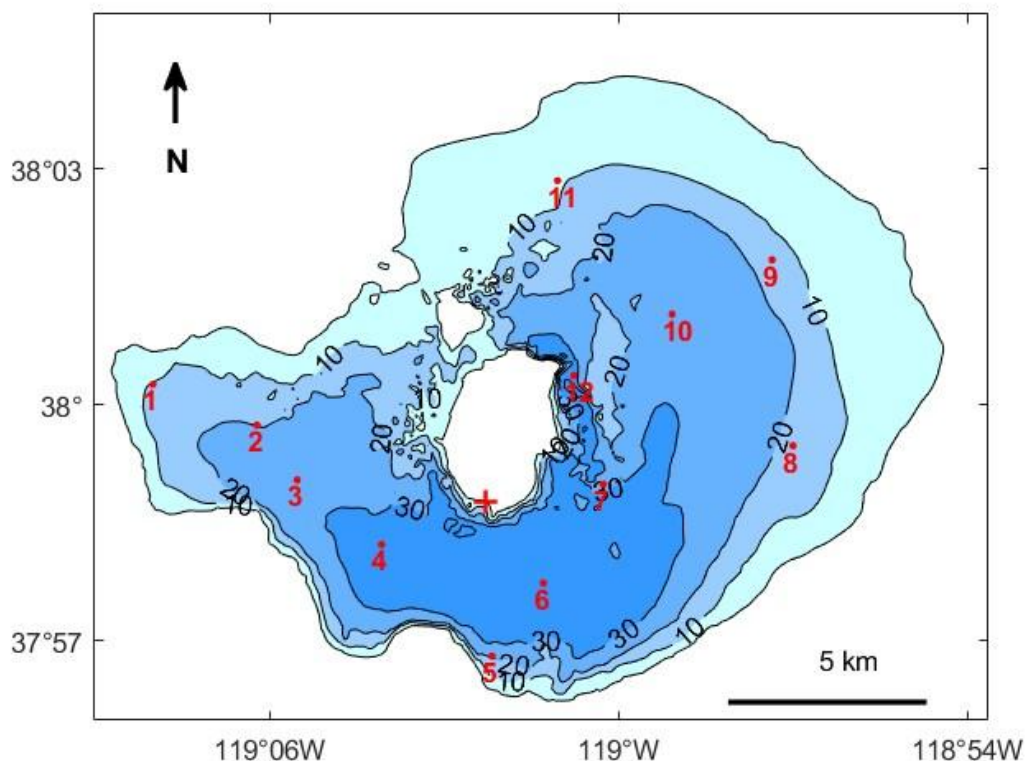
Meteorological measurements are recorded at a station located on the southwestern shore of Paoha Island at 1948 m elevation (Fig. 1), approximately 2 meters above the current elevation of the lake. Samples are collected at 1-minute intervals, with data logged every 5 minutes and stored on an Onset RX3004 logger; data are uploaded to LI-COR Cloud® web-based software at cellular connection intervals of 1 hour. The meteorological station was installed on 30 May 2023.

Wind speed and direction are measured at a height of 3 m above the surface of the island with an R.M. Young wind monitor (model 5103 with threshold of 1 m s^{-1} for propeller and 1.1 m s^{-1} for vane and accuracy of $\pm 0.3 \text{ m s}^{-1}$ or 1% of reading, and $\pm 3^\circ$ for wind direction). Mean wind speed and direction and maximum wind speed during each five-minute interval are recorded. Additional measurements include photosynthetically available radiation (PAR, spectral range 400 to 700 nm, Onset sensor S-LIA-M003 with a resolution of $2.5 \mu\text{mol m}^{-2} \text{ s}^{-1}$ and accuracy of $\pm 5 \mu\text{mol m}^{-2} \text{ s}^{-1}$), solar radiation (spectral range 300 to 1100 nm, Onset sensor S-LIB-M003 with resolution of 1.25 W m^{-2} and accuracy of $\pm 10 \text{ W m}^{-2}$ or $\pm 5\%$, if greater), barometric pressure (Onset sensor S-BPM-CM50 with resolution of 0.01 mbar and accuracy of ± 3.0 mbar), and relative humidity (RH) and air temperature (Onset sensor S-THC with a resolution of 0.02°C and of 0.01% for RH, and accuracy of $\pm 0.25^\circ\text{C}$ and $\pm 2.5\%$ from 10% to 90% RH or $\pm 5\%$ below 10% and above 90% RH). Rainfall rates and cumulative amounts are obtained with an unheated tipping bucket gauge (Onset sensor S-RGB-M002 with a resolution of 0.2 mm, and 1% accuracy for rainfall rates up to 12.7 cm h^{-1}).

Sampling Regime

The limnological monitoring program in 2025 included monthly surveys from February through December. Surveys include sampling at 12 stations (Fig. 1) over one or two days depending on the weather conditions. When conducted over two days, lakewide surveys and Station 6 profiles are conducted on consecutive days, when possible.

Fig. 1. Sampling stations on Mono Lake. Red points and numbers indicate permanently moored buoys, + sign indicates location of Paoha Island meteorological Station. Depth contours are in meters.



Field Procedures

In Situ Profiles

Depth, water temperature, conductivity, dissolved oxygen, fluorescence and turbidity are measured at twelve buoyed stations with a free-falling profiler (Rinko profiler model ASTD 102 with extended conductivity range): depth, resolution 0.02 m and accuracy $\pm 0.3\%$; temperature, resolution 0.001 $^{\circ}\text{C}$ and accuracy ± 0.01 $^{\circ}\text{C}$; conductivity, resolution 0.001 mS cm^{-1} and accuracy ± 0.01 mS cm^{-1} ; dissolved oxygen, resolution 0.01 mg L^{-1} and accuracy $\pm 2\%$. The Rinko oxygen probe is calibrated against Miller titrations (Walker et al. 1970) of Mono Lake water at a range of salinities. Fluorescence outputs require calibration for conditions in Mono Lake to correct readings for chlorophyll.

The profiler is lowered at a rate of $\sim 0.2 \text{ m s}^{-1}$ and sampled at 100-ms intervals or approximately every 2 cm. Pressure readings are converted to depth using ambient air pressure at

the time of readings and the density profile based on in-situ temperature and salinity. Relationships between conductivity, temperature, salinity, and density for the chemical composition of Mono Lake are given by Jellison et al. (1999a, b). Conductivity readings at in-situ temperatures (C_t) are converted to specific conductance at 25 °C (C_{25}) using:

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

where t is the in-situ temperature. The density of Mono Lake water is given by:

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

Total dissolved solids derived from conductivity for Mono Lake water is given by:

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

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

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

Mono Lake often has strong vertical temperature and salinity gradients. A mismatch in sensor time constants or water parcel sampled by the thermistor and conductivity electrode will result in spiking (MacIntyre and Jellison 2001). While the time constants for the Rinko thermistor and conductivity electrodes are both listed by the manufacturer as 0.2 s, laboratory experiments indicated thermistor and conductivity electrode time constants of 0.14 s and 0.05 s, respectively. Conductivity spiking was examined after shifting the temperature readings by 0, 0.1, 0.2, 0.3, 0.4, and 0.5 s relative to conductivity in profiles over the course of the year, with a 0.2 s shift providing the least amount of spiking. Therefore, temperature readings were shifted by 0.2 s when calculating standardized (25 °C) conductivity. Depending on the details of each profile spiking may still occur after accounting for the difference in sensor response times; spikes were removed by visually inspecting each profile and then conductivity readings were further smoothed by a 6-point (~0.12 m) moving average.

Time-series measurements of water temperature are obtained with RBR Solo® thermistors (accuracy 0.002 °C) sampling every ten seconds and deployed on moorings at Stations 3, 5 and 6. Uppermost thermistors were suspended below and shaded by a surface float,

and deeper ones were on a taut-line mooring suspended from a float ~0.5 to 1 m below the water surface. Moored RBR Concerto³ conductivity-temperature-depth sensors, PME (Precision Measurement Engineering) MiniDOT optical dissolved oxygen sensors with wipers to remove biofouling every 6 hours, and Turner C-Fluor chlorophyll sensors with wipers to remove biofouling every 6 hours, are deployed on the mooring lines at several depths.

Transparency is estimated as the depth a white Secchi disc, 20 cm in diameter, is visible, viewed on the shaded side of the boat to avoid glare, and, under calm conditions, if possible.

Vertical profiles of photosynthetically active radiation (400 to 700 nm, PAR) were obtained using a Licor LI-192 SB underwater sensor, and the attenuation coefficient of PAR was computed from the profiles.

Water Samples

Samples for chlorophyll and ammonium analyses are collected from nine discrete depths (0.2, 2, 8, 12, 16, 20, 24, 28, and 35 m) at Station 6, and with a 0 to 9 m integrating tube sampler at seven Stations (1, 2, 5, 6, 7, 8, and 11). Samples for ammonium analyses are filtered immediately upon collection through Gelman A/E glass-fiber filters and kept chilled and dark until returned to the laboratory. Water samples used for analysis of chlorophyll are filtered through a 120- μ m sieve to remove all stages of *Artemia* and kept chilled and dark until filtered in the laboratory.

Artemia Samples

Artemia are sampled by one net tow at each of the twelve, buoyed stations. Samples are taken with a plankton net (1 m x 0.30 m diameter, 120- μ m Nitex mesh) towed vertically through the water column. The depth of the tow varies seasonally and with station depth. During the hatching period (January–May), when nauplii may be distributed throughout the water column, net hauls extend to 1 m above the bottom at each station. After the oxycline becomes established and hatching is no longer evident (June–December), vertical tows are limited to 20 m at stations deeper than 20 m. At shallower stations, tows extend to 1 m above the bottom. Samples are preserved with 5% formalin in lake water. When adults are present, an additional net tow is taken from Stations 1, 2, 5, 6, 7, 8, and 11 to collect adult females for brood size and length analysis. A net efficiency factor of 70% was used (Lenz 1984).

Laboratory Procedures

Water Samples

Samples are returned to the laboratory and within 7 hours of collection are analyzed for ammonium and filtered for subsequent chlorophyll determinations. Chlorophyll samples are filtered onto 47 mm Whatman GF/F filters and kept frozen until the pigments are analyzed within one to two weeks.

Filters for chlorophyll *a* analyses are homogenized in 90% acetone and extracted at room temperature in the dark. Following clarification by centrifugation, absorption is measured at 750 and 663 nm on a spectrophotometer (Abbott Corporation, model SV1100D spectrophotometer). The sample is then acidified in the cuvette, and absorption again determined at the same wavelengths to correct for phaeopigments. Absorptions were converted to phaeophytin-corrected chlorophyll *a* concentrations with the formula (Golterman & Clymo, 1969):

$$Chl_s = 27.46[(A663_0 - A750_0) - 1.054(A663_a - A750_a)]1000v/V$$

where:

Chl_s = chlorophyll *a* concentration of sample ($\mu\text{g L}^{-1}$)

$A663_0$ = absorption at 663 nm before acidification

$A750_0$ = absorption at 750 nm before acidification

$A663_a$ = absorption at 663 nm after acidification

$A750_a$ = absorption at 750 nm after acidification

v = Volume of extract (mL)

V = Volume of filtered water (mL)

1.054 = volume correction after addition of 200 μL acid

During periods of low phytoplankton concentrations ($<5 \mu\text{g chl } a \text{ L}^{-1}$), fluorescence of extracted pigments is measured on a fluorometer (Turner Designs, model TD-700) calibrated using dilutions of samples measured spectrophotometrically. Fluorometric determination of chlorophyll *a* is obtained with the formula:

$$Chl_s = [(\tau/\tau - 1)(R_0 - R_a)]/(v/V)$$

where:

Chl_s = Chlorophyll *a* concentration of the sample ($\mu\text{g L}^{-1}$)

τ = ratio of standard R_b/R_a

R_0 = before acid fluorometer reading ($\mu\text{g L}^{-1}$)

R_a = after acid fluorometer reading of sample ($\mu\text{g L}^{-1}$)

v = volume extracted (mL)

V = volume filtered (mL)

Ammonium concentrations are measured using the indophenol blue method (Strickland & Parsons 1972). Internal standards are used to account for matrix effects in Mono Lake water.

Samples for particulate carbon and nitrogen (C:N) analyses were collected monthly at Station 6 using a 0–9 m integrated tube sampler and Van Dorn samplers at discrete depths (2, 16, and 24 m). Samples were passed through a 120- μm sieve to remove all stages of *Artemia*.

Particulate material was collected by filtering water onto pre-ashed 25 mm Whatman GF/F or Gelman A/E glass-fiber filters. Filters were ashed at 450 °C for 4 h prior to use. Following filtration, filters were acid-fumed over concentrated HCl for approximately 12 h to remove inorganic carbon, air-equilibrated in a fume hood, and dried at 50–60 °C for 12–16 h. Processed filters were stored frozen until analysis. Particulate carbon and nitrogen concentrations were determined using a CHN elemental analyzer at the Marine Science Institute Analytical Laboratory, University of California, Santa Barbara. Carbon and nitrogen concentrations were converted to molar units using atomic masses.

Artemia Samples

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

Live females collected for brood size and length analysis are kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females are randomly selected, isolated in individual vials, and preserved with 5% formalin in lake water. Brood size is determined by counting the number of eggs in the ovisac including those dropped

in the vial, and egg type and shape are noted. Female length (mm) is measured from the tip of the head to the end of the caudal furca (setae not included).

Artemia biomass (dry weight) is obtained from the whole sample or first split of counted samples by drying at 60 °C for 48 h.

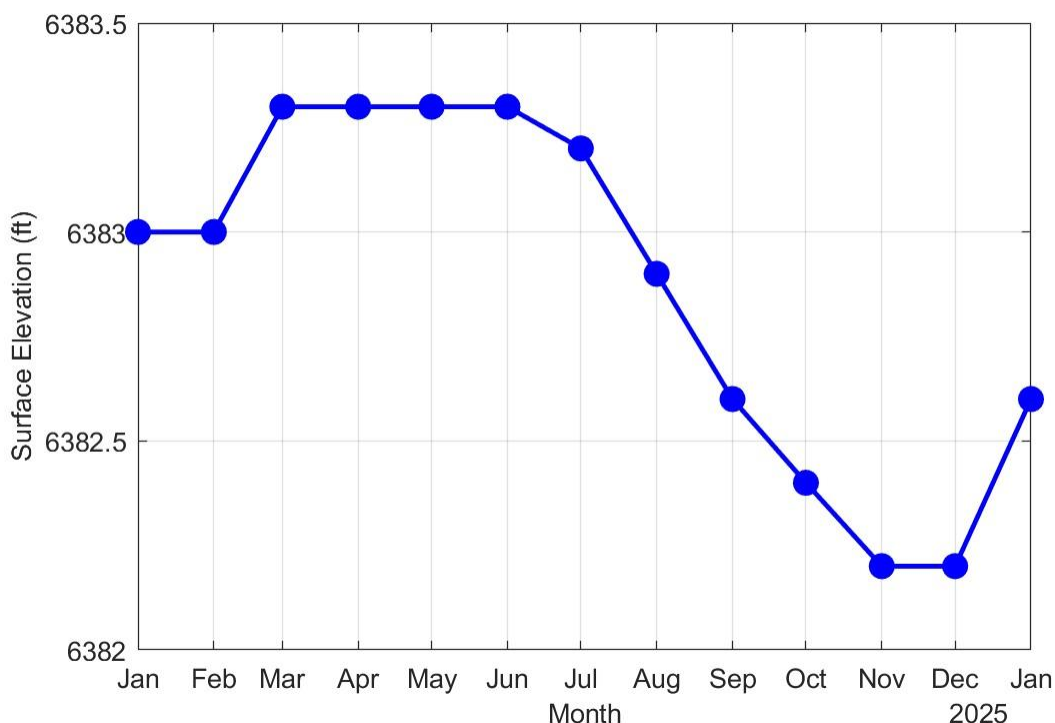
CHAPTER 3

RESULTS AND DISCUSSION

Surface Elevation

Snowmelt runoff, climatic conditions, and diversion policies in 2025 resulted in ~0.3 ft surface elevation rise from 6383 ft on 1 January 2025 to 6383.3 ft on 1 June 2025 (Fig. 2, Mono Lake Committee, pers. comm.). Beginning in July, lake level declined steadily through autumn, reaching an annual low of approximately 6382.2 ft in November. A slight increase was observed in December, with elevations rising to ~6382.3 ft by year's end.

Fig. 2. Mono Lake surface elevation, 2025 (ft asl, USGS datum).



Meteorological Data

Wind Speed and Direction

Wind has diel variation in the Mono Basin with WSW winds increasing in the afternoon. Daily minimum wind speed exceeded 1 m s^{-1} on 90 days. Exceptionally high hourly mean wind speeds of 17.8 m s^{-1} were observed on 2 February, when gusts up to 22.8 m s^{-1} were recorded

(Fig. 3). Several other periods of sustained higher winds occurred during late winter and autumn, most notably in February–March and October–December. Winds were predominately from the west southwest (Fig. 4).

Fig. 3. Hourly mean wind speed (m s^{-1}), 2025.

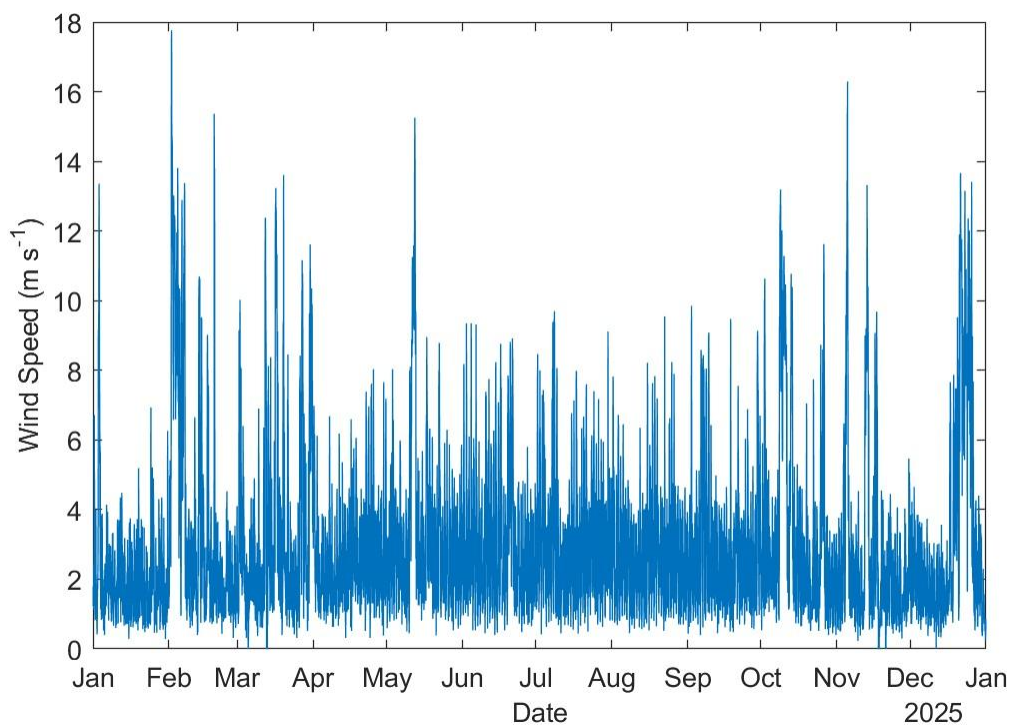
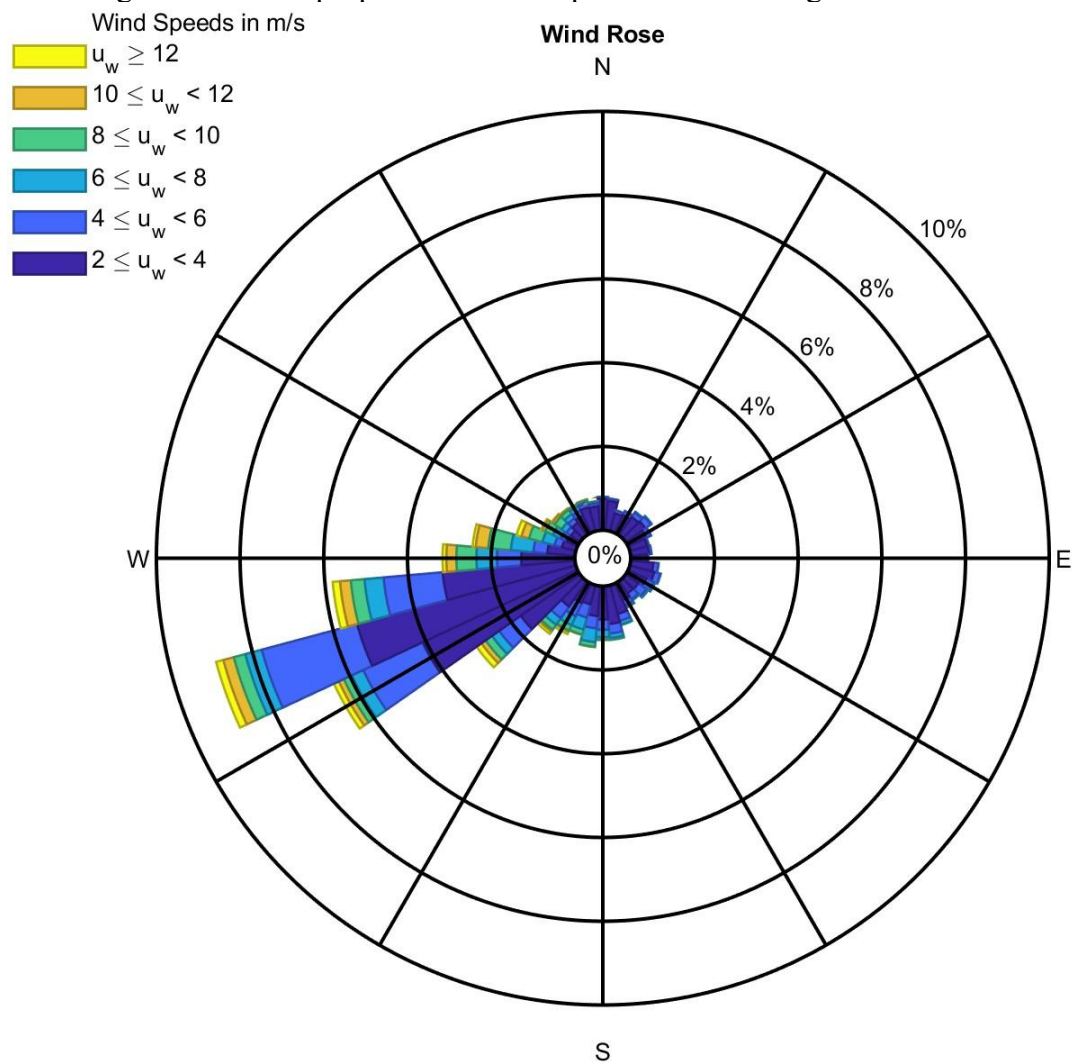


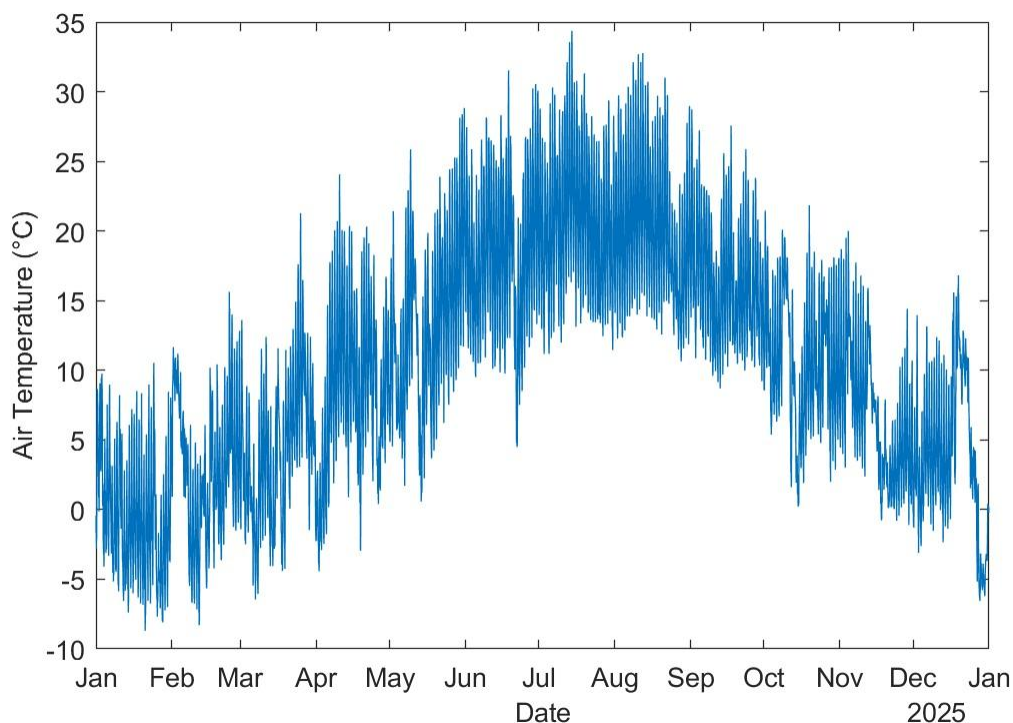
Fig. 4. Wind rose of hourly mean direction and speed, 2025. Colors denote wind speeds in m s^{-1} . Percentages refer to the proportion of time spent in each 10-degree wind direction sector.



Air Temperature

Hourly mean air temperatures generally ranged from ~12 to 29 °C in summer with several periods with highs of 30 to 34 °C in midsummer (Fig. 5). The maximum hourly mean temperature was 34.4 °C on 14 July. Winter hourly temperatures were typically ~-6 to 11 °C, with exceptionally cold temperatures (-5 to -10 °C) occurring briefly in January, February, and December. The minimum hourly mean temperature was -8.7 °C on 21 January.

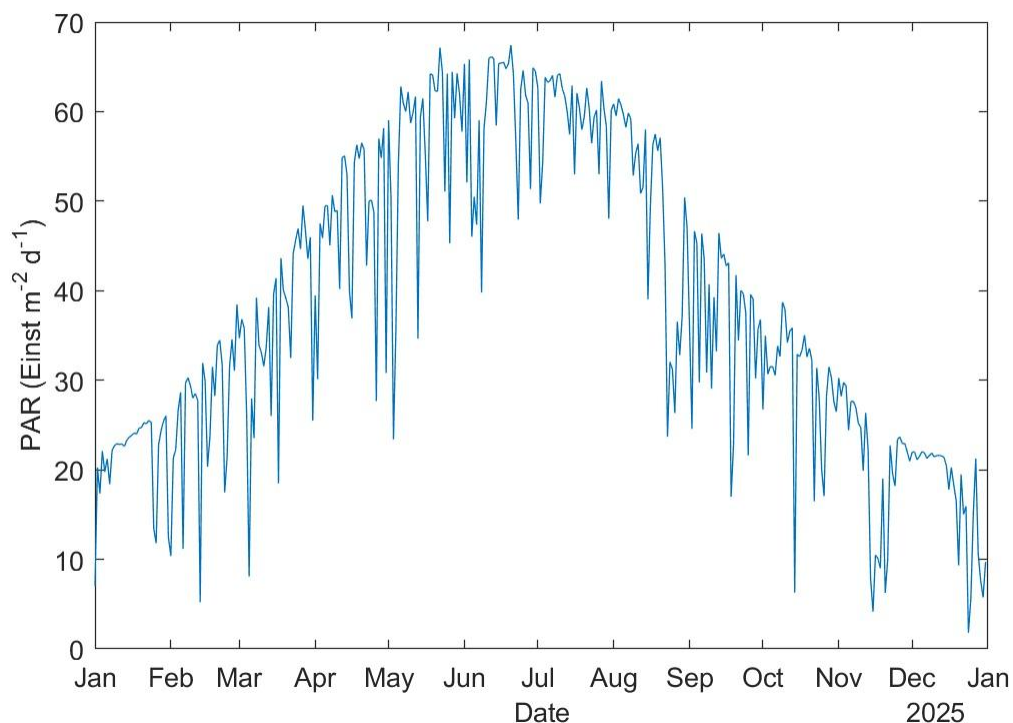
Fig. 5. Hourly mean air temperatures (°C) at Paoha Island, 2025.



Incident Photosynthetically Available Radiation (PAR)

Daily values of photosynthetically available radiation under clear skies range from about ~ 19.5 Einsteins $\text{m}^{-2} \text{day}^{-1}$ near the winter solstice to ~ 67.4 Einsteins $\text{m}^{-2} \text{day}^{-1}$ near the summer solstice (Fig. 6). However, daily values are reduced during cloudy periods. During 2025, the annual mean was 38.6 Einsteins $\text{m}^{-2} \text{day}^{-1}$, with daily values ranging from 1.8 Einsteins $\text{m}^{-2} \text{day}^{-1}$ on 24 December to 67.4 Einsteins $\text{m}^{-2} \text{day}^{-1}$ on 20 June.

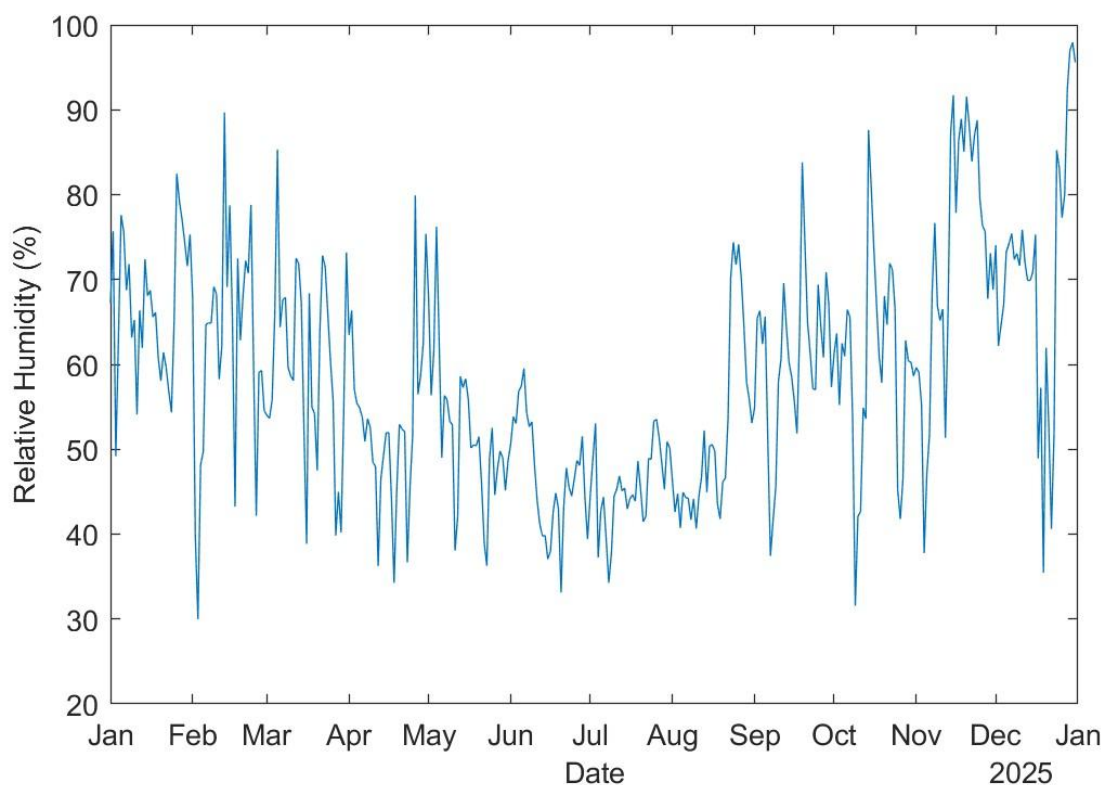
Fig. 6. Daily photosynthetically available radiation, 2025.



Relative Humidity and Precipitation

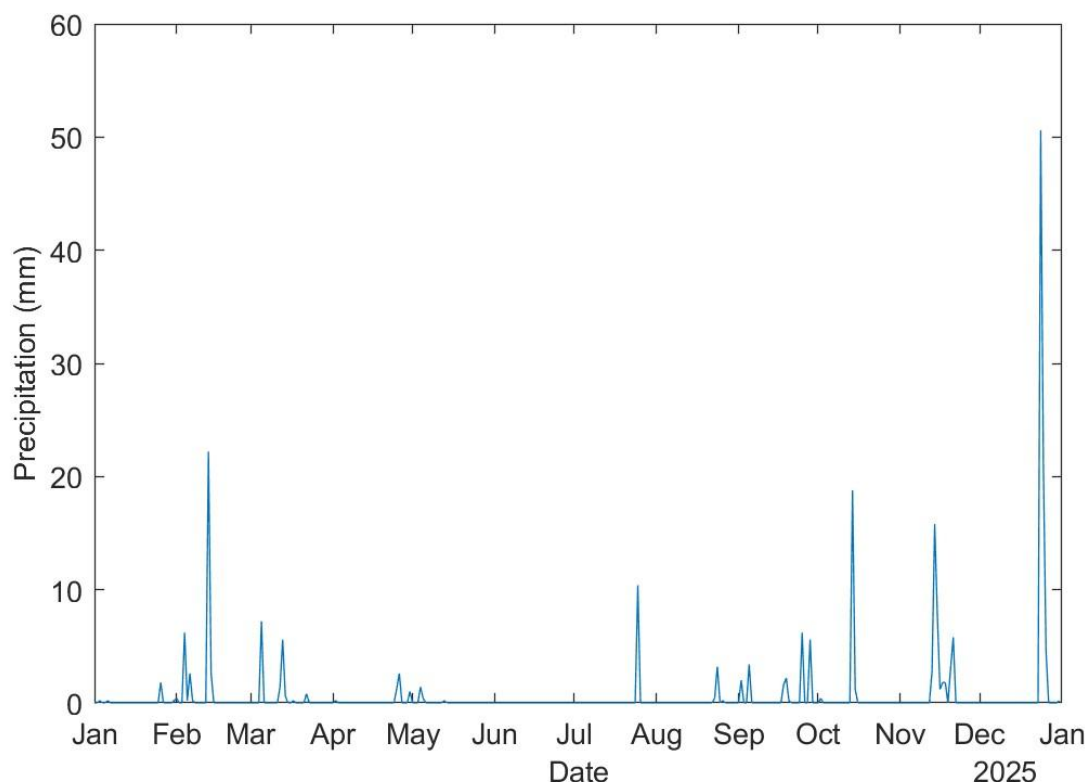
A general pattern in relative humidity of 40–57% in summer and mostly 50–79% in winter was observed (Fig. 7). Mean daily relative humidity values ranged from 30% on 3 February to 97.9% on 30 December.

Fig. 7. Mean daily relative humidity (%), 2025.



Paoha Island, located in the Sierra Nevada rain shadow, received 232 mm (9.13 in) of rain in 2025. The largest daily total occurred on 24 December (50.6 mm), when mean air temperature was 3.9 °C. Additional notable events occurred on 13 February (22.2 mm, mean air temperature 0.9 °C), 25 December (21.2 mm, 2.9 °C), 14 October (18.8 mm, 2.8 °C), and 14 November (15.8 mm, 7.6 °C) (Fig. 8). Mean daily air temperatures during these events were above freezing, indicating that precipitation likely fell primarily as rain, although the February event may have included mixed precipitation.

Fig. 8. Daily precipitation (mm) at Paoha Island, 2025.



Water temperatures

Seasonal thermal stratification

The annual pattern of thermal stratification in Mono Lake results from seasonal variations in climatic factors (e.g., air temperature, solar radiation, wind speed, humidity) and their interaction with density stratification arising from the timing and magnitude of freshwater inputs. The typical annual pattern observed for large temperate lakes differs from that in hypersaline Mono Lake due to the absence of ice cover, unique temperature-density properties, and variations in salinity. In Mono Lake, a winter period of circulation, which varies in depth, typically occurs from late November to early February after which seasonal thermal and salinity stratification are altered due to increased insolation and increased freshwater inflows. Six episodes of persistent stratification (meromixis) have occurred since 1982 (1983–1988, 1994–2003, 2005–2007, 2010–2012, 2017–2020, 2023–present) when vertical salinity gradients arose from above average snowmelt runoff and increased freshwater inflows and persisted through the

following year. During 2021 through 2022 winter holomixis (full water column circulation) occurred. In late 2022, partial mixing of upper waters into the hypolimnion occurred between November and December but a period of complete mixing did not occur and a 6th episode of meromixis has been initiated in 2023 and continued through 2025.

At centrally-located Station 6, water temperatures within the mixolimnion varied from approximately 3.0 °C on 11 February to a summer peak of 23.0 °C on 14 August, before cooling to 7.3 °C by 15 December 2025 (Table 1, Fig. 9, 10). Temperatures in the deep monimolimnion increased only slightly from 3.6 °C in February to 4.0 °C in December. Warming of the upper water (~8.4 °C) occurred between the March and April surveys. The depth of the thermocline (>1 °C m⁻¹) increased from 11 m in mid-May to approximately 18 m by mid-October. Cooling between October and November led to a further deepening of the top of the thermocline to ~21 m by mid-December, where it coincided with the chemocline.

Fig. 9. Seasonal water temperatures (°C) at Station 6, 2025. Red triangles indicate CTD surveys.

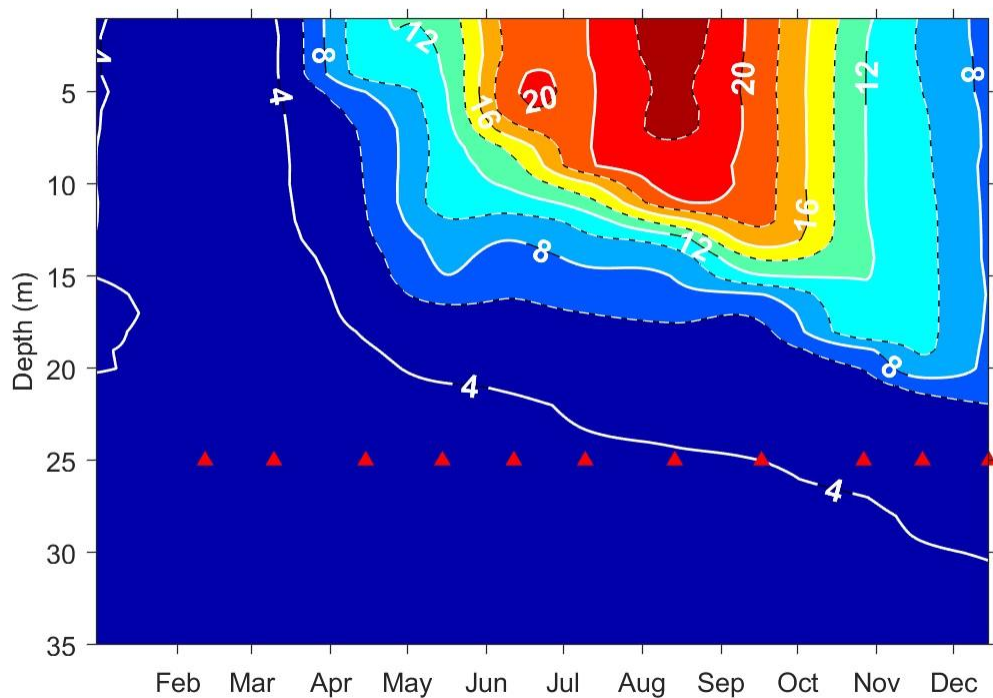
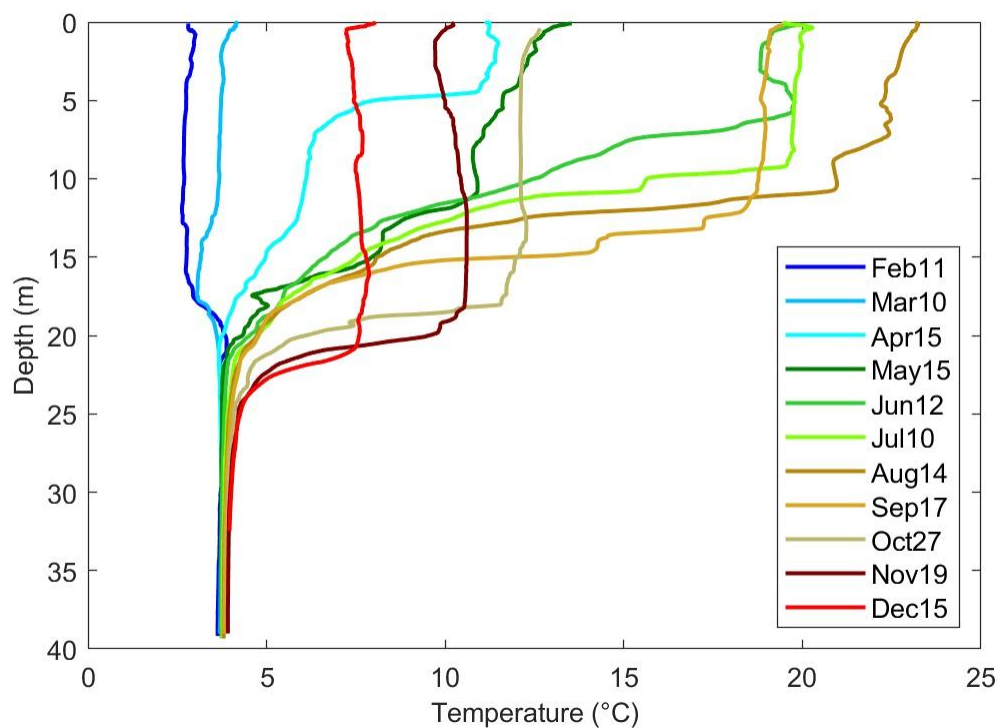


Fig. 10. Seasonal water temperatures (°C) at Station 6, 2025.



Vertical temperature profiles at Station 6 in 2025 indicated gradual deepening of the mixed layer during summer, with a marked shift between September and October as surface waters began to cool. By 15 December, the mixolimnion had cooled to ~ 7.3 °C, approximately 3.3 °C warmer than monimolimnetic waters (~ 4.0 °C). A persistent zone of slightly warmer water (~ 7.8 – 7.9 °C) was observed around 15–17 m, consistent with the chemocline (Table 1, Fig. 9, Fig. 10). These observations confirm the continuation of meromixis throughout 2025.

Table 1. Temperature (°C) at Station 6, February–December, 2025.

Depth (m)	2/11	3/10	4/15	5/15	6/12	7/10	8/14	9/17	10/27	11/19	12/15
1	3.0	3.9	11.4	12.7	19.1	19.9	23.0	19.1	12.5	9.8	7.3
2	2.9	3.7	11.4	12.5	18.8	19.9	22.8	19.1	12.2	9.7	7.3
3	2.9	3.8	11.2	12.2	18.8	19.9	22.6	19.0	12.1	9.8	7.4
4	2.8	3.8	11.0	12.0	19.5	19.8	22.3	18.9	12.1	9.9	7.4
5	2.7	3.7	8.0	11.6	19.8	19.8	22.3	18.8	12.1	10.0	7.4
6	2.7	3.7	7.0	11.4	19.4	19.8	22.5	19.0	12.1	10.2	7.6
7	2.7	3.7	6.4	11.1	17.4	19.7	22.4	19.0	12.1	10.3	7.7
8	2.7	3.7	6.2	10.8	14.7	19.7	21.7	18.9	12.1	10.3	7.7
9	2.7	3.7	6.2	10.8	13.5	19.6	20.9	18.9	12.1	10.4	7.5
10	2.7	3.7	6.1	10.9	12.5	15.7	20.9	18.8	12.1	10.4	7.5
11	2.7	3.6	6.0	10.8	11.1	13.1	19.7	18.7	12.1	10.5	7.6
12	2.6	3.6	5.9	9.7	9.3	10.8	15.2	18.3	12.2	10.6	7.6
13	2.7	3.4	5.7	8.5	8.1	9.5	11.0	17.2	12.3	10.6	7.6
14	2.8	3.2	5.3	8.3	7.2	8.4	9.0	14.3	12.2	10.6	7.7
15	2.8	3.2	5.0	7.9	6.7	7.5	8.1	11.8	12.0	10.6	7.8
16	2.7	3.1	4.7	6.7	6.1	6.8	7.5	7.9	11.9	10.6	7.9
17	2.9	3.1	4.4	5.3	5.5	6.0	6.4	6.4	11.7	10.6	7.8
18	3.1	3.3	4.1	5.0	5.4	5.4	5.6	5.6	11.6	10.5	7.7
19	3.6	3.5	3.9	4.5	4.8	5.1	5.1	5.0	7.6	10.2	7.6
20	3.8	3.6	3.8	4.3	4.5	4.7	4.7	4.8	6.1	9.5	7.6
21	3.9	3.7	3.7	3.9	4.1	4.2	4.4	4.4	5.2	6.5	7.3
22	3.7	3.7	3.7	3.8	3.9	4.1	4.2	4.2	4.6	5.2	5.9
23	3.8	3.7	3.7	3.8	3.9	4.0	4.1	4.1	4.5	4.7	4.9
24	3.8	3.7	3.7	3.7	3.8	4.0	4.0	4.1	4.2	4.4	4.4
25	3.8	3.7	3.7	3.8	3.8	3.9	4.0	4.0	4.1	4.2	4.3
26	3.8	3.7	3.7	3.8	3.8	3.9	3.9	4.0	4.1	4.2	4.2
27	3.8	3.7	3.7	3.7	3.8	3.9	3.9	3.9	4.0	4.1	4.1
28	3.8	3.7	3.7	3.7	3.8	3.8	3.9	3.9	4.0	4.0	4.1
29	3.8	3.7	3.7	3.7	3.8	3.8	3.9	3.9	3.9	4.0	4.0
30	3.7	3.7	3.7	3.7	3.8	3.8	3.9	3.9	3.9	4.0	4.0
31	3.7	3.7	3.7	3.7	3.8	3.8	3.9	3.9	3.9	4.0	4.0
32	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	3.9	4.0
33	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	
34	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	
35	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.8		3.9	
36	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.8		3.9	
37	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8		3.9	
38	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8		3.9	
39	3.6	3.7			3.7	3.8	3.8	3.8		3.9	

Spatial variability

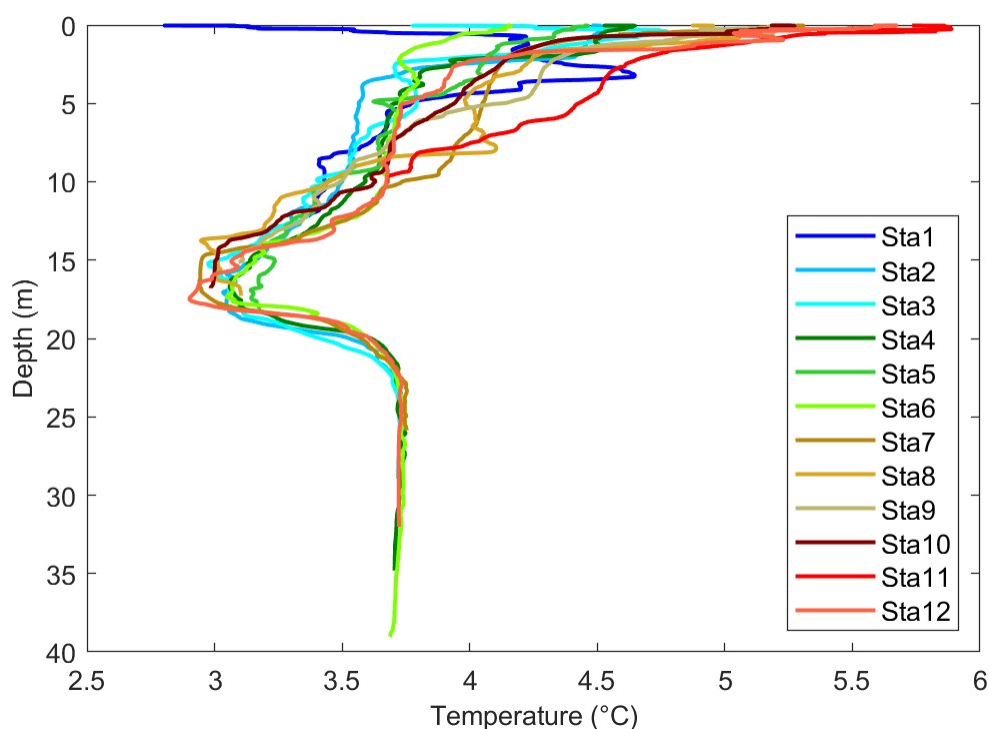
The complex morphometry of Mono Lake, steep-sided western basins, shallow sloping eastern basin, central islands, and islets with prevailing southwesterly winds and main freshwater inflows into the western basins, generates spatial heterogeneity in the lake's physical, chemical,

and biological properties. Here, we present temperature data from all 12 stations to illustrate major spatial patterns.

On 10 March 2025, thermal stratification was weak but evident, with the mixolimnion extending to ~15 m. Near-surface temperatures were generally $<5^{\circ}\text{C}$, but vertical gradients and thermal structure varied among stations. Eastern stations (stations 7-12) had warmer water in the upper 10–15 m compared to the western portion of the lake, stations 1-6 (Fig. 11). Beneath the thermocline (~16–18 m), temperatures were between $3.1\text{--}3.7^{\circ}\text{C}$ across the lake.

The noticeably warmer near-surface temperatures ($<1\text{ m}$ depth) at the eastern stations may be partially explained by diurnal heating and sampling later in the day. Stations are visited in numeric order on lakewide surveys and typically span 5–7 hours.

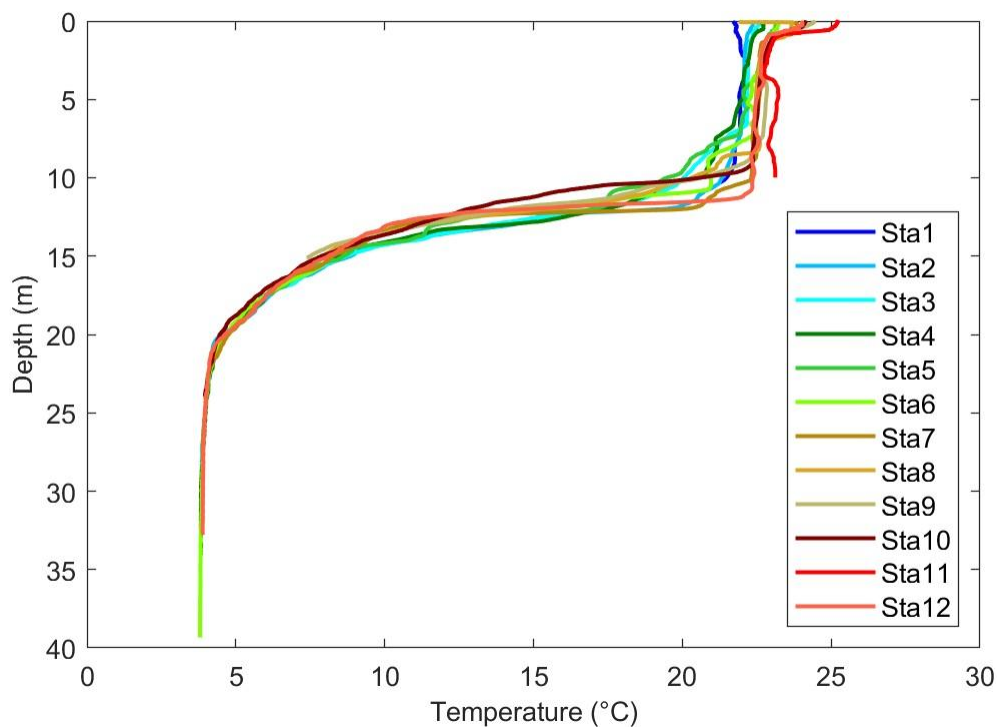
Fig. 11. Lakewide temperature profiles on 10 March 2025.



The lakewide temperature survey on 14 August 2025 showed strong and well-developed summer stratification across all stations (Fig. 12). Near-surface temperatures ranged from approximately $\sim 18\text{--}23^{\circ}\text{C}$, with warmest waters generally occurring at eastern stations (7–12). Western stations (1–6) had slightly cooler surface conditions (by $\sim 0.5\text{--}1^{\circ}\text{C}$), consistent with spatial differences observed earlier in the season.

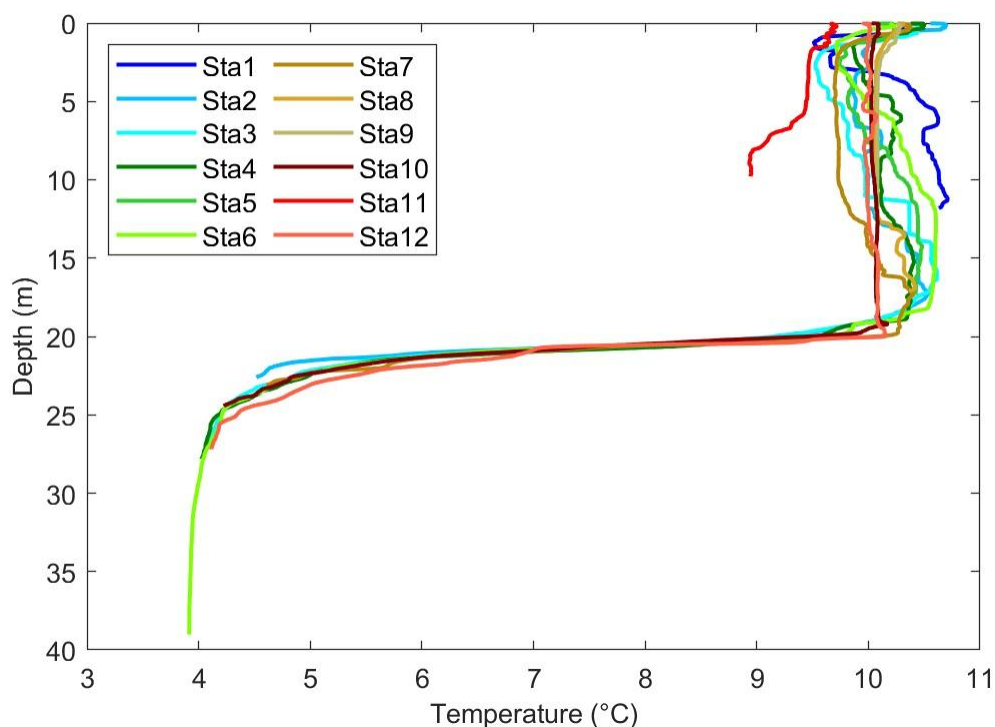
The thermocline was defined between approximately 12–18 m, where temperature declined with depth. Below ~18–20 m, temperatures decreased to ~4–5 °C and became relatively uniform across both the western and eastern sections, indicating persistence of a stable, cold monimolimnion. Vertical temperature gradients were strong in both sections, with slightly greater surface-to-deep contrast in the eastern section, where surface warming was more pronounced.

Fig. 12. Lakewide temperature profiles on 14 August 2025.



The lakewide temperature survey on 19 November 2025 revealed seasonal cooling of the mixolimnion, with near-surface temperatures between ~ 9.5 and 10.5 °C and a deepening of the mixed layer to approximately 20–22 m (Fig. 13). Spatial differences were evident across the lake, with eastern stations (stations 7–12) generally recording cooler surface and upper water column temperatures (by ~ 1 °C) than western stations (stations 1–6). The thermocline, where present, occurred near ~ 20 m and coincided with the chemocline. Below ~ 22 m, temperature profiles were nearly uniform across all stations, consistent with the presence of a stable monimolimnion.

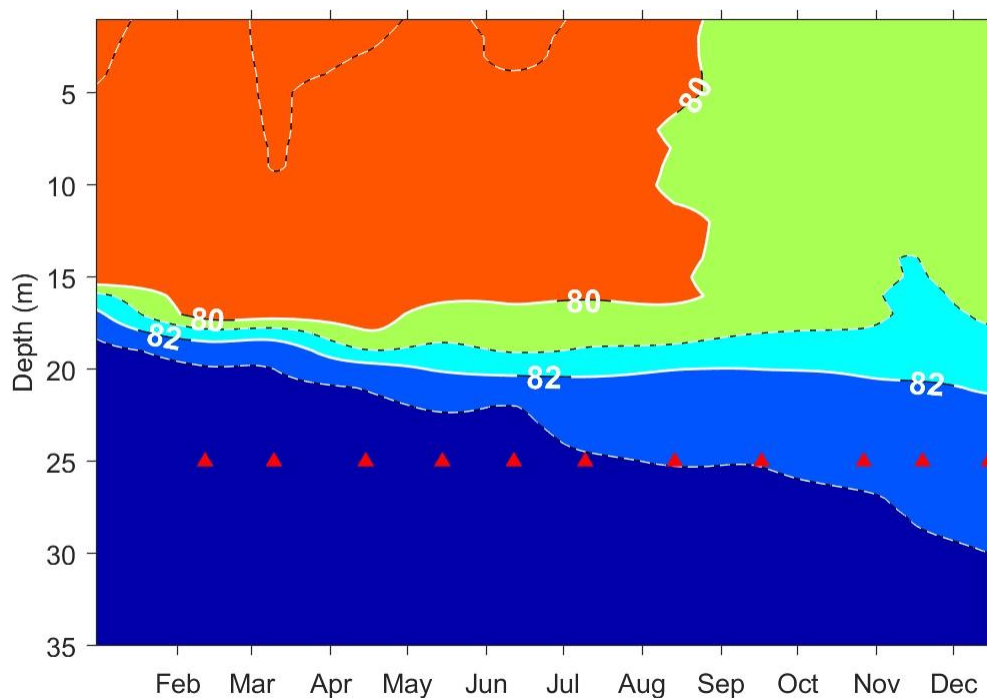
Fig. 13. Lakewide temperature profiles on 19 November 2025.



Specific Conductance and Salinity

Vertical profiles of specific conductance at Station 6 throughout 2025 confirm the continued presence of persistent chemical stratification and a chemocline (Table 2, Fig. 14). Conductance data from March, August, and November illustrate seasonal changes in the mixolimnion and the depth of the chemocline (Fig. 16, Fig. 17, Fig. 18).

Fig. 14. Specific conductance (mS cm^{-1} at 25°C) at Station 6, 2025. Red triangles indicate CTD surveys.



From February through July, the 80 mS cm^{-1} isocline remained between 17 and 18 m. Beginning in August, surface specific conductance exceeded 80 mS cm^{-1} , and by September through December, values $\geq 80 \text{ mS cm}^{-1}$ extended from the surface to over 20 m, indicating increased salinity throughout the mixolimnion due to evaporation reduced freshwater inflow and vertical mixing (Table 2, Fig. 14).

Fig. 15. Seasonal specific conductance at Station 6, 2025.

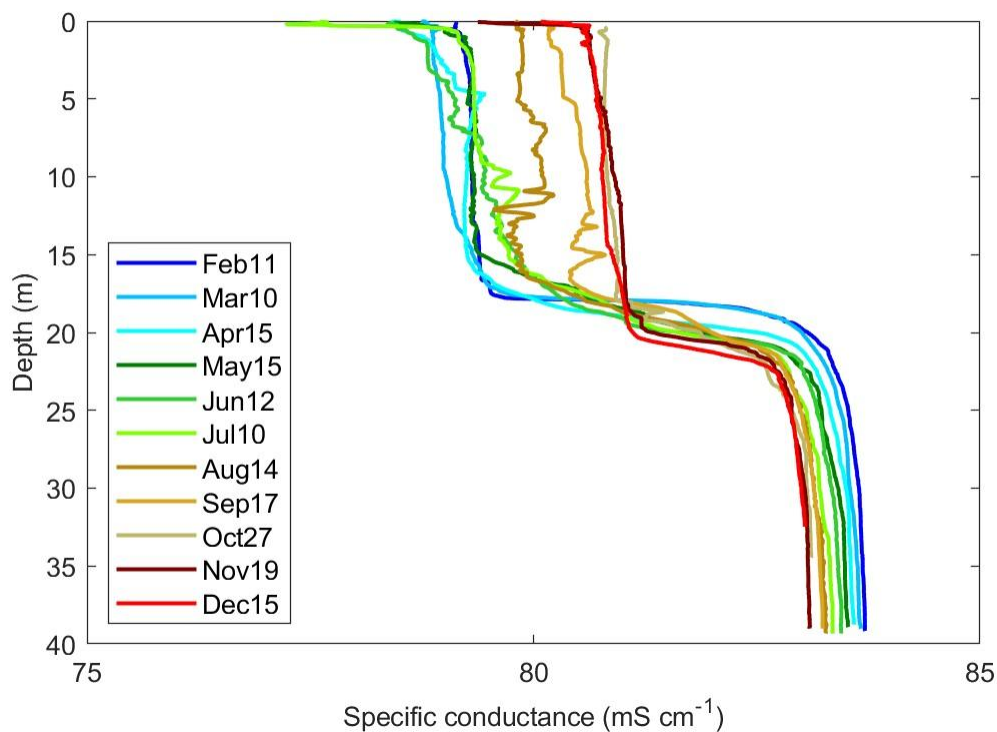


Table 2. Specific conductance (mS cm⁻¹ at 25°C) at Station 6, February–December, 2025.

Depth (m)	2/11	3/10	4/15	5/15	6/12	7/10	8/14	9/17	10/27	11/19	12/15
1	79.2	78.9	78.8	79.2	78.7	79.2	79.9	80.2	80.8	80.6	80.6
2	79.2	78.9	78.9	79.3	78.8	79.3	79.9	80.3	80.8	80.6	80.6
3	79.3	78.9	79.0	79.3	78.8	79.3	79.9	80.3	80.8	80.7	80.7
4	79.3	78.9	79.1	79.3	79.0	79.3	79.8	80.3	80.8	80.7	80.7
5	79.3	79.0	79.4	79.3	79.1	79.3	79.8	80.4	80.8	80.8	80.7
6	79.3	79.0	79.3	79.3	79.1	79.3	80.0	80.5	80.8	80.8	80.7
7	79.3	79.0	79.3	79.4	79.2	79.3	80.1	80.5	80.8	80.8	80.8
8	79.3	79.0	79.2	79.3	79.4	79.4	80.0	80.5	80.8	80.8	80.8
9	79.3	79.0	79.3	79.3	79.5	79.4	80.1	80.6	80.8	80.9	80.8
10	79.3	79.0	79.3	79.3	79.5	79.7	80.1	80.6	80.8	80.9	80.8
11	79.3	79.1	79.2	79.3	79.4	79.8	80.0	80.6	80.8	81.0	80.8
12	79.3	79.1	79.2	79.3	79.6	79.6	79.6	80.6	80.9	81.0	80.8
13	79.3	79.1	79.2	79.3	79.6	79.6	79.7	80.5	80.9	81.0	80.8
14	79.4	79.3	79.2	79.3	79.7	79.6	79.8	80.5	80.9	81.0	80.8
15	79.4	79.3	79.3	79.4	79.8	79.7	79.9	80.8	80.9	81.0	80.9
16	79.4	79.4	79.3	79.8	79.9	79.9	79.8	80.4	80.9	81.0	80.9
17	79.5	79.5	79.6	80.4	80.1	80.2	80.2	80.5	80.9	81.0	81.0
18	81.4	81.5	80.1	80.7	80.4	80.8	80.6	81.0	81.0	81.0	81.0
19	82.7	82.7	81.1	81.3	80.9	81.1	81.2	81.7	81.3	81.2	81.0
20	83.1	83.0	82.5	81.9	81.6	81.6	82.0	82.0	81.9	81.3	81.1
21	83.3	83.1	83.0	82.7	82.7	82.6	82.5	82.5	82.2	82.4	81.7
22	83.3	83.3	83.1	82.9	83.0	82.8	82.7	82.8	82.6	82.7	82.5
23	83.4	83.3	83.2	83.1	83.1	82.9	82.9	82.9	82.6	82.8	82.7
24	83.5	83.4	83.3	83.2	83.1	83.0	82.9	82.9	82.8	82.9	82.8
25	83.5	83.4	83.3	83.2	83.2	83.1	83.0	83.0	82.9	82.9	82.9
26	83.5	83.5	83.4	83.2	83.2	83.1	83.0	83.0	83.0	82.9	82.9
27	83.6	83.5	83.4	83.3	83.2	83.1	83.1	83.1	83.0	82.9	82.9
28	83.6	83.5	83.4	83.3	83.3	83.2	83.1	83.1	83.1	83.0	83.0
29	83.6	83.5	83.5	83.4	83.3	83.2	83.1	83.1	83.1	83.0	83.0
30	83.6	83.5	83.5	83.4	83.3	83.2	83.1	83.1	83.1	83.0	83.0
31	83.7	83.6	83.5	83.4	83.4	83.2	83.2	83.2	83.1	83.1	83.0
32	83.7	83.6	83.5	83.5	83.4	83.2	83.2	83.2	83.1	83.1	83.0
33	83.7	83.6	83.5	83.5	83.4	83.3	83.2	83.2	83.1	83.1	
34	83.7	83.6	83.5	83.5	83.4	83.3	83.2	83.2	83.1	83.1	
35	83.7	83.6	83.6	83.5	83.4	83.3	83.2	83.2		83.1	
36	83.7	83.6	83.6	83.5	83.4	83.3	83.2	83.2		83.1	
37	83.7	83.6	83.6	83.5	83.4	83.3	83.3	83.2		83.1	
38	83.7	83.6	83.6	83.5	83.4	83.3	83.3	83.2		83.1	
39	83.7	83.7			83.4	83.3	83.3	83.2		83.1	

On 10 March 2025, specific conductance (and salinity) in the upper 15 m ranged from ~ 78.9 (74.5 g kg^{-1}) to 79.3 mS cm^{-1} (75 g kg^{-1}), with a slight but consistent vertical increase. A sharper increase began at $\sim 16 \text{ m}$, and between 17 and 18 m, conductance increased from 79.5 (75.2 g kg^{-1}) to 81.5 mS cm^{-1} (77.7 g kg^{-1}), forming a well-defined chemocline. Below 20 m, values were between ~ 83.0 (79.6 g kg^{-1}) and 83.7 mS cm^{-1} (80.5 g kg^{-1}) (Fig. 16). At western stations, values in the upper 2 m were lower than eastern stations.

By 14 August 2025, near-surface conductance had increased slightly from early-season values, reaching ~ 79.9 – 80.1 mS cm^{-1} ($\sim 75.8 \text{ g kg}^{-1}$) in the upper 10 m. The chemocline remained sharp, with a distinct increase in conductance between ~ 17 and 20 m from ~ 80.2 (76.1 g kg^{-1}) to 82.0 mS cm^{-1} (78.3 g kg^{-1}). Below this transition zone, deep water conductivities remained between 83.0 and 83.3 mS cm^{-1} ($\sim 79.8 \text{ g kg}^{-1}$) (Fig. 17). Specific conductance profiles at western stations were slightly lower near the surface compared to eastern stations.

Fig. 16. Specific conductance (mS cm^{-1}), 10 March 2025.

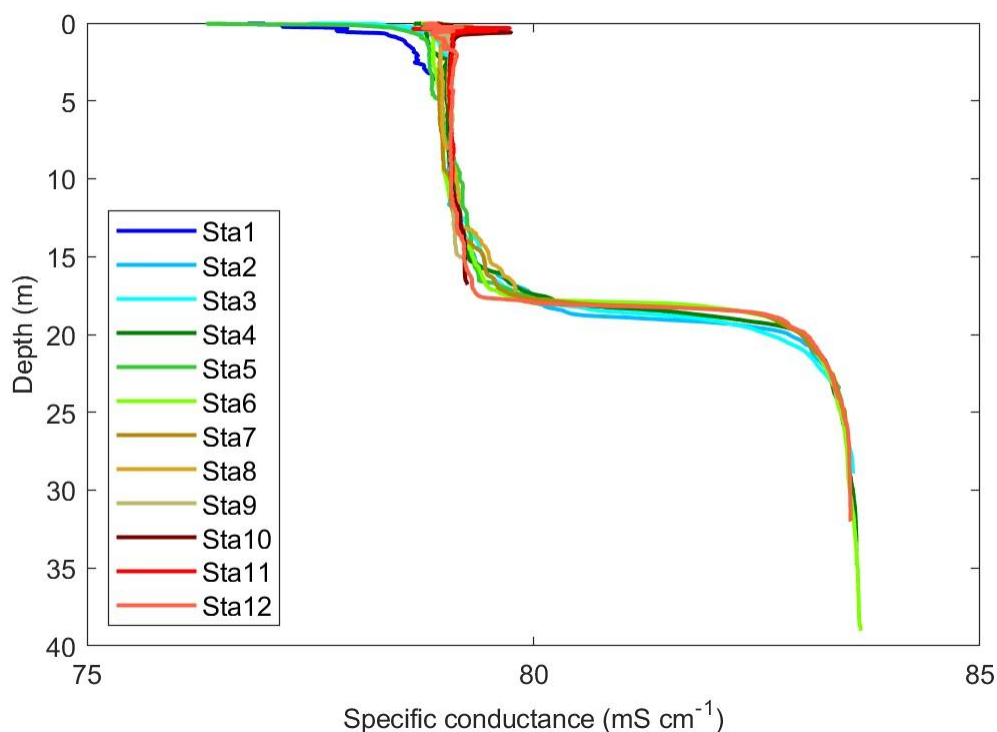
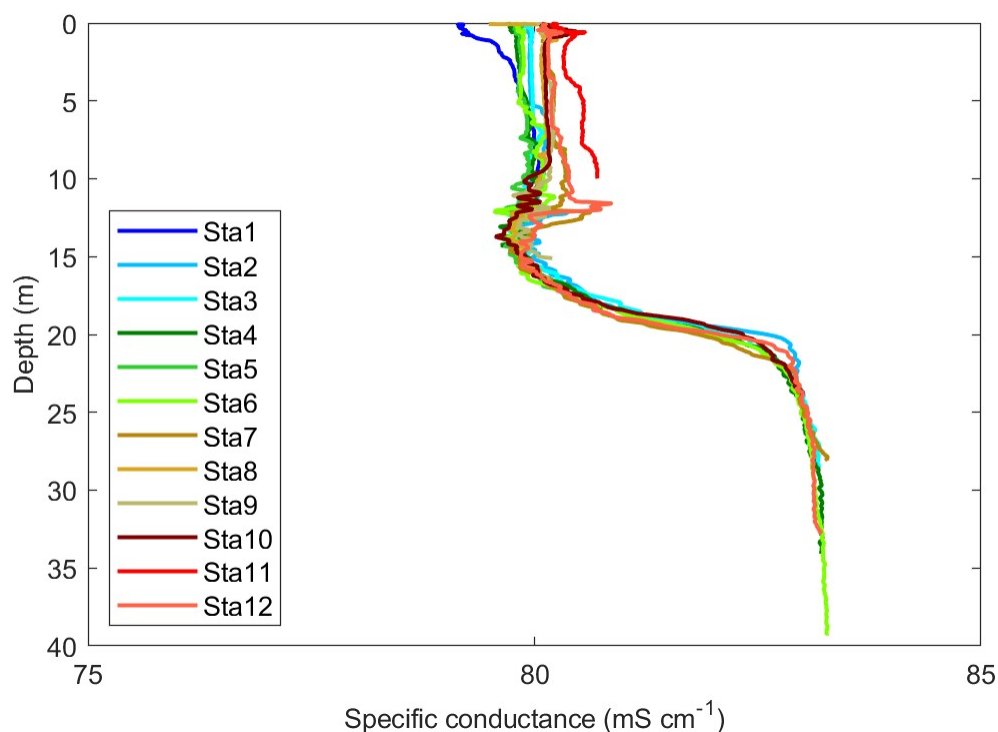
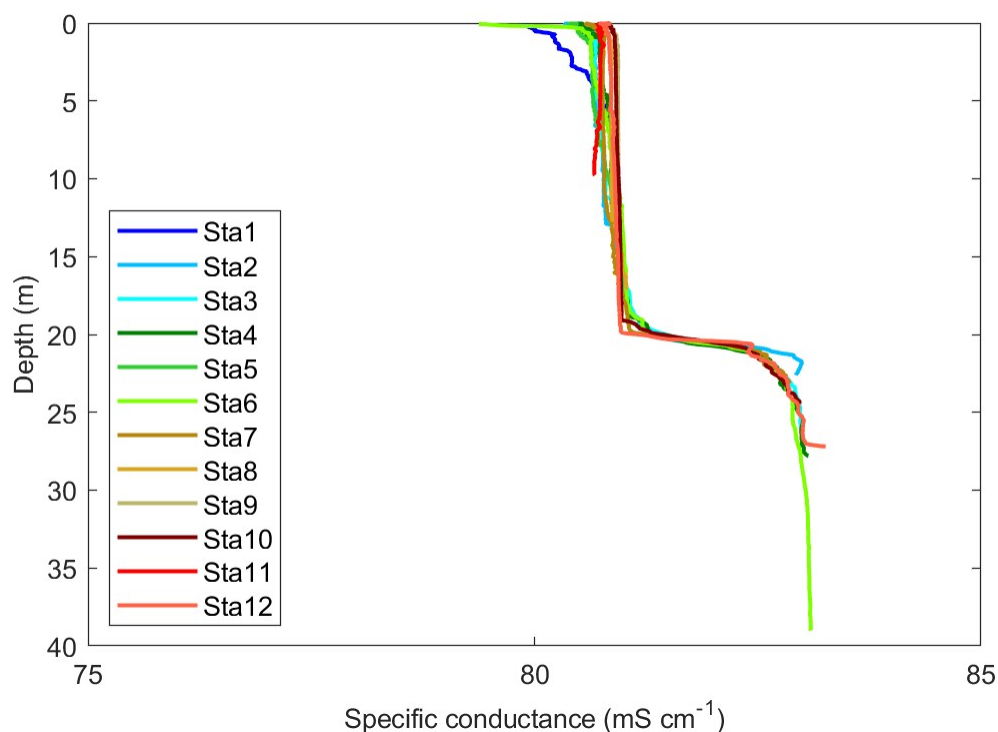


Fig. 17. Specific conductance (mS cm^{-1}), 14 August 2025.

On 19 November, further deepening of the upper mixed layer was observed. Specific conductance increased gradually to $\sim 81.0 \text{ mS cm}^{-1}$ (77.1 g kg^{-1}) in the upper 20 m. A chemocline occurred between 19 and 21 m, where conductance rose from 81.0 mS cm^{-1} (77.1 g kg^{-1}) to 82.6 mS cm^{-1} (79.1 g kg^{-1}), a $\sim 1.6 \text{ mS cm}^{-1}$ increase across 2 m. Below 21 m, the monimolimnion had values between ~ 82.6 and 83.0 mS cm^{-1} . Surface waters at western stations were slightly fresher than eastern stations, likely due to minor lake level rise and local runoff inputs (Fig. 18).

Fig. 18. Specific conductance (mS cm^{-1}), 19 November 2025.

The seasonal pattern of salinity stratification in 2025 is illustrated by specific conductance measurements at the centrally located deep Station 6 (Fig. 15). Throughout 2025, a persistent chemocline was present at Station 6, characterized by an increase in specific conductance. From February through August, specific conductance increased by approximately 2.0 mS cm^{-1} within a 2-meter interval (typically between 17–19 m), indicating a strong vertical salinity gradient. From September through December, the gradient weakened slightly, with specific conductance increasing by $\sim 1.5 \text{ mS cm}^{-1}$ over the same depth range.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows observed in the eastern Sierra Nevada and year-to-year climatic variation has led to complex patterns of seasonal density stratification. Much of the year-to-year variation in the plankton dynamics observed at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows and its effect on nutrient supply. The density difference between 2 and 32 m was 5.1 kg m^{-3} on 11 February, increased to a seasonal maximum of 8.7 kg m^{-3} on 12 June due to both

increased salinity and thermal stratification, and then declined steadily to 3.4 kg m^{-3} by 15 December (Fig. 19).

Seasonal density stratification reflects contributions from both thermal and salinity stratification (Fig. 18). At the peak density stratification on 12 June, salinity stratification contributed 5.3 kg m^{-3} , while thermal stratification contributed 3.6 kg m^{-3} to the overall density difference. Unlike 2024, when salinity stratification dominated and reached substantially higher values, stratification in 2025 had comparable contributions from thermal and chemical components. The comparatively lower magnitude of density stratification observed in 2025 suggests weaker meromictic stability relative to the previous year. Continued monitoring will determine whether the current episode of meromixis persists through 2026, depending on climatic conditions and water diversion policies (Fig. 20).

As in previous multi-year episodes of meromixis, variations in mixing influences nutrient supply and complicates interpretation of ecological responses to long-term salinity changes associated with lake level management (Fig. 21).

Fig. 19. Density stratification between 2 and 32 m, 2023–2025.

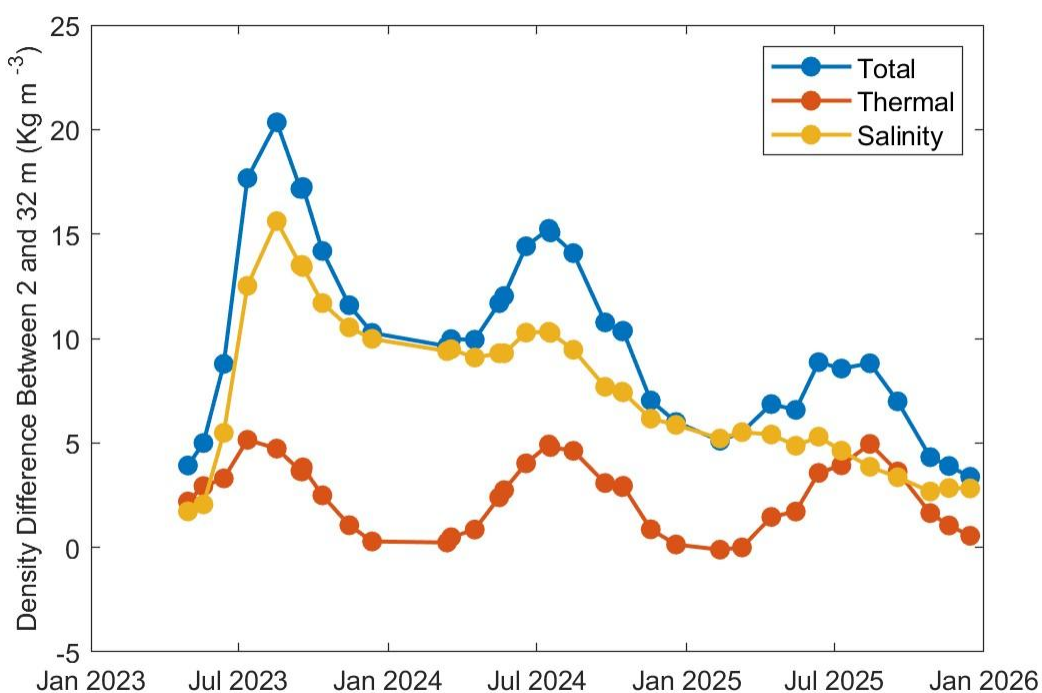


Fig. 20. Density stratification due to temperature and salinity, 1983–2025.

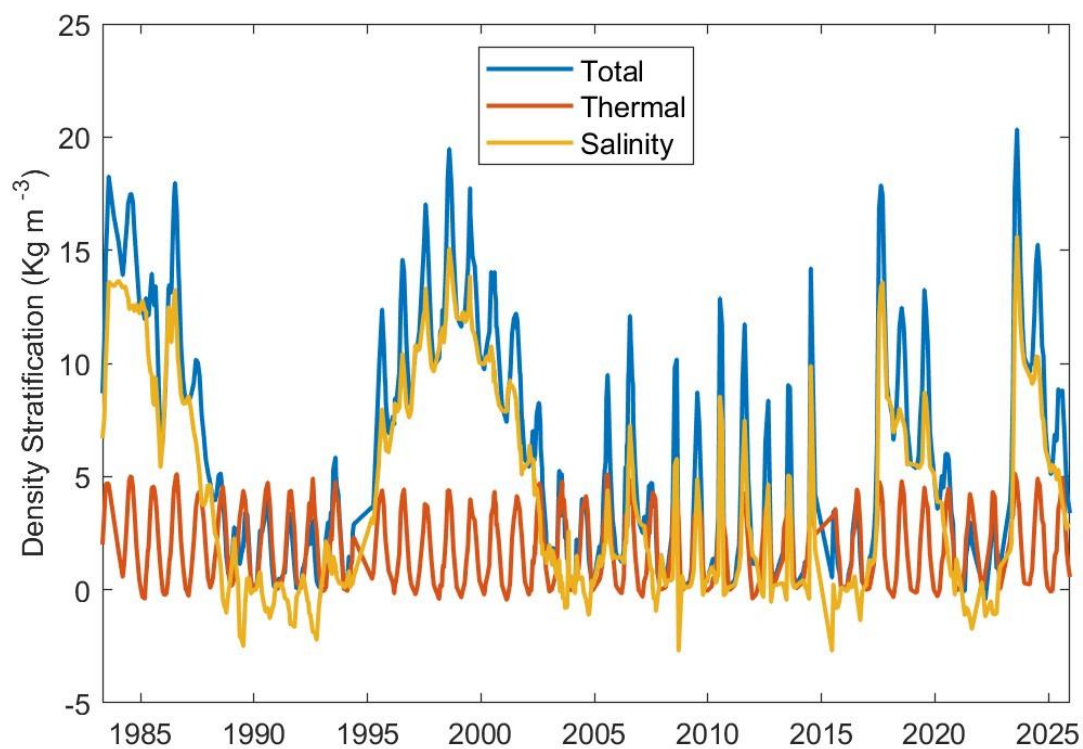
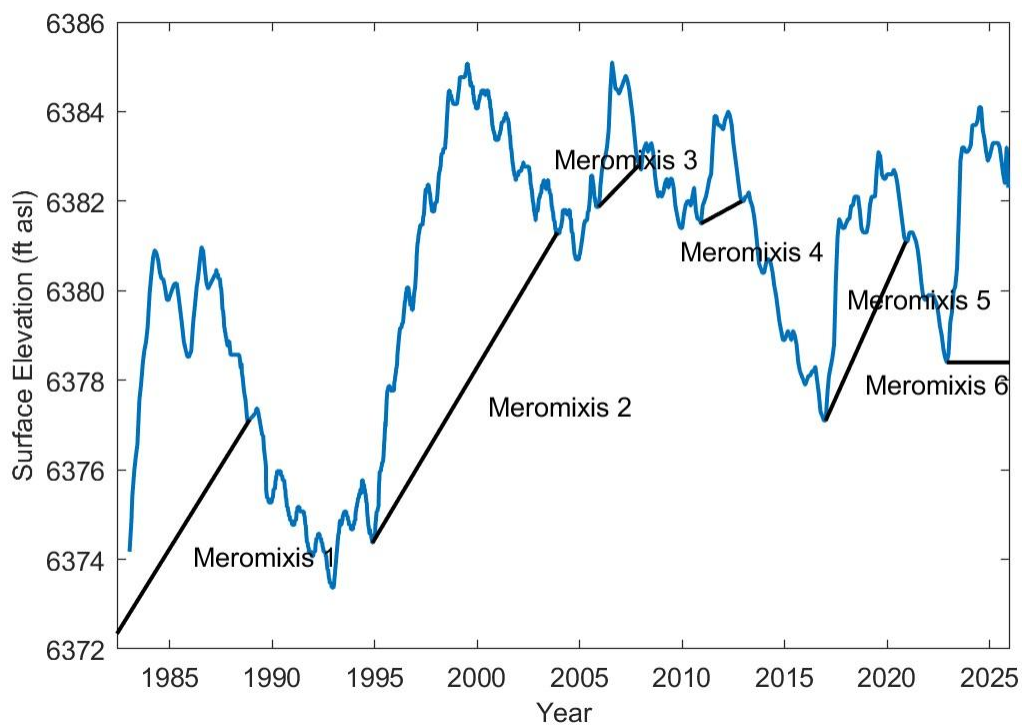


Fig. 21. Meromictic Episodes.



Transparency and Light Attenuation

In Mono Lake, variation in transparency is largely driven by changes in algal biomass, which is influenced by the balance between primary production and loss processes such as grazing by *Artemia*. Secchi depth serves as a useful proxy for lake clarity, reflecting seasonal shifts in phytoplankton abundance.

The lakewide mean Secchi transparency was 1.08 ± 0.05 m in February, 1.18 ± 0.02 m in March and 1.08 ± 0.04 m in April (Table 3), indicating relatively low transparency in early spring. As the season progressed, transparency increased, peaking at 6.85 ± 0.20 m in mid-August and remaining high during September (6.36 ± 0.15). This period coincides with the seasonal decline in phytoplankton biomass in summer due to grazing activity by *Artemia*.

Following the period of maximum water clarity, Secchi depth declined, dropping to 1.02 ± 0.03 m in October, and further to 0.83 ± 0.06 m in November and 0.82 ± 0.03 m in December (Table 3). This decline in transparency coincided with increasing chlorophyll concentrations in the upper water column ($38.6 \pm 1.4 \mu\text{g L}^{-1}$ in October, $60.9 \pm 2.1 \mu\text{g L}^{-1}$ in November and $73.3 \pm 1.4 \mu\text{g L}^{-1}$ in December), likely resulting from reduced grazing pressure as *Artemia* populations decline seasonally, along with possible nutrient supply from increased mixing.

Spatial differences in transparency between lake sectors were generally small relative to seasonal variation. During summer, the western sector had slightly greater transparency, with peak Secchi depths of 7.39 ± 0.19 m in August compared to 6.30 ± 0.15 m in the eastern sector (Table 3). However, this difference was not associated with higher phytoplankton biomass in the eastern sector, as mean chlorophyll concentrations during summer were similar between sectors and were in some cases slightly higher in the western sector (Table 9). This indicates that sector-scale differences in transparency during summer 2025 were likely influenced by non-algal particles, localized resuspension, or other factors rather than phytoplankton biomass alone.

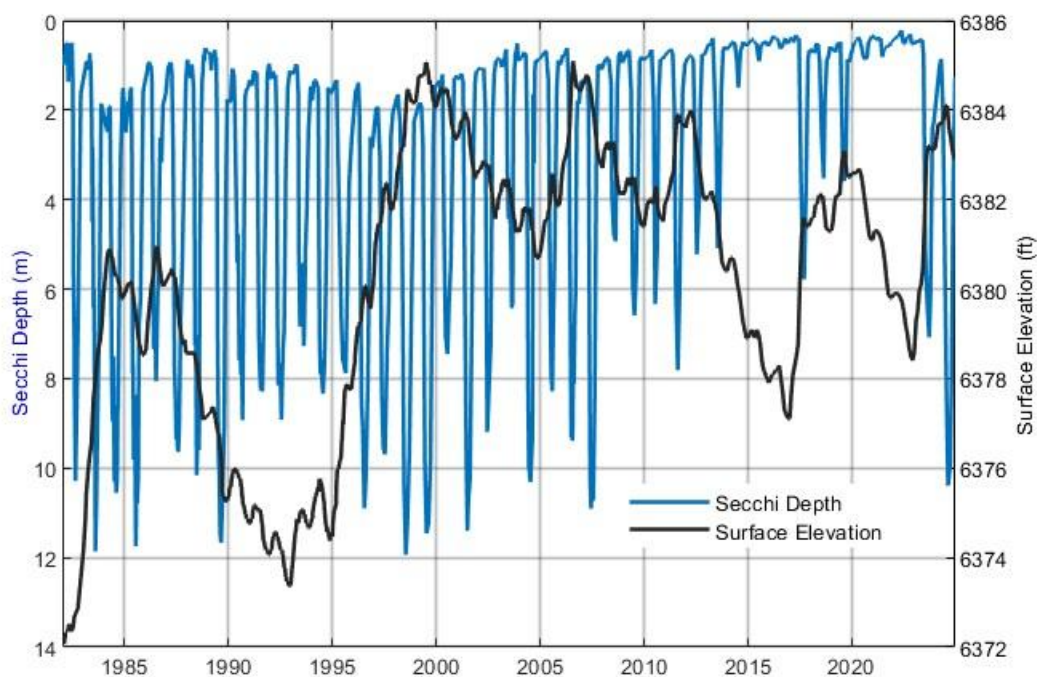
By late autumn and early winter, sector-scale differences in transparency diminished, coinciding with lakewide increases in phytoplankton biomass and reduced water clarity, indicating that biological processes again became the dominant control on transparency during this period.

Table 3. Secchi depths (m), February–December, 2025. S.E. is standard error. ‘n’ in last rows refers to number of stations averaged. Secchi depths for 11 February at stations 1, 2, 4, 5, 9, 10 and 12 are not reported due to weather conditions.

Station	Dates										
	2/11	3/10	4/15	5/15	6/12	7/10	8/14	9/17	10/27	11/19	12/15
Western sector											
1		1.20	0.90	2.80	5.75	6.50	8.25	5.60	1.00	0.50	0.80
2		1.30	1.10	2.40	5.50	6.20	7.20	6.10	1.00	0.50	0.90
3	1.00	1.20	1.10	2.20	5.25	5.90	7.10	6.10	1.10	0.60	0.80
4		1.20	1.10	2.00	5.30	5.45	7.20	6.50	1.00	0.80	0.80
5		1.20	1.20	2.50	5.10	5.30	7.60	6.50	1.10	0.80	0.90
6	1.00	1.20	0.90	1.90	4.90	5.00	7.00	6.20	0.80	0.80	0.80
Mean	1.00	1.22	1.05	2.30	5.30	5.73	7.39	6.17	1.00	0.67	0.83
S.E.	0.00	0.02	0.05	0.14	0.12	0.23	0.19	0.14	0.04	0.06	0.02
n	2	6	6	6	6	6	6	6	6	6	6
Eastern sector											
7	1.20	1.10	1.20	2.30	4.50	4.90	6.35	7.10	1.00	0.80	0.90
8	1.00	1.20	1.30	2.20	4.00	4.50	6.20	6.00	1.00	0.90	0.90
9		1.20	1.20	2.20	4.55	4.50	6.00	6.90	1.00	1.20	0.60
10		1.15	1.00	2.10	4.40	4.80	6.25	6.80	0.95	1.10	1.00
11	1.20	1.10	0.90	2.00	4.50	5.00	7.00	5.50	1.20	1.00	0.60
12		1.10	1.00	1.90	4.10	4.90	6.00	7.00	1.10	1.00	0.80
Mean	1.13	1.14	1.10	2.12	4.34	4.77	6.30	6.55	1.04	1.00	0.80
SE	0.07	0.02	0.06	0.06	0.10	0.09	0.15	0.26	0.04	0.06	0.07
n	3	6	6	6	6	6	6	6	6	6	6
Lakewide											
Mean	1.08	1.18	1.08	2.21	4.82	5.25	6.85	6.36	1.02	0.83	0.82
S.E.	0.05	0.02	0.04	0.08	0.16	0.19	0.20	0.15	0.03	0.06	0.03
n	5	12	12	12	12	12	12	12	12	12	12

The highest transparency observed in August 2025 (6.8 m) was lower than observed in 2023 (7.1 m) and 2024 (10.4), but higher than the two 3-yr periods of low summer transparency observed in 2014–2016 and 2020–2022 during declining lake levels (Fig. 22).

Fig. 22. Long-term changes in transparency (Secchi depth) and surface elevation.

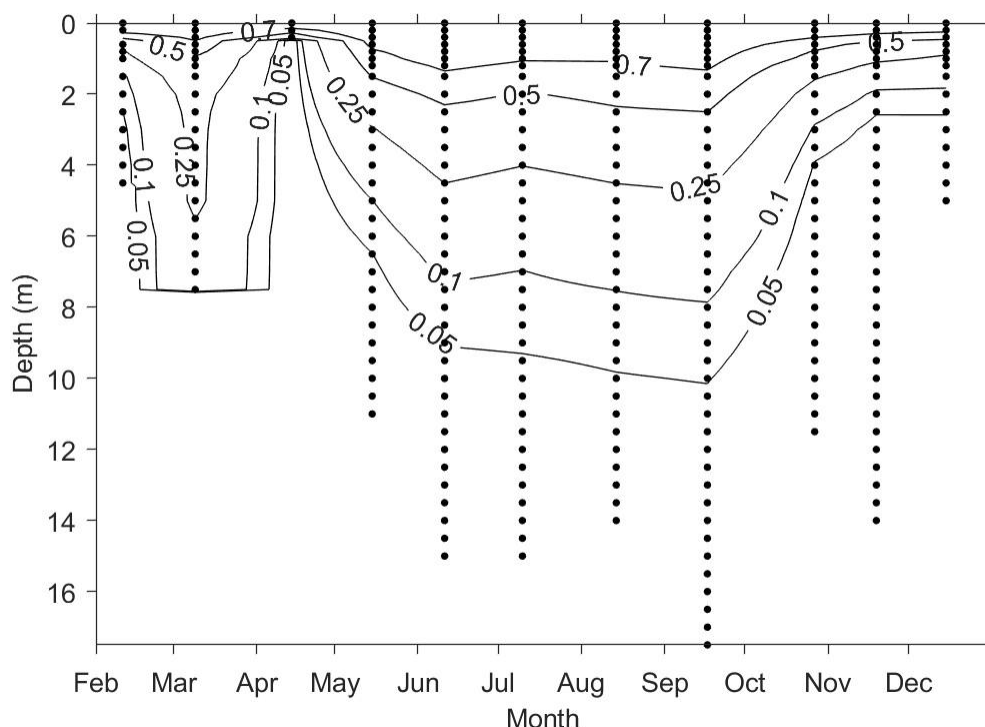


The attenuation of photosynthetically active radiation (PAR) within the water column varies seasonally and is related to changes in algal biomass (Fig. 23; Table 4).

Table 4. Attenuation coefficients (K_d) at Station 6, 2025. K_d values for 15 April are not reported due to instrument failure.

Dates K_d values	
2/11	0.72
3/10	0.55
5/15	0.44
6/12	0.40
7/10	0.36
8/14	0.31
9/17	0.35
10/27	0.62
11/19	1.12
12/15	0.98

Fig. 23. PAR light attenuation (fraction of surface) at Station 6, 2025.



Dissolved Oxygen

Dissolved oxygen concentrations are a function of salinity, temperature, and the balance between photosynthesis and community respiration. In the euphotic zone, dissolved oxygen concentrations are typically highest during the spring. As water temperatures and *Artemia* abundances population increase through the spring, dissolved oxygen concentrations decrease. Beneath the euphotic zone, bacterial and chemical processes deplete the oxygen once the lake stratifies. During meromictic periods, the monimolimnion remains anoxic throughout the year.

In 2025, dissolved oxygen concentrations in the upper water column (<12 m) ranged from 2.6 to 7.3 mg L⁻¹ (Table 5, Fig. 24, Fig. 25). During late winter and early spring (February–April), dissolved oxygen values were highest throughout the upper water column, with values ranging from 3.7–7.3 mg L⁻¹ between 1 and 12 m.

In mid-May, dissolved oxygen concentrations in surface waters (<12 m) declined, with values converging to approximately 3.9–4.1 mg L⁻¹. As stratification developed, dissolved oxygen concentrations continued to decrease in the uppermost waters (<8 m), ranging from 4.1–3.5 mg L⁻¹ in June, July, and August, and subsurface oxygen maxima developed between

approximately 8 and 14 m. During this period, dissolved oxygen concentrations at these depths ranged from 6.2 to 4.1 mg L⁻¹ in June, 7.2 to 3.8 mg L⁻¹ in July, and 6.4 to 3.9 mg L⁻¹ in August, coinciding with depths of elevated fluorescence, indicating active photosynthesis within the pycnocline.

In September, October, and November, dissolved oxygen concentrations were 4.3, 4.0, and 4.3 mg L⁻¹, respectively, from depths of 1 m to 11 m. On 15 December, dissolved oxygen concentrations were 5.8 mg L⁻¹ at 2 m depth and 3.4 mg L⁻¹ at 16 m depth. The water below 20 m was anoxic (<0.5 mg L⁻¹) throughout the year.

Fig. 24. Seasonal dissolved oxygen at Station 6, 2025. Dissolved oxygen data below 20 m on 10 March 2025 were deleted due to measurement artifacts during profiling.

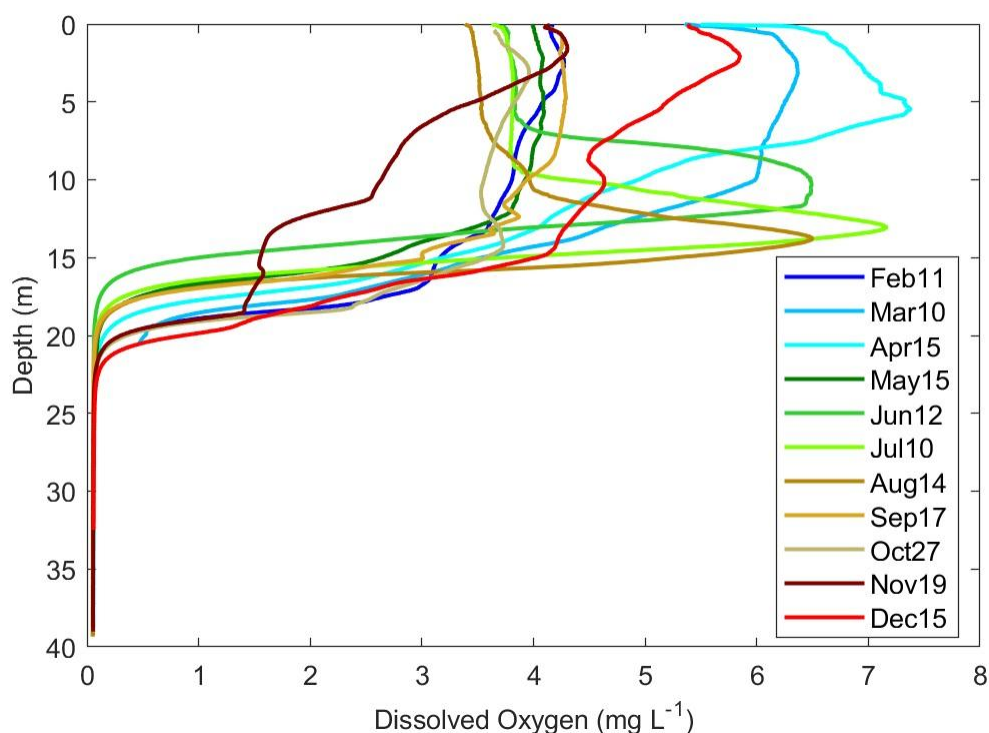


Fig. 25. Dissolved oxygen (mg L^{-1}) at Station 6, 2025. Red triangles indicate CTD surveys.

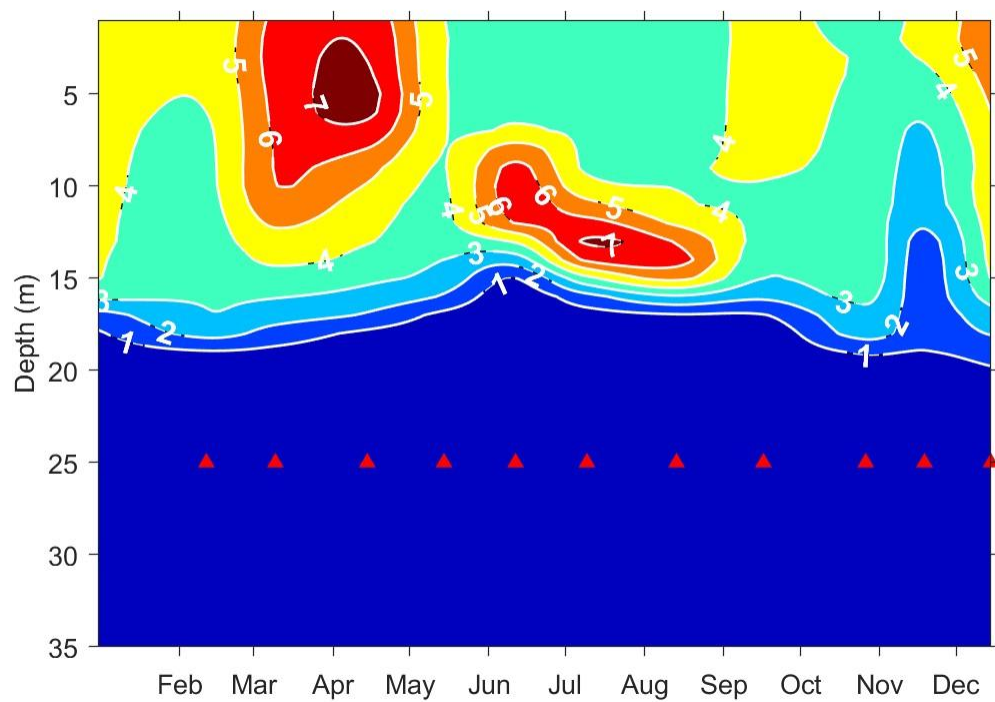


Table 5. Dissolved oxygen (mg L⁻¹) at Station 6, February–December, 2025. Dissolved oxygen data below 20 m on 10 March 2025 were deleted due to measurement artifacts during profiling.

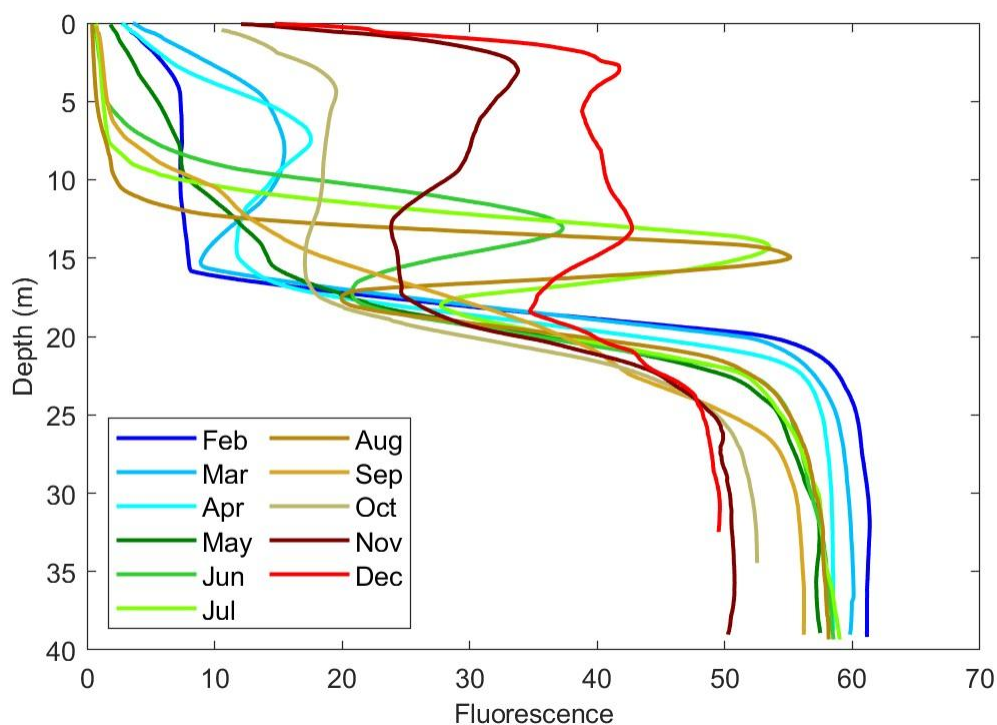
Depth (m)	2/11	3/10	4/15	5/15	6/11	7/10	8/14	9/17	10/28	11/19	12/15
1	4.2	6.2	6.7	4.0	3.8	3.8	3.5	4.3	3.7	4.3	5.7
2	4.3	6.3	6.8	4.1	3.8	3.8	3.5	4.2	3.9	4.3	5.8
3	4.2	6.4	7.0	4.1	3.8	3.8	3.5	4.3	4.0	4.1	5.7
4	4.2	6.3	7.1	4.1	3.8	3.8	3.5	4.3	3.9	3.8	5.4
5	4.1	6.2	7.3	4.1	3.8	3.8	3.5	4.3	3.8	3.5	5.2
6	4.0	6.2	7.2	4.1	3.9	3.8	3.5	4.3	3.7	3.1	5.0
7	3.9	6.1	6.7	4.1	4.1	3.8	3.6	4.2	3.7	2.9	4.8
8	3.9	6.0	6.0	4.0	5.5	3.8	3.7	4.2	3.6	2.8	4.5
9	3.8	6.0	5.3	4.0	6.2	3.8	3.9	4.1	3.6	2.7	4.5
10	3.8	6.0	4.9	3.9	6.5	4.3	4.0	3.9	3.6	2.6	4.6
11	3.7	5.6	4.5	3.9	6.5	5.3	4.1	3.8	3.5	2.6	4.6
12	3.7	5.1	4.3	3.8	6.0	6.3	4.8	3.8	3.6	2.1	4.4
13	3.6	4.7	4.1	3.5	4.1	7.2	5.9	3.7	3.7	1.7	4.3
14	3.4	4.2	3.7	3.0	2.5	6.2	6.4	3.3	3.7	1.6	4.2
15	3.2	3.5	3.2	2.6	1.0	3.7	5.3	3.0	3.6	1.6	4.0
16	3.1	3.1	2.7	1.9	0.4	1.6	2.9	2.2	3.2	1.6	3.4
17	2.9	2.5	1.9	0.7	0.2	0.5	0.9	1.0	2.8	1.5	2.6
18	2.3	1.6	0.8	0.3	0.1	0.2	0.3	0.3	2.4	1.4	2.1
19	0.9	0.7	0.3	0.2	0.1	0.1	0.1	0.1	1.1	1.0	1.5
20	0.3	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.9
21	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
22	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
23	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
24	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
25	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
26	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
27	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
29	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
30	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
31	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
32	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
33	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
34	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
35	0.1		0.1	0.1	0.1	0.1	0.1	0.1		0.1	
36	0.1		0.1	0.1	0.1	0.1	0.1	0.1		0.1	
37	0.1		0.1	0.1	0.1	0.1	0.1	0.1		0.1	
38	0.1		0.1	0.1	0.1	0.1	0.1	0.1		0.1	
39	0.1				0.1	0.1	0.1	0.1		0.1	

Fluorescence

Fluorescence measurements are related to phytoplankton chlorophyll and are influenced by variations in species composition, physiological state, and environmental conditions. Hence, the fluorescence profiles are used to indicate patterns and are not converted to chlorophyll concentrations.

At Station 6 in 2025, a seasonal pattern in fluorescence was observed (Fig. 26). In the upper water column (0–8 m), fluorescence values were relatively high from February through May, peaking in April, consistent with spring phytoplankton growth. Fluorescence began to decline in June, and remained low in surface waters through October. Beginning in July, fluorescence increased at subsurface depths, particularly below 7 m. A deep chlorophyll maximum (DCM) developed at ~13 m in August, and shifted slightly deeper in September and October, where peak values were observed at 15–16 m. By November and December, fluorescence values were more uniform in the upper 15 m, but increased noticeably at 16 m and deeper.

Fig. 26. Seasonal fluorescence profiles at Station 6, 2025.



Vertical Distributions of Temperature, Turbidity, Dissolved Oxygen, and Fluorescence (Station 6): Summer and Autumn

In 2025, vertical profiles at Station 6 revealed seasonal changes in temperature, turbidity, dissolved oxygen, and fluorescence (Figs. 11-14). In mid-April (Fig. 27), dissolved oxygen concentrations were elevated in the upper 15 m, while a fluorescence maximum occurred between

~15 and 20 m. This depth interval corresponds to the lower portion of the euphotic zone, defined here as the depth receiving approximately 1% of incident surface PAR, based on seasonal light attenuation measurements at Station 6. The fluorescence peak suggests increased phytoplankton biomass near the base of the euphotic zone, below the surface mixed layer.

By July (Fig. 28), a pronounced subsurface peak in both fluorescence and dissolved oxygen had formed between ~10 and 15 m, indicative of a localized phytoplankton maximum in the pycnocline. Elevated turbidity at this depth further supported the presence of biomass accumulation. This oxygen peak was likely the result of active photosynthesis occurring in a zone of reduced vertical mixing, where light remained sufficient.

Fig. 27. Temperature, turbidity, dissolved oxygen, and fluorescence at Station 6, 15 April 2025.

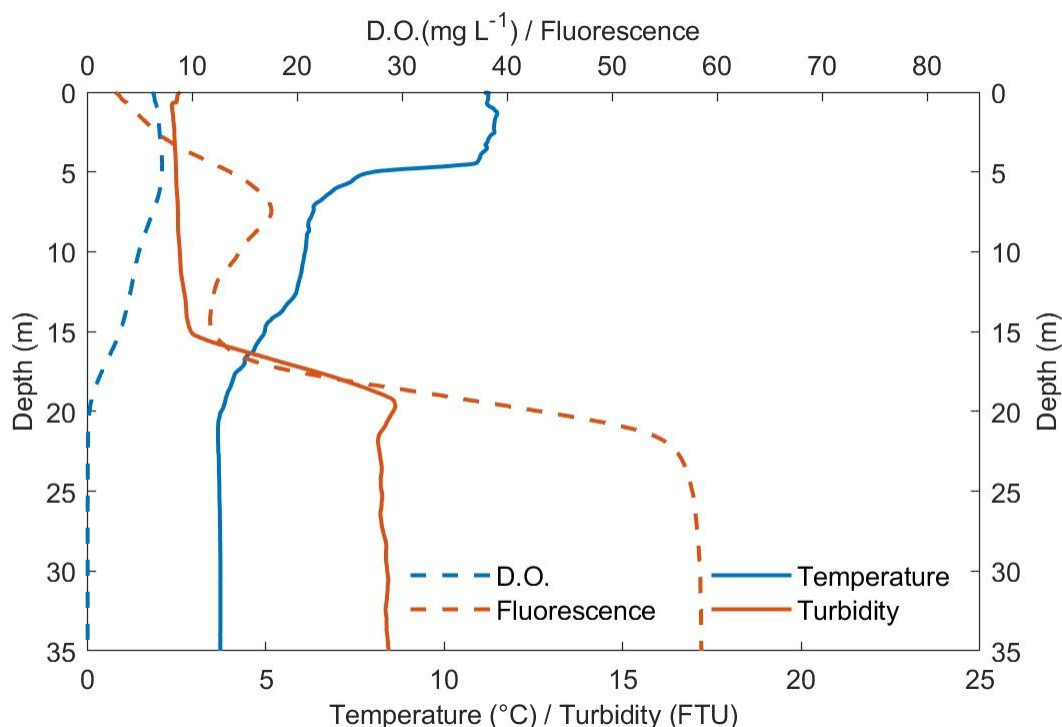
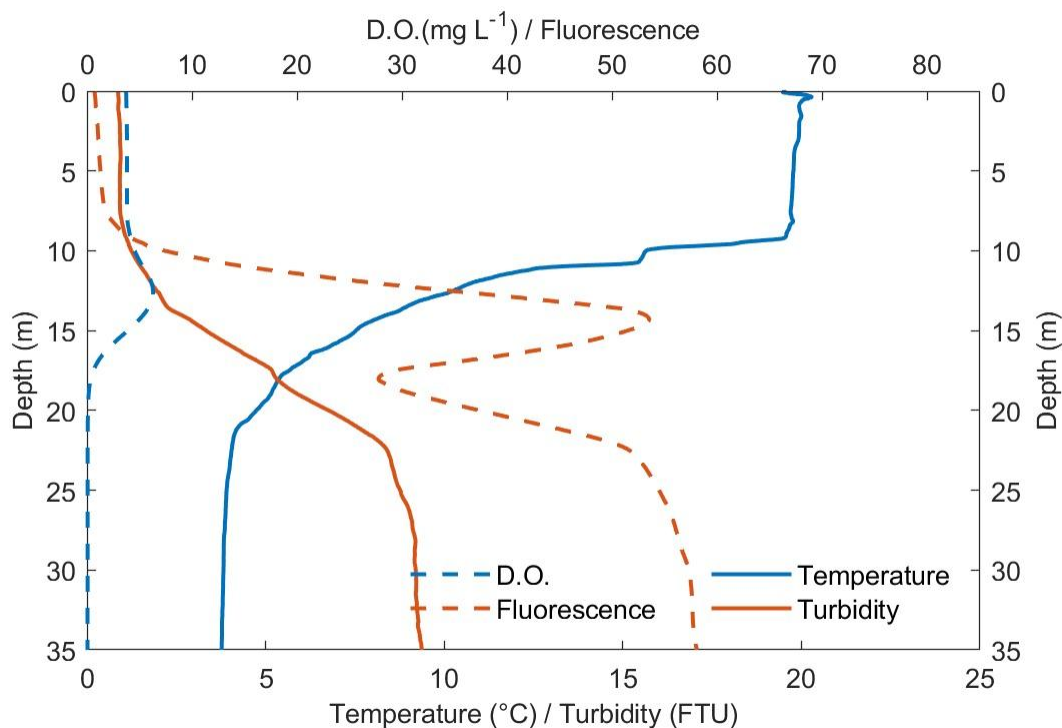


Fig. 28. Temperature, turbidity, dissolved oxygen, and fluorescence at Station 6, 10 July 2025.



In September (Fig. 29), the fluorescence and dissolved oxygen peaks persisted near 10 m but were less pronounced than in July, reflecting a seasonal decline in productivity and biomass. Turbidity remained elevated between ~10 and 15 m depth, indicating residual organic accumulation.

By December (Fig. 30), fluorescence and dissolved oxygen concentrations were redistributed vertically, increasing dissolved oxygen levels in the upper water column, consistent with increased oxygen solubility associated with lower water temperatures. Fluorescence had a broad subsurface maximum, while turbidity showed little vertical variation in the upper ~18 m. The deeper layers retained stratification, and monimolimnetic conditions remained stable.

Fig. 29. Temperature, turbidity, dissolved oxygen, and fluorescence at Station 6, 17 September 2025.

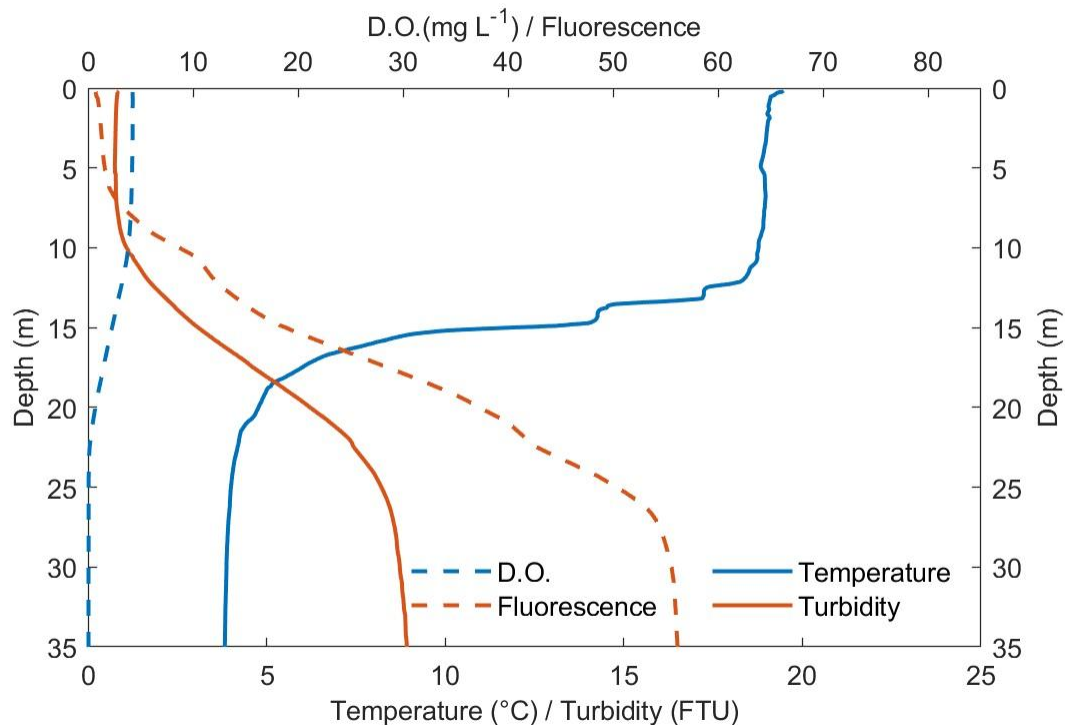
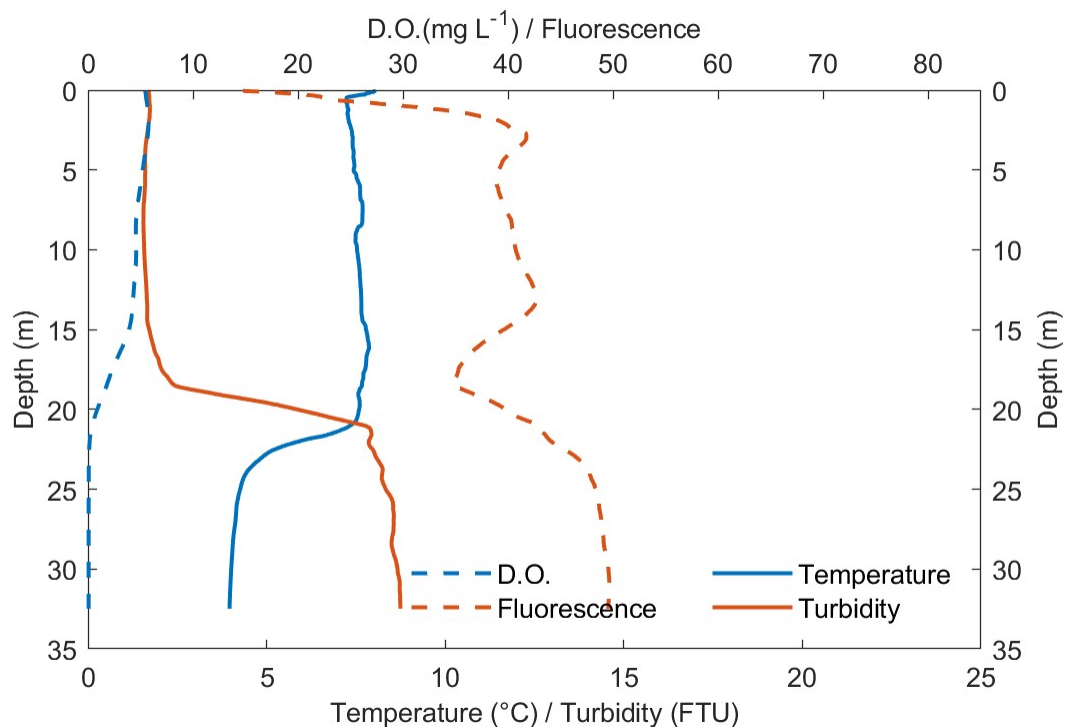


Fig. 30. Temperature, turbidity, dissolved oxygen, and fluorescence at Station 6, 15 December 2025.



Ammonium

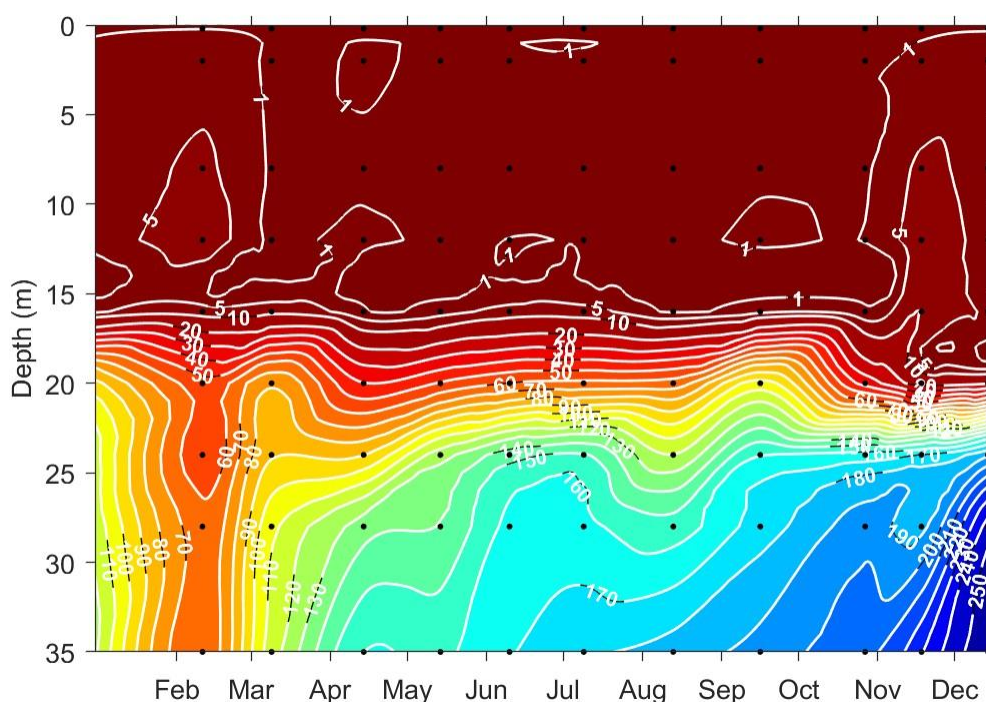
Nitrogen is the primary limiting macronutrient in Mono Lake, as phosphate is abundant year-round at concentrations between 350 and 450 μM (Melack and Jellison 1998). External nitrogen inputs are low compared to internal recycling fluxes within the lake (Jellison and Melack 1993a, b, c). Ammonium concentrations in the euphotic zone are influenced by a combination of excretion by *Artemia*, uptake by algae, upward fluxes from deeper layers, release from sediments, volatilization, and minor external inputs. Since a substantial portion of particulate nitrogen, in the form of algal detritus and *Artemia* fecal pellets, sinks and undergoes remineralization in the hypolimnion, vertical mixing plays a critical role in regulating internal nitrogen cycling throughout the year.

In 2025, ammonium concentrations at the deep, central Station 6 followed a seasonal trend, with low epilimnetic concentrations in the upper water column and an accumulation of ammonium in the hypolimnion over time (Table 6, Fig. 31). The profile on 11 February resulted from deep mixing and tilting density gradients that increased concentrations in the upper water and decreased deeper values. Chapter 4 includes a description of the changes in thermal stratification around this time based on moored sensors. By 15 May, ammonium concentrations in surface waters (≤ 8 m) were below 0.6 μM , while hypolimnetic concentrations increased to 50.8 μM at 20 m and 157.1 μM at 35 m.

Ammonium accumulation in deep waters continued throughout the summer, peaking at 193.8 μM at 35 m on 17 September and reaching a maximum of 260.4 μM by 15 December at 35 m. The high ammonium concentrations in October and November (>164 μM) from 24–35 m highlight the ongoing isolation of Mono Lake's monimolimnion, where organic matter remineralization leads to nutrient accumulation.

Table 6. Ammonium (μM) profiles at Station 6, February–December, 2025.

Depth (m)	Dates										
	2/11	3/10	4/14	5/15	6/11	7/10	8/14	9/17	10/28	11/19	12/15
0.2	4.5	0.7	1.1	0.6	1.1	1.5	0.5	0.7	0.5	0.9	3.3
2	4.3	0.4	1.3	0.6	0.8	0.7	0.5	0.7	0.9	1.4	2.5
8	5.5	0.8	0.7	0.6	0.7	0.4	0.5	0.7	0.7	5.6	2.6
12	7.2	0.6	1.6	0.7	1.0	0.8	0.5	1.7	1.2	7.1	3.1
16	7.0	8.0	1.5	3.1	6.8	6.8	0.6	3.6	1.7	10.0	4.4
20	53.9	78.5	40.4	50.8	60.3	62.6	64.8	104.0	36.2	16.4	19.2
24	52.9	88.8	89.8	125.5	145.3	150.8	120.4	159.4	164.5	170.3	188.7
28	64.4	106.8	135.1	140.6	162.3	162.0	154.6	174.6	195.0	187.1	244.3
35	62.7	114.9	159.9	157.1	169.3	179.0	184.7	193.8	207.4	229.2	260.4

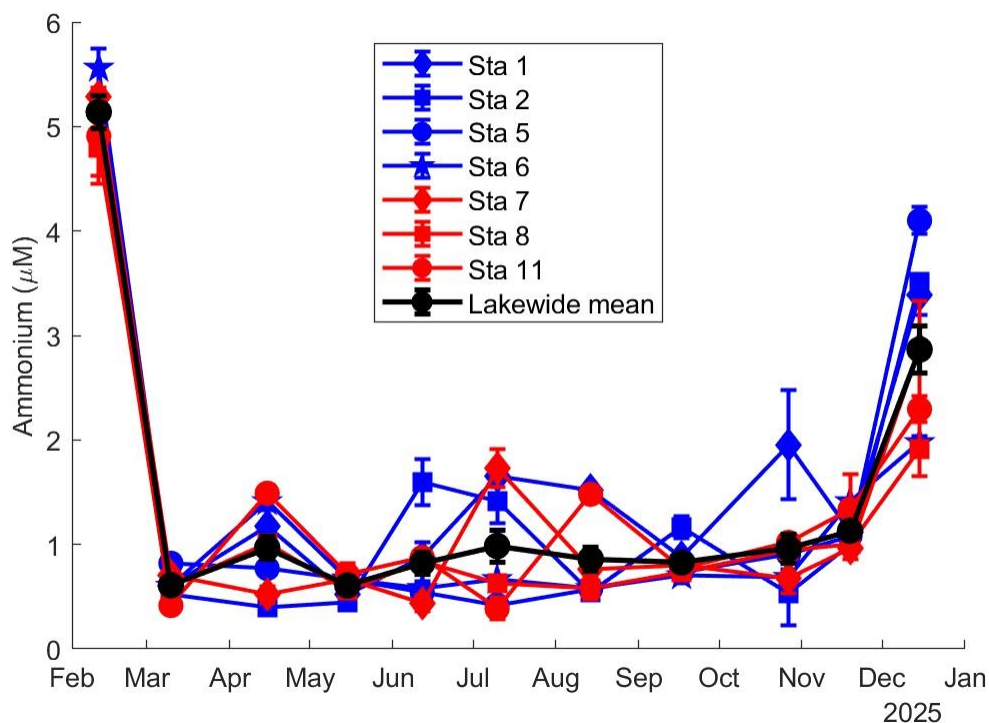
Fig. 31. Ammonium at Station 6, 2025. Isopleths are ammonium concentrations (μM). Black dots indicate CTD surveys and CTD depths.

Epilimnetic ammonium concentrations, as indicated by the upper 9-m lakewide integrated samples, were generally below 2 μM throughout most of the year, except for February and December, when mean ammonium concentrations ranged from 5.1 to 2.9 μM , respectively (Table 7). The lowest ammonium concentrations occurred in July, when surface values were as low as 0.38 μM . Spatial variability among stations was little evident (Fig. 32).

Table 7. Ammonium (μM) lakewide at 7 stations in upper 9 m of water column, February–December, 2025. S.E. is standard error. Ammonium concentrations for February at stations 1, 2, and 5 are not reported due to weather conditions.

Station	Dates										
	2/11	3/10	4/14	5/15	6/11	7/10	8/14	9/17	10/28	11/19	12/15
1		0.60	1.17	0.52	0.87	1.66	1.51	0.88	1.96	1.12	3.39
2		0.53	0.40	0.45	1.60	1.41	0.54	1.16	0.53	1.00	3.52
5		0.82	0.77	0.67	0.54	0.42	0.58	0.74	0.91	1.08	4.10
6	5.56	0.60	1.41	0.67	0.58	0.67	0.58	0.70	0.68	1.41	1.97
7	5.29	0.71	0.52	0.67	0.43	1.73	0.76	0.81	0.68	0.97	2.87
8	4.79	0.60	1.01	0.56	0.84	0.63	0.58	0.74	0.95	1.00	1.91
11	4.91	0.42	1.49	0.71	0.87	0.38	1.48	0.77	1.02	1.34	2.30
Mean	5.14	0.61	0.97	0.61	0.82	0.99	0.86	0.83	0.96	1.13	2.87
S.E.	0.18	0.05	0.16	0.04	0.15	0.22	0.17	0.06	0.18	0.07	0.32

Fig. 32. Ammonium (μM) in upper 9 m of the water column at 7 stations, 2025.



Phytoplankton

Phytoplankton abundance, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation. High phytoplankton abundance in spring is followed by low phytoplankton biomass during summer due to *Artemia* grazing.

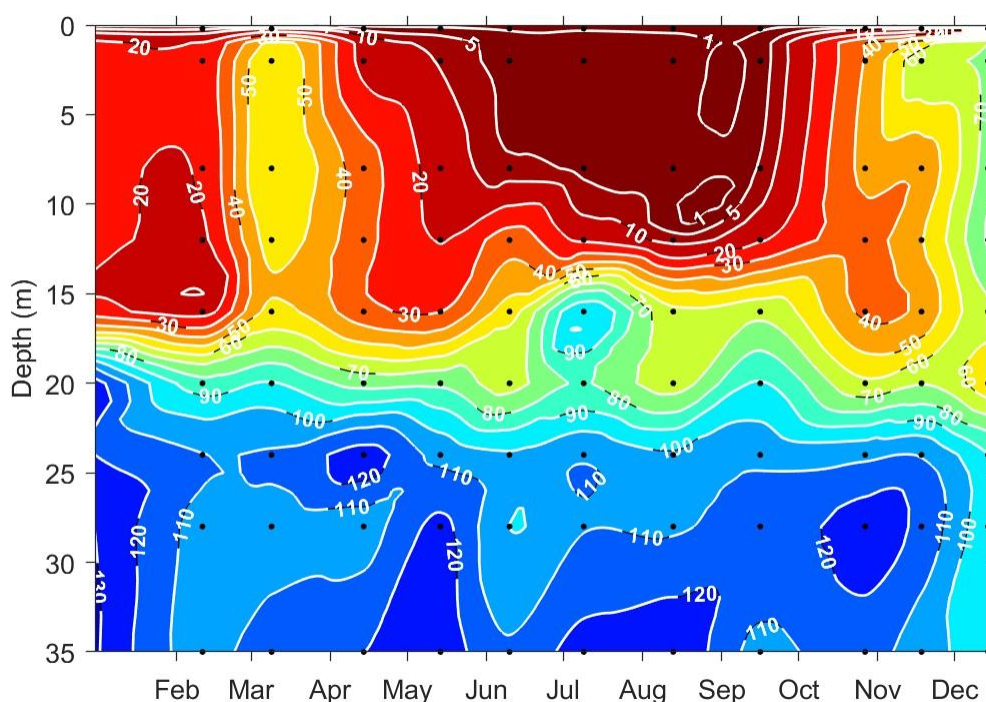
On 11 February 2025, chlorophyll concentrations at Station 6 remained relatively low throughout the water column (above 16 m depth), ranging from 16 to 24.1 $\mu\text{g chl L}^{-1}$ (Table 8, Fig. 33). During the 10 March survey, algal biomass had increased, with concentrations ranging from 46 to 60 $\mu\text{g chl L}^{-1}$. By April, epilimnetic algal biomass at 16 m depth declined to 33.9 $\mu\text{g chl L}^{-1}$, and near surface water (< 2 m) concentrations ranged from 15.3 to 17 $\mu\text{g chl L}^{-1}$. This downward trend continued in May, with near surface water (< 2 m) concentrations dropping further to 9.3 $\mu\text{g chl L}^{-1}$. The August survey recorded the lowest concentrations throughout the water column (above 12 m depth), ranging between 7.3 and 2.1 $\mu\text{g chl L}^{-1}$. Between September and November 2025, chlorophyll concentrations in the water column (above 12 m depth) at Station 6 increased from 18.8 to 66.2 $\mu\text{g chl L}^{-1}$. Levels continued increasing in winter (63.3 to 81.2 $\mu\text{g chl L}^{-1}$) as the *Artemia* population declined (Table 8, Fig. 33).

At depths of 20 m and below, chlorophyll concentrations were high during the 11 February survey and remained elevated until 15 May, ranging from 76.3 to 126.5 $\mu\text{g chl L}^{-1}$. Beginning in July, an increase in chlorophyll concentration at 16 m was observed, persisting through September before declining in October (Table 8, Fig. 33). This pattern suggests the formation of a deep chlorophyll maximum (DCM) at ~ 16 m, likely driven by stratification and nutrient availability. The stability of the pycnocline during late summer and autumn would have confined phytoplankton within this depth range, where light levels were still sufficient for photosynthesis and ammonium concentrations were elevated (Table 6). Between November and December, ammonium concentrations at 16 m increased, ranging from 4.4 to 10 μM , likely supporting sustained phytoplankton growth at this depth.

Profiles of fluorescence, turbidity, and extracted chlorophyll data at 16 m support the presence of a DCM, maintained by nutrient retention and stratification until early winter. The persistence of this structure in December, along with ammonium availability at 16 m, indicates a transition towards a more mixed but still stratified system, with deep nutrient regeneration continuing separately from surface and mid-depth biological processes.

Table 8. Chlorophyll *a* ($\mu\text{g L}^{-1}$) at Station 6, February–December 2025.

Depth (m)	Dates										
	2/11	3/10	4/14	5/15	6/11	7/10	8/14	9/17	10/28	11/19	12/15
0.2	18.1	46.0	15.3	7.9	3.2	2.9	2.1	3.0	39.7	46.1	63.3
2	24.1	58.5	17.0	9.3	3.0	3.5	2.3	2.8	40.6	66.2	73.5
8	21.5	60.0	34.7	15.7	6.6	4.0	3.2	5.8	43.0	43.3	75.2
12	18.7	53.1	33.1	19.7	34.8	18.3	7.3	18.8	36.8	49.5	81.2
16	16.0	52.4	33.9	29.8	55.8	98.6	63.0	66.9	38.0	43.1	68.5
20	84.4	90.7	76.3	78.0	66.2	80.7	65.3	90.7	62.1	69.4	53.2
24	110.4	111.3	124.1	106.9	101.6	109.0	101.7	106.9	107.7	109.2	90.4
28	105.6	103.3	106.2	121.9	99.9	109.4	108.7	115.0	123.6	117.2	93.5
35	105.2	119.0	119.9	126.5	111.8	124.4	127.2	107.5	114.5	103.1	99.0

Fig. 33. Chlorophyll *a* at Station 6, March–December, 2025. Isopleths of chlorophyll concentration ($\mu\text{g L}^{-1}$).

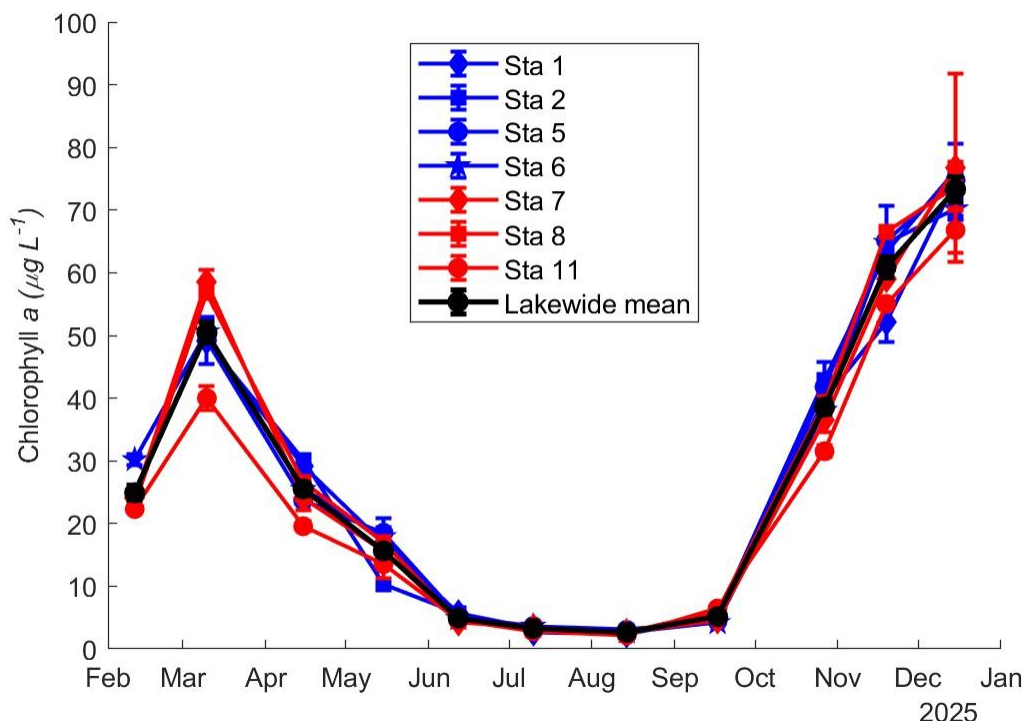
On 10 March 2025, chlorophyll *a* concentrations in upper 9-m integrated samples collected from seven lakewide stations were high and showed moderate spatial variability, ranging from 40.0 to 58.5 $\mu\text{g chl L}^{-1}$, with a lakewide mean of $50.5 \pm 2.3 \mu\text{g chl L}^{-1}$ (Table 9, Fig. 34). By mid-April, chlorophyll concentrations had declined substantially, ranging from 19.6

to $30.2 \mu\text{g chl L}^{-1}$, with a lakewide mean of $25.5 \pm 1.4 \mu\text{g chl L}^{-1}$. A continued decrease was observed by 15 May, when the lakewide mean dropped to $15.6 \pm 1.1 \mu\text{g chl L}^{-1}$.

Epilimnetic chlorophyll concentrations declined into early summer, reaching low values by the 11 June survey ($4.9 \pm 0.2 \mu\text{g chl L}^{-1}$) and decreasing further in July ($3.3 \pm 0.1 \mu\text{g chl L}^{-1}$). The lowest lakewide concentrations were observed in August, with a mean of $2.6 \pm 0.1 \mu\text{g chl L}^{-1}$. Beginning in September, chlorophyll concentrations increased slightly ($5.1 \pm 0.3 \mu\text{g chl L}^{-1}$) before rising in autumn. By 28 October, the lakewide mean increased to $38.6 \pm 1.4 \mu\text{g chl L}^{-1}$, followed by further increases in November ($60.9 \pm 2.1 \mu\text{g chl L}^{-1}$) and December ($73.3 \pm 1.4 \mu\text{g chl L}^{-1}$), marking a pronounced late-season phytoplankton bloom (Table 9, Fig. 34).

Table 9. Chlorophyll *a* ($\mu\text{g L}^{-1}$) at 7 stations in upper 9 m of water column, February–December 2025. S.E. is standard error. Chlorophyll *a* concentrations for February at stations 1, 2, and 5 are not reported due to weather conditions.

Station	Dates										
	2/11	3/10	4/14	5/15	6/11	7/10	8/14	9/17	10/28	11/19	12/15
1		49.1	29.2	16.8	5.7	2.7	2.4	5.3	39.9	52.1	74.6
2		49.1	30.2	10.3	5.7	3.2	2.8	5.2	42.9	63.3	76.3
5		49.2	23.7	18.5	5.2	3.6	3.0	4.4	41.8	65.2	74.8
6	30.2	50.6	25.4	17.9	4.8	3.6	2.7	4.2	38.0	64.9	70.2
7	24.1	58.5	24.0	15.5	4.2	3.4	2.7	4.5	36.5	59.0	76.8
8	23.0	56.9	26.6	17.0	4.4	3.5	2.7	6.0	39.2	66.6	73.8
11	22.3	40.0	19.6	13.5	4.5	2.8	2.2	6.4	31.5	55.0	66.8
Mean	24.9	50.5	25.5	15.6	4.9	3.3	2.6	5.1	38.6	60.9	73.3
S.E.	1.8	2.3	1.4	1.1	0.2	0.1	0.1	0.3	1.4	2.1	1.4

Fig. 34. Chlorophyll *a* ($\mu\text{g chl } a \text{ L}^{-1}$) in upper 9 m of the water column at 7 stations, 2025.

The large seasonal variation in epilimnetic chlorophyll concentrations (integrated over the upper 9 m) masked comparatively smaller spatial differences among stations throughout the year. During late winter and spring, chlorophyll concentrations were generally lower at eastern sector stations (Stations 7, 8, and 11) than at western sector stations (Stations 1, 2, 5, and 6). However, during summer months, mean chlorophyll concentrations were similar between sectors and, in some cases, slightly higher in the western sector. This indicates that sector-scale differences in phytoplankton biomass during 2025 were modest and secondary to strong seasonal controls, particularly grazing by *Artemia*.

By autumn and early winter, chlorophyll concentrations increased synchronously across all stations. Although seasonal increases dominated lakewide patterns, mean chlorophyll concentrations during the late-season bloom were slightly higher in the western sector than in the eastern sector (Table 9, Fig. 34).

***Artemia* Population Dynamics**

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

Hatching of Over-wintering Cysts and Maturation of the 1st Generation

Hatching of overwintering cysts is initiated by warming water temperatures and oxic sediment conditions. The peak of hatching usually occurs during March, but significant hatching may occur during February. A small amount of hatching may even occur during January in shallow nearshore regions. Lakewide *Artemia* abundance increased from $21,000 \pm 6,000 \text{ m}^{-2}$ in February to $25,000 \pm 10,000 \text{ m}^{-2}$ in March, indicating that the spring hatch was underway. By mid-April, lakewide abundance reached an early maximum of $45,000 \pm 7,000 \text{ m}^{-2}$ (Table 10, Table 11).

Table 10. Mean *Artemia* lakewide and sector abundances (m^{-2}), February–December 2025. Adult females are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac. Lakewide refers to Stations 1-12, western sector refers to Stations 1-6, and eastern sector refers to Stations 7-12. Exception: 11 February values are based only on data from stations 3, 6, 7, 8, and 11 due to weather conditions. Note: Before making inferences from this data, it is important to review the standard error associated with *Artemia* counts in Table 11.

	Instars Juveniles		Adults						Total	
	1-7	8-11	Male	Fem-und	Fem-empty	Fem-cyst	Fem-nauplii	Fem-total	total	
Lakewide										
2/11	20,463	105	36	0	28	0	0	28	64	20,632
3/10	25,453	18	3	0	0	0	0	0	3	25,475
4/15	45,111	27	0	0	0	0	0	0	0	45,137
5/15	10,047	25,439	2,475	0	3,890	0	0	3,890	6,365	41,851
6/12	11,791	11,415	9,095	13	8,665	1,006	54	9,738	18,833	42,039
7/10	7,223	3,360	10,664	0	5,030	6,030	248	11,308	21,972	32,555
8/14	6,539	771	11,362	121	1,060	7,398	423	9,001	20,362	27,673
9/17	6,536	805	13,779	0	7	4,517	791	5,315	19,095	26,435
10/27	709	761	575	0	293	122	5	421	996	2,466
11/19	330	161	104	2	80	2	2	86	189	681
12/15	320	94	74	0	20	2	2	23	97	511
Western Sector										
2/11	7,093	101	10	0	30	0	0	30	40	7,233
3/10	14,977	37	7	0	0	0	0	0	7	15,020
4/15	44,131	0	0	0	0	0	0	0	0	44,131
5/15	10,677	25,419	2,482	0	3,756	0	0	3,756	6,237	42,334
6/12	11,831	12,850	11,643	0	10,838	1,207	80	12,126	23,769	48,451
7/10	7,539	4,480	13,977	0	7,378	7,834	161	15,372	29,349	41,368
8/14	6,573	993	13,655	0	1,261	8,451	537	10,248	23,903	31,469
9/17	8,518	765	16,928	0	13	5,245	1,033	6,291	23,219	32,502
10/27	684	1,160	929	0	409	168	10	587	1,516	3,360
11/19	208	158	97	3	60	3	0	67	164	530
12/15	54	57	64	0	23	0	0	23	87	198
Eastern Sector										
2/11	29,376	107	54	0	27	0	0	27	80	29,564
3/10	35,929	0	0	0	0	0	0	0	0	35,929
4/15	46,090	54	0	0	0	0	0	0	0	46,144
5/15	9,416	25,459	2,468	0	4,024	0	0	4,024	6,492	41,368
6/12	11,751	9,980	6,546	27	6,492	805	27	7,351	13,897	35,627
7/10	6,908	2,240	7,351	0	2,683	4,225	335	7,243	14,594	23,742
8/14	6,506	550	9,068	241	858	6,345	309	7,753	16,821	23,877
9/17	4,554	845	10,630	0	0	3,789	550	4,339	14,970	20,369
10/27	734	362	221	0	178	77	0	255	476	1,573
11/19	453	164	111	0	101	0	3	104	215	832
12/15	587	131	84	0	17	3	3	23	107	825

Table 11. Standard errors of *Artemia* lakewide and sector means (Table 10), February–December 2025. Adult females are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac. Lakewide refers to Stations 1 -12, western sector refers to Stations 1-6, and eastern sector refers to Stations 7-12. Exception: 11 February values are based only on data from stations 3, 6, 7, 8, and 11 due to weather conditions.

	Instars Juveniles				Adults				Total	
	1-7	8-11	Male	Fem-und	Fem-empty	Fem-cyst	Fem-nauplii	Fem-total		total
Lakewide										
2/11	5,840	29	31	0	15	0	0	15	28	5,865
3/10	10,403	13	3	0	0	0	0	0	3	10,404
4/15	6,649	27	0	0	0	0	0	0	0	6,664
5/15	618	1,894	389	0	388	0	0	388	680	2,545
6/12	1,533	1,589	1,135	13	1,160	228	30	1,249	2,129	4,067
7/10	1,513	530	1,387	0	908	805	70	1,615	2,875	3,913
8/14	1,239	119	937	121	194	703	75	827	1,548	1,872
9/17	1,260	219	2,668	0	7	921	155	1,053	3,675	4,752
10/27	91	255	172	0	123	42	4	167	318	617
11/19	86	32	22	2	19	2	2	19	39	127
12/15	131	26	16	0	6	2	2	5	19	155
Western Sector										
2/11	3,431	80	10	0	10	0	0	10	20	3,531
3/10	6,222	26	7	0	0	0	0	0	7	6,245
4/15	3,518	0	0	0	0	0	0	0	0	3,518
5/15	819	3,266	449	0	352	0	0	352	642	4,008
6/12	2,751	2,573	1,471	0	1,786	392	55	1,830	2,556	6,858
7/10	1,898	753	1,828	0	1,089	1,112	110	1,928	3,345	5,081
8/14	1,260	134	767	0	363	771	107	946	1,466	879
9/17	1,947	294	4,887	0	13	1,729	260	1,979	6,827	8,611
10/27	147	466	283	0	244	82	7	330	578	1,149
11/19	59	39	20	3	21	3	0	24	40	127
12/15	38	30	25	0	10	0	0	10	28	91
Eastern Sector										
2/11	3,231	27	54	0	27	0	0	27	46	3,281
3/10	19,839	0	0	0	0	0	0	0	0	19,839
4/15	13,482	54	0	0	0	0	0	0	0	13,515
5/15	923	2,261	682	0	729	0	0	729	1,271	3,515
6/12	1,663	1,913	953	27	918	242	27	1,110	1,915	3,048
7/10	2,536	411	853	0	488	560	79	1,075	1,847	3,240
8/14	2,272	156	1,080	241	129	1,067	89	1,221	1,837	2,981
9/17	1,276	352	1,863	0	0	727	124	761	2,449	3,240
10/27	120	69	23	0	38	18	0	47	58	191
11/19	153	55	40	0	30	0	3	30	70	214
12/15	213	39	23	0	6	3	3	6	28	240

Table 12. Percentage in different classes for *Artemia* lakewide and sector means (Table 10), February–December 2025. Adult females are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac. Lakewide refers to Stations 1 -12, western sector refers to Stations 1-6, and eastern sector refers to Stations 7-12. Exception: 11 February values are based only on data from stations 3, 6, 7, 8, and 11 due to weather conditions. Adult female "und", "cyst", and "nauplii", given as percentage of ovigerous females. Adult female "empty" given as percentage of adult females. "Instars 1-7", "Instars 8-11", "Adult male", "Adult fem total", "Adult total" given as percentage of total shrimp.

	Instars Juveniles		Adults						Total
	1-7	8-11	Male	Fem-und	Fem-empty	Fem-cyst	Fem-nauplii	Fem-total	total
Lakewide									
2/11	99.2	0.5	0.2	0.0	100.0	0.0	0.0	0.1	0.3
3/10	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/15	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/15	24.0	60.8	5.9	0.0	100.0	0.0	0.0	9.3	15.2
6/12	28.0	27.2	21.6	1.3	89.0	93.8	5.0	23.2	44.8
7/10	22.2	10.3	32.8	0.0	44.5	96.0	4.0	34.7	67.5
8/14	23.6	2.8	41.1	1.5	11.8	93.2	5.3	32.5	73.6
9/17	24.7	3.0	52.1	0.0	0.1	85.1	14.9	20.1	72.2
10/27	28.8	30.9	23.3	0.0	69.7	96.1	3.9	17.1	40.4
11/19	48.5	23.6	15.3	33.3	94.1	33.3	33.3	12.6	27.8
12/15	62.6	18.4	14.4	0.0	85.7	50.0	50.0	4.6	19.0
Western Sector									
2/11	98.1	1.4	0.1	0.0	100.0	0.0	0.0	0.4	0.6
3/10	99.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/15	25.2	60.0	5.9	0.0	100.0	0.0	0.0	8.9	14.7
6/12	24.4	26.5	24.0	0.0	89.4	93.8	6.3	25.0	49.1
7/10	18.2	10.8	33.8	0.0	48.0	98.0	2.0	37.2	70.9
8/14	20.9	3.2	43.4	0.0	12.3	94.0	6.0	32.6	76.0
9/17	26.2	2.4	52.1	0.0	0.2	83.5	16.5	19.4	71.4
10/27	20.4	34.5	27.6	0.0	69.7	94.3	5.7	17.5	45.1
11/19	39.2	29.7	18.4	50.0	90.0	50.0	0.0	12.7	31.0
12/15	27.1	28.8	32.2	0.0	100.0	0.0	0.0	11.9	44.1
Eastern Sector									
2/11	99.4	0.4	0.2	0.0	100.0	0.0	0.0	0.1	0.3
3/10	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/15	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/15	22.8	61.5	6.0	0.0	100.0	0.0	0.0	9.7	15.7
6/12	33.0	28.0	18.4	3.1	88.3	93.8	3.1	20.6	39.0
7/10	29.1	9.4	31.0	0.0	37.0	92.6	7.4	30.5	61.5
8/14	27.2	2.3	38.0	3.5	11.1	92.0	4.5	32.5	70.4
9/17	22.4	4.1	52.2	0.0	0.0	87.3	12.7	21.3	73.5
10/27	46.7	23.0	14.1	0.0	69.7	100.0	0.0	16.2	30.3
11/19	54.4	19.8	13.3	0.0	96.8	0.0	100.0	12.5	25.8
12/15	71.1	15.9	10.2	0.0	71.4	50.0	50.0	2.8	13.0

During the April survey, the population consisted almost entirely of naupliar instars, with instars 1–7 accounting for approximately 99.9% of total abundance (Table 15). The population was dominated by mid-naupliar stages, particularly instar 5 (41.9%), followed by instars 4 (19.4%) and 3 (14.9%). Instars 1 and 2 together accounted for 13.2% of the population, while instars 6 and 7 comprised a minor fraction. Juveniles (instars 8–11) represented only 0.1% of total abundance, and adults were absent, indicating that the population was composed almost entirely of newly developed cohorts at this time (Table 13, Table 15).

By mid-May, total lakewide abundance declined to $42,000 \pm 4,000 \text{ m}^{-2}$ as the spring cohort matured (Table 10, Table 11, Table 12). Population structure shifted substantially, with juveniles becoming the dominant class and accounting for 62.9% of total abundance. Adults were present at a lakewide mean abundance of $6,000 \pm 1,000 \text{ m}^{-2}$, representing 13.6% of the population, while naupliar instars comprised a much smaller fraction than observed in April (Table 13, Table 14, Table 15).

In June, total abundance remained high at $47,000 \pm 6,000 \text{ m}^{-2}$, and adult abundance increased to $21,000 \pm 3,000 \text{ m}^{-2}$, indicating maturation of the first generation (Table 10, Table 11). Adults accounted for approximately 44% of the total population, juveniles for 29.5%, and naupliar instars for less than 27% combined. This marked the onset of adult dominance within the population (Table 15).

From July through September, lakewide abundance gradually declined but remained substantial, with mean abundances of $36,000 \pm 4,000 \text{ m}^{-2}$ in July, $29,000 \pm 3,000 \text{ m}^{-2}$ in August, and $25,000 \pm 8,000 \text{ m}^{-2}$ in September (Table 10, Table 11). Adults formed the dominant fraction of the population during this period, accounting for 64.2% in July, 74.2% in August, and 75.5% in September, while juvenile and naupliar stages continued to decline (Table 15).

A seasonal decline occurred in autumn. Total lakewide abundance decreased to $2,000 \pm 300 \text{ m}^{-2}$ in October, followed by further declines to $600 \pm 100 \text{ m}^{-2}$ in November and $500 \pm 200 \text{ m}^{-2}$ in December (Table 10, Table 11). By late autumn and early winter, both nauplii and juveniles were rare across the lake, and adults comprised the majority of the remaining population before declining to very low abundance by December (Table 13, Table 15).

Spatial patterns in 2025 differed from those observed in 2024. During the spring hatch, naupliar abundance was high in both sectors, but no persistent eastern-sector dominance was observed (Fig. 35). In April, peak abundances occurred in both sectors with similar contributions of early instars. From May through September, the western sector generally supported slightly higher total abundance than the eastern sector, particularly during periods of adult dominance in summer. This pattern persisted into early autumn, after which abundances declined to similarly low levels in both sectors.

Overall, the seasonal progression of *Artemia* abundance in 2025 followed the same general sequence observed in 2024—spring hatch, summer adult dominance, and autumn decline. However, in 2025, the spring hatch produced a pronounced peak of early instars in April, followed by sustained high abundance and a rapid transition to adult dominance through June.

Table 13. Mean *Artemia* lakewide and sector instar analysis (m⁻²), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Instars 8-11 refers to juveniles. Note: Before making inferences from this data, it is important to review standard errors associated with *Artemia* counts in Table 14.

	1	2	3	4	5	6	Instars		Adults	Total
							7	8-11		
Lakewide										
2/11	18,566	2,339	1,087	387	332	86	151	86	65	23,099
3/10	11,466	18,186	5,714	1,207	322	11	9	29	6	36,950
4/15	2,897	4,725	8,543	11,164	24,087	5,358	713	46	0	57,534
5/15	1,495	1,196	529	414	2,001	2,437	1,794	26,306	5,680	41,851
6/12	4,139	4,024	2,437	805	621	138	230	13,889	20,788	47,071
7/10	2,483	3,196	2,506	897	276	0	0	3,679	23,363	36,401
8/14	920	1,299	1,529	1,230	1,311	368	0	885	21,707	29,250
9/17	316	195	328	466	1,995	995	1,403	437	18,936	25,070
10/27	14	34	29	40	132	178	230	549	701	1,909
11/19	29	43	37	32	32	14	43	207	201	638
12/15	49	37	26	46	72	40	46	92	89	497
Western Sector										
2/11	2,716	423	161	181	40	101	40	20	20	3,702
3/10	5,739	6,313	3,722	1,147	121	0	15	50	10	17,118
4/15	4,346	4,145	6,841	10,342	16,258	5,191	966	0	0	48,089
5/15	1,730	1,087	684	362	1,972	2,817	2,254	28,773	6,117	45,795
6/12	5,594	4,748	2,575	1,167	483	40	241	15,091	24,306	54,245
7/10	2,575	2,052	2,374	1,046	402	0	0	4,467	28,410	41,328
8/14	644	926	1,087	1,006	1,006	322	0	1,006	25,473	31,469
9/17	402	221	443	584	3,058	1,368	1,751	382	21,368	29,577
10/27	0	35	5	15	80	146	201	714	855	2,052
11/19	30	55	30	35	15	15	35	191	176	584
12/15	20	15	5	5	15	5	5	70	80	221
Eastern Sector										
2/11	23,850	2,978	1,395	456	429	80	188	107	80	29,564
3/10	19,101	34,017	8,370	1,288	590	27	0	0	0	63,394
4/15	966	5,500	10,812	12,260	34,527	5,580	376	107	0	70,127
5/15	1,180	1,341	322	483	2,039	1,932	1,180	23,018	5,097	36,593
6/12	2,200	3,058	2,254	322	805	268	215	12,287	16,097	37,505
7/10	2,361	4,722	2,683	698	107	0	0	2,629	16,633	29,832
8/14	1,288	1,797	2,119	1,529	1,717	429	0	724	16,687	26,291
9/17	201	161	174	309	577	496	939	510	15,694	19,061
10/27	34	34	60	74	201	221	268	329	496	1,717
11/19	27	27	47	27	54	13	54	228	235	711
12/15	87	67	54	101	148	87	101	121	101	865

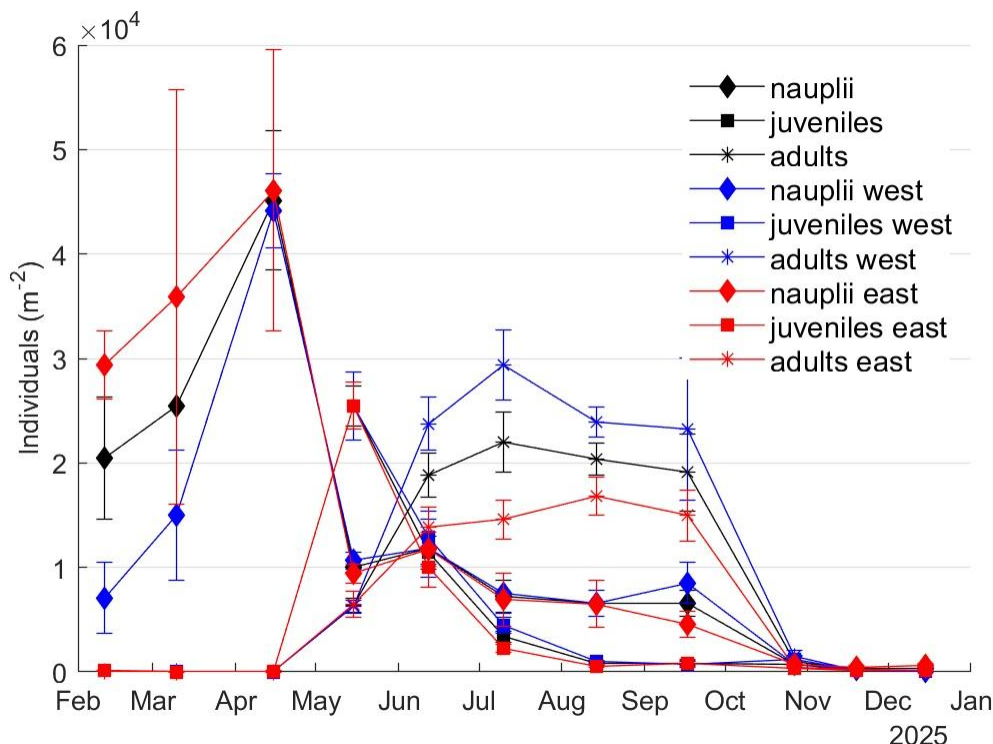
Table 14. Standard errors of *Artemia* lakewide and sector instar analysis (Table 13), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Instars 8-11 refers to juveniles.

	1	2	3	4	5	6	Instars 7	8-11	Adults	Total
Lakewide										
2/11	5,653	642	468	97	151	5	62	29	36	6,869
3/10	4,352	9,785	2,536	454	168	11	6	23	6	16,933
4/15	1,382	956	1,609	1,398	5,321	675	207	46	0	8,398
5/15	423	233	152	131	227	313	297	2,879	980	4,098
6/12	1,456	714	264	233	234	74	116	2,325	2,634	6,294
7/10	715	1,064	691	408	227	0	0	629	3,145	3,851
8/14	293	344	326	427	505	120	0	150	2,344	2,650
9/17	123	46	122	143	848	315	687	140	5,843	7,649
10/27	14	7	14	13	41	26	40	144	171	259
11/19	12	17	17	16	14	4	13	41	57	146
12/15	20	19	19	36	44	34	34	27	25	215
Western Sector										
2/11	2,493	3,863	2,482	715	70	0	10	38	10	9,621
3/10	2,237	1,270	1,227	324	1,981	412	315	0	0	3,296
4/15	662	222	212	212	374	462	341	3,908	968	5,293
5/15	2,367	1,156	348	274	383	40	154	3,396	3,078	8,966
6/12	1,197	870	987	736	402	0	0	892	3,066	5,253
7/10	237	178	222	511	489	147	0	201	1,659	1,323
8/14	192	51	193	236	1,262	461	1,074	206	10,030	12,968
9/17	0	13	5	10	16	33	59	221	279	413
10/27	13	28	17	22	10	5	17	48	53	179
11/19	8	15	5	5	15	5	5	45	41	142
12/15	2,493	3,863	2,482	715	70	0	10	38	10	9,621
Eastern Sector										
2/11	2,843	93	497	97	163	0	71	27	46	3,281
3/10	8,316	20,522	5,151	646	352	27	0	0	0	34,787
4/15	322	1,626	3,258	3,524	9,745	1,676	54	107	0	18,254
5/15	537	512	186	161	284	186	234	4,241	2,132	6,109
6/12	590	279	465	161	246	142	215	3,539	3,221	6,036
7/10	838	2,091	1,169	215	107	0	0	458	3,285	3,299
8/14	609	741	585	822	1,077	234	0	232	3,299	6,165
9/17	145	93	94	105	294	233	899	220	5,349	6,454
10/27	34	7	23	7	84	31	52	68	105	312
11/19	27	18	37	27	29	7	24	82	128	285
12/15	35	35	44	80	90	77	73	20	31	405

Table 15. Lakewide and sector percentage (given as percentage of total shrimp) in different classes for *Artemia* instar analysis (Table 13), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, the western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Instars 8-11 refers to juveniles. Instars 1 – 7 given as percentage of total instars, “Instars 8-11”, and “Adults” given as percentage of total shrimp.

	1	2	3	4	5	6	Instars		Adults	Total
							7	8-11		
Lakewide										
2/11	80.9	10.2	4.7	1.7	1.4	0.4	0.7	0.4	0.3	100
3/10	31.1	49.3	15.5	3.3	0.9	0.0	0.0	0.1	0.0	100
4/15	5.0	8.2	14.9	19.4	41.9	9.3	1.2	0.1	0.0	100
5/15	15.2	12.1	5.4	4.2	20.3	24.7	18.2	62.9	13.6	100
6/12	33.4	32.5	19.7	6.5	5.0	1.1	1.9	29.5	44.2	100
7/10	26.5	34.2	26.8	9.6	2.9	0.0	0.0	10.1	64.2	100
8/14	13.8	19.5	23.0	18.5	19.7	5.5	0.0	3.0	74.2	100
9/17	5.5	3.4	5.8	8.2	35.0	17.5	24.6	1.7	75.5	100
10/27	2.2	5.2	4.4	6.1	20.1	27.1	34.9	28.8	36.7	100
11/19	12.5	18.8	16.3	13.8	13.8	6.3	18.8	32.4	31.5	100
12/15	15.5	11.8	8.2	14.5	22.7	12.7	14.5	18.5	17.9	100
Eastern Sector										
2/11	74.2	11.5	4.4	4.9	1.1	2.7	1.1	0.5	0.5	100
3/10	33.6	37.0	21.8	6.7	0.7	0.0	0.1	0.3	0.1	100
4/15	9.0	8.6	14.2	21.5	33.8	10.8	2.0	0.0	0.0	100
5/15	15.9	10.0	6.3	3.3	18.1	25.8	20.7	62.8	13.4	100
6/12	37.7	32.0	17.3	7.9	3.3	0.3	1.6	27.8	44.8	100
7/10	30.5	24.3	28.1	12.4	4.8	0.0	0.0	10.8	68.7	100
8/14	12.9	18.5	21.8	20.2	20.2	6.5	0.0	3.2	80.9	100
9/17	5.1	2.8	5.7	7.5	39.1	17.5	22.4	1.3	72.2	100
10/27	0.0	7.3	1.0	3.1	16.7	30.2	41.7	34.8	41.7	100
11/19	14.0	25.6	14.0	16.3	7.0	7.0	16.3	32.8	30.2	100
12/15	28.6	21.4	7.1	7.1	21.4	7.1	7.1	31.8	36.4	100
Eastern Sector										
2/11	81.2	10.1	4.7	1.6	1.5	0.3	0.6	0.4	0.3	100
3/10	30.1	53.7	13.2	2.0	0.9	0.0	0.0	0.0	0.0	100
4/15	1.4	7.9	15.4	17.5	49.3	8.0	0.5	0.2	0.0	100
5/15	13.9	15.8	3.8	5.7	24.1	22.8	13.9	62.9	13.9	100
6/12	24.1	33.5	24.7	3.5	8.8	2.9	2.4	32.8	42.9	100
7/10	22.3	44.7	25.4	6.6	1.0	0.0	0.0	8.8	55.8	100
8/14	14.5	20.2	23.9	17.2	19.3	4.8	0.0	2.8	63.5	100
9/17	7.0	5.6	6.1	10.8	20.2	17.4	32.9	2.7	82.3	100
10/27	3.8	3.8	6.8	8.3	22.6	24.8	30.1	19.1	28.9	100
11/19	10.8	10.8	18.9	10.8	21.6	5.4	21.6	32.1	33.0	100
12/15	13.5	10.4	8.3	15.6	22.9	13.5	15.6	14.0	11.6	100

Fig. 35. Lakewide *Artemia* abundance during 2025; nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).



Ovoviviparous Reproduction and the Second Generation

Ovoviviparous reproduction depends on ambient food levels and age. *Artemia* produce multiple broods and ovoviviparous reproduction occurs primarily with the first brood, rarely occurring in second and subsequent broods.

In 2025, adult females were first observed in May, when lakewide female abundance reached $4,000 \pm 400$ m^{-2} . At this time, all females were non-ovigerous, with empty ovisacs, indicating that reproductive activity had not yet begun. Ovoviviparous reproduction became evident in June, when ovigerous females first appeared at a lakewide mean abundance of approximately $1,000$ m^{-2} (Table 16, Table 17). Differentiated egg masses during June were dominated by cysts ($1,000 \pm 200$ m^{-2}), with only a small contribution from naupliar eggs (55 ± 30 m^{-2}), indicating an early bias toward cyst production.

Reproductive activity increased substantially during mid- to late summer. In July, ovigerous female abundance increased to $6,000 \pm 800$ m^{-2} , and differentiated egg masses were

again strongly dominated by cysts ($6,000 \pm 800 \text{ m}^{-2}$) relative to naupliar eggs ($250 \pm 70 \text{ m}^{-2}$). Ovigerous female abundance remained high in August ($8,000 \pm 800 \text{ m}^{-2}$), with cyst production continuing to dominate ($7,000 \pm 700 \text{ m}^{-2}$) and a modest increase in naupliar egg production ($400 \pm 70 \text{ m}^{-2}$). By September, nearly all females were ovigerous ($5,000 \pm 1,000 \text{ m}^{-2}$), and differentiated eggs continued to favor cyst production ($5,000 \pm 900 \text{ m}^{-2}$) over naupliar eggs ($800 \pm 200 \text{ m}^{-2}$) (Table 16, Table 17, Table 18; Fig. 36).

Reproductive output declined in autumn as overall adult abundance decreased. Female abundance dropped to $400 \pm 200 \text{ m}^{-2}$ in October and to $100 \pm 20 \text{ m}^{-2}$ in November, with only small numbers of ovigerous females present and minimal egg production late in the year. By December, reproduction was negligible as adult abundance declined to very low levels.

Table 16. Mean *Artemia* lakewide and sector reproductive summary (m^{-2}), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Adult female are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac. Before making inferences from these data, review standard errors associated with *Artemia* counts in Table 17.

	Total	Ovigery	empty	und	cyst	Adult females nauplii
Lakewide						
2/11	28	0	28	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	3,890	0	3,890	0	0	0
6/12	9,738	1,073	8,665	13	1,006	54
7/10	11,308	6,278	5,030	0	6,030	248
8/14	9,001	7,941	1,060	121	7,398	423
9/17	5,315	5,309	7	0	4,517	791
10/27	421	127	293	0	122	5
11/19	86	5	80	2	2	2
12/15	23	3	20	0	2	2
Western Sector						
2/11	30	0	30	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	3,756	0	3,756	0	0	0
6/12	12,126	1,288	10,838	0	1,207	80
7/10	15,372	7,995	7,378	0	7,834	161
8/14	10,248	8,987	1,261	0	8,451	537
9/17	6,291	6,278	13	0	5,245	1,033
10/27	587	178	409	0	168	10
11/19	67	7	60	3	3	0
12/15	23	0	23	0	0	0
Eastern Sector						
2/11	27	0	27	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	4,024	0	4,024	0	0	0
6/12	7,351	858	6,492	27	805	27
7/10	7,243	4,561	2,683	0	4,225	335
8/14	7,753	6,895	858	241	6,345	309
9/17	4,339	4,339	0	0	3,789	550
10/27	255	77	178	0	77	0
11/19	104	3	101	0	0	3
12/15	23	7	17	0	3	3

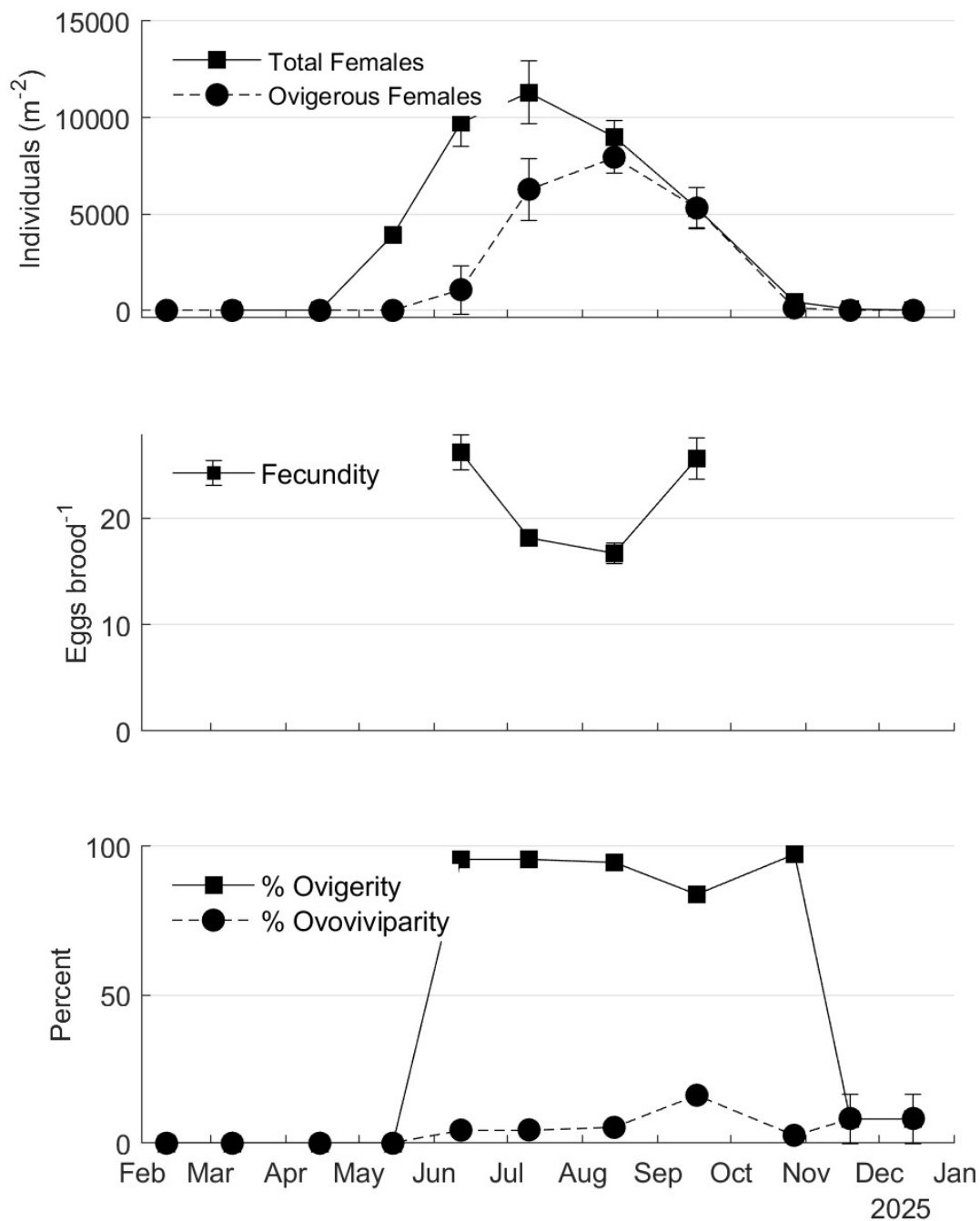
Table 17. Standard errors of *Artemia* lakewide and sector reproductive summary (Table 16), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Adult females are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac.

	Total	Ovigery	empty	und	cyst	Adult females nauplii
Lakewide						
2/11	15	0	15	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	388	0	388	0	0	0
6/12	1,249	239	1,160	13	228	30
7/10	1,615	804	908	0	805	70
8/14	827	771	194	121	703	75
9/17	1,053	1,053	7	0	921	155
10/27	167	45	123	0	42	4
11/19	19	3	19	2	2	2
12/15	5	2	6	0	2	2
Western Sector						
2/11	10	0	10	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	352	0	352	0	0	0
6/12	1,830	422	1,786	0	392	55
7/10	1,928	1,127	1,089	0	1,112	110
8/14	946	786	363	0	771	107
9/17	1,979	1,982	13	0	1,729	260
10/27	330	88	244	0	82	7
11/19	24	4	21	3	3	0
12/15	10	0	10	0	0	0
Eastern Sector						
2/11	27	0	27	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	729	0	729	0	0	0
6/12	1,110	234	918	27	242	27
7/10	1,075	628	488	0	560	79
8/14	1,221	1,249	129	241	1,067	89
9/17	761	761	0	0	727	124
10/27	47	18	38	0	18	0
11/19	30	3	30	0	0	3
12/15	6	4	6	0	3	3

Table 18. *Artemia* lakewide and sector reproductive summary percentages (Table 16), February–December 2025. Lakewide refers to Stations 1, 2, 5, 6, 7, 8, and 11, western sector refers to Stations 1, 2, 5, and 6, and eastern sector refers to Stations 7, 8, and 11. Exception: 11 February values are based only on data from stations 6, 7, 8, and 11 due to weather conditions. Adult females are separated depending on eggs present: und, undifferentiated egg mass; empty, empty ovisac; cyst, cysts in ovisac; nauplii, naupliar eggs in ovisac. "Ovigery" and "empty" are given as percentages of total number of females. "und" is given as percentage of ovigerous females. Cyst and nauplii are given as percentage of individuals with differentiated egg masses.

	Total	Ovigery	empty	und	cyst	Adult females nauplii
Lakewide						
2/11	100	0	100	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/12	100	11	89	1	94	5
7/10	100	56	44	0	96	4
8/14	100	88	12	2	93	5
9/17	100	100	0	0	85	15
10/27	100	30	70	0	96	4
11/19	100	6	94	33	33	33
12/15	100	14	86	0	50	50
Western Sector						
2/11	100	0	100	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/12	100	11	89	0	94	6
7/10	100	52	48	0	98	2
8/14	100	88	12	0	94	6
9/17	100	100	0	0	84	16
10/27	100	30	70	0	94	6
11/19	100	10	90	50	50	0
12/15	100	0	100	0	0	0
Eastern Sector						
2/11	100	0	100	0	0	0
3/10	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/12	100	12	88	3	94	3
7/10	100	63	37	0	93	7
8/14	100	89	11	4	92	4
9/17	100	100	0	0	87	13
10/27	100	30	70	0	100	0
11/19	100	3	97	0	0	100
12/15	100	29	71	0	50	50

Fig. 36. Reproductive characteristics of *Artemia* during 2025. Lakewide mean abundance of total females and ovigerous females (top), brood size (middle), and percent of females ovoviviparous and ovigerous (bottom). Vertical lines are the standard errors of the estimates.



Lakewide mean fecundity ranged from 13 to 21 eggs brood⁻¹ between June and September (Table 19; Fig. 36). Mean individual fecundity increased during October, November, and December (29, 41, and 37 eggs brood⁻¹, respectively), likely reflecting increased food availability; however, total reproductive output remained low during this period due to the small number of adult females present. Mean adult female length varied from 8.3 to 10.1 mm over the course of the year.

Table 19. *Artemia* fecundity summary, June–December 2025. “%cyst” and “%indented” refers to the percentage of the type (cyst or naupliar) and shape (indented or round) of the eggs, respectively. S.E. is standard error. ‘n’ refers to number of stations averaged. ‘#fem’ refers to number of females averaged.

	#eggs/brood		%cyst	%indented	Female length (mm)		n	#fem
	Mean	S.E.			Mean	S.E.		
Lakewide								
6/12	26	1.2	91	49	9	0.1	7	70
7/10	18	0.8	97	66	9	0.1	7	70
8/14	17	0.8	90	6	9	0.1	7	70
9/17	26	1.2	90	14	10	0.1	7	70
10/27	52	11.1	71	29	10	0.4	4	7
11/19	74	0.0	0	0	9	0.0	1	1
Western Sector								
7/10	18	1.0	98	78	9	0.1	4	40
8/14	16	1.0	98	5	9	0.1	4	40
9/17	24	1.7	93	18	9	0.1	4	40
10/27	57	14.2	80	40	10	0.4	2	5
11/19	0	0.0	0	0	0	0.0	0	0
Eastern Sector								
7/10	19	1.1	97	50	9	0.1	3	30
8/14	17	1.3	80	7	9	0.2	3	30
9/17	28	1.4	87	10	10	0.1	3	30
10/27	41	19.5	50	0	10	1.5	2	2
11/19	74	0.0	0	0	9	0.0	1	1

Artemia Biomass

In 2025, mean lakewide *Artemia* biomass was low in late winter/early spring (0.3 ± 0.1 g dry weight m⁻² in February, 0.1 ± 0.0 in March, 0.5 ± 0.1 in April), then increased rapidly with maturation of juveniles and adults in late spring. Biomass reached 5.0 ± 0.4 g dry weight m⁻² in May and remained high through summer, peaking at 8.3 ± 0.6 g dry weight m⁻² in mid-August.

Following the summer peak, biomass declined in autumn (5.4 ± 1.0 in September, 0.5 ± 0.1 in October) and remained low into winter (0.3 ± 0.1 in November, 0.2 ± 0.0 in December) (Table 20).

The seasonal trajectory of *Artemia* biomass in 2025 was similar to that observed in 2024, characterized by a spring increase, summer maximum, and autumn decline. However, differences were observed in both timing and magnitude, with biomass in 2024 peaking in July (7.8 ± 1.0 g dry weight m^{-2}), whereas in 2025 the maximum occurred slightly later and reached a marginally higher value in August (8.3 ± 0.6 g dry weight m^{-2}).

Spatial differences in *Artemia* biomass between lake sectors were generally smaller than seasonal changes and did not alter the overall biomass trajectory observed in 2025. Both western and eastern sectors had similar timing of biomass increase in spring, attainment of peak values in summer, and decline in autumn. However, modest differences in magnitude were observed at times, with the western sector generally supporting slightly higher biomass during peak summer conditions. These differences were short-lived and inconsistent across months, indicating that lakewide environmental controls dominated biomass dynamics, while sector-scale variability played a secondary role.

Table 20. *Artemia* biomass (g dry weight m⁻²) summary, February–December 2025. S.E. is standard error. ‘n’ in last column refers to number of stations averaged.

Date	Mean	S.E.	n
Lakewide			
2/11	0.3	0.1	5
3/10	0.1	0.0	12
4/15	0.5	0.1	12
5/15	5.0	0.4	12
6/12	7.7	0.7	12
7/10	5.7	0.9	12
8/14	8.3	0.6	12
9/17	5.4	1.0	12
10/27	0.5	0.1	12
11/19	0.3	0.1	12
12/15	0.2	0.0	11
Western Sector			
2/11	0.2	0.0	2
3/10	0.1	0.0	6
4/15	0.5	0.0	6
5/15	4.9	0.7	6
6/12	8.9	1.0	6
7/10	7.3	1.6	6
8/14	9.3	0.5	6
9/17	5.5	1.1	6
10/27	0.8	0.2	6
11/19	0.2	0.0	6
12/15	0.1	0.1	5
Eastern Sector			
2/11	0.4	0.1	3
3/10	0.2	0.1	6
4/15	0.6	0.2	6
5/15	5.1	0.6	6
6/12	6.5	0.7	6
7/10	4.1	0.4	6
8/14	7.3	0.9	6
9/17	5.2	1.6	6
10/27	0.3	0.0	6
11/19	0.4	0.2	6
12/15	0.2	0.0	6

CHAPTER 4

FURTHER ANALYSES

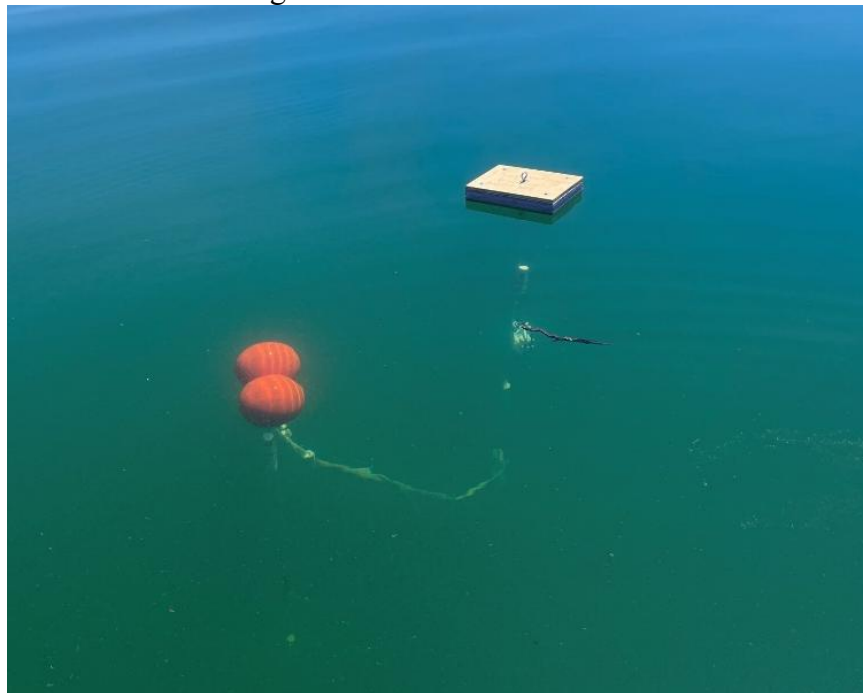
Thermal Structure, Conductivity, and Dissolved Oxygen

Methods

Time-series measurements of water temperature were obtained with thermistors deployed on vertical arrays. Thermistor arrays had the upper-most loggers suspended below and shaded by a surface float, and deeper ones were on taut-line moorings with a float ~1 to 1.5 m below the water surface (Fig. 37). The thermistors were RBR Solo® thermistors, individually calibrated by the vendor (accuracy ± 0.002 °C), sampled at 0.1 Hz at depths shown in figures below.

Conductivity was measured with RBR Concerto³ conductivity-temperature-depth (CTD) sensors, individually calibrated by vendor (conductivity with extended range, accuracy ± 0.003 mS cm⁻¹; temperature accuracy ± 0.002 °C; depth (pressure) accuracy $\pm 0.05\%$ full range). Specific conductance, also known as SC or C25, in which the temperature dependence of conductivity is normalized to 25 °C was calculated as described in Chapter 2. Density was calculated from the time series temperature and SC as described in Chapter 2. Dissolved oxygen was measured with optical sensors (PME MiniDOT loggers; accuracy of 5% of measurement or 0.3 mg L⁻¹, whichever is larger, and resolution of 0.01 mg L⁻¹) recording every 10 minutes. In comparison to dissolved oxygen concentrations near 100% saturation with atmospheric air measured by Miller titration, values produced by the PME algorithm for the same elevation and salinity were about 10% higher. DO sensors had PME wipers attached that eliminated biofouling.

Fig. 37. Surface float (tan wooden square) with sensors suspended below and connected to subsurface buoys (orange round) at about 1 m below lake surface with additional sensors below on taut line with weight on bottom.



Results

Thermal structure

The temperature records at Station 6 and Station 3 from November 2024 until May 2025 show decreasing temperatures during fall, minimum temperatures in the upper water column in January and February 2025, and development of stratification initially in the upper 5 m in late February (Day of Year (DOY) 420) and throughout the water column by the beginning of April (DOY456) (Fig. 38, Fig. 39). Patterns were similar at both locations. A key feature at both locations is the erosion of a layer of warmer water initially centered at 15 m in late fall and ultimately at 20 m until DOY 399 (early February 2025) when a period of high winds occurred (see Chapter 3).

Persistence of such inverse stratification is feasible due to an increase in specific conductance at those depths which leads to stable density stratification. The loss of the warm layer and the deepening of the salinity gradient was caused by strong wind events. The time series temperatures indicate not only the loss of the warm layer, but abrupt warming of water in the lower water column. The heating at depth indicated the mixing influenced the full water column, the mixing event also led to mixing of NH_4 as described in Chapter 3. The importance

of wind mixing events can also be seen in the up and down motions of the thermocline, as evidenced by evidenced by closely spaced isotherms, with warming in spring. A particularly notable event occurred near DOY 500 (~13 May). These mixing events serve to mix heat downwards.

Fig. 38. Temperature at Station 6 from Nov 2024 to May 2025. Sensor locations are indicated by the red dots. Data were collected at 10 second intervals and averaged over two hours. Each black line is an isotherm, that is, a line indicating the same temperature over time.

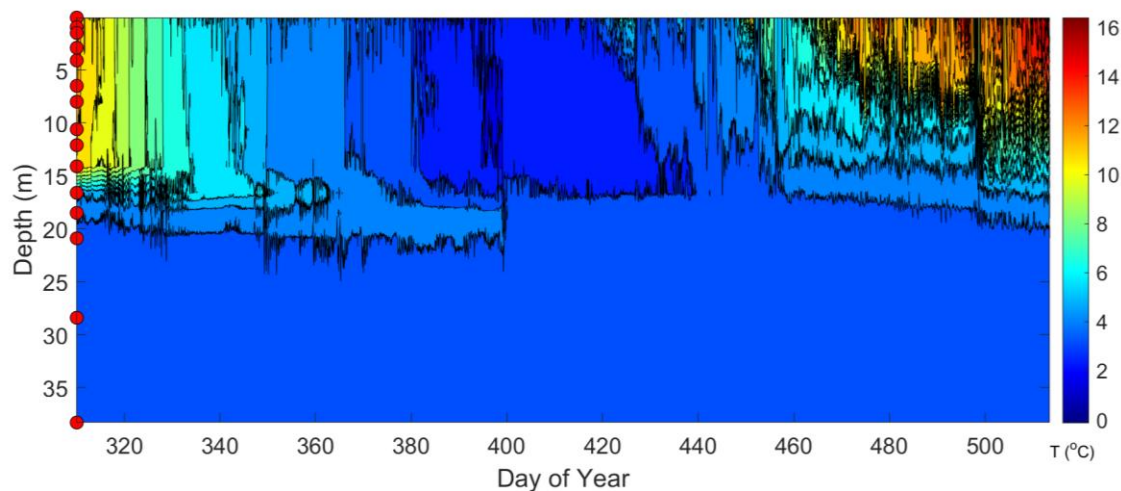
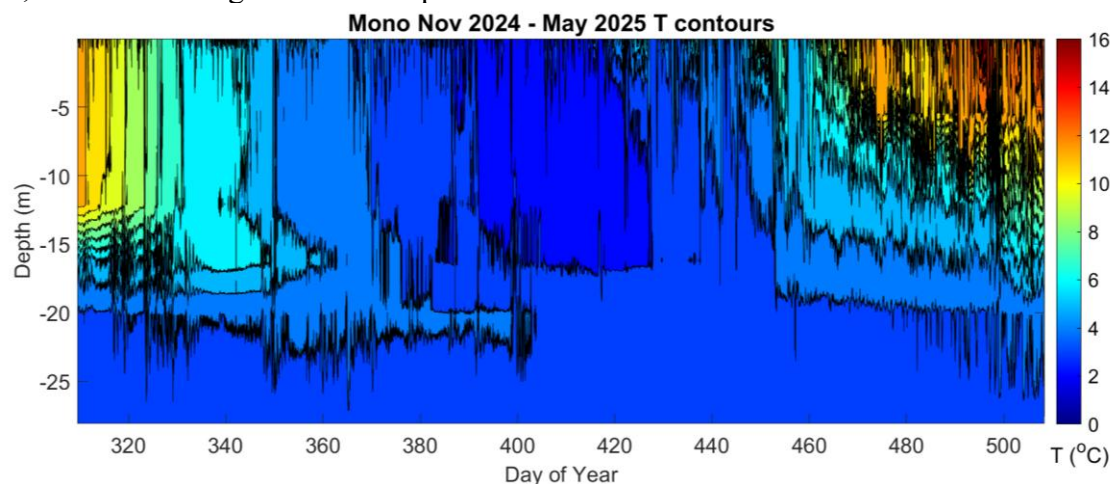


Fig. 39. Temperature at Station 3 from Nov 2024 to May 2025. Sensor locations were deployed at depths of 0.05, 0.8, 1.5, 2.1, 3.4, 4.4, 5.4, 6.9, 7.9, 9.3, 12.1, 16.2, 20.2, and 28.1 m. Data were collected at 10-second intervals and averaged over two hours. Each black line is an isotherm, that is, a line indicating the same temperature over time.



Temperature data obtained from May 2025 until October 2025 illustrate the intensification of heating and of stratification through late summer (DOY 240, 28 August 2025) and then the subsequent cooling and weakening of stratification in the upper water column. At all

stations, summer temperatures reached 25°C and the depth of the mixed layer reached nearly 10 m. Throughout May and until DOY 200 (19 July), wind mixing events led to stepwise increases in the depth of the upper mixed layer. This process involves southwesterly winds, acting along the long axis of the lake, causing downwelling to the north and upwelling to the south followed by a cycle of downwelling and upwelling.

Station 6 is located mid-lake so upwelling events can be muted there. However, these events can be seen at Station 5. For instance, a strong wind event late on DOY 172 led to downwelling to 12 m at Station 5 followed by upwelling. The thermocline descended about 1.5 m. Such events persisted throughout the summer but had little effect on thermocline deepening from 19 July (DOY 200) until 2 September (DOY 245). The wind event at that time caused the thermocline to deepen by 2 m. Two more events in which the thermocline deepened appreciably occurred through the end of the record, by which time, due to decreases in solar radiation, increases in heat loss from latent heat fluxes, as well as the upward mixing of colder water, temperatures in the surface had decreased to 13°C. The combined processes of wind mixing and heat loss led the thermocline to descend from 10 m to ~15 m depth from early September until the third week of October.

Fig. 40. Contours of temperature at Station 6 from May to October 2025. Sensor locations were deployed at depths of 0.05, 0.95, 1.5, 2.9, 4.1, 6.5, 8.0, 10.6, 12.1, 14.1, 16.6, 18.5, 20.9, and 28.4 m. Data were averaged over 24-minute intervals, and 25 contour levels were used. Days of Year (DOY) begin on 1 January 2025.

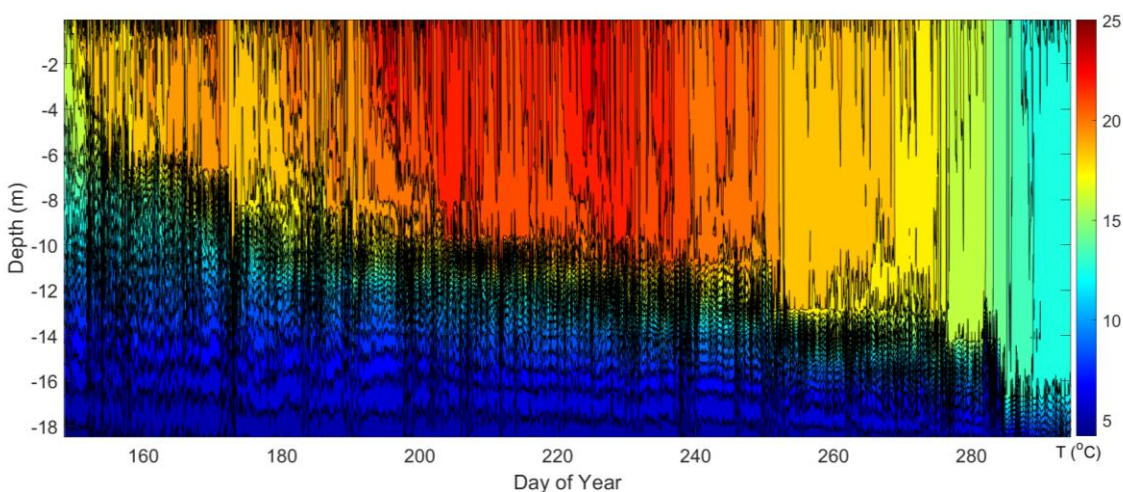


Fig. 41. Contours of temperature at Station 5 from May to October 2025.

Note: Sensor locations were deployed at depths of 0.05, 1.0, 2.5, 4.5, 6.5, 8.5, 10.5, 12.5, 14.5, and 16.5 m. Data were averaged over 24-minute intervals, and 25 contour levels were used. Days of Year (DOY) begin on 1 January 2025.

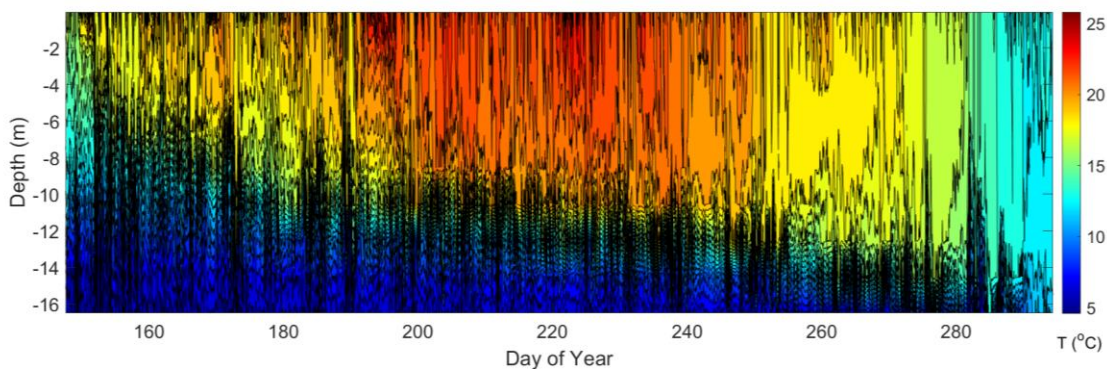
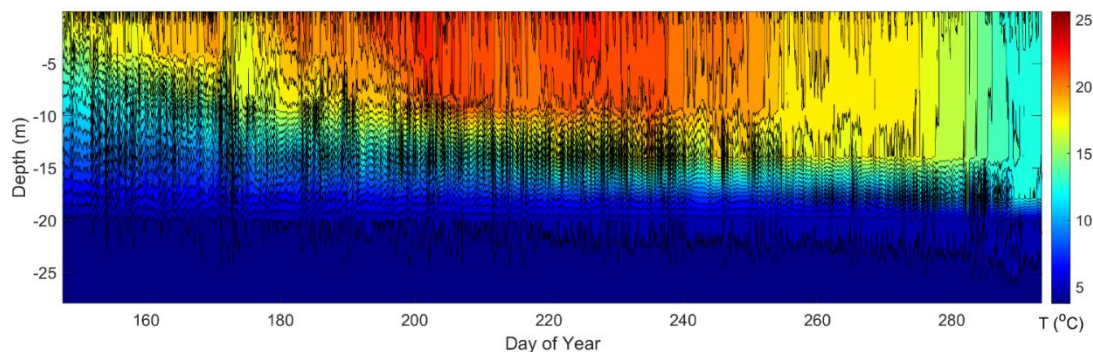


Fig. 42. Contours of temperature at Station 3 from May to October 2025. Sensor locations were deployed at depths of 0.05, 1.5, 1.9, 3.9, 7.8, 9.2, 13.9, 17.9, 20.1, and 28.0 m. Data were averaged over 24-minute intervals, and 25 contour levels were used. Days of Year (DOY) begin on 1 January 2025.



Salinity structure

Specific conductance (SC) was stratified in fall but as the mixing extended into the thermocline (Fig. 38), values of SC decreased at 15.6 m and became more similar to those in the upper mixed layer (5.8, 9.5, and 12.6 m). The frequent spikes are indicative of internal wave activity. As the mixed layer further descended, SC at 15.6 m was within 0.1 or 0.2 mS cm^{-1} of that in the overlying water. After DOY 406, SC at 15.6 m continued to fluctuate from internal wave motions but was $\sim 79.5 \text{ mS cm}^{-1}$. In contrast, as stratification developed above 15.6 m, SC in the overlying water slowly decreased such that by late May the difference in SC between 9.5 and 15.6 m was 0.3 mS cm^{-1} . SC was slightly higher at 5.6 m than within the thermocline at 9.5 and 12.6m.

Fig. 43. Specific conductance (SC) at Station 6 from November 2024 to May 2025. Sensor locations were deployed at depths of 5.6, 9.5, 12.6, and 15.6 m. Data were averaged over two-hour intervals. The step on DOY 399 occurred because the taut line mooring declined into the sediments by approximately 1 m.

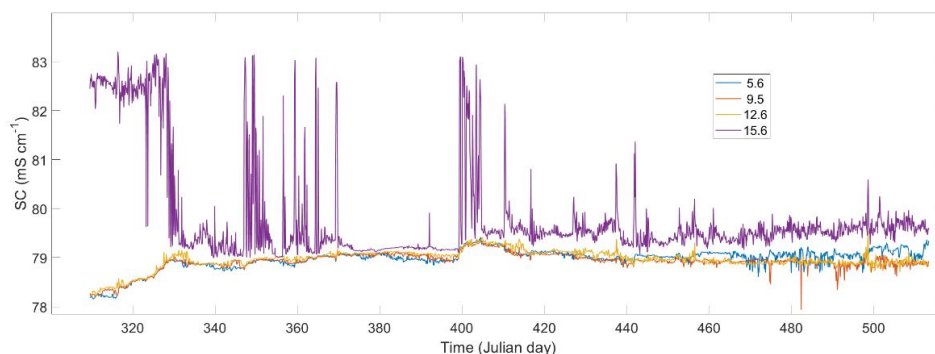
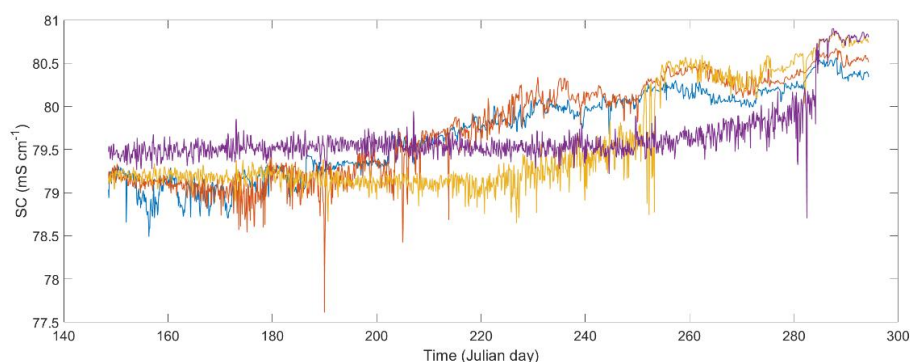


Fig. 44. Specific conductance (SC) at Station 6 from May to October 2025. Sensor locations were deployed at depths of 5.8, 9.5, 12.8, and 15.6 m. Data were averaged over two-hour intervals.



Specific conductance initially shows water with slightly lower SC near the surface and an increase with depth. However, over time, the patterns change. Notably, with the high wind even late on DOY 172, SC at 5.8 and 9.5 m increased to the values at 12.8 m, indicating a mixing event. By DOY 187, SC at 5.8 m increased abruptly and, with a few exceptions, exceeded that at 9.5 and 12.8 m until DOY 204. By that time the upper mixed layer had deepened such that the sensor at 9.5 m was in the mixed layer. As a result, SC at 9.5 m increased such that SC at 5.8 and 9.5 m were equal. After DOY 212, SC at 5.8 and 9.5 m exceeded that at 15.6 m. SC at 12.8 m gradually increased beginning on DOY 220.

A large mixing event on DOY 252 deepened the upper mixed layer to ~13 m such that SC at 12.8 m increased to values similar to those at 9.5 m. From that date until DOY 284, SC at

the 3 shallower depths exceeded SC at 15.6 m although SC at 15.6 m began to rise. The strong mixing event on DOY 284 deepened the upper mixed layer to 16 m and SC at 15.6 m rapidly increased. Despite the similarities in temperature (Fig. 40), SC was least at the surface and highest at 12.8 and 15.6 m.

The increases in SC at the shallower depths beginning after DOY 185 are likely a result of evaporation which leads to a loss of freshwater and retention of solutes. The increases in SC as the depth of the two deeper sensors was closer to or within the thermocline points to increased exchange between the thermocline and the upper mixed layer. The larger amplitude of internal waves in the temperature record at Station 5 illustrates this connection more readily than the data from Station 6 (Fig. 40, Fig. 41). SC at 6.5 m at Station 3 increased from 79 to 80 $\mu\text{S cm}^{-1}$ from May to October 2025, an increase similar to that at 5.8 m at Station 6 (data not shown).

Density structure

Mixing around DOY 332 associated with winds and fall cooling reduced but did not eliminate the density difference between water in the thermocline at 15.6 m and that at the three depths above within the upper mixed layer. From DOY 374 to 399, the density gradient was the lowest of the winter period, 0.0002 kg m^{-3} . From DOY 410 onwards, the density decreased where the water column was warming (5.6, 9.5, and 12.6 m). The decrease in density at 15.6 m on DOY 440 resulted from increasing temperatures in spring.

During spring, summer, and fall 2025, increasing temperatures in the mixed layer led to decreased density at 5.8 and 9.5 m through ~DOY 202. However, despite water temperature remaining relatively stable in the mixed layer until DOY 240, the increase in SC beginning on DOY 202 led to density increasing in the upper mixed layer. Density increased at 12.6 m through DOY 245. As temperatures increased at this depth for much of the record, the increases in density are due to an overall increase in SC, likely due to some mixing with the water above (Fig. 42). After DOY 245, density continued to increase from 5.6 to 12.6 m but was less than that at 15.8 m. However, the final mixing event led to a diminution of the differences in density in the upper 15.6 m. Density did increase from 5.8 m to 15.6 m, but the difference was only 0.0005 kg m^{-3} . Consequently, the interaction of the strong wind-induced mixing events and evaporation led to a reduction in the density difference from 5.8 to 15.6 m, depths which initially extended from

the upper mixed layer to below the thermocline. This mixing primed the lake for deeper mixing in the coming winter.

Fig. 45. Density at Station 6 from November 2024 to May 2025. Sensor locations were deployed at depths of 5.6, 9.5, 12.6, and 15.6 m. Data were averaged over two-hour intervals.

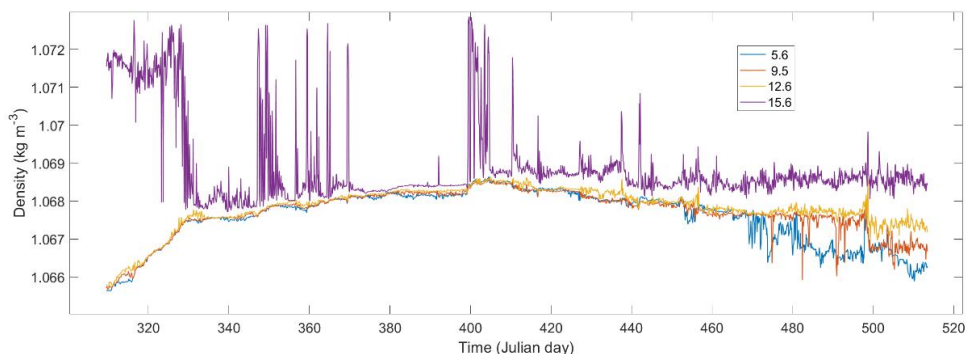
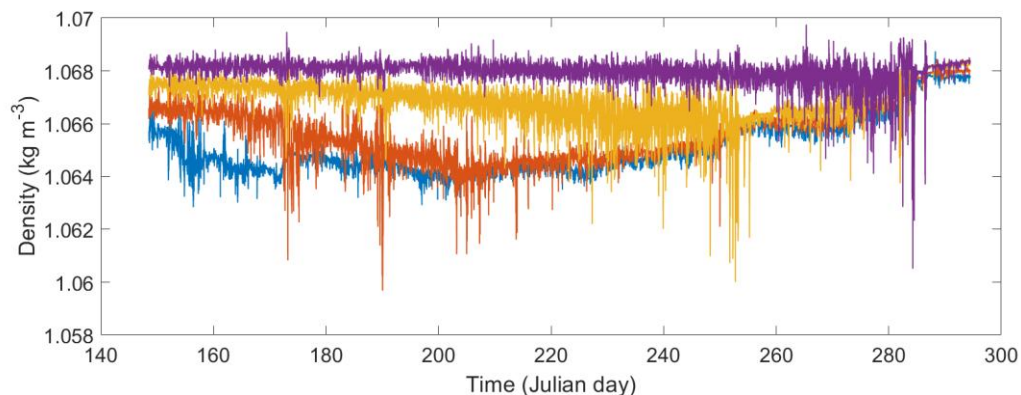


Fig. 46. Density at Station 6 from May to October 2025. Sensor locations were deployed at depths of 5.8, 9.5, 12.8, and 15.6 m. Data were averaged over two-hour intervals.



Dissolved Oxygen

Dissolved oxygen concentrations were recorded from November 2024 through October 2025 at Stations 3 and 6 (Fig. 47, Fig. 48, Fig. 49). Data from Station 6 at 1.3 m for November 2024 through May 2025 are not available due to sensor loss.

At Station 3 (4.4 m), dissolved oxygen from November 2024 through May 2025 ranged from 3.8 to 9.9 mg L⁻¹ (Fig. 47). Water temperature during this period ranged from 2.3 to 14.1 °C. Dissolved oxygen concentrations were generally higher during colder months and had increased variability as temperatures rose in spring. From May through October 2025, dissolved

oxygen concentrations declined during the warmer months. At Station 3 (4.3 m), dissolved oxygen ranged from 3.8 to 7.6 mg L⁻¹ (Fig. 48). Water temperature ranged from 12.9 to 22.9 °C.

At Station 6 (4.5 m), dissolved oxygen from May through October 2025 ranged from 1.5 to 6.9 mg L⁻¹, with a mean of 4.8 mg L⁻¹ (Fig. 49). Water temperature ranged from 12.8 to 23.0 °C. The lowest dissolved oxygen concentrations occurred during peak summer temperatures. Overall, the high-frequency sensor data indicate strong seasonal patterns in dissolved oxygen during 2025, with higher concentrations during colder months and reduced concentrations during summer warming. Dissolved oxygen concentrations in the mixolimnion were generally within ranges suitable for aerobic metabolism (above ~2 mg L⁻¹).

Fig. 47. Dissolved oxygen and water temperature at Station 3 from November 2024 through May 2025. Sensor location was deployed at depth 4.4 m. Dissolved oxygen is shown as the blue line (mg L⁻¹) and water temperature as the red line (°C). Data were averaged over 10-minute intervals. Days of Year (DOY) are shown on a continuous scale, with DOY 366 corresponding to 1 January 2025.

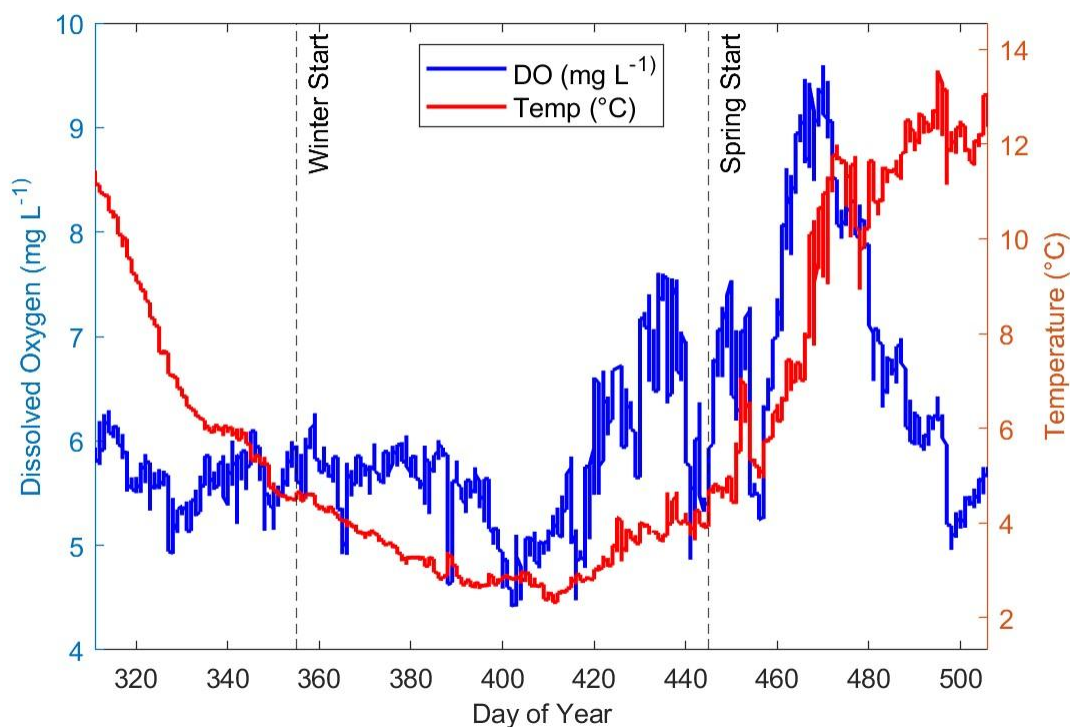


Fig. 48. Dissolved oxygen and water temperature at Station 3 from May through October 2025. Sensor location was deployed at depth 4.3 m. Dissolved oxygen is shown as the blue line (mg L^{-1}) and water temperature as the red line ($^{\circ}\text{C}$). Data were averaged over 10-minute intervals. Days of Year (DOY) begin on 1 January 2025.

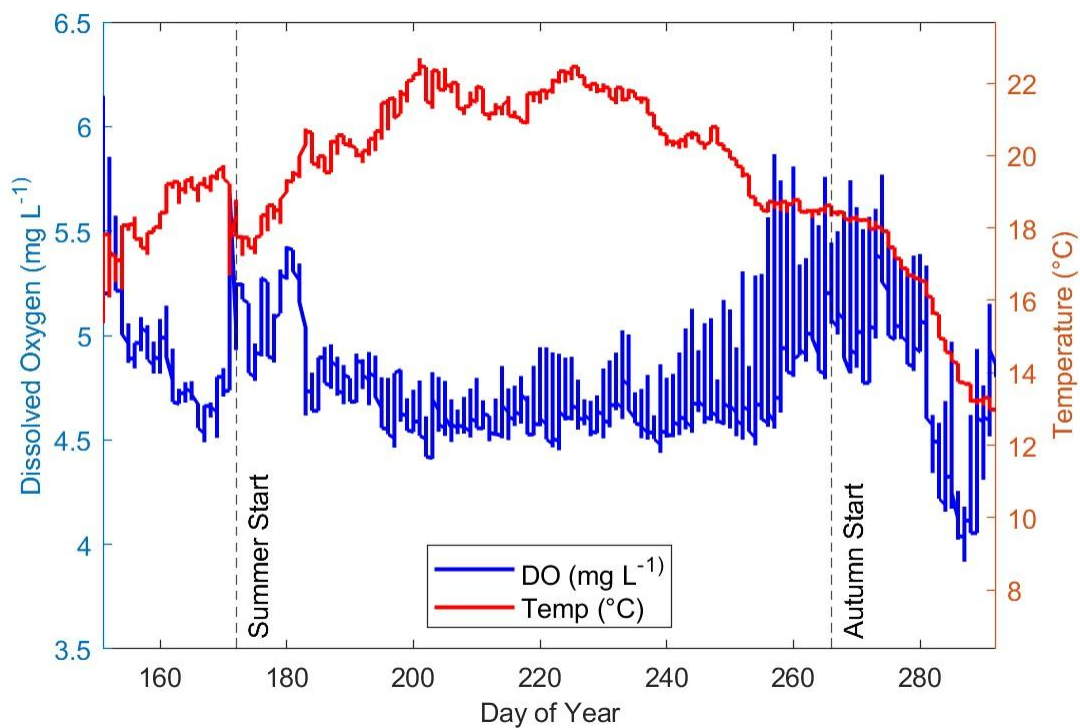
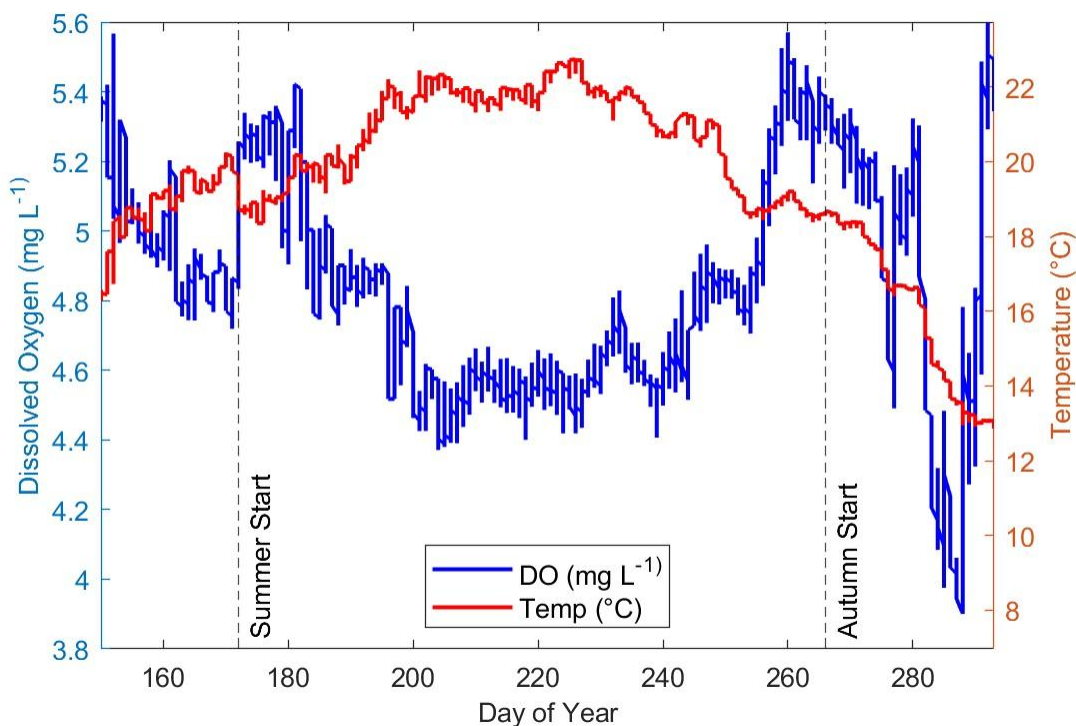


Fig. 49. Dissolved oxygen and water temperature at Station 6 from May through October 2025. Sensor location was deployed at depth 4.5 m. Dissolved oxygen is shown as the blue line (mg L^{-1}) and water temperature as the red line ($^{\circ}\text{C}$). Data were averaged over 10-minute intervals. Days of Year (DOY) begin on 1 January 2025.



Particulate Carbon and Nitrogen

Particulate organic carbon (POC) and particulate organic nitrogen (PN) are fundamental indicators of suspended biological material and biogeochemical cycling in Mono Lake. These particulate pools integrate phytoplankton biomass, detrital material, and microbial components, and therefore reflect the balance between production, grazing, sedimentation, and remineralization processes. Because Mono Lake supports a simplified pelagic food web dominated by phytoplankton and *Artemia monica*, variability in particulate C and N has implications for trophic transfer to higher consumers (Jellison and Melack 1993a).

The molar carbon-to-nitrogen ratio (C:N) of particulate matter provides insight into ecosystem conditions. Phytoplankton elemental composition is commonly compared to the Redfield ratio (C:N = 6.6 mol:mol; Redfield 1958), but deviations are expected in response to light, temperature, nutrient availability, and species composition (Geider and La Roche 2002). Elevated C:N ratios may indicate nitrogen limitation, increased detrital contribution, or altered physiological state, whereas lower ratios may reflect enhanced nitrogen availability or shifts in

community structure. In stratified systems, restricted vertical transport of regenerated nitrogen can influence both particulate concentrations and stoichiometry (Jellison and Melack 1988, 1993c).

Mono Lake has experienced substantial physical and chemical variability over recent decades, including periods of strong stratification and meromixis that altered nutrient distributions and primary production dynamics (Jellison and Melack 1988; 1993c). Such changes affect the vertical distribution of particulate material and may modify seasonal patterns in elemental composition. Long-term monitoring of particulate C and N is therefore essential for evaluating ecosystem response to hydrologic variability, climatic forcing, and internal nutrient cycling.

The 2025 monitoring effort quantifies particulate carbon and nitrogen concentrations and molar C:N ratios across depths and seasons at established stations. By examining temporal and vertical variability in these elemental pools, this study provides a basis for assessing changes in phytoplankton biomass and nutrient status in Mono Lake.

Methods

Laboratory procedures

Samples for particulate carbon and nitrogen (C:N) analyses were collected monthly at Station 6 using a 9 m integrated tube sampler and a Van Dorn sampler at 2, 16, and 24 m. Samples were passed through a 120- μm sieve to remove all stages of *Artemia*. Particulate material was collected by filtering water onto pre-ashed 25 mm Whatman GF/F glass-fiber filters. Filters were ashed at 450 °C for 4 h prior to use. Following filtration, filters were acid-fumed over concentrated HCl for approximately 12 h to remove inorganic carbon, air-equilibrated in a fume hood, and dried at 50–60 °C for 12–16 h. Processed filters were stored frozen until analysis. Particulate carbon and nitrogen concentrations were determined using a CHN elemental analyzer at the Marine Science Institute Analytical Laboratory, University of California, Santa Barbara. Carbon and nitrogen concentrations were converted to molar units using atomic masses.

Results

Seasonal trends in upper water column

Particulate carbon (PC) and particulate nitrogen (PN) had pronounced seasonal and vertical variability at Station 6 from April through December 2025 (Table 21). In the upper water column (2 m and 9-m integrated samples), concentrations declined from spring through late summer. At 2 m, PC decreased from 337 μM on 15 April to 66 μM on 14 August, before remaining low at 75 μM on 17 September, an overall decline of nearly 80% from spring maxima. PN followed a similar pattern, decreasing from 31 μM in April to 7 μM in August and 5 μM in September. The 9-m integrated samples had a comparable reduction. PC declined from 307 μM in April to 77 μM in August and reached a seasonal minimum of 44 μM in September. PN decreased from 28 μM in April to 8 μM in August and 4 μM in September.

Beginning in October, particulate concentrations increased. At 2 m, PC rose to 190 μM on 27 October and continued increasing to 330 μM in November and 353 μM by 15 December. PN increased in parallel (21 μM in October, 37 μM in November, 35 μM in December). The 9-m integrated samples exhibited a similar resurgence, with PC increasing to 201 μM in October and reaching 339 μM in December.

Mid- and Deep-Water Concentrations (16 m and 24 m)

Particulate concentrations at 16 m had clear seasonal variability and were higher than surface values through most of the year (Table 21). PC increased from 317 μM in April to a summer maximum of 571 μM in July. Concentrations then declined through late summer, reaching 219 μM in September. During autumn and early winter, PC stabilized between 218 and 286 μM (October–December). PN followed the same pattern, increasing from 32 μM in April to 60 μM in July, decreasing to 20 μM in September, and recovering to 33 μM by December. These patterns indicate substantial mid-depth accumulation during peak summer conditions, followed by late-season reduction and partial recovery.

At 24 m, particulate concentrations were consistently the highest observed in the water column. PC ranged from 1,025 to 1,141 μM between April and July, exceeding 900 μM during the entire period. Concentrations declined to 922–935 μM in August–September and reached a seasonal minimum of 904 μM in November. Despite this decrease, deep-water concentrations remained elevated relative to both 16 m and surface values. PC increased to 949 μM in

December. PN had a similar seasonal trajectory, declining from 101 μM in April to 76 μM in September before increasing to 80 μM by December. Overall, these depth profiles highlight persistent vertical structure in particulate carbon and nitrogen, with pronounced summer increases at 16 m and sustained accumulation at 24 m throughout the year.

Stoichiometry (C:N)

Despite pronounced seasonal variability in particulate concentrations, molar C:N ratios were comparatively constrained (Table 21). Across all depths and dates, C:N ratios ranged from ~7.5 to 11. Surface waters had modest late-summer declines. At 2 m, C:N decreased from 9.2 in April to 7.9 in August, followed by an increase to 10.1 in September. During autumn, C:N ratios at 2 m were 7.7–8.6. The 9-m integrated samples had similar behavior, with C:N values between 8.5 and 9.6 in spring–summer, decreasing to 7.7 in October before increasing slightly to 9.2 in November and 8.3 in December.

Mid-depth waters had moderate seasonal variability. At 16 m, C:N values ranged from 8.5–8.8 during spring, increased to 11.1 in August, and declined to 7.5–8.0 during October–December. Deep waters had slightly higher ratios during autumn. At 24 m, C:N increased from 9.3 in April to 10.5 in September and remained between 10.0 and 10.4 through October and November before stabilizing at 10.1 in December. Overall, although particulate carbon and nitrogen concentrations varied substantially across seasons and depths, molar C:N ratios remained comparatively constrained.

Carbon:Chl

Despite pronounced seasonal variability in particulate carbon and chlorophyll concentrations, bulk particulate C:Chl ratios showed clear seasonal and vertical structure (Table 21). Across all depths and dates, C:Chl ranged from approximately 3.3 to 31.6 $\mu\text{mol C per } \mu\text{g Chl-a}$. Surface waters exhibited the highest summer ratios. At 2 m, C:Chl increased from 19.8 in April to a maximum of 31.6 in June and remained elevated through September (27.1), before declining sharply to 4.7–5.0 during October–December. The 9-m integrated samples showed similar behavior, increasing from 12.1 in April to 22.8–28.6 in July–August, then decreasing to ~5 in October–December (4.8–5.3).

Mid-depth waters showed more moderate variability. At 16 m, C:Chl was 9.4–10.2 in April–May, declined to 5.8–6.0 in July–August, reached a minimum of 3.3 in September, and

remained ~4.2–6.0 through December. Deep waters were comparatively constrained. At 24 m, C:Chl remained between 6.5 and 10.5 across the season, with modest declines in October (6.5) and higher values in early summer and December (10.1–10.5).

Vertical patterns

Depth profiles highlight a pronounced increase in PC and PN with depth, with the sharpest contrast between the upper samples (2 m and 9-m integrated) and 24 m. This pattern is consistent with a system where particles are either accumulated at depth or where surface particulate concentrations decrease more rapidly due to grazing, dilution, or export over the spring–summer transition.

Depth profiles indicate strong vertical contrasts during summer, when surface and 9-m integrated C:Chl ratios were elevated relative to mid and deep waters. By autumn, C:Chl ratios decreased markedly in surface layers, reducing vertical gradients. In contrast, 24 m ratios remained comparatively stable across the study period, consistent with a deeper particulate pool less sensitive to rapid seasonal changes in surface chlorophyll.

Table 21. Summary of particulate carbon, particulate nitrogen, and carbon:chlorophyll ratios at Station 6 from April through December 2025. Particulate carbon and nitrogen concentrations are reported in μM , and the carbon:chlorophyll ratio is expressed as $\mu\text{mol C per } \mu\text{g Chl-a}$. Concentrations for the 9-m integrated sample on 11 June were not reported due to a laboratory analysis error.

		Dates								
	Depth (m)	4/15	5/15	6/11	7/10	8/14	9/17	10/27	11/19	12/15
Carbon										
	9-m int.	307	164		83	77	44	201	325	339
	2	337	157	96	106	66	76	190	330	353
	16	317	305	448	571	378	219	218	258	286
	24	1092	1068	1025	1141	922	935	936	904	949
Nitrogen										
	9-m int.	28	16		8	8	4	22	31	35
	2	31	15	8	11	7	6	21	37	35
	16	32	30	44	60	29	20	23	29	33
	24	101	94	91	106	83	76	77	78	80
C:N ratio										
	9-m int.	9.6	8.8		8.5	8.6	9.1	7.7	9.2	8.3
	2	9.2	9.3	10.0	8.6	7.9	10.1	7.8	7.7	8.6
	16	8.5	8.6	8.8	8.2	11.1	9.5	8.0	7.7	7.5
	24	9.3	9.7	9.7	9.2	9.6	10.5	10.4	10.0	10.1
C:Chl ratio										
	9-m int.	12.1	9.2		22.8	28.6	10.5	5.3	5.0	4.8
	2	19.8	16.9	31.6	30.1	29.4	27.1	4.7	5.0	4.8
	16	9.4	10.2	8.0	5.8	6.0	3.3	5.7	6.0	4.2
	24	8.8	10.0	10.1	10.5	9.1	8.7	6.5	8.3	10.5

Photosynthesis and Respiration

Photosynthesis by phytoplankton is a key component of primary production in Mono Lake and supports higher trophic levels including *Artemia* and nesting and migratory birds. Planktonic primary production is the net result of photosynthesis and respiration, which is determined by the abundance and physiological condition of the phytoplankton, temperature, nutrient, and light environments. Phytoplankton abundance is the balance of growth and loss processes where losses include *Artemia* grazing, sinking, and cell senescence. The complex, non-linear interactions of these processes are challenging to unravel and require further analyses of the on-going monitoring measurements.

Prior studies of phytoplankton photosynthesis in Mono Lake were based on uptake of ^{14}C -bicarbonate and examined seasonal and inter-annual variations and relations with environmental factors. Jellison and Melack (1988) reported that phytoplankton primary production was two to three times higher during the spring of 1983 than in the springs of 1984 and 1985, following the development of strong chemical stratification which limited the upward supply of ammonium. Sixty-eight percent of the seasonal variation in the chlorophyll-specific rate of carbon uptake was explained by a regression on temperature (53%), chlorophyll *a* (12%), and the carbon:chlorophyll *a* ratio (3%). Jellison and Melack (1993c) measured photosynthetic activity in Mono Lake during a period spanning the onset (1983), persistence (1984-1987), and breakdown of meromixis (1988). A gradual increase in photosynthetic production occurred before meromixis ended, and annual production was greatest in 1988. Most of the variation in rates of light-saturated carbon uptake normalized to chlorophyll *a* was explained by temperature (60%) and indices of the light and nutrient environments accounted for an additional 8%.

In 2025, an approach was implemented to estimate both photosynthesis and respiration by phytoplankton from changes in dissolved oxygen (DO). Continuous, high-frequency DO measurements were made in containers with lake water incubated in the laboratory under different light levels. Changes in DO concentration in the light represent net ecosystem production, and changes in the dark record respiration.

Methods

Laboratory procedures

Mono Lake water was collected at Station 6 from 2 m depth using a peristaltic pump. *Artemia* were removed from sampled water using a funnel equipped with a 120- μm mesh screen. Upon arrival at the laboratory, sampled water was maintained at lake temperature in dark conditions until the experiment began. Prior to the start of the experiment, water samples were mixed and filtered again through a 120- μm sieve. Duplicate bottles (1-gallon PET bottles, Uline S-15711) were filled, one DO sensor (PME MiniDOT) was placed in each bottle, and DO concentrations and temperatures were recorded every 10 min. DO concentration was adjusted for salinity of Mono Lake, with values of 70 ppt at 2 m depth, and for the local elevation at SNARL of 2160 m.

Bottles were incubated in a water bath and illuminated by full-spectrum (blue 420–470 nm, green 500–570 nm, and red 610–680 nm wavelengths) LED lamps under a 12h:12 h

dark:light cycle at three light levels and in the dark. Light intensities were measured in the water bath with a submersible cosine-corrected PAR quantum sensor at multiple depths and positions. Different light levels were obtained by enclosing bottles in neutral density screens. Dark bottles were incubated in a separate dark water bath. Water samples were taken at the beginning of the experiment and at the end of the experiment from each replicate sample bottle, for measurements of chlorophyll *a* concentration ($\mu\text{g L}^{-1}$) obtained with GF/F filter extraction analyses (see methods in Chapter 2).

Calculations of metabolic rates

Net Ecosystem Production (NEP) is determined from daytime changes in DO and include photosynthesis and respiration. DO changes per hour were averaged over the 12-hour illuminated periods. Rates are reported per hour.

Respiration rate is calculated from the decline in DO during nighttime in containers illuminated during the day (RL) and in containers incubated only in the dark (RD). Changes per hour were averaged over the 12-hour dark periods. Rates are reported per hour.

Data Standardization for Seasonal Comparisons

Because incubation duration varied among months (2 days in April and June, 4 days in May, 1 day in July and December, and 3 days in September–November), seasonal comparisons of metabolic rates were standardized using values from the first complete light–dark cycle (Day 1) of each experiment. Prolonged incubations can introduce bottle effects, including accumulation of dissolved organic carbon, shifts in microbial community structure, and nutrient recycling within containers, which may elevate respiration rates over successive days. Therefore, Day 1 values are used for cross-month seasonal comparisons, while multi-day trajectories are presented separately to illustrate within-incubation dynamics.

Results

Monthly Incubation Summary

Monthly incubations were conducted from April through December 2025 (Table 22). August is not presented due to light interference during incubation. The incubation times varied among months as follow: 48 hours in April, 96 hours in May, 48 hours in June, 24 hours in July, 72 h in September–November, and 24 hours in December. Water temperatures ranged from 6.0

to 20.3 °C, and chlorophyll *a* concentrations ranged from 3.0 µg L⁻¹ to 88.2 µg L⁻¹. Calculated values for NEP, RL and RD are summarized in Tables 23-30.

Table 22. Summary of photosynthesis and respiration incubation experiments conducted during 2025. Temperature range represents the water temperature during each incubation period. PAR values indicate the irradiance levels used for the light treatments, and are reported as daily irradiance ($\text{E m}^{-2} \text{d}^{-1}$) and instantaneous irradiance ($\mu\text{mol m}^{-2} \text{s}^{-1}$). Chlorophyll-a concentrations were measured at the beginning and end of each incubation. Dark treatments represent bottles incubated without light.

Incubation Dates	Temperature Range ($^{\circ}\text{C}$)	PAR ($\text{E m}^{-2} \text{d}^{-1}$)	PAR ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Chla Start ($\mu\text{g L}^{-1}$)	Chla End ($\mu\text{g L}^{-1}$)
4/18–20/2025	7.7 – 9	10	224	15.0	15.1
		6	137	15.0	15.9
		4	101	15.0	19.5
		1	34	15.0	13.5
		Dark	Dark	15.0	16.0
5/15–19/2025	10.5 – 12.8	10	224	9.3	13.8
		6	137	9.3	16.3
		4	101	9.3	15.9
		1	34	9.3	18.3
		Dark	Dark	9.3	11.0
6/11–13/2025	14.5 – 15.9	10	224	3.0	5.0
		6	137	3.0	5.8
		4	101	3.0	6.4
		1	34	3.0	7.3
		Dark	Dark	3.0	3.7
7/15/2025	17.8 – 20.3	10	224	3.2	5.1
		6	137	3.2	5.2
		4	101	3.2	5.6
		1	34	3.2	1.5
		Dark	Dark	3.2	3.3
9/19–22/2025	16 – 17.2	10	224	5.1	5.5
		6	137	5.1	8.6
		4	101	5.1	12.0
		1	34	5.1	11.2
		Dark	Dark	5.1	3.0
10/28–31/2025	9.9 – 10.8	10	224	44.5	40.7
		6	137	44.5	48.7
		4	101	44.5	40.4
		1	34	44.5	45.3
		Dark	Dark	44.5	45.0
11/21–24/2025	7.2 – 8.3	10	224	67.7	88.2
		6	137	67.7	82.0
		4	101	67.7	74.8
		1	34	67.7	78.5
		Dark	Dark	67.7	71.5
12/19/2025	6 – 6.9	10	224	71.8	72.4
		6	137	71.8	77.3
		4	101	71.8	71.9
		1	34	71.8	69.8
		Dark	Dark	71.8	72.1

Seasonal Patterns in Net Ecosystem Production (Standardized to Day 1)

Seasonal comparisons of net ecosystem production (NEP) were based on rates measured during the first complete light–dark cycle (Day 1) of each monthly incubation. NEP exhibited strong seasonal variation from April through December 2025.

During spring (Table 23, Table 24, Table 25, Table 26), NEP was moderate. On 19 April, NEP ranged from 28 to 47 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ across light treatments, coinciding with chlorophyll *a* concentrations near 15 $\mu\text{g L}^{-1}$. On 16 May, NEP ranged from 19 to 41 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$, with chlorophyll *a* approximately 9 $\mu\text{g L}^{-1}$. These values indicate active but moderate autotrophic production during mid-spring. During early summer (June–July), NEP declined substantially. In 12 June, NEP ranged from 6 to 21 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$, and on 15 July values ranged from 1 to 15 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$, with the lowest rate observed under the lowest light treatment. Chlorophyll *a* concentrations during this period were approximately 3 $\mu\text{g L}^{-1}$, representing the lowest phytoplankton biomass observed during the year (Table 22). These results indicate reduced autotrophic activity during early summer.

NEP increased again in autumn. On 20 September, NEP ranged from 23 to 53 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ across light treatments. On 29 October, NEP increased further, ranging from 71 to 95 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$. The highest Day-1 rates were observed on 22 November, when NEP ranged from 117 to 179 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$. Chlorophyll *a* concentrations increased markedly during this period, reaching as high as 88.2 $\mu\text{g L}^{-1}$ (Table 21). On 19 December, NEP remained elevated, ranging from 84 to 117 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ despite low incubation temperatures (6–6.9 °C). Chlorophyll *a* concentrations remained high (~72 $\mu\text{g L}^{-1}$), indicating sustained phytoplankton biomass late in the year (Table 27, Table 28, Table 29, Table 30).

Within-Incubation Changes in NEP During Extended Experiments

During multi-day incubations (May, September–November), NEP frequently increased over successive light–dark cycles. For example, in May NEP increased from 19–41 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ on Day 1 to as high as 59 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ by Day 4 (Table 24). Similar progressive increases were observed during autumn incubations, particularly in September (Table 27, Table 28, Table 29). These trends suggest dynamic physiological or community responses within the incubation bottles over time and may reflect acclimation, nutrient recycling, or accumulation of recently

fixed organic carbon. Consequently, later incubation days are interpreted as within-experiment responses rather than direct seasonal comparisons.

Seasonal Patterns in Respiration (Standardized to Day 1)

Seasonal comparisons of respiration were based on rates measured during the first complete light–dark cycle of each monthly incubation (Tables 23–30).

On 19 April, respiration in light-incubated bottles (RL) ranged from 11 to 17 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ across light treatments, while respiration in continuously dark bottles (RD) was 15 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$. Rates were moderate and showed limited variation among PAR levels (Table 23). On 16 May, Day 1 RL ranged from 7 to 11 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 15 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$. These values were similar to April and indicate moderate community respiration during mid-spring (Table 24). Respiration declined in early summer. On 12 June, RL ranged from 9 to 13 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 7 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$. In 15 July, RL was approximately 10 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ across treatments and RD was 12 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ (Table 25, Table 26). These lower rates coincided with minimum chlorophyll *a* concentrations ($\sim 3 \mu\text{g L}^{-1}$), indicating reduced community metabolic activity during early summer.

Respiration increased again during autumn. On 20 September, RL ranged from 12 to 13 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 8 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ (Table 27). By 29 October, RL ranged from 13 to 15 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 10 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ (Table 28). The highest respiration rates were observed on 22 November, when RL ranged from 15 to 21 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 21 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ (Table 29). On 15 December, RL ranged from 1 to 13 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and RD was 11 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ (Table 30).

Within-Incubation Changes in Respiration During Extended Experiments

On 16 May, respiration increased substantially over the four-day incubation. RL rose from 7–11 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ on Day 1 to as high as 29–48 $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ by Day 4, particularly under the lower PAR treatments (Table 24). This progressive increase suggests enhanced community oxygen demand over successive light–dark cycles, potentially reflecting accumulation of recently fixed organic carbon and stimulation of microbial respiration within the incubation bottles. Similar but less pronounced increases were observed during other multi-day incubations in autumn.

Table 23. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 19–20 April 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$ and were used to estimate metabolic rates under each light treatment.

Dates	4/19	4/20
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	47	55
RL	12	20
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	42	53
RL	11	23
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	28	34
RL	17	25
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	47	46
RL	15	18
Dark		
RD	15	10

Table 24. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 16–19 May 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	5/16	5/17	5/18	5/19
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$				
NEP	41	43	38	37
RL	11	19	30	34
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$				
NEP	39	39	37	39
RL	10	16	24	35
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$				
NEP	27	39	47	51
RL	8	17	30	45
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$				
NEP	19	33	50	59
RL	7	18	29	48
Dark				
RD	15	12	14	18

Table 25. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 12–13 June 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	6/12	6/13
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	21	22
RL	9	11
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	19	20
RL	13	13
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	12	16
RL	9	11
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$		
NEP	6	15
RL	9	13
Dark		
RD	7	8

Table 26. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 15 July 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	7/15
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	12
RL	10
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	15
RL	10
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	7
RL	10
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	1
RL	10
Dark	
RD	12

Table 27. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 20–22 September 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	9/20	9/21	9/22
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	53	70	105
RL	12	39	70
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	36	26	56
RL	11	28	45
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	39	68	102
RL	13	41	87
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	23	48	83
RL	12	33	83
Dark			
RD	8	12	26

Table 28. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 29–31 October 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	10/29	10/30	10/31
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	95	95	67
RL	13	21	36
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	93	92	61
RL	11	20	28
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	92	99	70
RL	15	22	34
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	71	83	72
RL	14	23	35
Dark			
RD	10	12	33

Table 29. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 22–24 November 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	11/22	11/23	11/24
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	179	163	161
RL	21	55	69
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	161	148	153
RL	12	48	61
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	164	166	172
RL	18	65	92
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$			
NEP	117	124	125
RL	15	41	58
Dark			
RD	21	17	15

Table 30. Mean hourly estimates of net ecosystem production (NEP) and respiration (RL) from incubation experiments conducted 19 December 2025 under different light treatments. Dissolved oxygen (DO) changes are expressed as $\mu\text{g O}_2 \text{ L}^{-1} \text{ h}^{-1}$.

Dates	12/15
PAR = 10 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	117
RL	13
PAR = 6 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	106
RL	3
PAR = 4 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	107
RL	2
PAR = 1 $\text{E m}^{-2} \text{ d}^{-1}$	
NEP	84
RL	1
Dark	
RD	11

Light Effects on Net Ecosystem Production

The effect of light intensity on net ecosystem production (NEP) varied seasonally throughout 2025. One-way ANOVA was conducted separately for each month in which replicate incubations were available (Table 31). During April, May, June, and September, NEP did not differ significantly among the four light treatments (10, 6, 4, and 1 E m⁻² d⁻¹). Although higher light levels often yielded numerically greater NEP values, variability among incubation days was sufficient that differences among treatments were not statistically significant ($p > 0.05$). July and December incubations were conducted on single dates. Although duplicate bottles were used for each light treatment, statistical comparisons among light levels for those months should be interpreted cautiously because replication reflects technical rather than day-to-day biological variability. Therefore, statistical comparisons among light levels were not possible for those months.

In contrast, significant light effects were observed during the autumn (Table 31). In October, NEP differed significantly among light treatments (one-way ANOVA, $p \approx 0.04$). Mean NEP was highest at 4 and 10 E m⁻² d⁻¹ and lowest at 1 E m⁻² d⁻¹, indicating reduced production under the lowest light condition. The strongest light effect occurred in November (one-way ANOVA, $p < 0.001$). During this peak bloom period, NEP at 4 and 10 E m⁻² d⁻¹ was substantially greater than at 1 E m⁻² d⁻¹. Production at 6 E m⁻² d⁻¹ was intermediate. These results indicate that under high-biomass conditions, primary production became increasingly responsive to light availability. Overall, light limitation was not statistically detectable during low- and moderate-biomass periods but became significant during peak autumn bloom conditions.

Table 31. Summary of monthly light effects on Net Ecosystem Production (NEP), 2025.

Month	Replicate Days (n)	ANOVA F (df)	p-value ($\alpha=0.05$)	Light Level
April	2	$F_{3,4} = 1.51$	> 0.30	$10 \text{ E m}^{-2} \text{ d}^{-1}$
May	4	$F_{3,12} = 0.42$	> 0.70	$4 \text{ E m}^{-2} \text{ d}^{-1}$
June	2	$F_{3,4} = 2.62$	≈ 0.18	$10 \text{ E m}^{-2} \text{ d}^{-1}$
July	1	—	—	$6 \text{ E m}^{-2} \text{ d}^{-1}$
September	3	$F_{3,8} = 0.88$	> 0.45	$10 \text{ E m}^{-2} \text{ d}^{-1}$
October	3	$F_{3,8} = 4.32$	≈ 0.04	$4 \text{ E m}^{-2} \text{ d}^{-1}$ ($\approx 10 \text{ E m}^{-2} \text{ d}^{-1}$)
November	3	$F_{3,8} = 17.8$	< 0.001	$10 \text{ \& } 4 \text{ E m}^{-2} \text{ d}^{-1}$
December	1	—	—	$10 \text{ E m}^{-2} \text{ d}^{-1}$

REFERENCES

- Geider, R. J., and J. La Roche. 2002. Redfield revisited: variability of C:N:P in marine microalgae and its biochemical basis. *European Journal of Phycology* 37: 1–17.
- Golterman, H. L., and R. S. Clymo. 1969. *Methods for chemical analysis of fresh waters*. IBP Handbook No. 8.
- Heath, H. 1924. The external development of certain phyllopods. *Journal of Morphology* 38: 453–483.
- Jellison, R., and J. M. Melack. 1988. Photosynthetic activity of phytoplankton and its relation to environmental factors in hypersaline Mono Lake, California. *Hydrobiologia* 158: 69–88.
- Jellison, R., and J. M. Melack. 1993a. Meromixis in hypersaline Mono Lake, California. I. Stratification and vertical mixing during the onset, persistence, and breakdown of meromixis. *Limnology and Oceanography* 38: 1008–1019.
- Jellison, R., L. Miller, J. M. Melack, and G. L. Dana. 1993b. Meromixis in hypersaline Mono Lake, California. II. Nitrogen fluxes. *Limnology and Oceanography* 38: 1020–1039.
- Jellison, R., and J. M. Melack. 1993c. Primary production during the onset and breakdown of meromixis in Mono Lake, California. *Limnology and Oceanography* 38: 1019–1031.
- Jellison, R., S. MacIntyre, and F. J. Millero. 1999a. Density and conductivity properties of Na–CO₃–Cl–SO₄ brine from Mono Lake, California, USA. *International Journal of Salt Lake Research* 8: 41–53.
- Jellison, R., S. MacIntyre, and F. J. Millero. 1999b. Density and conductivity properties of Na–CO₃–Cl–SO₄ brine from Mono Lake, California, USA (erratum). *International Journal of Salt Lake Research* 8: 384.
- Jellison, R., C. Vignardi, and J. M. Melack. 2024. Mono Basin Annual Monitoring Reports. Section III. Mono Lake Limnological Monitoring 2023 Annual Report. Submitted to the California State Water Resources Control Board by the Los Angeles Department of Water and Power.
- Lenz, P. H. 1984. Life-history analysis of an *Artemia* population in a changing environment. *Journal of Plankton Research* 6: 967–983.
- MacIntyre, S., and R. Jellison. 2001. Nutrient fluxes from upwelling and enhanced turbulence at the top of the pycnocline in Mono Lake, California. *Hydrobiologia* 466: 13–29.
- Melack, J. M., and R. Jellison. 1998. Limnological conditions in Mono Lake: contrasting monomixis and meromixis in the 1990s. *Hydrobiologia* 384: 21–39.
- Redfield, A. C. 1958. The biological control of chemical factors in the environment. *American Scientist* 46: 205–221.
- Strickland, J. D. H., and T. R. Parsons. 1972. *A practical handbook of seawater analysis*. Bulletin of the Fisheries Research Board of Canada.
- Walker, K. F., W. D. Williams, and U. T. Hammer. 1970. The Miller method for oxygen determination applied to saline lakes. *Limnology and Oceanography* 15: 815–818.

Section IV. Mono Basin Waterfowl Habitat
Restoration Program 2025 Monitoring
Report

Prepared by Matthew E. Reiter and Deborah House



Point Blue
Conservation
Science

Mono Basin Waterfowl Habitat Restoration Program

**Monitoring Report
2025**



Launching survey boat for fall migration surveys (credit: M. Reiter)

Mono Basin Waterfowl Habitat Restoration Program

2025 Monitoring Reprt

Prepared by

Point Blue Conservation Science

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Rush Creek (credit: M. Reiter)

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Website link:

www.migratoryshorebirdproject.org

Point Blue Conservation Science – Point Blue’s 160 scientists work to reduce the impacts of climate change, habitat loss, and other environmental threats while developing nature-based solutions to benefit both wildlife and people.

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EXECUTIVE SUMMARY

In 2025, Dr. Matt Reiter of Point Blue Conservation Science (Point Blue) was approved as the incoming interim waterfowl director. Starting in August, Dr. Reiter administered the Mono Basin waterfowl monitoring program which included conducting boat-based fall waterfowl surveys, testing the feasibility of using an uncrewed aerial vehicle (UAV) for surveying waterfowl, and using a UAV to gather high resolution imagery to use in the development of a satellite remote sensing model to document waterfowl habitat conditions. Outgoing waterfowl director Deborah House conducted the waterfowl surveys, and the Point Blue UAV team of Annie Schmidt and Christina Burnham performed the drone work.

We experienced several challenges this year that hampered our ability to conduct all the waterfowl surveys as planned including poor weather conditions, mechanical problems with the boats, and encounters with submerged objects. Of the four planned shoreline surveys, we were able to conduct one complete shoreline survey and three partial surveys. Of the 15 total shoreline segments, four areas were surveyed on each of the four surveys, three were surveyed three times, five segments were surveyed twice, and three had one survey.

Despite the abbreviated waterfowl survey schedule, we documented relatively high numbers of waterfowl using Mono Lake in 2025. We recorded 32,842 waterfowl of nine species on our surveys, including the highest single one-day count of Northern Shoveler (18,016) as compared to the entire 2002 to 2023 period of record. This high count of Northern Shovelers at Mono Lake on September 18 resulted in the 2025 waterfowl total being the fourth highest annual shoreline waterfowl count at Mono Lake since structured surveys were initiated in 2002.

Boat-based surveys at Mono Lake are less efficient but inherently much safer than the aerial survey method used from 2002 to 2023. Based on our experience this year, boat-based waterfowl surveys of the shoreline are not without their own challenges, however. Successful use of a boat may require Point Blue having a local waterfowl survey team dedicated to conducting these surveys; consisting of a suitable boat, a captain, and a trained surveyor. This team would need some flexibility in their schedule to effectively alter survey plans based on the weather forecasts or conditions encountered.

UAV surveys for waterfowl suggested that flights need to occur at least 40m above groups of waterfowl to prevent flushing the group and even higher flights may be preferable. Imagery indicated that waterfowl are readily detectable and a computer vision model could be developed to automate the counting of ducks from UAVs. However, whether waterfowl species can be delineated is unclear. We also collected imagery across 1,182 ha of Mono Lake shoreline and riparian zones that will be used to develop an initial remote sensing model. Early assessment suggests the following habitat classes maybe be detectable: (1) water, (2) cottonwood/willow, (3) bare shoreline, (4) desert scrub, (5) fresh meadow, (6) alkali meadow, and (7) tufa. Additional ground-based collection of model training data is needed to refine habitat classes.

INTRODUCTION

Mono Lake is a high-elevation terminal saline lake located on the east slope of the Sierra Nevada in Mono County, California. Mono Lake is widely known for its value to waterbirds due to the high seasonal abundance of aquatic invertebrates, primarily the Mono Lake brine shrimp (*Artemia monica*) and alkali flies (*Cirrus* spp.). Over the previous 30 years, the salinity has averaged approximately 83 gm/L, but perennial creeks and multiple springs provide freshwater resources for waterfowl and other waterbirds that use Mono Lake.

In 1940, the City of Los Angeles (City) obtained permits from the Department of Public Works, Division of Water Resources to divert water from four tributary streams to Mono Lake (SWRCB 1994). The diverted water was to be exported to the City for municipal water use. It was acknowledged at the time that these diversions would negatively impact the Mono Basin, however using the water for domestic purposes was considered to be its highest use. Thus, the City began diverting water from Rush, Lee Vining, Parker and Walker creeks in 1941. These diversions resulted in reduced freshwater inflow to the lake, drying of creek channels, loss of riparian vegetation, declines in lake level, increased lake salinity, and other associated environmental changes. The City further expanded the capacity of its aqueduct system in 1970 and subsequently increased the amount of water exported from the Mono Basin. In 1974, the State Water Resources Control Board (SWRCB) issued water rights licenses that provided for the continuance of these diversions. The diversions caused an ever-increasing drop in lake level, and the ecological impacts became more evident.

In response to the observed ecological impacts, the City's water rights in the Mono Basin were first challenged in 1979. In a case that eventually reached the Supreme Court, the SWRCB was directed to reevaluate the City's licenses and take into consideration impacts on the environment and public trust resources. Following hearings, additional legal challenges, and an environmental review, the SWRCB issued revised water rights licenses under the Mono Lake Basin Water Right Decision 1631 in 1994 (SWRCB 1994). Decision 1631 limited water diversions from the Mono Basin and required the City of Los Angeles to perform ecological restoration in the Mono Basin, including waterfowl habitat restoration. The Mono Basin Waterfowl Habitat Restoration Plan (LADWP 1996), approved by the SWRCB in 1998 (SWRCB 1998), included waterfowl population and habitat monitoring. Breeding and fall migrating waterfowl populations and habitat monitoring have been conducted annually since.

Order WR 98-05 (SWRCB 1998) additionally required that the waterfowl restoration program be carried out under the direction of a waterfowl expert(s) approved by the Chief of the Division of Water Rights (i.e. "Mono Basin Waterfowl Director"). Dr. Matthew Reiter of Point Blue Conservation Science (Point Blue) was named the interim Mono Basin Waterfowl Director in August 2025, a position previously held by Dr. Brian White (2001 to 2012) and Ms. Deborah House (2013 to 2024).

The transition to the new interim director took place in August, after the summer breeding waterfowl survey period. The 2025 summer breeding surveys were conducted by Los Angeles

Department of Water and Power staff and contractors, and thus those results will not be covered in this report. Point Blue initiated their program with the fall waterfowl surveys in September, and additional projects included testing the feasibility of using an uncrewed aerial vehicle (UAV) for surveying waterfowl and to document waterfowl habitat conditions.

2025 CONDITIONS

The 2025 runoff for the Mono Basin was forecasted at 69% of normal which is considered a “dry-normal” year (LADWP 2025). These runoff conditions resulted in only a slight increase in lake level of 0.3 feet in early spring. The lake reached its maximum level for the year of 6,383.3 feet above mean sea level in June. At the end of summer, the elevation of Mono Lake began a steady decline through the fall months. The lake level was 6,382.6 feet in September and reached its low for the year of 6382.2 feet in November. Although still below the target level of 6,392 feet, this is the third year in a row that Mono Lake remained above 6,382 feet throughout the year.

FALL WATERFOWL POPULATION MONITORING

Methods

The survey methodology and schedule for 2025 was developed in consultation with the outgoing waterfowl director and approval by the Mono Basin Monitoring Administrative Team (MAT). Although the fall waterfowl monitoring program established in 2002 consisted of six fall surveys of Mono Lake, Bridgeport Reservoir and Crowley Reservoir, the 2025 waterfowl surveys focused on Mono Lake, and the monitoring included conducting additional studies to inform potential future improvements to the program.

In 2025, Point Blue proposed to conduct four shoreline waterfowl surveys by boat at Mono Lake with Deborah House, seasonal Point Blue Mono Basin Waterfowl Ecologist and outgoing Mono Basin waterfowl director, as the lead surveyor. These surveys were to coincide with seasonal surveys 1 (S1) through 4 (S4) (early September through mid-October) as conducted from 2002 to 2023 (House and Honda 2024) and have typically had the highest counts. Based on an assessment of the monitoring program conducted in 2018 (House and Honda 2018), the waterfowl totals from these four surveys have been strongly correlated with annual waterfowl totals ($r = 0.97$) and therefore were expected to provide an appropriate index of total fall waterfowl use of Mono Lake in 2025. Funding for the program was not established in time to conduct S1 however, so we completed the four surveys, S2 through S5, conducting a survey every two weeks from mid-September to the end of October.

Although aerial surveys are a very efficient way to survey Mono Lake and the primary survey method used since 2002, there was insufficient time to find a qualified pilot. In addition, there is considerable risk in conducting low level aerial surveys and previous boat-based surveys had proven effective, thus we elected to conduct this year's surveys by boat. We conducted boat surveys by circumnavigating the shoreline in a clockwise pattern, averaging ~200-250 meters from shore and traveling at a speed of approximately 8–10 mph. Adjustments to speed or the distance from shore were made based on wind conditions, lighting, the shoreline topography

and the presence of submerged tufa. The objective was to maintain a relatively slow but consistent speed that allowed for the detection and identification of waterfowl near or on shore but avoid the premature flushing of birds. When large numbers of birds were encountered, or when traversing areas of submerged tufa, speeds were slowed considerably or forward momentum was stopped to allow for a more accurate count, and to identify waterfowl to species. Waterfowl species were recorded by shoreline segments using the previously established boundaries which divide the shoreline into 15 segments of varying lengths (Fig. 1). The boat surveys were planned as a complete shoreline survey, thus surveying all 15 shoreline segments four times in 2025.

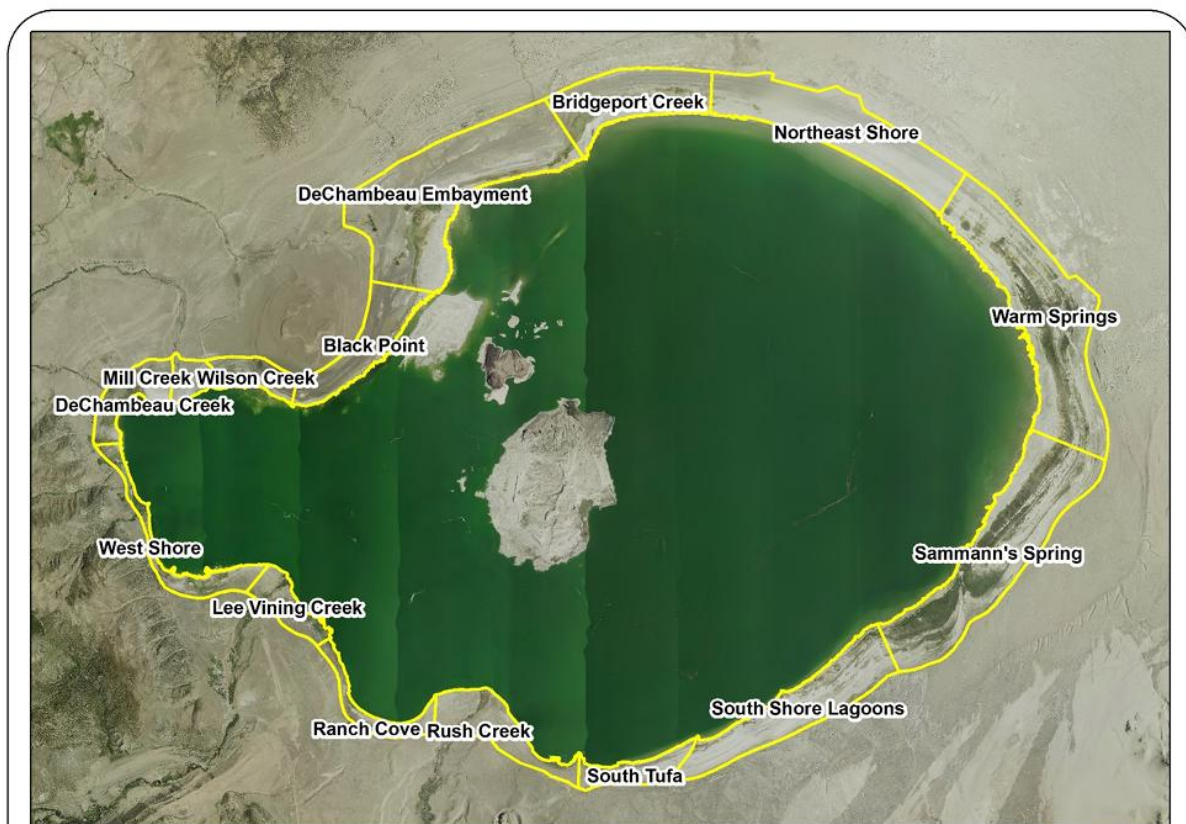


Figure 1. Shoreline segments

Weather and boat issues plagued our attempts to complete these surveys as planned. Point Blue does not have its own boat and thus we sought assistance from other local researchers for this first season. We had initially coordinated with the UCSB limnology team to use their 17-foot Boston Whaler and boat captain, but the boat developed mechanical issues and was unavailable after the second survey in early October. In addition, both surveys conducted with UCSB only covered a portion of the shoreline due to high winds.

For the last two surveys (S4 and S5), we worked with Oikonos Ecosystem Knowledge who provided a Klamath boat and captain. We were able to complete one full shoreline survey on October 16 (S4). We had good weather on October 30, but an unfortunate encounter with a submerged tufa resulted in damage to the boat's engine and we needed to abort the survey.

Over the course of the season, we were able to conduct one complete shoreline survey on October 16 (S4). The other three surveys covered: 12 of the 15 shoreline segments (S2, September 18), seven segments (S3, October 2), and four segments (S5, October 30; Table 1). Four shoreline segments on the west end of the lake were counted in all surveys (West Shore (WESH), DeChambeau Creek (DECR), Mill Creek (MICR) and Wilson Creek (WICR).

The S2 boat survey on September 18, which was aborted after completing the survey of Sammann's Spring, was supplemented with a ground survey of Rush Creek and Lee Vining Creek deltas. Although some areas were not surveyed on this date, we feel S2 captured most waterfowl present at Mono Lake on that day, because no other large flocks were seen while traveling back to the dock, and all the historically high use areas were surveyed. The S3 boat survey on October 2, also aborted due to high winds, was also supplemented by a ground survey of the DeChambeau Embayment, but survey data are lacking for other historically high use areas (e.g., SASP). In this report we will evaluate our results in the context of data collected over the six surveys per season at Mono Lake between 2002 and 2023.

Table 1. Survey method and shoreline areas surveyed in 2025

Shoreline Area	Survey Date and Method			
	18-Sep-2025	2-Oct-2025	16-Oct-2025	30-Oct-2025
Black Point (BLPO)	BOAT	BOAT	BOAT	NO SURVEY
Bridgeport Creek (BRCR)	BOAT	BOAT	BOAT	NO SURVEY
DeChambeau Creek (DECR)	BOAT	BOAT	BOAT	BOAT
DeChambeau Embayment (DEEM)	BOAT	GROUND	BOAT	NO SURVEY
Lee Vining Creek (LVCR)	GROUND	NO SURVEY	BOAT	NO SURVEY
Mill Creek (MICR)	BOAT	BOAT	BOAT	BOAT
Northeast Shore (NESH)	BOAT	NO SURVEY	BOAT	NO SURVEY
Ranch Cove (RACO)	NO SURVEY	NO SURVEY	BOAT	NO SURVEY
Rush Creek (RUCR)	GROUND	NO SURVEY	BOAT	NO SURVEY
Sammann's Spring (SASP)	BOAT	NO SURVEY	BOAT	NO SURVEY
South Tufa (SOTU)	NO SURVEY	NO SURVEY	BOAT	NO SURVEY
South Shore Lagoons (SSLA)	NO SURVEY	NO SURVEY	BOAT	NO SURVEY
Warm Springs (WASP)	BOAT	NO SURVEY	BOAT	NO SURVEY
West Shore (WESH)	BOAT	BOAT	BOAT	BOAT
Wilson Creek (WICR)	BOAT	BOAT	BOAT	BOAT

Data Summary & Analysis

Waterfowl totals were summed by species, survey and shoreline segment. All comparisons to previous years data were based on shoreline survey data only and excluded the historical data from the cross-lake transects. We present the total waterfowl recorded on our shoreline

surveys as compared to the 2002 to 2023 annual shoreline totals. We calculated the mean +/- SE of the 2002 to 2023 shoreline waterfowl totals and compared the number of waterfowl recorded on the 2025 surveys.

Table 2. Waterfowl species totals by survey

Species	18-Sep-25	2-Oct-25	16-Oct-25	30-Oct-25	TOTALS
Canada Goose	0	0	57	0	57
Northern Shoveler	18016	3704	2099	13	23832
Gadwall	47	70	6	3	126
American Wigeon	2	0	7	2	11
Mallard	134	63	242	0	439
Northern Pintail	3	0	0	12	15
Green-winged Teal	0	30	26	90	146
Unidentified dabbling duck	3029	0	20	1	3050
Bufflehead	0	1	0	0	1
Ruddy Duck	178	1895	2286	806	5165
Total	21409	5763	4743	927	32842

In addition, we evaluated how well our 2025 survey data could predict the total number of waterfowl at Mono Lake, given the reduced survey effort. Simple linear regression was used to determine how well survey data from a single complete shoreline survey in mid-October (S4) could predict the annual shoreline totals from six complete surveys using the 2002 to 2023 data. Also, because we were able to survey four shoreline areas on all four surveys conducted in 2025, we analyzed how well the combined survey data from these four seasonal surveys (S2 through S5) of the same four shoreline areas (WESH, DECR, MICR, AND WICR) could predict annual shoreline totals from the six complete shoreline surveys. All count data were log-transformed to meet model assumptions. For each dataset, we evaluated totals for the Northern Shoveler and Ruddy Duck, which are the two most abundant species at Mono Lake in early fall, and for all waterfowl species combined.

Results

Total Counts

In 2025, we recorded 32,842 waterfowl of nine species on our surveys (Table 2). Northern Shoveler was far more abundant overall than all other species. The number of Northern Shoveler on the September 18 survey (18,016) represented the highest single day count of this

species as compared to 2002 to 2023. Despite a reduced survey effort in 2025, the presence of large numbers of Northern Shovelers at Mono Lake on September 18 resulted in the 2025 total being the fourth highest annual shoreline waterfowl total at Mono Lake since structured surveys were initiated in 2002 (Fig. 2).

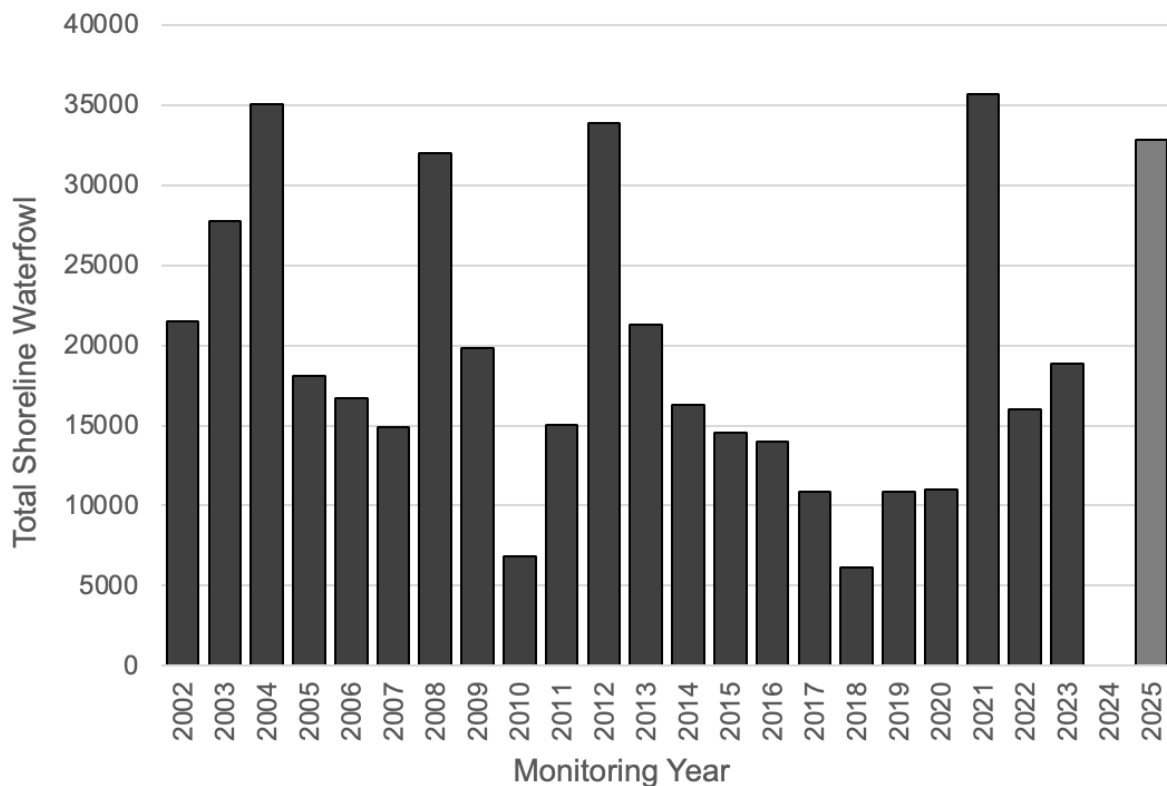


Figure 2. Fall shoreline waterfowl totals at Mono Lake, 2002 to 2025. Note — fewer surveys were conducted in 2025 compared to all other years.

On three of the four surveys conducted, the number of waterfowl recorded was significantly above the long-term mean (Fig. 3). Following a record high count on the S2 survey in mid-September, waterfowl totals declined considerably but remained above the long-term mean through mid-October. The number of waterfowl on S5 at the end of October (927) was slightly below the long-term mean; however, this survey covered only four of the 15 shoreline segments. The number of waterfowl recorded in 2025 was thus above the long-term mean from mid-September through mid-October, despite the abbreviated coverage.

In the absence of 2025 data for S1 and S6, we evaluated what percentage of the annual fall waterfowl totals these surveys typically recorded. Waterfowl totals for the S1 survey accounted for an average of 23% (range of 12.6% to 57.6%) of the fall totals previously reported (Fig. 4). The S6 survey accounted for ~8% (range of 1.4% to 25.2%) of the annual total. S2 has accounted for 14% to 45% of the annual totals but comprised 65% of the 2025 total (Fig. 4).

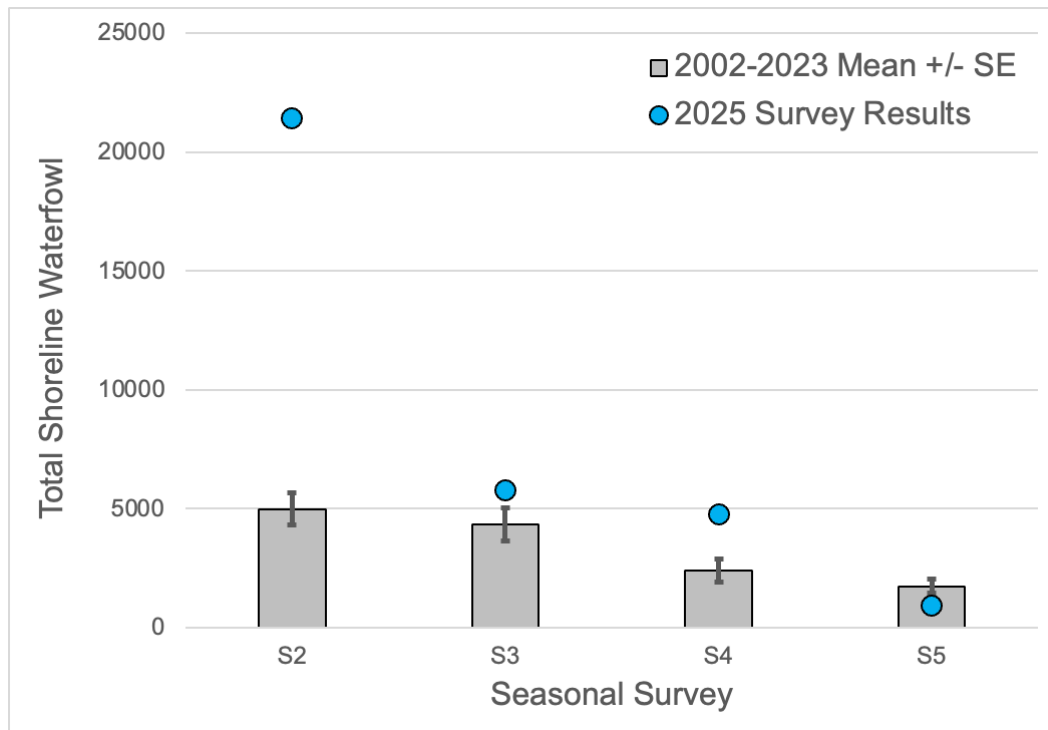


Figure 3. The 2025 shoreline waterfowl totals (blue circles) vs. the annual total 2002 to 2023 mean +/- SE.

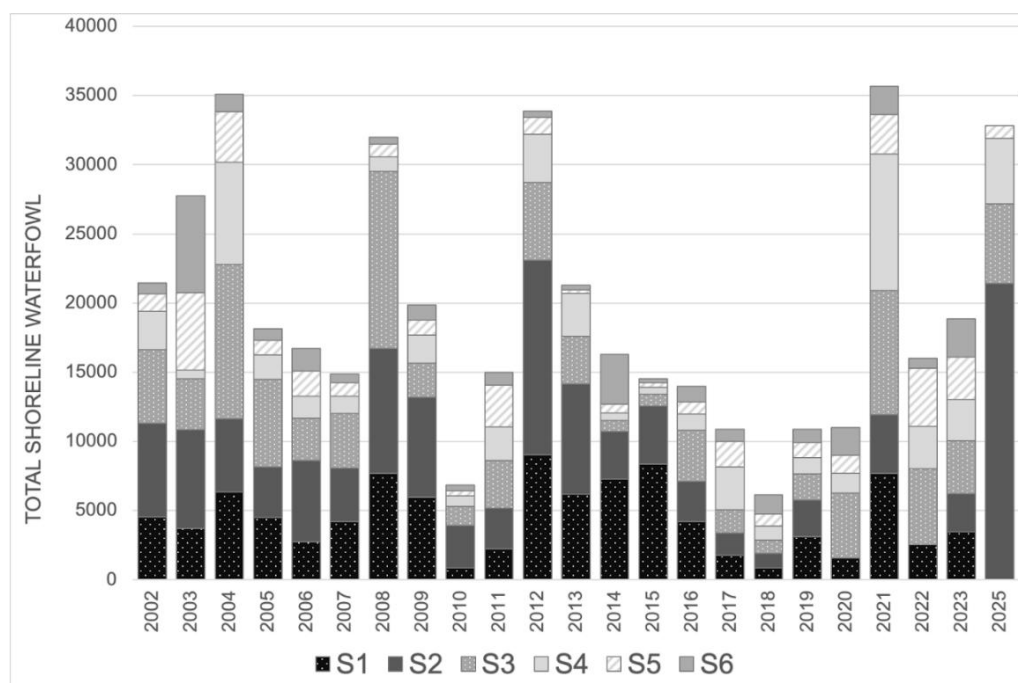


Figure 4. Total shoreline waterfowl by year and seasonal survey period

Spatial Distribution

Overall, 2025 total waterfowl count varied by shoreline segment in part due to survey effort. While our high count at Wilson Creek matched this segment as historically having the most

waterfowl, other segments like Black Point (BLPO), Dechambeau Creek (DECR) and Sammann's Spring (SASP) had much higher-than-average total counts as well (Fig. 5). Despite a full four counts, Mill Creek (MICR) had lower than average numbers of waterfowl. From mid-September to mid-October, waterfowl counts were highest at Wilson Creek as compared to other surveyed segments, but by the end of October, the number of waterfowl at this shoreline location had dropped notably. Waterfowl numbers are typically high at Wilson Creek early in fall as Northern Shovelers congregate in this area of the shoreline (House 2024). Most Northern Shovelers had left Mono Lake by the October 30 survey (Table 3), and relatively few waterfowl were seen at Wilson Creek on that survey. Limited coverage of other shoreline areas limits further assessment of seasonal spatial distribution.

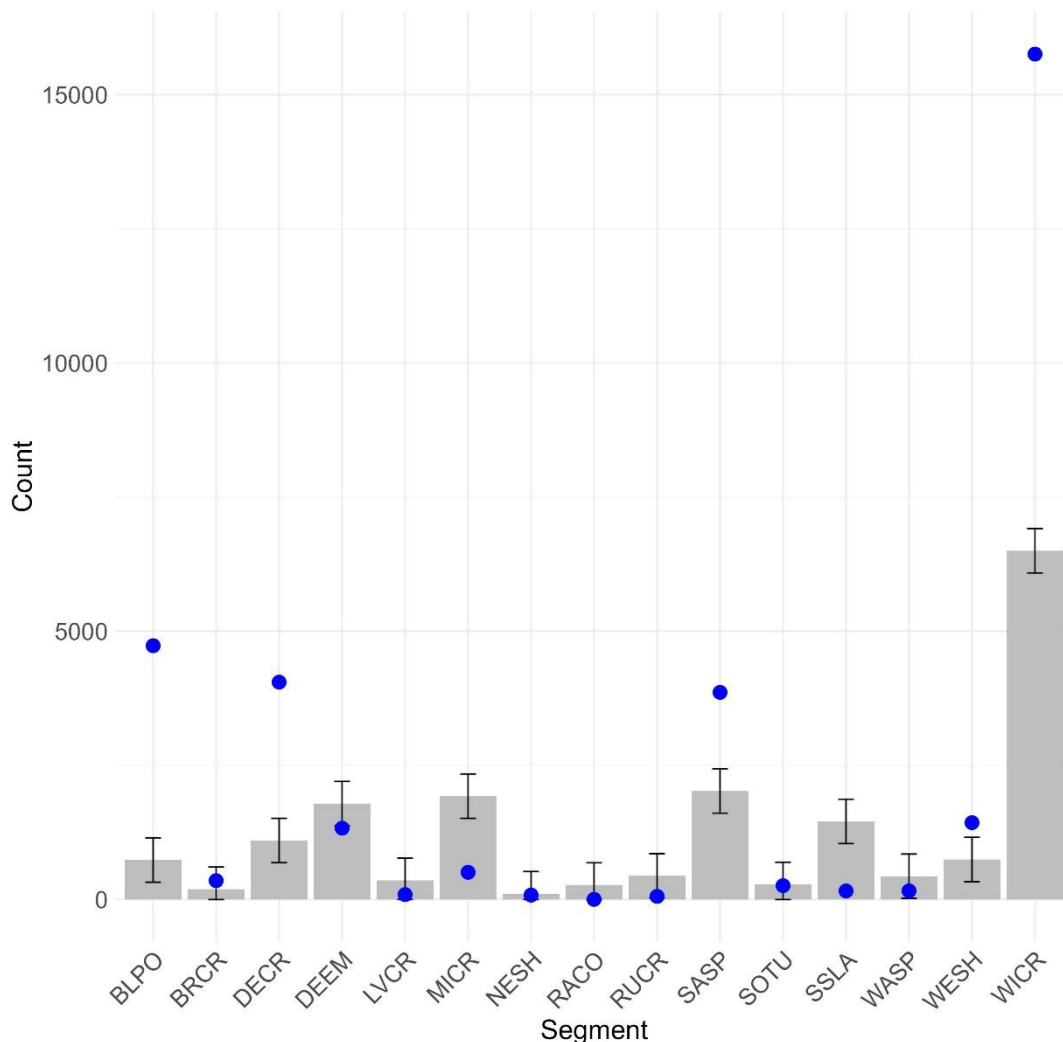


Figure 5. Mean (+/- SE) total fall migration survey waterfowl count by shoreline segment and the 2025 total count (blue circles).

Table 3. Waterfowl totals by shoreline segment and survey. Areas not surveyed are indicated by gray columns and “NS” in row segment total.

SEGMENT	SEASONAL SURVEY AND DATE			
	2	3	4	5
	18-Sep-2025	2-Oct-2025	16-Oct-2025	30-Oct-2025
BLPO	3501	1000	230	NS
BRCR	2	120	230	NS
DECR	2684	796	153	419
DEEM	79	158	1093	NS
LVCR	3	NS	89	NS
MICR	117	320	26	44
NESH	5	NS	78	NS
RACO	NS	NS	4	NS
RUCR	37	NS	22	NS
SASP	3814	NS	47	NS
SOTU	NS	NS	259	NS
SSLA	NS	NS	160	NS
WASP	102	NS	60	NS
WESH	65	553	478	337
WICR	11000	2816	1814	127
Total	21409	5763	4743	927

Trend

We used a linear regression of the total count (log transformed) of waterfowl by year to examine long-term trends in abundance. When including the total count from all years in the regression we found a non-significant yet declining trend ($\beta_{\text{year}} = -0.02$, $P = 0.14$; Fig. 6). We also examined the trend in total abundance in the four segments with four surveys (S2–S5) for the full time series 2002–2025. We again found a declining but non-significant trend ($\beta_{\text{year}} = -0.04$, $P = 0.12$) for the count of all waterfowl.

Survey Assessment

Using the 2002 to 2023 data, we fit a linear regression to test if one complete shoreline survey in mid-October (S4) could predict the total yearly waterfowl, the total yearly Northern Shoveler, or total yearly Ruddy Ducks. The results of linear regression indicated that S4 alone was a poor predictor of each of these variables (Table 4). The combined totals from S2, S3, S4 and S5 of the four areas surveyed (WESH, DECR, MICR and WICR) were a much better predictor of the above variables (Table 4). The results of the regression indicated that waterfowl totals from the four surveys of these four segments explained 43.6% of the variation in total annual shoreline waterfowl ($P < 0.001$). This value was 36.5% for Northern Shoveler ($P = 0.003$) and 44.9% for Ruddy Ducks ($P < 0.001$). We are currently assessing the required survey effort needed to efficiently quantify waterfowl trends in the lake and will report on these findings in our final

technical report.

Table 4. Results of the linear regression models comparing various survey efforts to total counts.

Variables/Model	r ²	P
Log Total Waterfowl S4 ~ Log Total annual shoreline waterfowl	0.25	0.180
Log NSHO S4 ~ Log Total annual Northern Shoveler	0.14	0.100
Log RUDU S4 ~ Log Total annual Ruddy Duck	0.13	0.088
Log Total waterfowl S2 through S5 (WESH, DECR, MICR, WICR) ~ Log Total annual waterfowl	0.44	<0.001
Log Total NSHO S2 through S5 (WESH, DECR, MICR, WICR) ~ Log Total annual Northern Shoveler	0.37	0.003
Log Total RUDU S2 through S5 (WESH, DECR, MICR, WICR) ~ Log Total annual Ruddy Duck	0.45	<0.001

UNCREWED AERIAL VEHICLE WATERFOWL SURVEY ASSESSMENT

Uncrewed Aerial Vehicles (UAV) are increasingly being used to conduct surveys of waterfowl and initial findings suggest these can be quite accurate in both detecting, counting and identifying species (e.g., Dundas et al. 2021, Mackell et al. 2024). Additionally, the

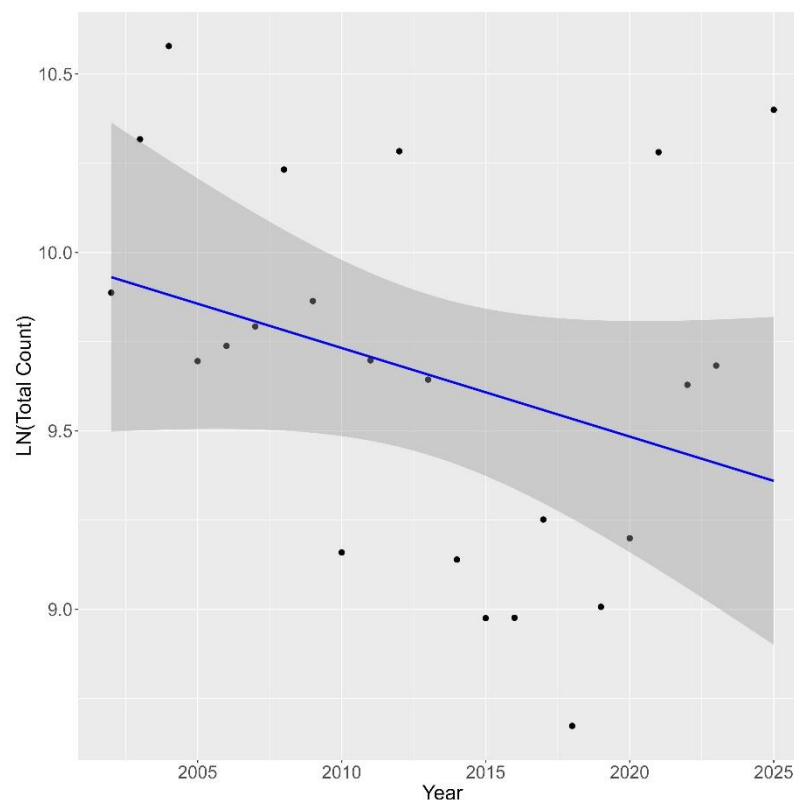


Figure 6. Fitted linear regression of natural log of total count of waterfowl 2002 – 2025 ($\beta_{\text{year}} = -0.02$, $P = 0.14$).

computational and quantitative tools with which to process and analyze UAV gathered imagery of waterfowl are increasingly available (e.g., Loken et al. 2026). As part of our initial efforts to identify alternative techniques for monitoring waterfowl at Mono Lake that are safer and more sustainable than aerial surveys but equally or more accurate, between 1 and 3 October 2025, we conducted UAV flights at Mono Lake. As part of these flights, we sought to understand the impact to waterfowl behavior in response to the UAV and to gather imagery to evaluate the ability to count and identify waterfowl in the habitats along the Mono Lake

shoreline.

Methods

Flights

We flew UAVs (DJI Mavic 3 Enterprise with 20 MP camera) in three areas of the Mono Lake shoreline with known concentrations of waterfowl and waterfowl habitats: South Shore Lagoons (SSLA), Sammann's Spring (SASP), and Wilson Creek (WICR). At WICR, we tested UAV launched from a boat during the fall waterfowl survey on October 2 and then again from a ground-based launch on October 3. At SSLA and SASP on October 1 and then at WICR on October 2 we were able to assess the behavior of waterfowl in response to the UAV flown at different altitudes above ground/lake level (agl) by coupling the flights with simultaneous ground observations. During the October 1 flights, we started the UAV at 100 m agl when approaching areas of waterfowl and then once overhead lowered the UAV slowly and recorded observations of behavior. Based on the results from October 1 altitude testing, we flew October 2 and 3 flights at 40m agl.

Image Processing

Imagery of the waterfowl captured from the UAVs between 30m and 50m were stitched into georeferenced orthomosaics using the program Metashape (Agisoft, v2.0.4) and then prepared for computer vision model training by clipping the imagery into tiles that will be labeled to generate an annotated dataset of waterfowl observations that can be used to train a YOLOv8 object detection model. Results of the initial modeling effort will be included in our final technical report.

Results

Our observations indicated that 40-45m agl waterfowl were not affected by the presence of the UAV. However, as the UAV lowered below 40m agl the observed behaviors were variable but included, looking up, swimming away, and flushing. In some instances, the group of waterfowl started to fly right at 40m while in other cases we were able to get the UAV down to 25m before the waterfowl flushed.

Initial assessment of the imagery suggested that waterfowl can be identified in imagery flown at or below 50m agl though the ability to identify species may be limited (Fig. 7). Species level identification may be improved with a higher resolution camera. We are currently assessing the accuracy of a computer vision model.



Figure 7. UAV images of waterfowl on Mono Lake near Sammann's springs on 1 October 2025 taken at ~40m above ground level.

UNCREWED AERIAL VEHICLE IMAGERY FOR REMOTE SENSING OF HABITAT

One of the requirements of the license for water diversions at Mono Lake is annual photos of the shoreline to document changes in conditions. These data have been collected using either an airplane or helicopter. Though these images provide data with which assess shoreline change they represent a single time of the year, require detailed knowledge of conditions in previous years for interpretation, and involve access to airplanes or helicopters. Since the start of monitoring in 2002 there have been significant advances in the ability to use satellite based remote sensing to track conditions on earth, including better access to imagery and improved models with which to more objectively quantify changing conditions on the landscape. To build a remote sensing model, we used UAVs to collect high resolution imagery needed to generate an extensive ground validation set.

Methods

Between 1 and 3 October 2025, we flew two UAVs at 70m agl to gather images of the Mono Lake shoreline representing a wide array of land covers across 10 different sites. We used 8 – 10 ground control points in every survey zone to enhance the accuracy of georeferencing. We also collected ground-based data for remote sensing models using a Garmin GPSMap 67i. Images were stitched into georeferenced orthomosaics using Metashape. Orthomosaics were imported to ArcGIS Pro (Esri, Redlands, CA) to generate ground validation data for remote sensing modeling in Google Earth Engine.

Results

Stitched imagery resulted in orthomosaics with 3–5 cm resolution for 1,182 ha of Mono Lake shoreline for multiple regions of the Mono Lake shoreline (Fig. 8). Initial image review indicated that we may be able to generate data for developing a remote sensing model for up to seven

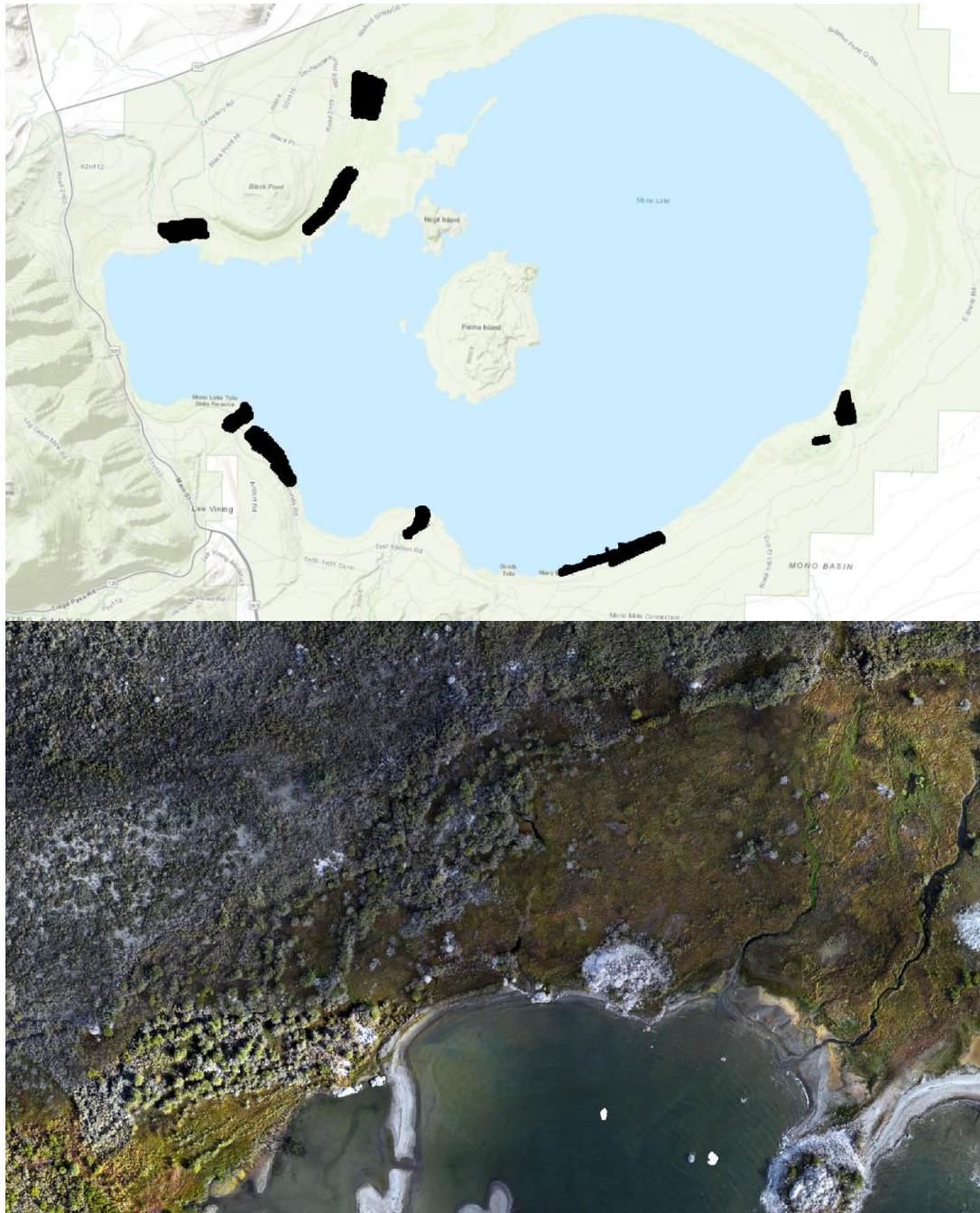


Figure 8. Location of areas flown with UAV to gather imagery for a satellite based land cover classification model (top) and example of imagery (3 cm pixels) from near Wilson Creek with water, willows, bare shoreline, desert scrub, fresh meadow and tufa (bottom).

land cover classes: (1) water, (2) cottonwood/willow, (3) bare shoreline, (4) desert scrub, (5) fresh meadow, (6) alkali meadow, and (7) tufa. In combination with our data collected in the field, we anticipate having 50 – 100 points for each possible landcover.

SUMMARY AND NEXT STEPS

Boat Surveys

Waterfowl totals at Mono Lake in fall of 2025 were above the 2002 to 2023 long-term mean. This was largely due to a record high number of Northern Shovelers recorded on the mid-September survey. Wilson Creek remained an important early season staging area, particularly for Northern Shovelers, as evidenced by the record high numbers present in mid-September. Despite the reduced survey coverage, our results documented high use and thus verify that there was no concerning decline in fall waterfowl numbers at Mono Lake in fall of 2025. However, the long-term trend still suggests a potential decline in waterfowl over the 23-year period.

Our experience conducting boat surveys was instructive for considering how to best conduct the fall waterfowl surveys into the future. Boat-based surveys at Mono Lake are less efficient but inherently much safer than the aerial survey method used from 2002 to 2023. Based on our experience this year, boat-based waterfowl surveys of the shoreline are not without their own challenges. Successful use of a boat may require Point Blue having a local waterfowl survey team dedicated to conducting these surveys; consisting of a suitable boat, a captain, and a trained surveyor. This team would need some flexibility in their schedule to effectively alter survey plans based on the weather forecasts or conditions encountered.

Submerged obstacles will continue to be a challenge at Mono Lake, however, additional experience navigating near shore areas will likely help the team develop strategies to minimize or avoid high risk areas. If feasible and practical, the use of UAVs to survey certain areas with high concentrations of submerged objects may provide an alternative (see below).

We are currently completing a detailed assessment of both the summer breeding surveys and fall surveys to determine the optimal level of effort that is needed to adequately track changes in waterfowl populations at Mono Lake. Our preliminary assessment in this report suggests that four surveys of the four western most units are likely significantly correlated with the total waterfowl along the shoreline, however there was still some substantial unexplained variance. We will provide a full summary of our design assessment and recommendations for future surveys in our final technical report.

UAV for Waterfowl

Our initial assessment suggested that UAVs could be used to gather imagery on waterfowl if they are flown >40m above the birds. Launching from a boat or from land are both options though if using UAVs as the primary survey method launching from land is logistically easier. Review of the imagery thus far suggests that given the camera used in 2025, identifying

individuals to species may be difficult. We will continue to assess this possibility and consider the potential to upgrade our UAV platform with enhanced imagery capabilities. We will be developing an initial computer vision model over the coming month to assess baseline accuracy for automating the detection and counting of waterfowl from UAV surveys. The details of these results will be provided in our final technical report. Pending a positive outcome from our initial modeling efforts, more work will be needed to fully assess the ability of a UAV approach for fall waterfowl surveys. We also did not collect any UAV data on breeding waterfowl which may also be a consideration for the 2026 field season.

UAV for Habitat

UAV flights provided an efficient approach to gather widespread data with which to build a satellite-based remote sensing classification model for land cover and waterfowl habitat surrounding Mono Lake. While initial review of the imagery indicated that we could likely delineate up to seven distinct land cover classes, we will better understand whether these can be delineated spectrally once we build out the initial remote sensing model using multispectral satellite data over the coming months. Once we have a sense of the accuracy of our initial model, consultation with stakeholders will be warranted to determine whether additional resolution in the habitat classes (e.g., specific vegetation species) is needed. Further, we anticipate the need for additional validation of the model we develop in the coming field season to determine if it can work to delineate variation in habitat conditions between the summer and fall. While the historic aerial photography was only collected once per year, a shift to using a satellite-based approach will provide the opportunity to track seasonal variation in flooded habitats and to link habitat extent and condition more directly to waterfowl surveys. Ultimately, if habitat can be a very strong predictor of waterfowl abundance, whether during breeding or migration, it may prove to be a surrogate for counting birds in the future.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Dundas, S.J., et al. 2021. Quantifying Waterfowl Numbers: Comparison of Drone and Ground-Based Survey Methods for Surveying Waterfowl on Artificial Waterbodies. *Drones* 5(1): 5.

House, D.J. 2024. Fall migration of the Northern Shoveler at hypersaline Mono Lake, California. *Western Birds* 55:261–279. DOI:10.21199/WB55.4.2.

House, D. and M. Honda. 2018. Mono basin waterfowl habitat restoration program periodic overview report. Prepared for the State Water Resources Control Board.

House, D. and M. Honda. 2024. Mono basin waterfowl habitat restoration program. 2023 monitoring report. Prepared for the State Water Resources Control Board.

Loken, Z., K.M. Ringelman, A. Mini, J.D. James, and M. Mitchell. 2026. DuckNet: An open-source deep learning tool for waterfowl species identification in UAV imagery. *Remote Sensing in Ecology and Conservation* 12:113–128. <https://doi.org/10.1002/rse2.70028>.

Los Angeles Department of Water and Power. 1996. Mono Basin waterfowl habitat restoration plan, in response to the Mono Lake Basin Water Right Decision 1631. Report to the State Water Resources Control Board. <https://www.monobasinresearch.org/legal/1996waterfowlplan.pdf>.

Los Angeles Department of Water and Power (LADWP). 2024. Mono Basin runoff year 2025–2026 annual operations plan. Licenses 10191 and 10192. May 2025.

Mackell, D.A., et al. 2024. Surveying waterfowl broods in wetlands using aerial drones. *San Francisco Estuary and Watershed Science* 22(3) <https://doi.org/10.15447/sfews.2024v22iss3art2>

State Water Resources Control Board (SWRCB). 1994. Mono Lake Basin Water Right Decision 1631. https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1631.pdf

State Water Resources Control Board (SWRCB). 1998. State of California State Water Resources Control Board Order WR 98-05. In the matter of stream and waterfowl habitat restoration plans and Grant Lake operations and management plan submitted by the Los Angeles Department of Water and Power pursuant to the requirements of Water Right Decision 1631 (Water Rights Licenses 10191 and 10192, Applications 8042 and 8043). September 2, 1998.