

**Spatial and Temporal Patterns in  
Oxygen and Temperature in the  
Redwillow Watershed, 2022–2023**

**Final Report**



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Sherwood Park, Alberta, Canada T8A 6J7

April 2024

**ACA PROJECT  
REPORT**

**Spatial and Temporal Patterns in Oxygen and  
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**Final Report**

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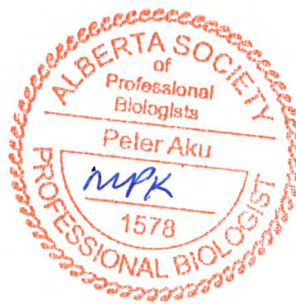
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## EXECUTIVE SUMMARY

Arctic grayling (*Thymallus arcticus*) were historically abundant in the Redwillow Hydrologic Unit Code (HUC) 6 watershed but have been extirpated from the Beaverlodge River HUC 8 watershed sub-basin since the mid-1990s and are thought to be in decline in the Redwillow River HUC 8 watershed sub-basin as well. Alberta Conservation Association (ACA) has been working in the Beaverlodge River watershed since 2004 to improve riparian health and water quality with the hope of bringing Arctic grayling back to the watershed. In this study, we assessed the spatial and temporal distribution of summer (August) water temperature and winter dissolved oxygen (DO), two key limiting factors for suitable Arctic grayling habitat, throughout the Beaverlodge River and Redwillow River watersheds to allow for comparison between the two watersheds and to help determine the suitability of the Beaverlodge River watershed to support Arctic grayling reintroduction.

In 2022–2023, we installed 61 temperature and 11 DO loggers throughout the Redwillow and Beaverlodge HUC 8 watershed sub-basins. Data integrity was maintained at 35 temperature and 10 DO sites, but compromised at the remaining sites due to large reductions in water levels and dry stream beds. Mean summer water temperature in 2022 in the Beaverlodge River watershed was categorized by thermal tolerance for Arctic grayling and was Optimal (7.5–17.0°C) at 17 sites, but in the Avoidance category (17.1–20.0°C) at ten sites and Stressed category (20.1–25.0°C) at two sites. Mean summer water temperature in the Redwillow River watershed was Optimal for Arctic grayling at two sites, but in the Avoidance category at three sites and Stressed category at one site. Mean winter DO concentrations in the Beaverlodge River watershed (n = 7) and Redwillow River watershed (n = 3) were above acute stress threshold for salmonids (>3.5 mg/L) at two sites each. Stream temperature and DO increased downstream (lower elevation) and were higher in mainstem creeks and rivers. Based on DO logger results in 2022–2023, portions of the Beaverlodge and Redwillow rivers were suitable overwintering habitat for Arctic grayling, but not the tributaries. However, dry sections in the Beaverlodge River watershed may impede fish passage between summer thermal refuge and overwintering habitat. Water temperature, overwintering DO concentrations, and water quantity may be limiting Arctic grayling recovery in the Beaverlodge River HUC 8 watershed.

**Key words:** Arctic grayling, Beaverlodge, Redwillow, temperature, dissolved oxygen, water quality, Alberta.

## ACKNOWLEDGEMENTS

Funding to purchase temperature loggers for this project was provided by TC Energy. Alberta Conservation Association employees Taylor Dickson, David Jackson, and Nikita Lebedynski helped to install and retrieve dataloggers. We thank the many landowners who allowed us access to their land. Thank you to the Beaverlodge Arctic grayling Society, the Mighty Peace Watershed Alliance, and the West County Watershed Alliance for their local knowledge and support. We also thank Benjamin Kissinger (fRI Research) for logistical support and coordinating our work with Ryan MacDonald (MacHydro) and Devin Cairns (MacHydro) who provided us with results from the Redwillow Watershed spatial statistical network stream temperature model.

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## 1.0 INTRODUCTION

The Redwillow Hydrological Unit Code 6 (HUC 6) watershed extends from British Columbia into Alberta and consists of two sub-watersheds: the Beaverlodge River HUC 8 watershed and the Redwillow River HUC 8 watershed (hereafter referred to as the Beaverlodge River watershed and the Redwillow River watershed, respectively). The Redwillow HUC 6 watershed historically supported some of the highest reported Arctic grayling (*Thymallus arcticus*) spawning runs in all of Alberta (Lucko 1993). However, these populations have either declined substantially or are near extirpation (Cahill 2015). The last documented capture of Arctic grayling in the Beaverlodge River watershed was in 1994 and the population is currently considered functionally extirpated; the Redwillow River watershed sub-basin population, considered the last remaining population in the Redwillow HUC 6 watershed, is also thought to be in decline (Cahill 2015). Poor water quality, habitat degradation, altered stream flows, and barriers to fish movement are among reasons for the decline of the Arctic grayling from the Redwillow HUC 6 watershed (Carl et al. 1992, AECOM 2009). Alberta Conservation Association (ACA) has been working in the Beaverlodge River watershed since 2004 to improve riparian health and water quality with the hope of bringing Arctic grayling back to this watershed.

Stream temperature and dissolved oxygen (DO) are two primary indicators of water quality and quantity that can influence fish presence and distribution in a watershed. The optimal temperature range and overwintering DO concentration for adult Arctic grayling is 7.5–17.0°C and above 3.5 mg/L, respectively (Hubert et al. 1985, Lohr et al. 1996). Stream temperatures and DO concentrations outside of these preference ranges for salmonid species can lead to reduced feeding, growth rates (Wootton 1998), and locomotion (Lohr et al. 1996), resulting in reduced survival and fitness. When salmonids are chronically exposed to thermal and/or oxygen stressors, they will attempt to change their behaviour or location to alleviate stress. If they are unable to find thermal refuge or suitable oxygen concentrations, they may even abandon an entire river system or die (Liermann 2001).

The optimal temperature range for Arctic grayling is 7.5–17.0°C with an upper incipient lethal temperature for prolonged exposure of 23.0–25.0°C (Lohr et al. 1996). Wojcik (1955) found that Arctic grayling were stressed in temperatures above 17.2°C.

Davis et al. (2019) found that Arctic grayling exhibited significant behavioural and physiological response to under-ice DO levels below 4.0 mg/L, and AEP (1997) suggested that DO below 3.5 mg/L over one day can have acute health effects on salmonids.

In this study, we assessed the spatial and temporal distribution of summer temperature and winter DO in the Beaverlodge River watershed, where Arctic grayling are functionally extirpated, compared to the Redwillow River watershed, where Arctic grayling still exist, to help

determine the suitability of the Beaverlodge River watershed to support Arctic grayling reintroduction.

## **2.0 STUDY AREA**

For the purposes of this report, we discuss portions of the watersheds located in Alberta. The Redwillow HUC 6 watershed is in northwestern Alberta, west of Grande Prairie, in the Peace River drainage and consists of two sub-basins: the Redwillow River watershed and the Beaverlodge River watershed (AECOM 2009, Redwillow Watershed Restoration Team 2015). The Beaverlodge River watershed is 144,241 ha (Redwillow Watershed Restoration Team 2015) and is made up of the Beaverlodge River and its main tributaries: Beavertail Creek, Windsor Creek, and Steeprock Creek (Figure 1). The Beaverlodge River flows into the Redwillow River, just before the Redwillow confluence with the Wapiti River. The Redwillow River watershed is 67,288 ha and is made up of the Redwillow River and its main tributaries: Lattice Creek, Diamond Dick Creek, and the Beaverlodge River (Figure 1).

The Beaverlodge River watershed has high land-use disturbance in comparison to other watersheds in the Peace River watershed (Upper Peace Fisheries Management Unpubl. Report). Ninety-two percent and 65% of the Beaverlodge River and Redwillow River watersheds, respectively, are in the white zone of the province where agriculture is the dominant land use (AECOM 2009).

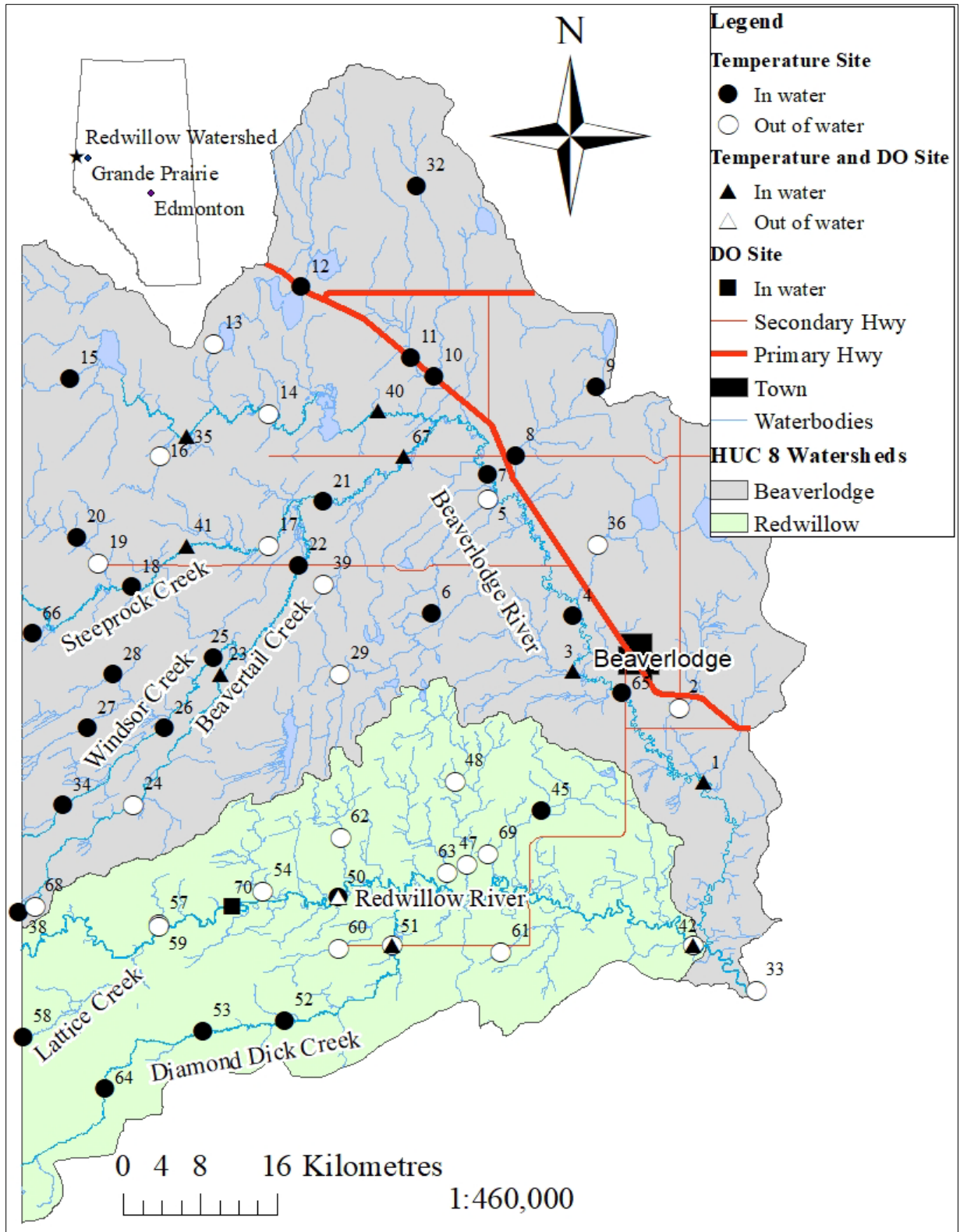


Figure 1. Temperature and dissolved oxygen (DO) sampling locations and data integrity status (stayed in water vs. out of water) in the Redwillow HUC 6 watershed in northwestern Alberta.

### **3.0 MATERIALS AND METHODS**

#### **3.1 Temperature and winter dissolved oxygen measurements**

We deployed 61 temperature HOBO Pendant MX water temperature loggers and 11 CME minidot DO loggers in the Redwillow HUC 6 watershed to collect summer water temperatures and winter DO concentrations (Figure 1). We monitored water temperatures from late June to mid-October 2022, and winter DO from November 2022 to April 2023. We had intended to also monitor summer DO during July and August to complement stream temperature data but were delayed due to shipping issues incurred when refurbishing loggers. We randomly selected sampling sites from a larger GIS-derived list of stream crossing locations, at varying elevations, in easy-to-access locations. Dataloggers were installed according to the Government of Alberta's standard operating procedures for watershed surface water temperature monitoring (AEP Unpubl. Report). Each datalogger was protected by white PVC housing fastened to a vertical T-bar tethered with a length of cable to a secure shoreline anchor. T-bars were embedded in the stream substrate so that loggers were approximately 15 cm above the substrate. Loggers were deployed in locations that were representative of the stream reach and, when possible, positioned in well mixed thalweg sections of runs/glides/pools with sufficient depth during low flow periods. When possible, installation locations were upstream of road crossings and tributary confluences that could influence temperatures. We avoided placing temperature loggers in deep-pool habitats to reduce the potential for thermal stratification (Lewis 1999).

We retrieved data from 60 of the 61 temperature logger locations; one logger was not recovered. Data integrity was maintained in 35 of the 60 sites; data from the remaining 25 sites were excluded from analyses as loggers were out of water in August due to large fluctuations in water levels at eight sites and no water (dry streambed) at the remaining 17 sites. We retrieved data from 11 DO logger locations. Data integrity was maintained at 10 of 11 sites with one DO logger freezing into the ice.

For each sampling site, we used RStudio (RStudio 2022.10.0) to determine the daily mean, minimum, and maximum DO and temperature. We assigned water temperatures into five Arctic grayling thermal categories (Table 1) based on information in the literature, to determine where suitable Arctic grayling thermal habitat was available. We plotted temperature from August 1 to 31, 2022, during the hottest part of the summer, when Arctic grayling are most susceptible to thermal stress, to determine where thermal refuge was available in the Beaverlodge and Redwillow river watersheds. We assigned 3.5 mg/L as the minimum winter DO concentration for overwintering Arctic grayling. We plotted DO from November 1, 2022 to April 15, 2023, coinciding with ice-on periods, to determine where suitable Arctic grayling overwintering habitat was available in the Beaverlodge River and Redwillow River watersheds. We did not evaluate summer DO concentrations as loggers were unavailable until late summer.

Table 1. Thermal tolerance categories for Arctic grayling, adapted from Wojcik (1955), Hubert et al. (1985), and Lohr et al. (1996).

Thermal Tolerance Category	Temperature (°C)
Below optimal	<7.5
Optimal	7.5–17.0
Avoidance	17.1–20.0
Stressed	20.1–25.0
Death	>25.0

### 3.2 Spatial statistical network stream temperature predictions

In a complementary study, MacDonald Hydrology Consultants Ltd (MacHydro) was retained by fRI Research to develop an initial stream temperature model for the Redwillow HUC 6 watershed using the data collected from this study. Data were only included if there were more than 15 days of complete temperature records in August (when water temperatures are expected to be the highest) and the DO logger was under water during this entire period. A Spatial Statistical Network (SSN) model described by Ver Hoef et al. (2014) was updated with Open STARS (Peterson and Ver Hoef 2014) and fit to these data using elevation, slope, solar radiation, minimum air temperature, barren land, and total precipitation as co-variates. The resultant model produces continuous, predictive stream temperature data for the entire watershed where only discrete data points would otherwise be available.

### 3.3 Air temperature and precipitation measurements

Air temperature and precipitation measurements were extracted from the Beaverlodge climate station (Government of Canada 2023a) between August 1 and 31, 2022, to help describe the local climate. Air temperature was compared to 21 years of historical data from 2001 to 2022 using a Welch’s t-test to determine if 2022 air temperature was representative of a normal year and put our study’s results into context. Historical hydrometric data for the Beaverlodge River (station 07GD001) was extracted from the Environment and Climate Change Canada Historical Hydrometric Data website (Government of Canada 2023b). Daily discharge for 2022 was compared to 30 years of historical data from 1992 to 2022 to determine if 2022 discharge levels were representative of a normal year. Discharge data for the Redwillow River were unavailable during 2022.

## 4.0 RESULTS

### 4.1 Spatial and temporal temperature patterns

In the Beaverlodge River watershed, 18 sample sites were within the Optimal thermal tolerance category for the most consecutive hours, while ten sites were within the Avoidance category and one site within the Stressed category for the most consecutive hours (Table 2, Appendix 1). In the Redwillow River watershed, two sites were within the Optimal thermal tolerance category for the most consecutive hours, while three sites were within the Avoidance category and one site within the Stressed category for the most consecutive hours (Table 2, Appendix 2). Owing to the low number of temperature loggers with reliable data in the Redwillow River watershed, results from this watershed should be interpreted with caution.

Mean August water temperature in the Beaverlodge River watershed was categorized as Optimal for Arctic grayling at 17 sites, Avoidance at ten sites, and Stressed at two sites (Appendix 3). Mean August water temperature in the Redwillow River watershed was categorized as Optimal for Arctic grayling at two sites, Avoidance at three sites, and Stressed at one site (Appendix 3).

Temperatures measured in the summer of 2022 were more often optimal at higher elevation, small tributary sites than lower elevation, mainstem creek and rivers. At lower elevations, temperatures were often in the Avoidance and Stressed thermal tolerance categories. Portions of Steeprock Creek, a historical spawning area for Arctic grayling, and portions of the Beaverlodge River were dry by mid-August.

Table 2. Consecutive hours in each thermal tolerance category at Beaverlodge River and Redwillow River watershed temperature logger locations, August 1–31, 2022.

Watershed	Site	# Consecutive Hours in Each Thermal Tolerance Level (°C)			
		Optimal 7.5–17.0	Avoidance 17.1–20.0	Stressed 20.1–25.0	Death >25.0
Beaverlodge River	1	7	40	138	0
	3	12	30	30	0
	4	2	59	34	3
	6	720	0	0	0
	7	16	210	54	0
	8	720	0	0	0
	9	524	7	0	0
	10	504	9	0	0
	11	693	16	0	0

Watershed	Site	# Consecutive Hours in Each Thermal Tolerance Level (°C)			
		Optimal 7.5–17.0	Avoidance 17.1–20.0	Stressed 20.1–25.0	Death >25.0
	12	64	305	30	0
	15	92	127	12	0
	18	87	16	12	0
	20	428	12	0	0
	21	44	302	31	0
	22	65	145	14	0
	23	95	53	12	0
	25	81	66	12	0
	26	675	3	0	0
	27	75	129	4	0
	28	455	9	0	0
	32	238	15	0	0
	34	228	137	0	0
	35	283	59	0	0
	38	698	8	0	0
	40	668	16	0	0
	41	96	33	10	0
	65	31	56	0	0
	66	259	76	5	0
	67	14	427	54	0
Redwillow	45	452	16	0	0
River	50	13	36	51	8
	52	18	33	12	0
	53	23	32	7	0
	58	93	39	11	0
	64	47	425	0	0

#### 4.2 Spatial statistical network stream temperature predictions

Results from the SSN model predict August average stream temperature ranges from 14°C to 22°C throughout the Redwillow HUC 6 watershed (Figure 2), with an  $R^2$  of 0.87. Water temperature was Optimal for Arctic grayling in headwaters and small tributaries with Stressed and/or Avoidance temperatures being detected downstream in mainstem creeks (Steepprock



Creek, Lattice Creek, Diamond Dick Creek, portions of Beavertail Creek). Much of the Beaverlodge and Redwillow rivers were above optimal temperatures for Arctic grayling with the lower elevations being in the Stressed category. A 14-km section of the Redwillow River, starting from the confluence with the Wapiti River and moving upstream, had water temperatures that would cause Arctic grayling death. Based on model results, the headwaters of Windsor Creek, Beavertail Creek, and Steeprock Creek, all in the Beaverlodge River watershed, are expected to have optimal water temperatures for Arctic grayling; however, portions of Steeprock Creek were dry by mid-August and impassable to fish.

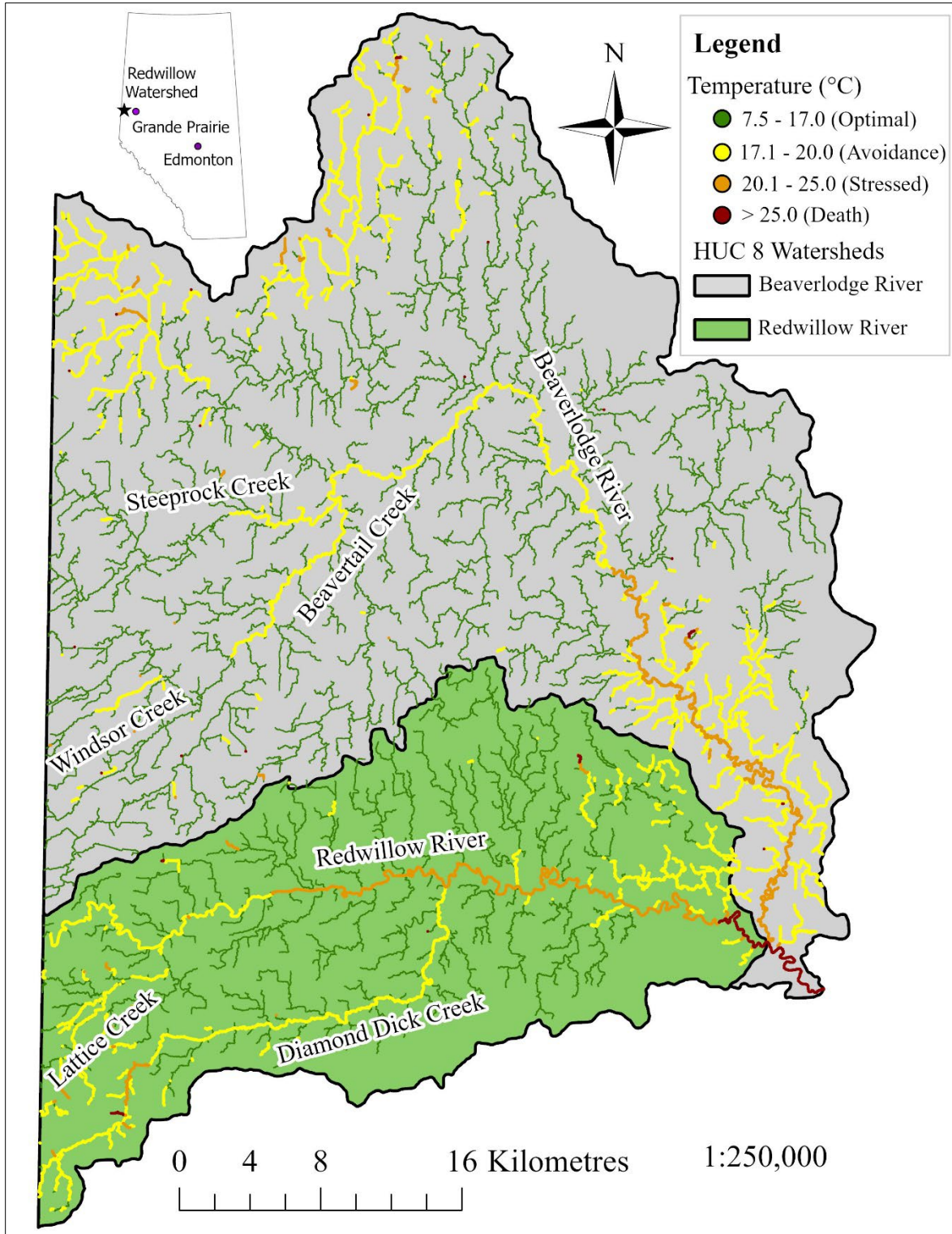


Figure 2. Simulated average stream temperature for August 2022 in the Redwillow HUC 6 watershed in northwestern Alberta using the Spatial Statistical Network model. (SSN model produced by MacHydro and reproduced with permission from fRI Research).

### 4.3 Spatial and temporal winter dissolved oxygen patterns

All seven sites in the Beaverlodge River watershed had extended periods of poor DO below the acute stress threshold for salmonids (<3.5 mg/L), ranging from 32 hours to 3,961 hours (Table 3, Appendix 4). In the Redwillow River watershed, one site maintained DO concentrations above the acute stress threshold, while the other two sites experienced poor DO concentrations for extended periods of time (Table 3, Appendix 5). Mean DO concentrations were above the acute threshold at two of the seven sites in the Beaverlodge River watershed, and two of the three sites in the Redwillow River watershed (Appendix 6). All four sites that had DO concentrations above the acute threshold for Arctic grayling were in the mainstem Beaverlodge and Redwillow rivers, and three of the four were at lower elevations.

Table 3. Consecutive hours below acute stress dissolved oxygen (DO) threshold for Arctic grayling (<3.5 mg/L) at Beaverlodge River and Redwillow River watershed logger stations, November 1, 2022–April 15, 2023.

Watershed	Site	# Consecutive Hours Below Acute DO (<3.5 mg/L)
Beaverlodge River	1	113
	3	32
	23	1,305
	35	3,728
	40	3,961
	41	3,876
	67	3,365
Redwillow River	42	47
	51	1,765
	70	0

#### 4.4 Air temperature and precipitation

The average air temperature in the Redwillow HUC 6 watershed at the Beaverlodge Reference Climate Station climate station (Government of Canada 2023a) between August 1 and 31, 2022, was 18.1°C with a maximum of 31.0°C on August 25 and a minimum of 6.7°C on August 28. Average August air temperature was significantly higher in 2022 than the previous 21 years ( $t_{(676)} = 5.91$ ,  $p < 0.01$ ), coinciding with similar trends observed in the Peace River Basin and associated with global warming (Zaghloul et al. 2022). There was a total of 26.0 mm of precipitation in August 2022 with the largest rainfall event (17.2 mm) occurring on August 1. Daily discharge in the Beaverlodge River during 2022 was comparable to historical averages with a later than average freshet (Appendix 7). Daily flow rates were above average for a short period of time in mid- to late May 2022 but within the upper and lower quartiles of a 30-year average by mid-June and into August when stream temperature was evaluated. Discharge data were unavailable in the Redwillow River HUC 8 watershed in 2022.

#### 5.0 DISCUSSION

Data collected in 2022 and 2023 indicate that there are large portions of the Beaverlodge and Redwillow river watersheds that are not suitable for all life stages of Arctic grayling due to high summer water temperatures and/or low winter DO. Lower elevation and mainstem watercourses appear to have the least suitable summer water temperatures. In particular, the Beaverlodge and Redwillow river mainstems, Steeprock Creek, sections of Beavertail Creek, Diamond Dick Creek, and Lattice Creek appear thermally unsuitable for Arctic grayling. However, the upper reaches of Beavertail Creek and Windsor Creek in the Beaverlodge River watershed may have suitable thermal refuge for Arctic grayling. Daily average air temperatures in 2022 were significantly higher than the previous 21-year average and may have influenced stream temperatures during the summer of 2022. With global temperatures trending upward, 2022 may not be considered an anomaly in the long term.

Winter DO concentrations suggest that there are large portions of the Beaverlodge and Redwillow river watersheds that are not suitable for overwintering Arctic grayling. The Beaverlodge River mainstem, in lower elevations, and the Redwillow River mainstem were the only watercourses where we recorded DO concentrations suitable for overwintering Arctic grayling.

Dry sections in the Beaverlodge River and Steeprock Creek in 2022 made fish passage between summer thermal refuge and overwintering habitat unlikely. Furthermore, the dry sections of watershed in 2022 do not appear to be an anomaly since daily river discharge was within the upper and lower confidence intervals of a 30-year average. Therefore, Arctic grayling would not be able to migrate from optimal summer thermal habitat in the headwaters of the Beaverlodge

watershed to suitable overwintering DO areas near the bottom of the watershed. We did not observe any dry sections in the Redwillow River watershed that would impede fish movement during the transition from summer to winter range. The impediment to fish movement in the Beaverlodge River watershed caused by dry sections of watercourse may be another reason why Arctic grayling are extirpated from this watershed but still present in the Redwillow River watershed where Arctic grayling can freely move to seek suitable habitat. Owing to high summer water temperatures, low winter DO concentrations, and sections of watercourse that are impassable for fish due to a lack of water, the Beaverlodge River watershed is unlikely to currently support Arctic grayling reintroduction.

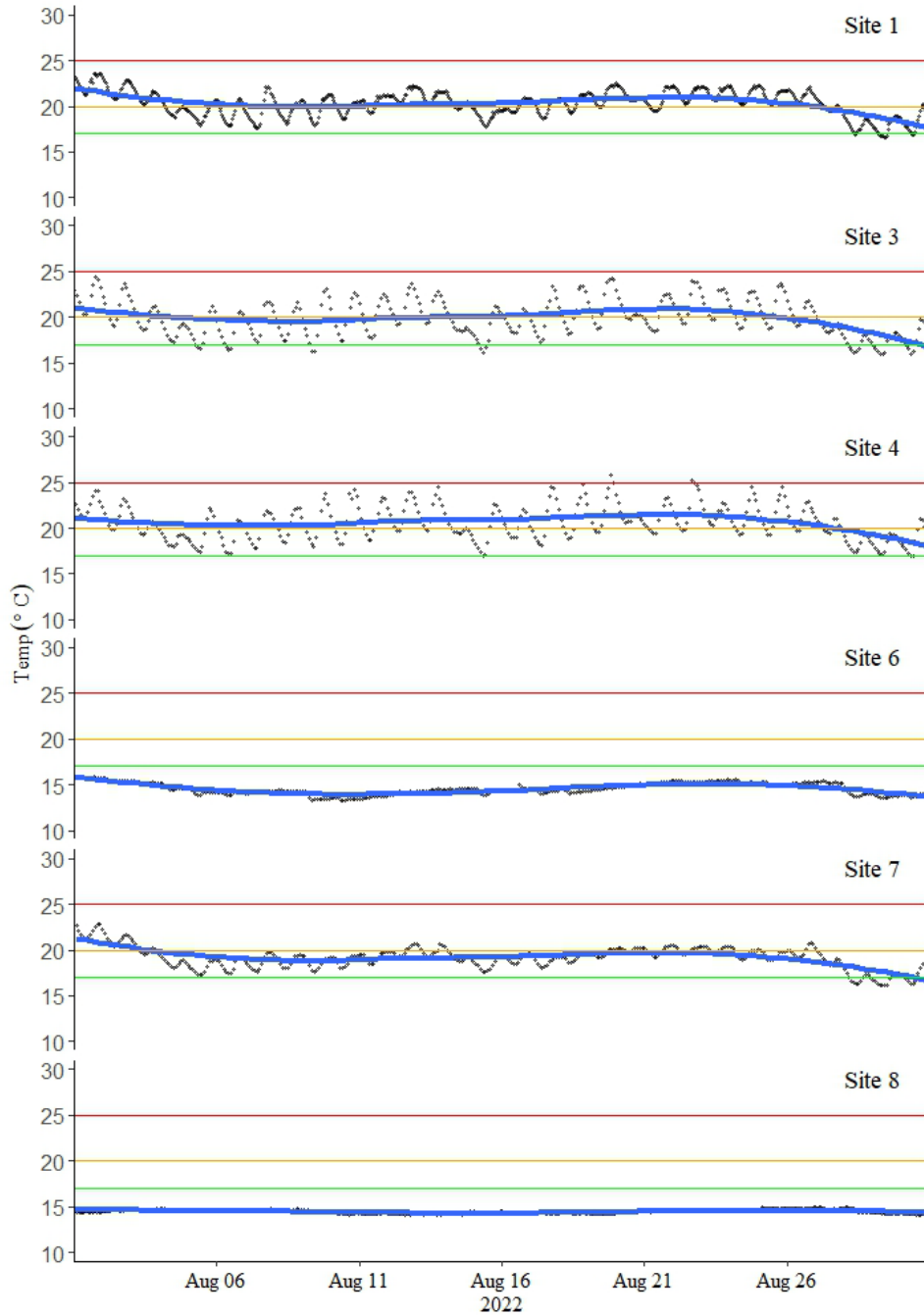
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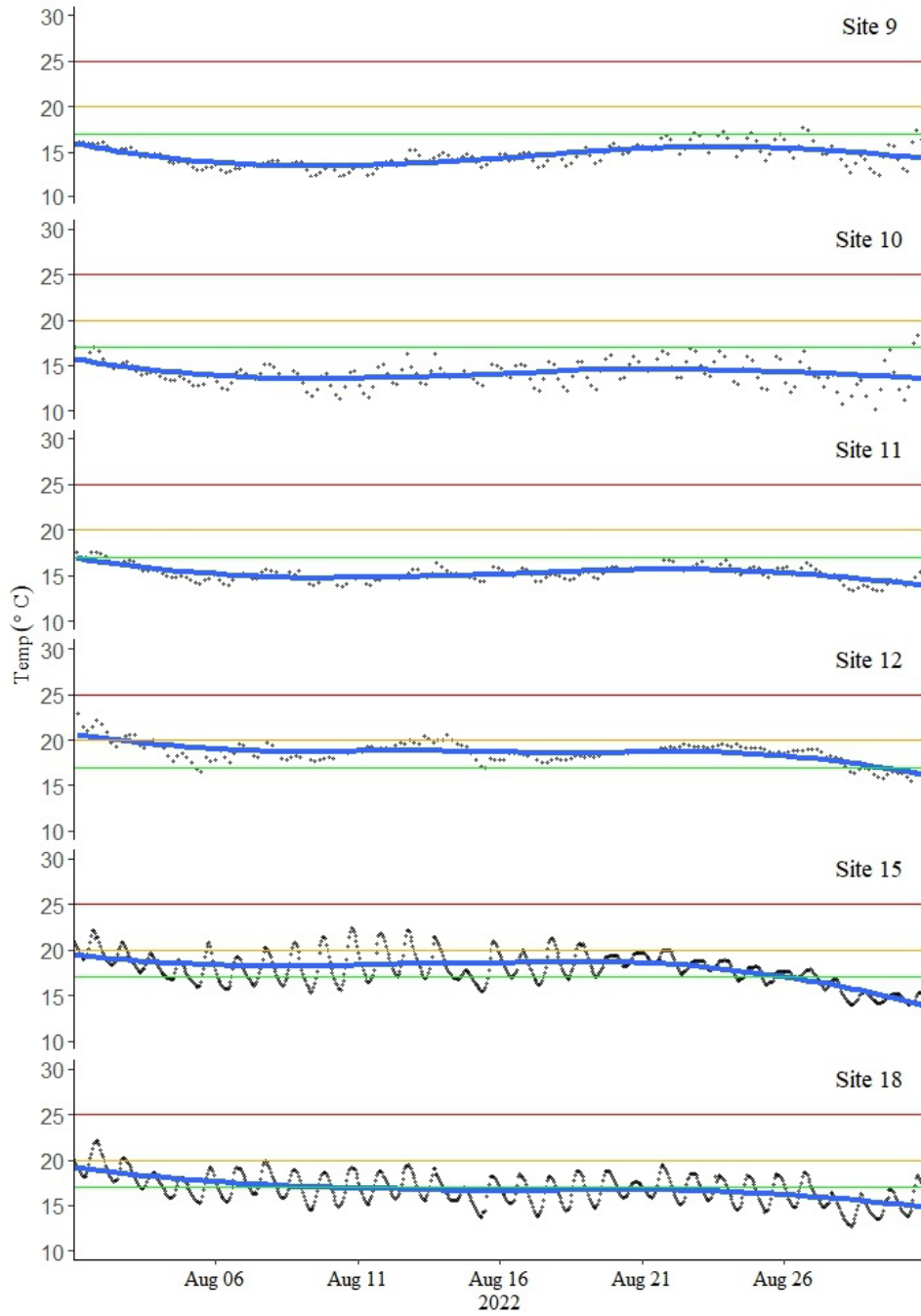
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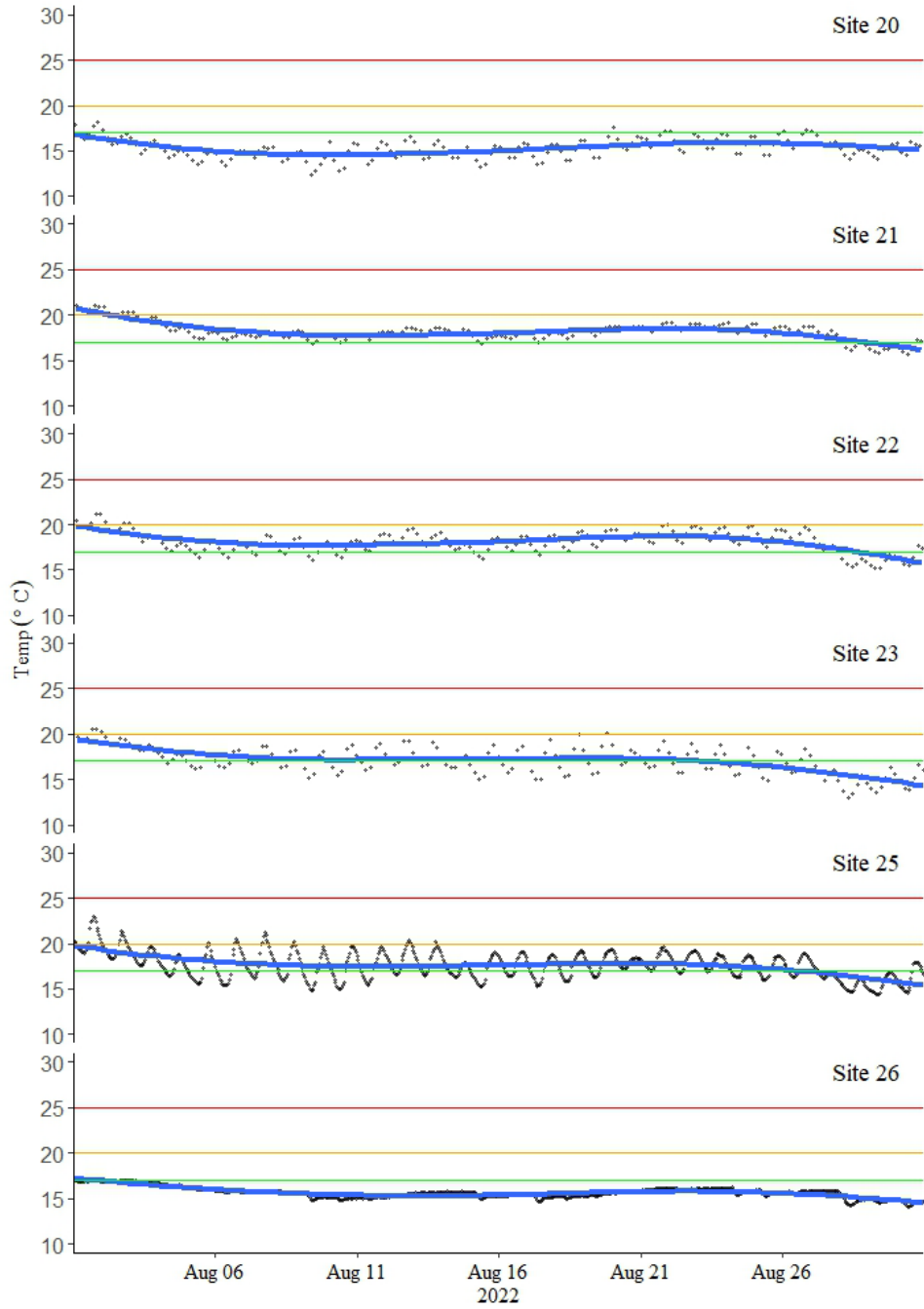
## 7.0 APPENDICES

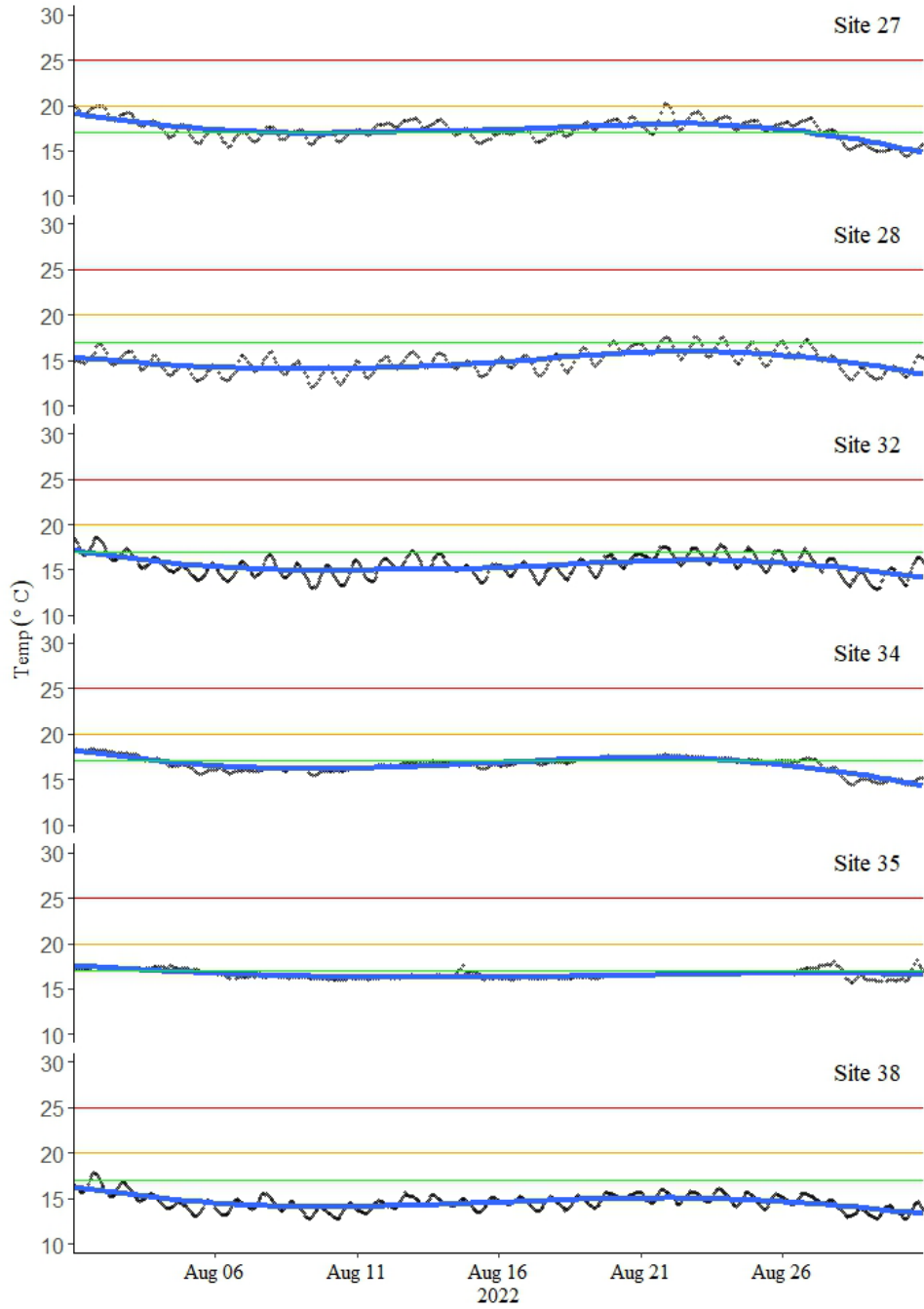
Appendix 1. Hourly temperature (dots) and line of best fit (blue line) at each site in the Beaverlodge River watershed August 1–31, 2022. Green, yellow, and red lines represent temperature thresholds for Arctic grayling corresponding to Optimal ( $\leq 17.0^{\circ}\text{C}$ ), Avoidance ( $17.1\text{--}20.0^{\circ}\text{C}$ ), and Stressed ( $20.1\text{--}25.0^{\circ}\text{C}$ ), respectively.

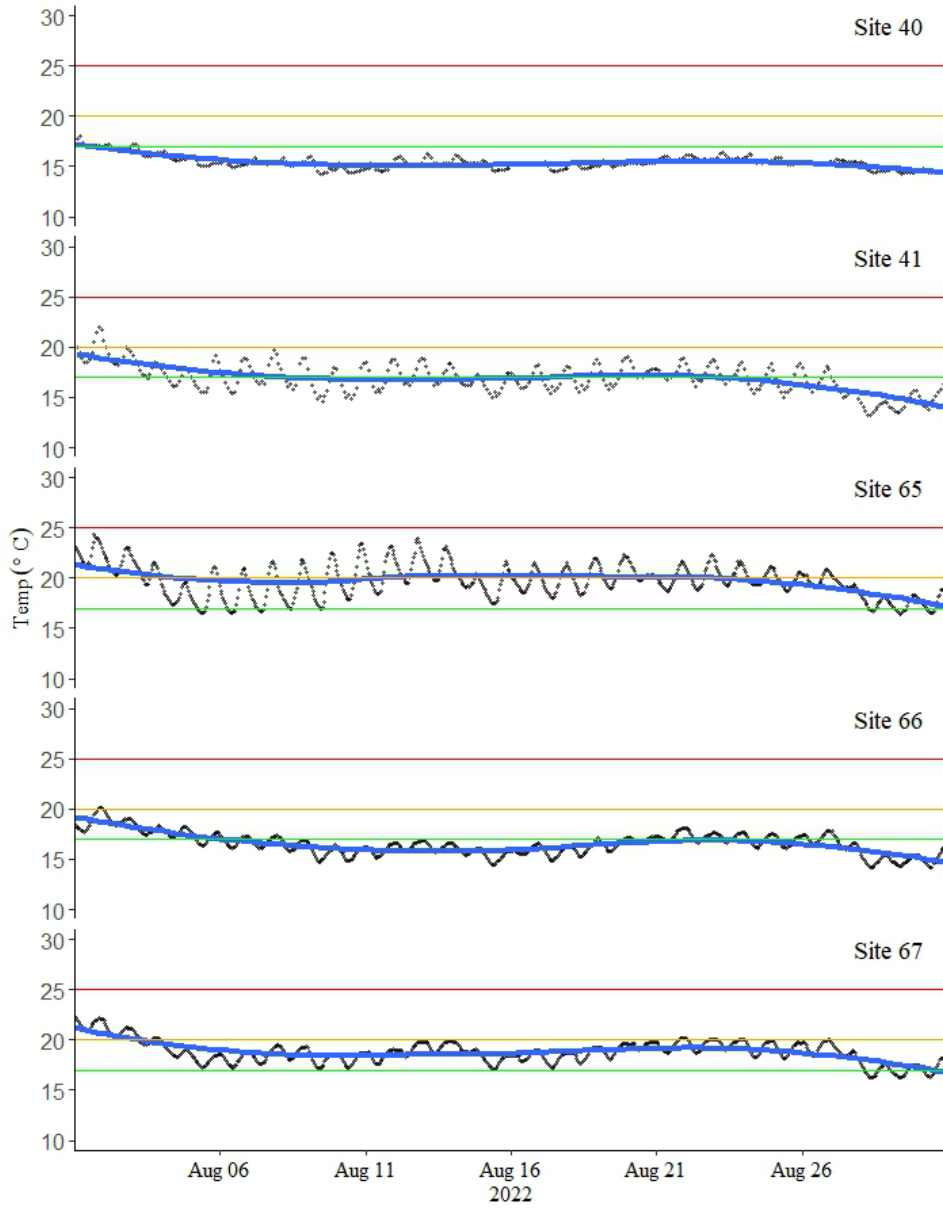




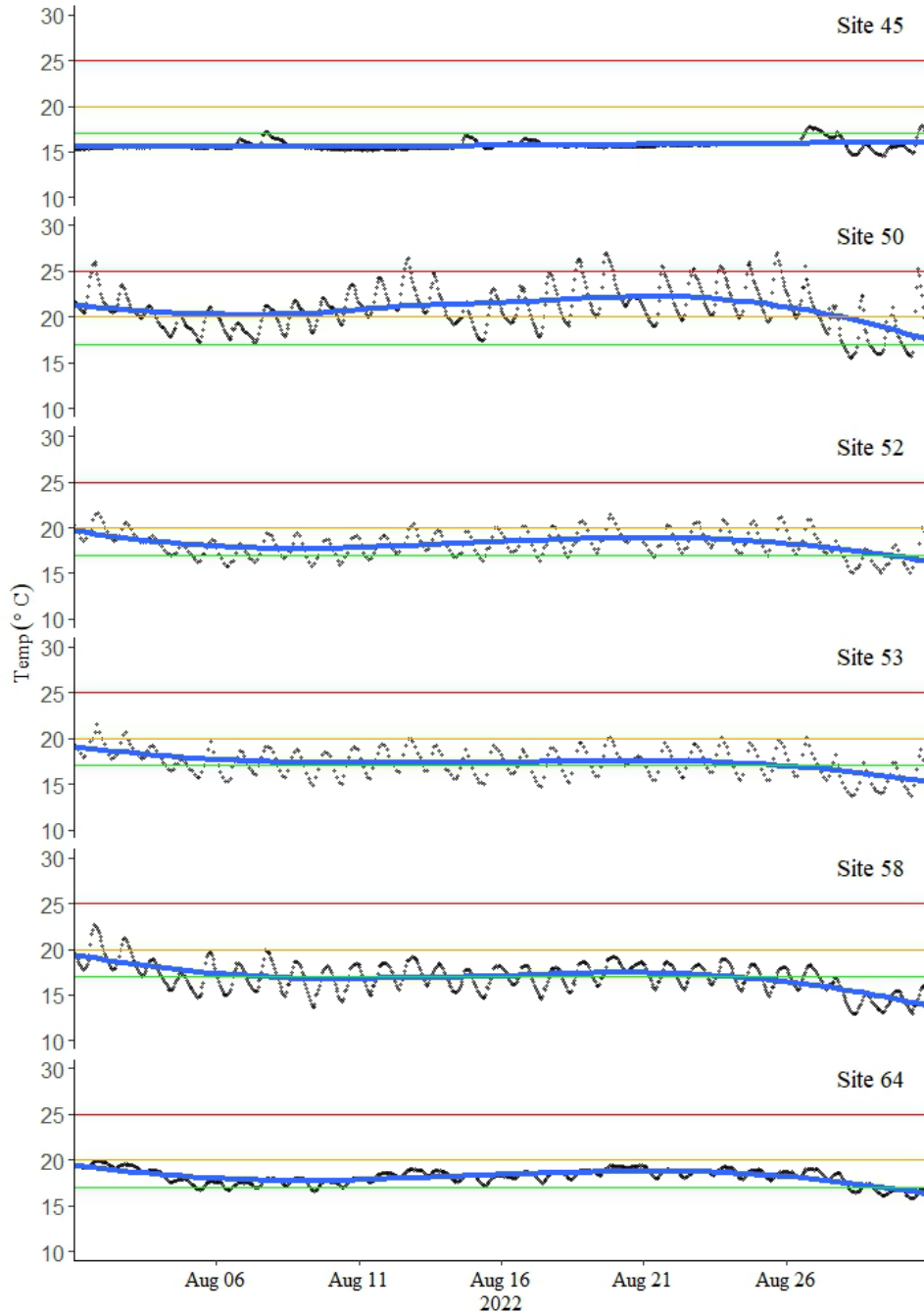








Appendix 2. Hourly temperature (dots) and line of best fit (blue line) at each site in the Redwillow River watershed, August 1–31, 2022. Green, yellow, and red lines represent temperature thresholds for Arctic grayling corresponding to Optimal ( $\leq 17.0^{\circ}\text{C}$ ), Avoidance ( $17.1\text{--}20.0^{\circ}\text{C}$ ), and Stressed ( $20.1\text{--}25.0^{\circ}\text{C}$ ), respectively.

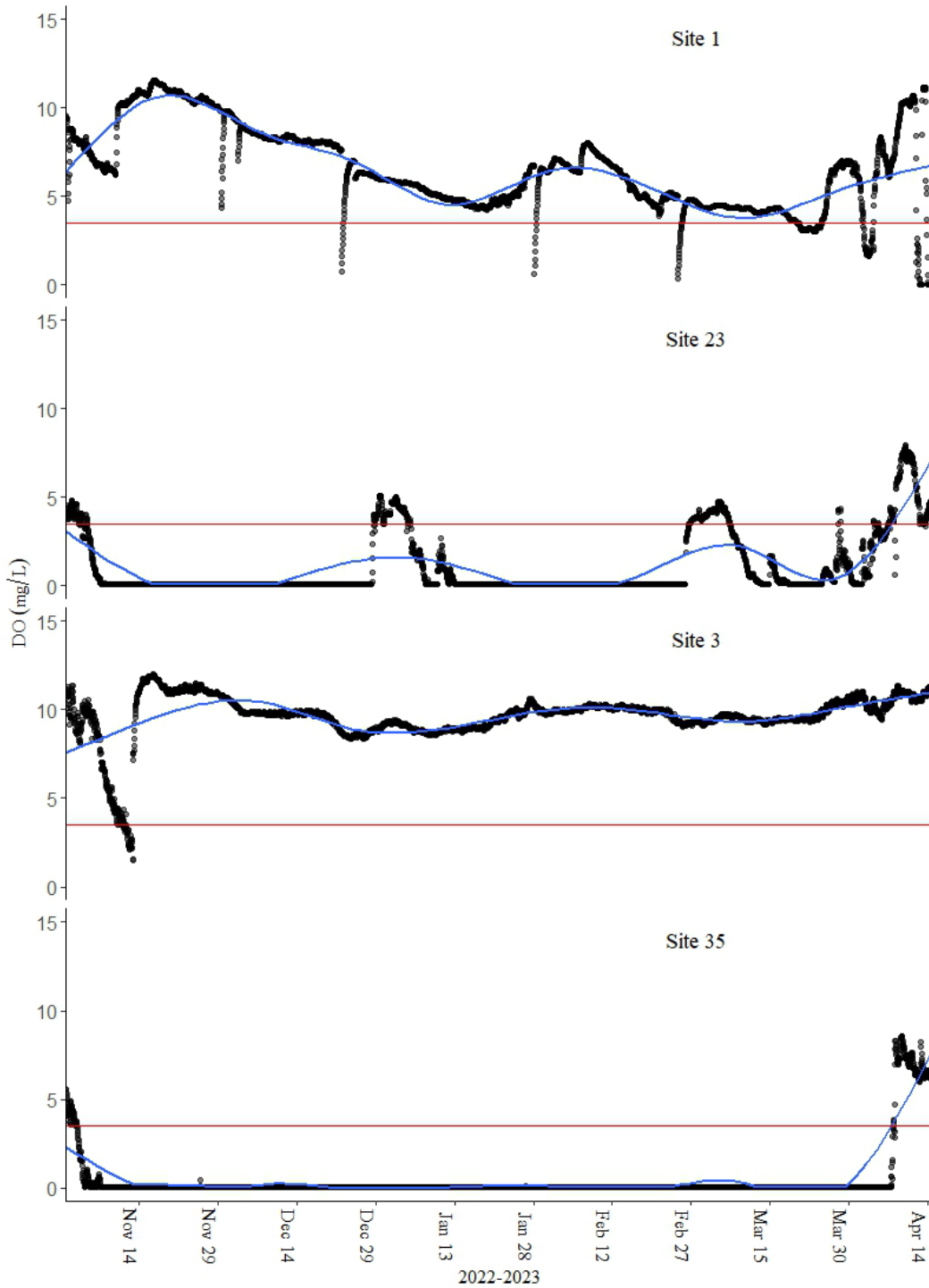


Appendix 3. Descriptive statistics for temperature in the Beaverlodge River and Redwillow River watersheds, August 1–31, 2022.

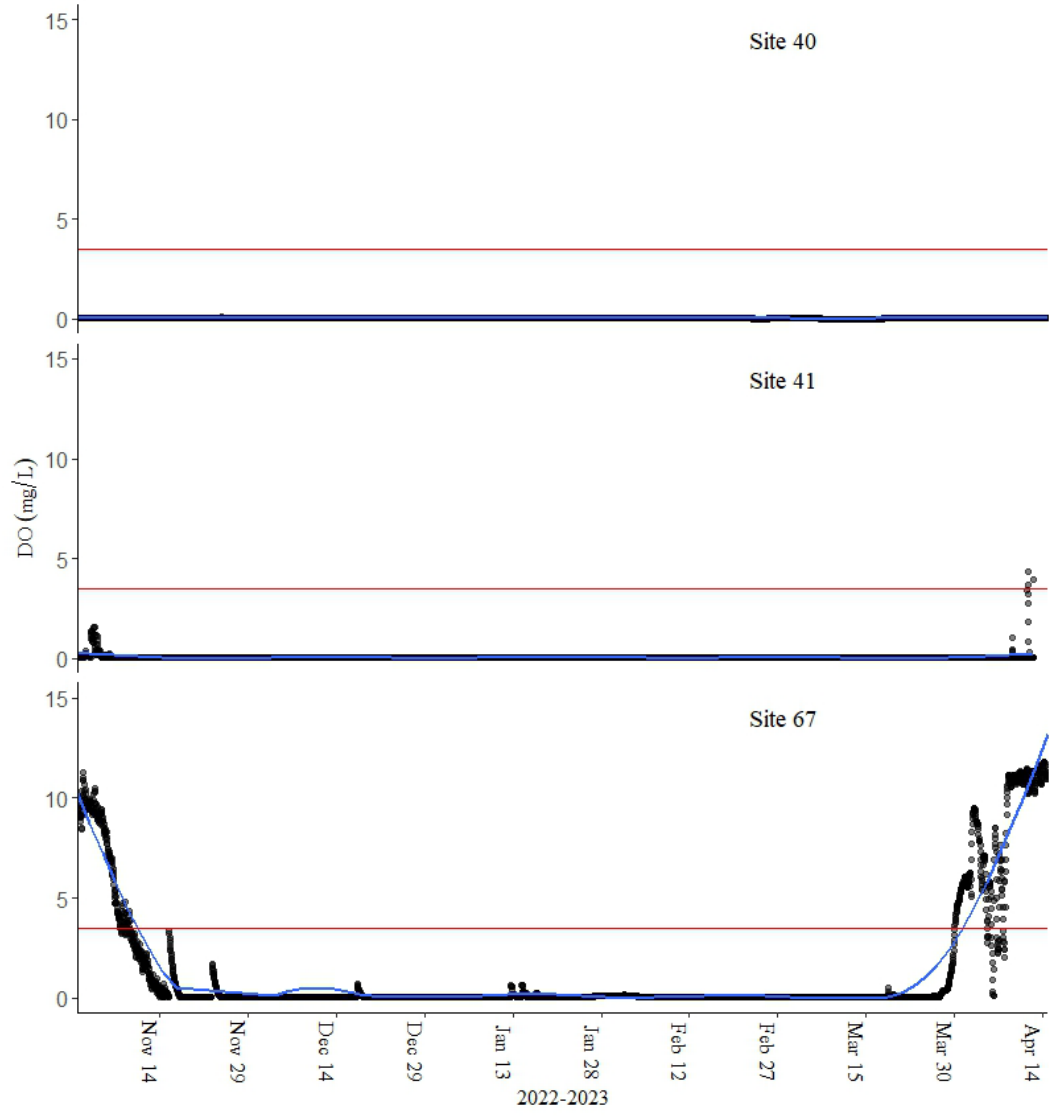
Watershed	Site	Mean	Median	SD	Range	Maximum	Minimum	Count
Beaverlodge River	1	20.2	20.4	1.4	7.0	23.6	16.6	744
	3	19.9	19.8	2.0	8.8	24.6	15.9	744
	4	20.6	20.5	1.9	8.9	25.7	16.9	744
	6	14.5	14.4	0.7	2.8	16.0	13.2	744
	7	19.1	19.2	1.3	6.8	22.8	16.0	744
	8	14.5	14.5	0.2	0.9	15.0	14.1	744
	9	14.6	14.5	1.2	5.9	17.8	11.8	744
	10	14.0	14.0	1.8	16.1	20.7	4.6	744
	11	15.2	15.1	0.9	4.3	17.7	13.3	744
	12	18.5	18.6	1.3	7.9	23.1	15.2	744
	15	17.8	17.8	1.9	9.0	22.4	13.4	744
	18	16.8	16.7	1.7	9.4	22.1	12.7	744
	20	15.2	15.2	1.1	6.0	18.1	12.2	744
	21	18.1	18.1	1.1	5.5	21.1	15.6	744
	22	18.0	18.1	1.2	6.3	21.4	15.1	744
	23	17.0	17.0	1.6	7.8	20.7	13.0	744
	25	17.5	17.5	1.5	8.6	23.0	14.4	744
	26	15.6	15.7	0.6	3.1	17.0	13.9	744
	27	17.3	17.3	1.2	5.8	20.2	14.5	744
	28	14.9	14.8	1.2	5.6	17.6	12.0	744
32	15.5	15.4	1.1	5.7	18.6	12.9	744	
34	16.6	16.7	0.9	4.0	18.4	14.4	744	
35	16.6	16.5	0.5	2.6	18.2	15.6	744	
38	14.6	14.5	0.9	5.3	17.8	12.5	744	
40	15.4	15.4	0.7	3.9	18.0	14.1	744	
41	16.8	16.8	1.5	9.0	22.0	13.0	744	
65	19.6	19.6	1.7	7.9	24.3	16.5	744	
66	16.5	16.5	1.1	6.0	20.2	14.2	744	

Watershed Temperature (°C)	Site	Mean	Median	SD	Range	Maximum	Minimum	Count
	67	18.8	18.7	1.2	6.2	22.4	16.2	744
Redwillow River	45	15.7	15.6	0.5	3.3	17.9	14.6	744
	50	20.9	20.8	2.4	11.6	27.0	15.4	744
	52	18.2	18.2	1.4	6.8	21.8	15.0	744
	53	17.3	17.4	1.5	8.0	21.5	13.5	744
	58	16.9	16.9	1.7	10.1	22.7	12.6	744
	64	18.1	18.2	0.9	4.2	19.9	15.7	744

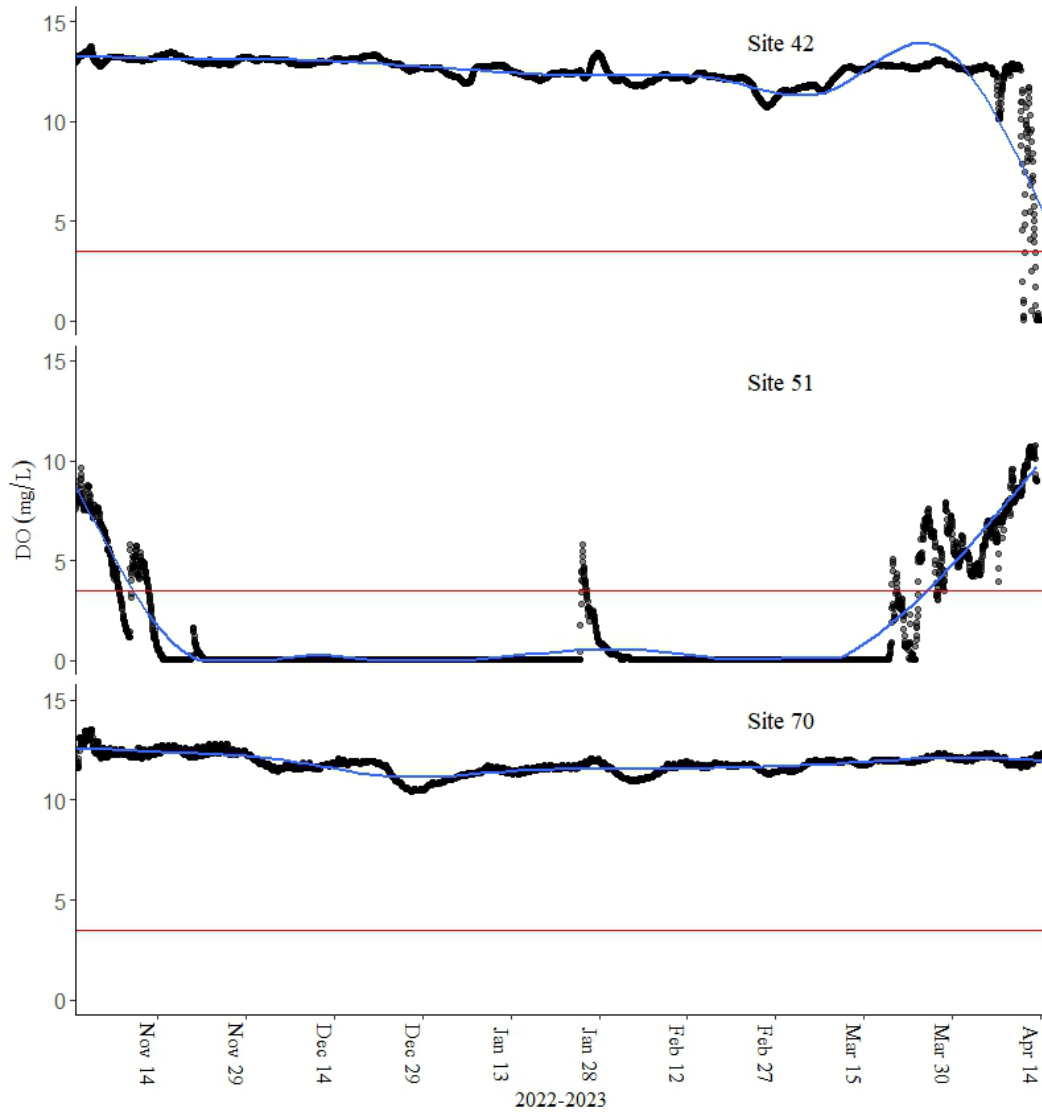
Appendix 4. Hourly dissolved oxygen (dots) and line of best fit (blue line) in the Beaverlodge River, November 1, 2022–April 15, 2023. The red line represents dissolved oxygen acute stress threshold (<3.5 mg/L) for Arctic grayling.







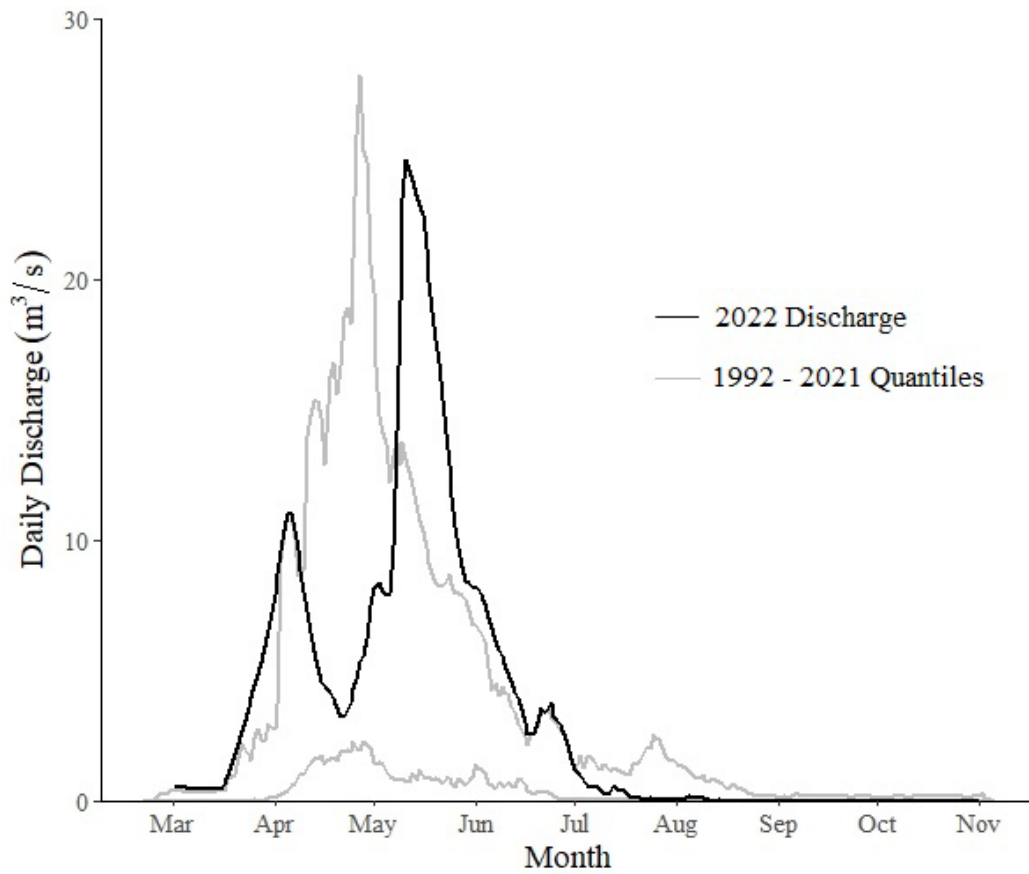
Appendix 5. Hourly dissolved oxygen (dots) and line of best fit (blue line) in the Redwillow River watershed, November 1, 2022–April 15, 2023. The red line represents dissolved oxygen acute stress threshold (<3.5 mg/L) for Arctic grayling.



Appendix 6. Descriptive statistics for dissolved oxygen in the Beaverlodge River and Redwillow River watersheds, November 1, 2022–April 15, 2023.

Watershed DO (mg/L)	Site	Mean	Median	SD	Range	Maximum	Minimum	Count
Beaverlodge River	1	6.50	6.33	2.42	11.52	11.55	0.03	3,984
	3	9.64	9.78	1.30	10.48	12.00	1.52	3,984
	23	1.09	0.08	1.76	7.89	7.97	0.08	3,984
	35	0.45	0.02	1.59	8.53	8.55	0.02	3,984
	40	0.06	0.06	0.02	0.08	0.10	0.02	3,984
	41	0.04	0.03	0.17	4.36	4.38	0.02	3,902
	67	1.37	0.05	3.07	11.78	11.83	0.05	3,984
Redwillow River	42	12.30	12.69	1.87	13.70	13.74	0.04	3,984
	51	1.41	0.05	2.62	10.71	10.75	0.04	3,922
	70	11.80	11.81	0.47	3.09	13.54	10.44	3,984

Appendix 7. Daily discharge ( $\text{m}^3/\text{s}$ ) in 2022 (black) and upper and lower 95% quantiles for 1992–2022 (grey) for the Beaverlodge River. Data from hydrometric station 07GD001 near Beaverlodge, AB.





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