



2020 Data Summary of Wet Nitrogen Deposition at Rocky Mountain National Park

Natural Resource Report NPS/NRSS/ARD/NRR—2023/2490



ON THE COVER

Photograph of view from Loch Vale towards Timberline Falls in Rocky Mountain National Park.
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Abstract

The National Park Service is working with the Colorado Department of Public Health and Environment and the Environmental Protection Agency Region 8 (referred to as the Memorandum of Understanding agencies) to reduce atmospheric nitrogen deposition at Rocky Mountain National Park due to its detrimental effects on park ecosystems. The data summarized in this report informs these agencies, stakeholders, and the public about the current status and trends of nitrogen deposition in accordance with the RMNP Nitrogen Deposition Reduction Plan (NDRP). Analyses include assessment of progress along the glidepath and trend analyses for RMNP and other regional sites for the following time periods: long-term/period of record (>32 years), since the 2006 inception of the NDRP, and short-term (the most recent 7 years). Wet N deposition in 2020 at Loch Vale in RMNP was above the glidepath. Long-term trends showed that N deposition levels are stable (no trend), with ammonium concentrations increasing at most of sites and nitrate concentrations decreasing at all sites. Wet N Deposition decreased at Loch Vale in RMNP for the first time since the inception of the NDRP (2006–2020). Other short-term trends indicated that ammonium concentrations were stable, but nitrate concentrations decreased at some sites.

Introduction

The purpose of this data summary is to inform the Memorandum of Understanding (MOU) agencies, stakeholders, and the public about the current status and trends of wet nitrogen (N) deposition in accordance with the [Nitrogen Deposition Reduction Plan](#) (NDRP) for Rocky Mountain National Park (RMNP). Full reports on Monitoring and Tracking Wet Nitrogen Deposition at RMNP were peer-reviewed and published annually from 2009 to 2013. In 2014, however, it was decided that a summary of the data would be compiled and distributed annually between milestone years. This data summary is reviewed by the MOU agencies including the National Park Service, the Environmental Protection Agency Region 8 and the Colorado Department of Public Health and Environment. During future milestone years (2022, 2027, and 2032), a full report will be published and undergo external review.

The analyses presented here to track wet nitrogen deposition at RMNP, include:

- 1) assessment of progress along the glidepath, and
- 2) trend analyses for RMNP and other regional sites for the following time periods:
 - long-term/period of record (>32 years),
 - since 2006 (inception of the NDRP), and
 - short-term (the most recent 7 years).

Methods and Results

Background information and a complete description of the monitoring is provided in the last full report, [2017 Monitoring and Tracking Wet Nitrogen Deposition at Rocky Mountain National Park](#) (Morris et al. 2019). There were several changes made to the methods in 2018, including a new approach for data substitution when data (sample concentrations and precipitation amounts) were invalid or missing, and more strict criteria for reporting significant trends over time (see [2018/2019 Data Summary of Wet Nitrogen Deposition at Rocky Mountain National Park](#) for explanation).

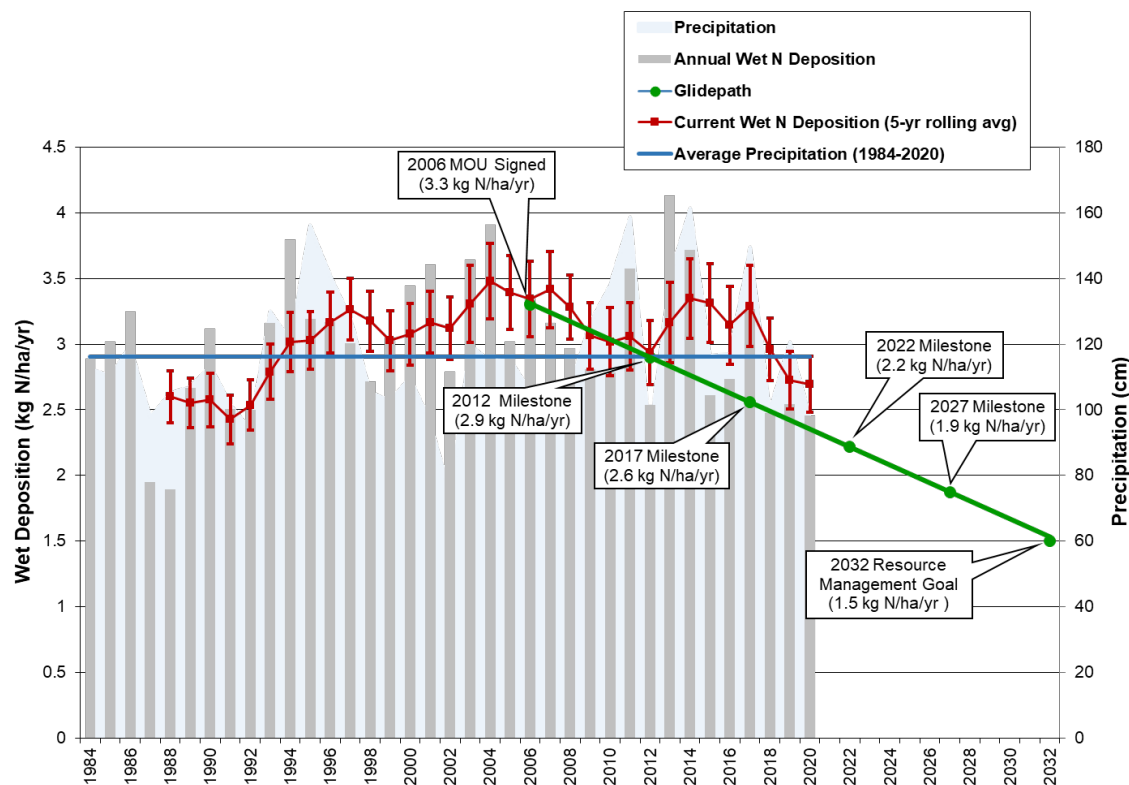


Figure 1. The glidepath compared to annual and 5-year average of wet N deposition. Annual wet N deposition in 2020 was around 2.5 kg N/ha/yr, similar to the last 2 years. The 2020 5-year rolling average (2.7 ± 0.22 kg N/ha/yr) remains above the glidepath (~ 2.4 kg N/ha/yr). Precipitation in 2020 was below average. Error bars are based on a Monte Carlo simulation.

Wet N deposition data through 2020 are presented in Figures 2–8 and Tables 1–8 and are available on the [National Atmospheric Deposition Program \(NADP\) website](#).

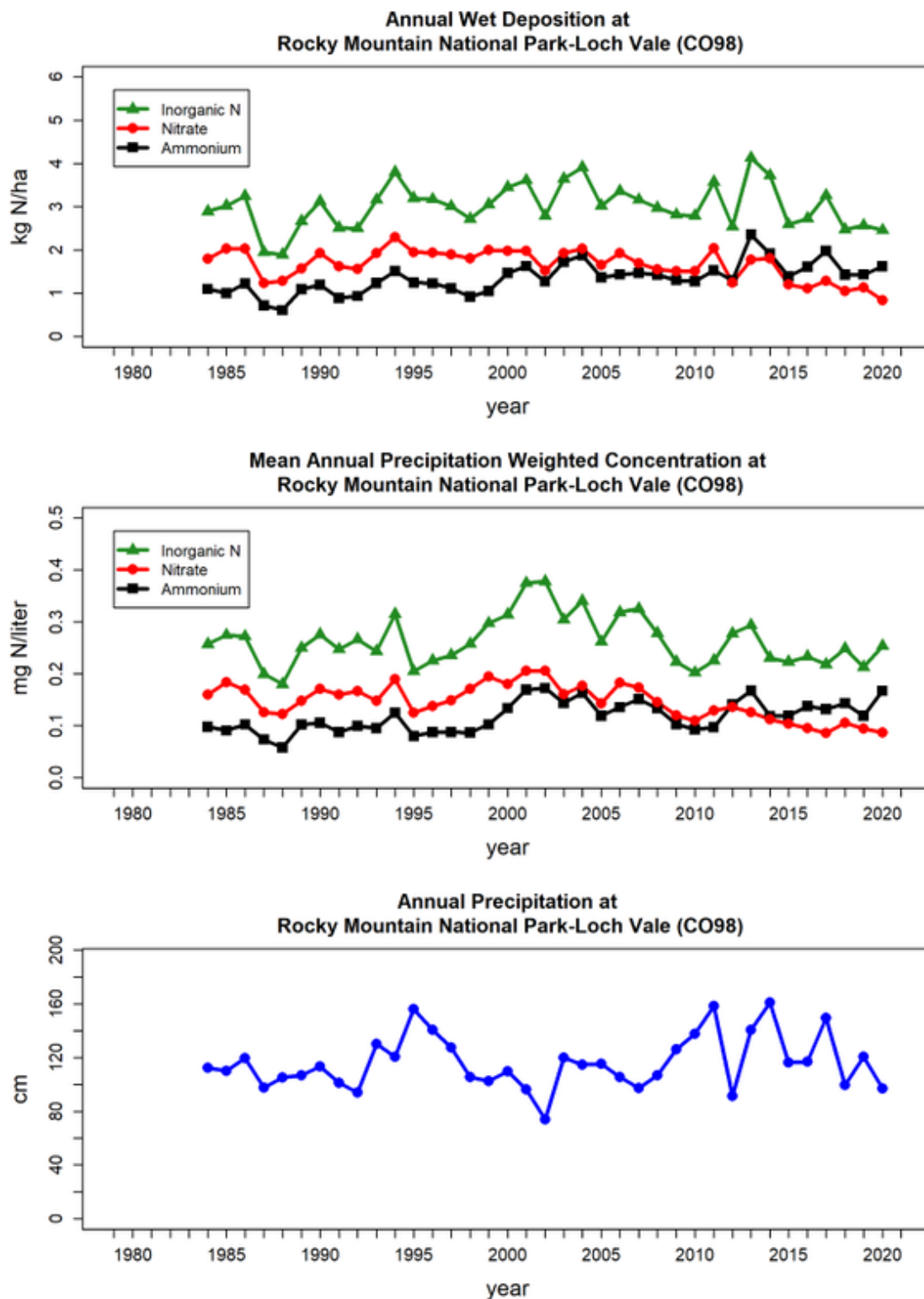


Figure 2. Data at Loch Vale, RMNP using the data substitution methods for missing/invalid sample concentration and precipitation amount. Precipitation in 2020 was lower in 2020 than in 2019. Concentrations of nitrate were slightly lower in 2020 and ammonium was higher, compared recent years. Wet nitrogen deposition was around 2.5 kg N/ha/yr for the last three years.

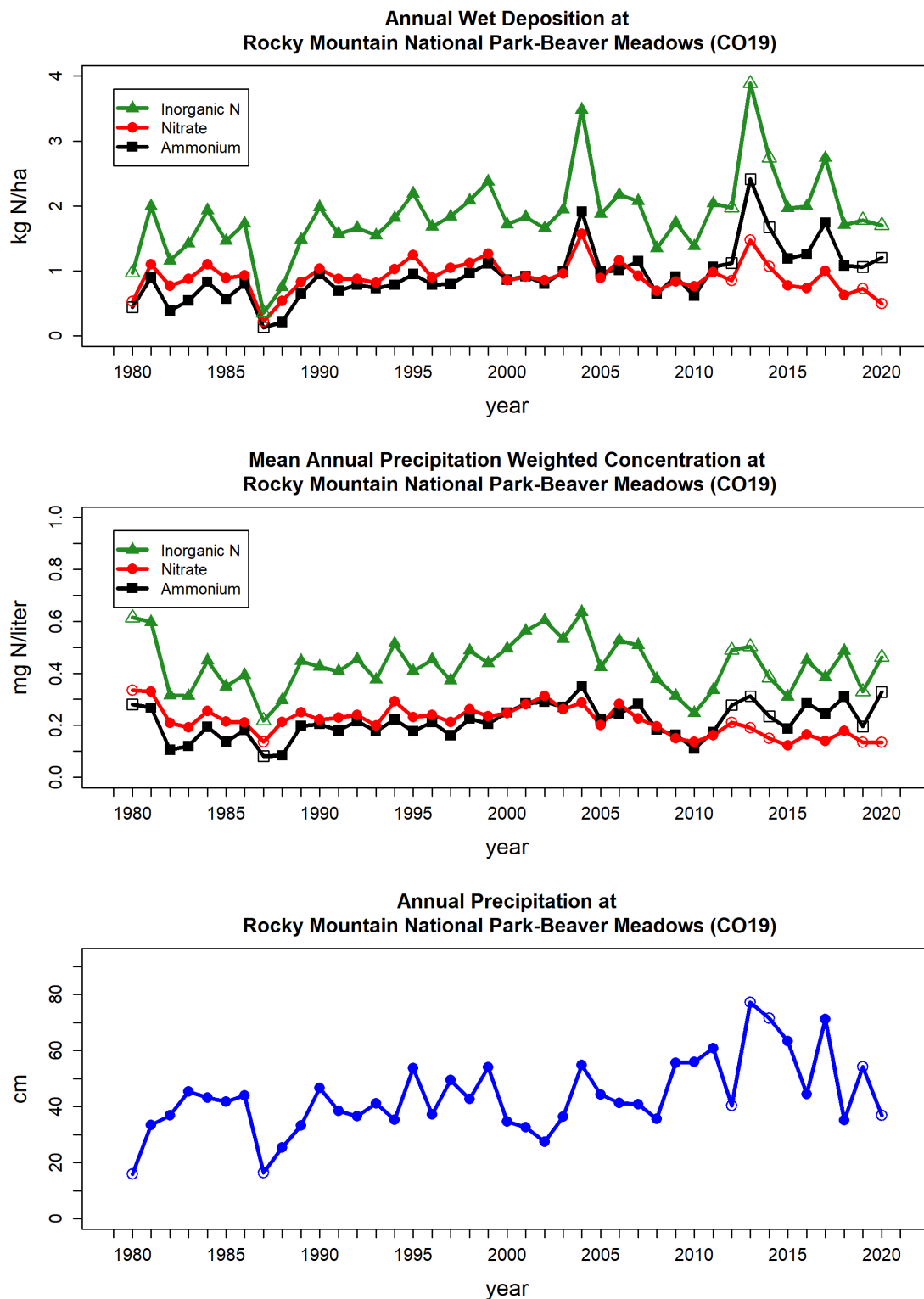


Figure 3. Precipitation decreased in 2020 compared to 2019, while concentrations of ammonium increased and nitrate stayed the same, resulting in similar deposition in 2020 to the last 2 years at Beaver Meadows, RMNP. Open symbols demark years when NADP Data Completeness were not met.

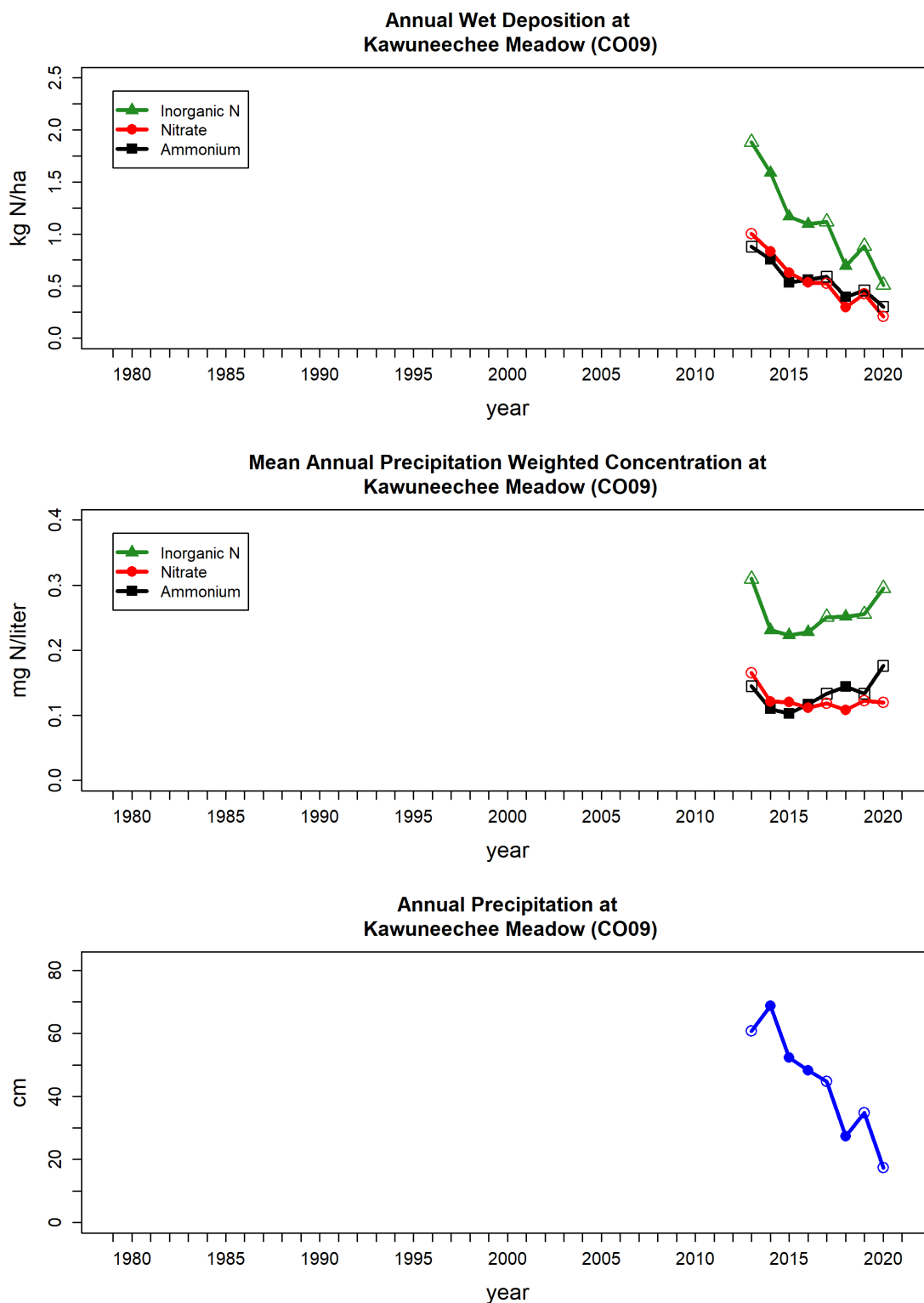


Figure 4. Precipitation decreased to the lowest on record in 2020. Concentrations of nitrate remained about the same and ammonium increased, compared to 2019. However, due in part to low precipitation, wet N deposition in 2020 was also the lowest on record at Kawuneechee Meadow, RMNP. Open symbols demark years when NADP Data Completeness were not met.

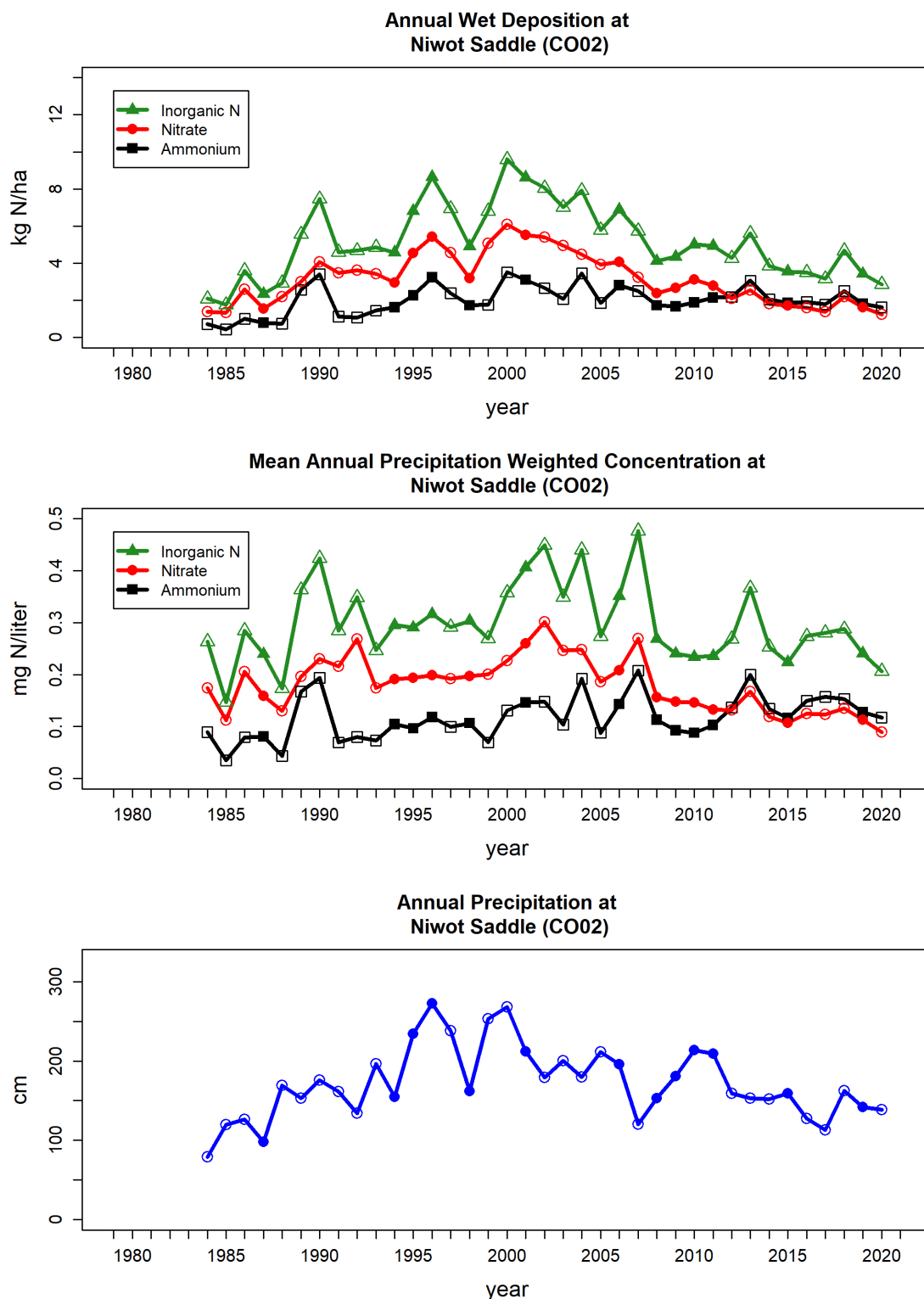


Figure 5. Precipitation was about the same in 2020 as 2019, while concentrations also decreased slightly, resulting in decreased wet N deposition in 2020 at Niwot Saddle, compared to recent years. Open symbols demark years when NADP Data Completeness were not met.

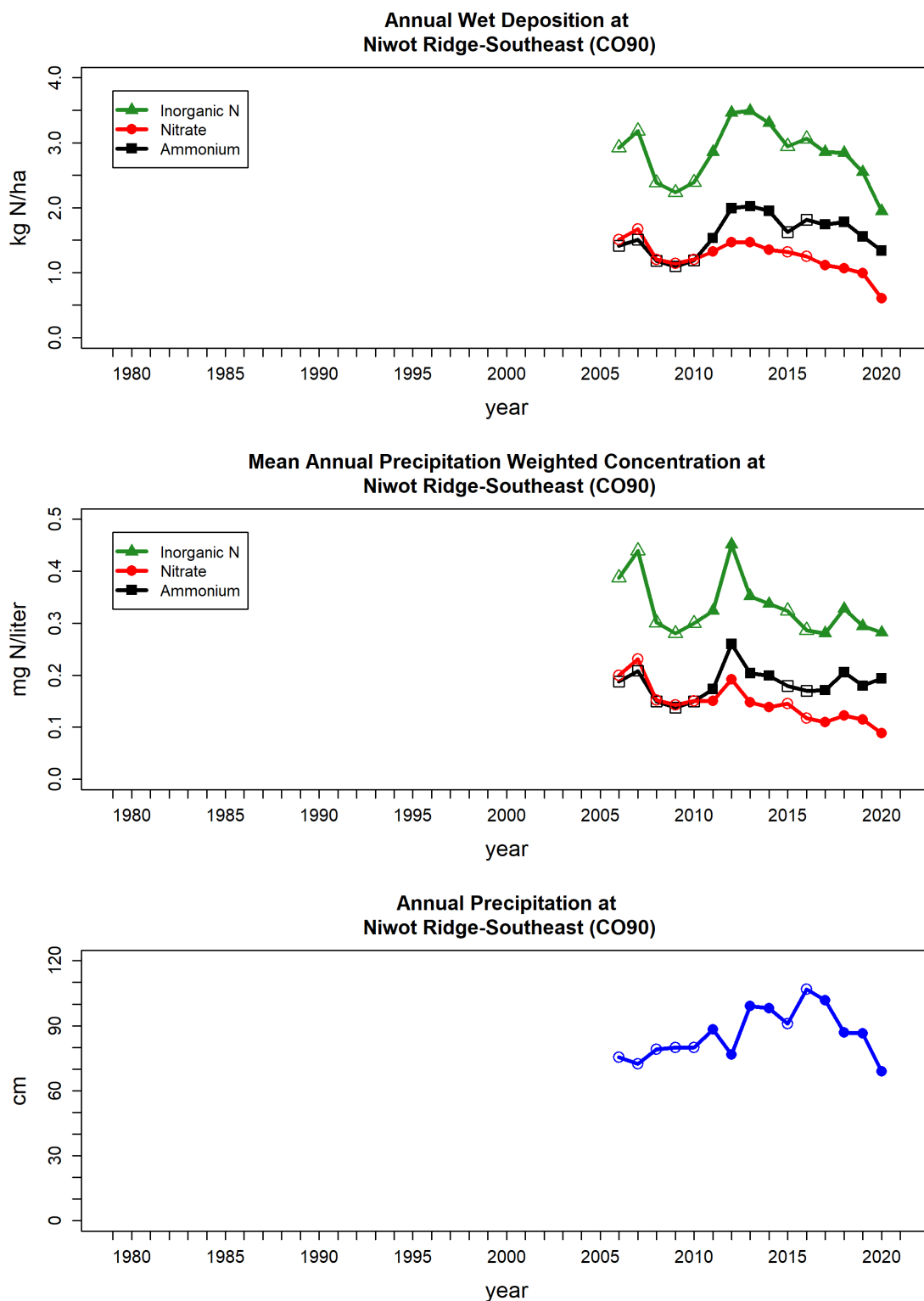


Figure 6. Precipitation decreases in 2020 while ammonium concentrations increased slightly and nitrate concentrations decreased, resulting in a decrease in wet N deposition in 2020 at Niwot Ridge-Southeast. Open symbols demark years when NADP Data Completeness were not met.

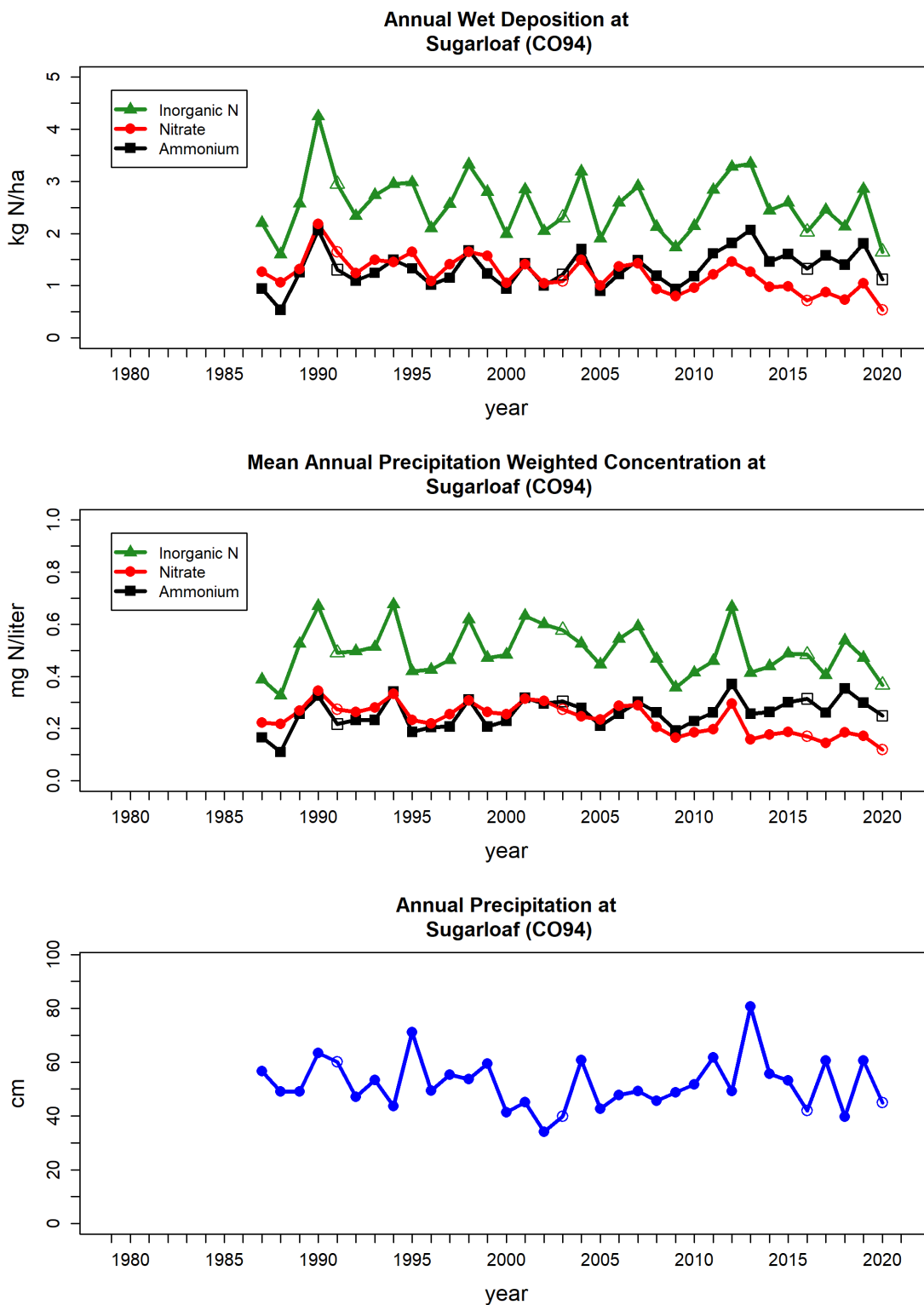


Figure 7. Precipitation decreased in 2020 compared to 2019 while concentrations of ammonium and nitrate decreased slightly, resulting in a decrease in wet N deposition at Sugarloaf, compared to recent years. Open symbols demark years when NADP Data Completeness were not met.

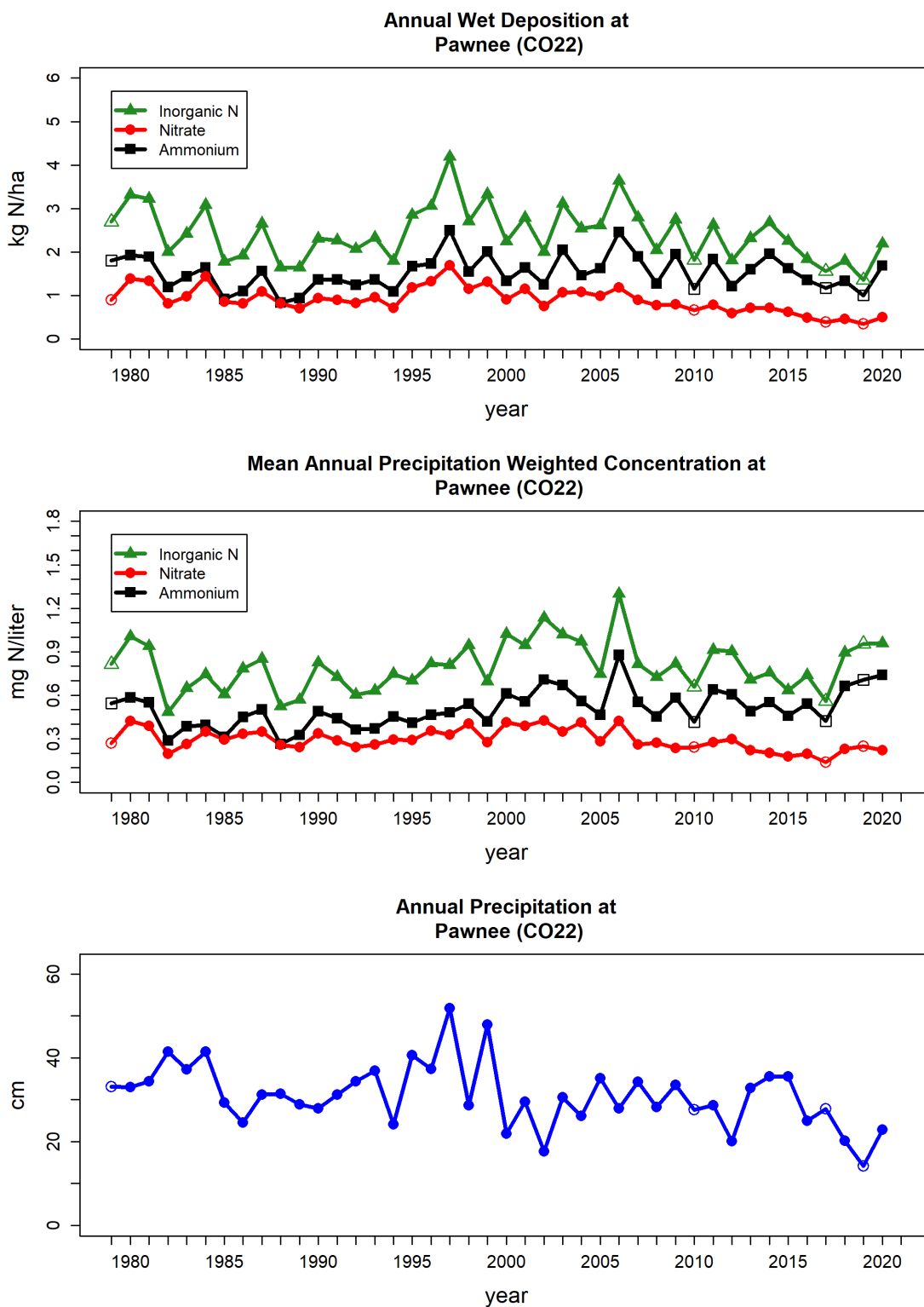


Figure 8. Precipitation increased in 2020 compared to 2019. Concentrations of nitrate decreased slightly, and ammonium increased slightly, resulting in an increase in wet N deposition at Pawnee compared to 2019. Open symbols demark years when NADP Data Completeness were not met.

Table 1. Long-term trends in **wet nitrogen deposition** over the period of record (through 2020). Significant trends were determined at the 95 percent confidence level (p-value $\leq$ 0.05). [NA, trend not available due to failure to meet data completeness criteria].

Site Name	Start Year	Trend (kg N/ha/yr)	P-value	Significant Trends
Loch Vale	1984	0.001	0.969	no trend
Beaver Meadows	1981	0.014	0.021	increasing
Niwot Saddle	1986	NA	NA	NA
Sugarloaf	1987	0.002	0.803	no trend
Pawnee	1980	-0.005	0.633	no trend

Table 2. Long-term trends in **precipitation-weighted mean ammonium concentrations** over the period of record (through 2020). Significant trends were determined at the 95 percent confidence level (p-value $\leq$ 0.05). [NA, trend not available due to failure to meet data completeness criteria].

Site Name	Start Year	Trend (μ eq/L/yr)	P-value	Significant Trends
Loch Vale	1984	0.112	<0.001	increasing
Beaver Meadows	1981	0.207	<0.001	increasing
Niwot Saddle	1986	NA	NA	NA
Sugarloaf	1987	0.118	0.133	no trend
Pawnee	1980	0.286	0.007	increasing

Table 3. Long-term trends in **precipitation-weighted mean nitrate concentrations** over the period of record (through 2020). Significant trends were determined at the 95 percent confidence level (p-value $\leq$ 0.05). [NA, trend not available due to failure to meet data completeness criteria].

Site Name	Start Year	Trend (μ eq/L/yr)	P-value	Significant Trends
Loch Vale	1984	-0.113	0.002	decreasing
Beaver Meadows	1981	-0.152	0.008	decreasing
Niwot Saddle	1986	NA	NA	NA
Sugarloaf	1987	-0.250	0.001	decreasing
Pawnee	1980	-0.205	0.004	decreasing

Table 4. Long-term trends of **precipitation** over the period of record (through 2020). Significant trends were determined at the 95 percent confidence level ($p\text{-value} \leq 0.05$). [NA, trend not available due to failure to meet data completeness criteria].

Site Name	Start Year	Trend (cm/yr)	P-value	Significant Trends
Loch Vale	1984	0.258	0.314	no trend
Beaver Meadows	1981	0.408	0.035	increasing
Niwot Saddle	1986	NA	NA	NA
Sugarloaf	1987	0.099	0.617	no trend
Pawnee	1980	-0.186	0.056	no trend

Table 5. Trends of **wet nitrogen deposition** since 2006 (2006–2020) and 7 year (2014–2020) time periods. Significant trends were determined at the 95 percent confidence level ($p\text{-value} \leq 0.05$). [NA, trend not available due to failure to meet data completeness criteria]. Kawuneechee Meadow began monitoring in 2013.

Site Name	Since 2006 NDRP Inception (15 year)			7 year		
	Trend (kg N/ha/yr)	P-value	Significant Trends	Trend (kg N/ha/yr)	P-value	Significant Trends
Loch Vale	-0.049	0.038	decreasing	-0.112	0.072	no trend
Beaver Meadows	-0.004	1	no trend	NA	NA	NA
Kawuneechee Meadow	–	–	–	NA	NA	NA
Niwot Saddle	NA	NA	NA	NA	NA	NA
Niwot Ridge-Southeast	NA	NA	NA	-0.191	0.028	decreasing
Sugarloaf	0.005	0.76	no trend	0.035	0.807	no trend
Pawnee	-0.08	0.016	decreasing	-0.116	0.221	no trend

Table 6. Trends for **precipitation-weighted mean ammonium concentrations** since 2006 (2006–2020) and 7 year (2014–2020) time periods. Significant trends were determined at the 95 percent confidence level ($p\text{-value} \leq 0.05$). [NA, trend not available due to failure to meet data completeness criteria]. Kawuneechee Meadow began monitoring in 2013.

Site Name	Since 2006 NDRP Inception (15 year)			7 year		
	Trend ($\mu\text{eq/L/yr}$)	P-value	Significant Trends	Trend ($\mu\text{eq/L/yr}$)	P-value	Significant Trends
Loch Vale	0.094	0.357	no trend	-0.144	0.66	no trend
Beaver Meadows	0.185	0.346	no trend	NA	NA	NA
Kawuneechee Meadow	–	–	–	NA	NA	NA
Niwot Saddle	NA	NA	NA	NA	NA	NA
Niwot Ridge-Southeast	NA	NA	NA	-0.582	0.076	no trend
Sugarloaf	0.153	0.605	no trend	0.037	1	no trend
Pawnee	-0.271	0.609	no trend	0.055	1	no trend
Pawnee	-0.08	0.016	decreasing	-0.116	0.221	no trend

Table 7. Trends for **precipitation-weighted mean nitrate concentrations** since 2006 (2006–2020) and 7 year (2014–2020) time periods. Significant trends were determined at the 95 percent confidence level ($p\text{-value} \leq 0.05$). [NA, trend not available due to failure to meet data completeness criteria]. Kawuneechee Meadow began monitoring in 2013.

Site Name	Since 2006 NDRP Inception (15 year)			7 year		
	Trend ($\mu\text{eq/L/yr}$)	P-value	Significant Trends	Trend ($\mu\text{eq/L/yr}$)	P-value	Significant Trends
Loch Vale	-0.396	0.001	decreasing	-0.276	0.135	no trend
Beaver Meadows	0.419	0.029	decreasing	NA	NA	NA
Kawuneechee Meadow	–	–	–	NA	NA	NA
Niwot Saddle	NA	NA	NA	NA	NA	NA
Niwot Ridge-Southeast	NA	NA	NA	-0.644	0.018	decreasing
Sugarloaf	-0.533	0.017	decreasing	-0.412	0.303	no trend
Pawnee	-0.850	0.002	decreasing	-1.106	0.269	no trend

Table 8. Trends for **precipitation** since 2006 (2006–2020) and 7 year (2014–2020) time periods. Significant trends were determined at the 95 percent confidence level (p-value ≤ 0.05). [NA, trend not available due to failure to meet data completeness criteria]. Kawuneechee Meadow began monitoring in 2013.

Site Name	Since 2006 NDRP Inception (15 year)			7 year		
	Trend (cm/yr)	P-value	Significant Trends	Trend (cm/yr)	P-value	Significant Trends
Loch Vale	0.685	0.767	no trend	-5.537	0.230	no trend
Beaver Meadows	1.488	0.283	no trend	NA	NA	NA
Kawuneechee Meadow	–	–	–	NA	NA	NA
Niwot Saddle	NA	NA	NA	NA	NA	NA
Niwot Ridge-Southeast	NA	NA	NA	-6.242	0.086	no trend
Sugarloaf	0.970	0.127	no trend	0.453	1.000	no trend
Pawnee	-0.369	0.631	no trend	-2.472	0.221	no trend

Summary

The analyses presented in this data summary allow us to answer the following questions:

- 1) Is current wet nitrogen deposition in RMNP on or below the NDRP glidepath?

Current wet N deposition (5-year rolling average) in 2020 at Loch Vale in RMNP was 2.7 ± 0.22 kg/ha/yr which is 0.3 kg/ha/yr above the glidepath (~ 2.4 kg/ha/yr) and outside the 95% confidence interval.

- 2) Has wet nitrogen deposition decreased at RMNP and other sites in the region over the long-term (period of record)?

Wet N deposition has not decreased at RMNP or other sites in the region over the long-term. An increasing trend was reported by Burns 2003 for Loch Vale in RMNP for the period 1984–2000. Trend analyses since then (for 1984–2008 and through 2020) show no trend for all of the sites, except Beaver Meadows in RMNP. Data from Beaver Meadows indicate an increase in wet N deposition and precipitation for the period of record. Ammonium concentration data show an increase at both sites in RMNP and Pawnee but not at Sugarloaf over the long-term. Nitrate concentration data show a decreasing trend at all sites that met data completion criteria over the long-term.

- 3) Has wet nitrogen deposition decreased at RMNP and other sites in the region since the inception of the NDRP in 2006?

Wet N deposition decreased at Loch Vale in RMNP for the first time since the inception of the NDRP, from 2006 to 2020. Wet N deposition also decreased at Pawnee during this time frame. Concentrations of ammonium showed no trends at all sites and concentrations of nitrate decreased at all four sites that met completion criteria.

- 4) Has wet nitrogen deposition decreased at RMNP and at other sites in the region in the short-term (7 year)?

Wet N deposition has not recently decreased at RMNP or other sites in the region, except at Niwot Ridge-Southeast. Concentrations of ammonium showed no trends at all sites and concentrations of nitrate decreased only at Niwot Ridge-Southeast.

Literature Cited

- Burns, D. A. 2003. Atmospheric nitrogen deposition in the Rocky Mountains of Colorado and Southern Wyoming, USA – a review and analysis of past study results. *Environmental Pollution* 37:921–932.
- Morris, K. 2021. 2018/2019 data summary of wet nitrogen deposition at Rocky Mountain National Park. Natural Resource Report NPS/NRSS/ARD/NRR—2021/2339. National Park Service, Fort Collins, Colorado. <https://doi.org/10.36967/nrr-2288455>.
- Morris, K., A. Mast, G. Wetherbee, J. Baron, J. Cheatham, J. Bromberg, L. Devore, J. Hou, K. Gebhart, M. Bell, D. Gay, M. Olson, T. Weinmann, and D. Bowker. 2019. 2017 Monitoring and tracking wet nitrogen deposition at Rocky Mountain National Park: February 2019. Natural Resource Report NPS/NRSS/ARD/NRR—2019/1905. National Park Service, Fort Collins, Colorado.

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