Winter Dissolved Oxygen Conditions of the Whitemud River and Willow Creek Watersheds, Alberta, 2016 – 2017

Alberta Conservation Association

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EXECUTIVE SUMMARY

Cumulative landscape disturbances have resulted in the widespread decline of lotic fisheries across Alberta and have been linked to anoxic conditions in many Alberta streams. Low dissolved oxygen (DO) concentrations in winter months can be a significant limiting factor for fish production, particularly for cold-water fish species in Alberta, such as Arctic grayling, and Westslope cutthroat trout. Past measurements suggest winter DO concentrations are below federal and provincial guidelines for cold-water fish species in some Alberta streams, and approach sub-lethal concentrations in others. From November 2016 to May 2017 we monitored the Whitemud River watershed in northwest Alberta, and the Willow Creek watershed in southwest Alberta to determine if winter DO concentrations were limiting for the cold-water priority species, Arctic grayling and Westslope cutthroat trout. We monitored under-ice DO concentrations at eight sites in the Whitemud River watershed, and six sites in Willow Creek watershed using datasonde dataloggers. We conducted bi-weekly snapshot measurements with hand-held YSI DO meters at all datasonde sites, and on all major tributaries entering the Whitemud River and Willow Creek mainstems.

Winter DO concentrations varied considerably among datasonde sites in both watersheds and we observed no clear trends based on datasonde measurements alone. One of seven datasonde sites in the Whitemud River watershed, and one of five in the Willow Creek watershed recorded DO concentrations that remained above the chronic effects threshold for aquatic life throughout the winter months. However, using combined results between hand-held and datasonde DO measurements, we determined that the majority of the Whitemud River mainstem remained suitable for salmonids throughout the winter, whereas the tributaries and North Whitemud River did not, due to low DO concentrations and site-specific frozen conditions. In the Willow Creek watershed the upstream reaches tended to have suitable winter DO concentrations for salmonids wherever streams did not freeze to the bottom.

Correlation between datasonde and YSI DO concentration data was low in both watersheds, with coefficients of 0.49 and 0.48 for the Whitemud River watershed and the Willow Creek watershed, respectively. The collection of DO concentration data from sites in deep run sections of faster flowing water, instead of slower pools, may improve correlation between the two methods.

Key words: Alberta, Whitemud River, Willow Creek, winter, dissolved oxygen, datasonde, YSI.

ACKNOWLEDGEMENTS

Funding for this project was provided by Alberta Conservation Association (ACA). Thank you to ACA sampling crew members, Jeff Forsyth, Brad Hurkett, Dave Jackson, Tyler Johns, Garret McKen, and Scott Seward for their hard work in the field. Thank you to Kevin Fitzsimmons (ACA) for support with data analysis in Rstudio. We extend our sincere gratitude to all landowners who allowed us to access sampling sites on their land.

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1.0 INTRODUCTION

Cumulative landscape disturbances have resulted in the widespread decline of lotic fisheries across Alberta (Stevens et al. 2010; Norris 2012; AECOM 2009). Inputs of phosphorus from surrounding land management practices have been linked to anoxic conditions in several rivers across the province (Norris 2012; Redwillow Watershed Restoration Team 2015; AECOM 2009; Stevens et al. 2010). Winter dissolved oxygen (DO) deficit in particular has been hypothesized as a potential cause of Arctic grayling (*Thymallus arcticus*) extirpations (Norris 2012), and a significant limiting factor for cold-water fish species production.

Winter DO is quick and simple to measure and has a linear relationship with water quality indices (Sánchez et al 2007). Preliminary winter DO measurements in the Peace River region conducted by Alberta Environment and Parks (AEP), in the Cadotte River and Heart River watersheds, suggest DO concentrations fall below Canadian Council of Ministers of the Environment (CCME) guidelines for cold-water species (CCME 1999). Concentrations of DO below 6.5 mg/L are believed to impair freshwater aquatic life and chronic effects may occur after seven days below the threshold (AEP 1997; CCME 1999); concentrations below 5.0 and 3.5 mg/L over one day, can have acute health effects on aquatic life and salmonids, respectively (AEP 1997).

The scope of winter DO deficit in lotic waters across the province of Alberta is unknown. Similarly, the impacts of winter DO deficit on the presence and distribution of priority cold-water fish species such as Arctic grayling, bull trout (*Salvelinus confluentus*), Athabasca rainbow trout (*Oncorhynchus mykiss*) (Wilcox pers. comm.) and Westslope cutthroat trout (*Oncorhynchus clarki lewisi*) (Johnson pers. comm) requires further investigation. We conducted broad scale measures of winter DO across two candidate watersheds, Whitemud River, and Willow Creek, to determine if winter DO deficit occurs. The primary objective of this study was to document winter DO concentrations on a watershed scale and investigate the occurrence of winter DO deficit for priority species, Arctic grayling and Westslope cutthroat trout.

2.0 STUDY AREA

2.1 Whitemud River watershed

The Whitemud River watershed is situated in northwestern Alberta, northwest of the town of Peace River (Figure 1). The upstream half of the watershed originates in the boreal forest of the green zone and the downstream half flows through the white zone before entering the Peace River. Within the green zone, industrial logging occurs in proximity to the Whitemud River and throughout the watershed. Further downstream, the river flows through a grazing reserve and private agricultural land of the white zone. Arctic grayling, considered a *Species of Special Concern* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), were once considered extensive throughout the watershed, however there are recent concerns that their distribution may be shrinking (Kayedon Wilcox, AEP, pers comm.). Widespread sampling within the past decade suggests Arctic grayling are primarily restricted to the upper third of the watershed (Kayedon Wilcox, AEP, pers. comm).

2.2 Willow Creek watershed

The Willow Creek watershed is situated in southwestern Alberta, northwest of the town of Fort Macleod (Figure 1). Originating in the Montane and Aspen Parkland regions of the green zone along the eastern slopes of the Rocky Mountains, the creek flows through the Mixed Grassland region in the white zone before entering the Oldman River. It provides municipal water to the town of Claresholm and irrigation water to surrounding agricultural development via diversions, dams, and reservoirs. Livestock operations are widespread throughout the watershed, often in close proximity to Willow Creek. Westslope cutthroat trout, listed as *Threatened* under Species At Risk Act (SARA) legislation, were once distributed throughout the watershed but are now restricted to isolated pockets in the upper headwater reaches. Due to the amount of land use activity and historical presence of Westslope cutthroat trout, this watershed was identified as a suitable candidate for the study (Craig Johnson, AEP, pers. comm). Anecdotal reports suggest the water quality has diminished considerably in recent decades. Where fishing and swimming were once popular near Claresholm (Craig Johnson, AEP, pers. comm), periodic algal blooms and undesirable water quality now occur, conditions which are often accompanied by low DO concentrations.

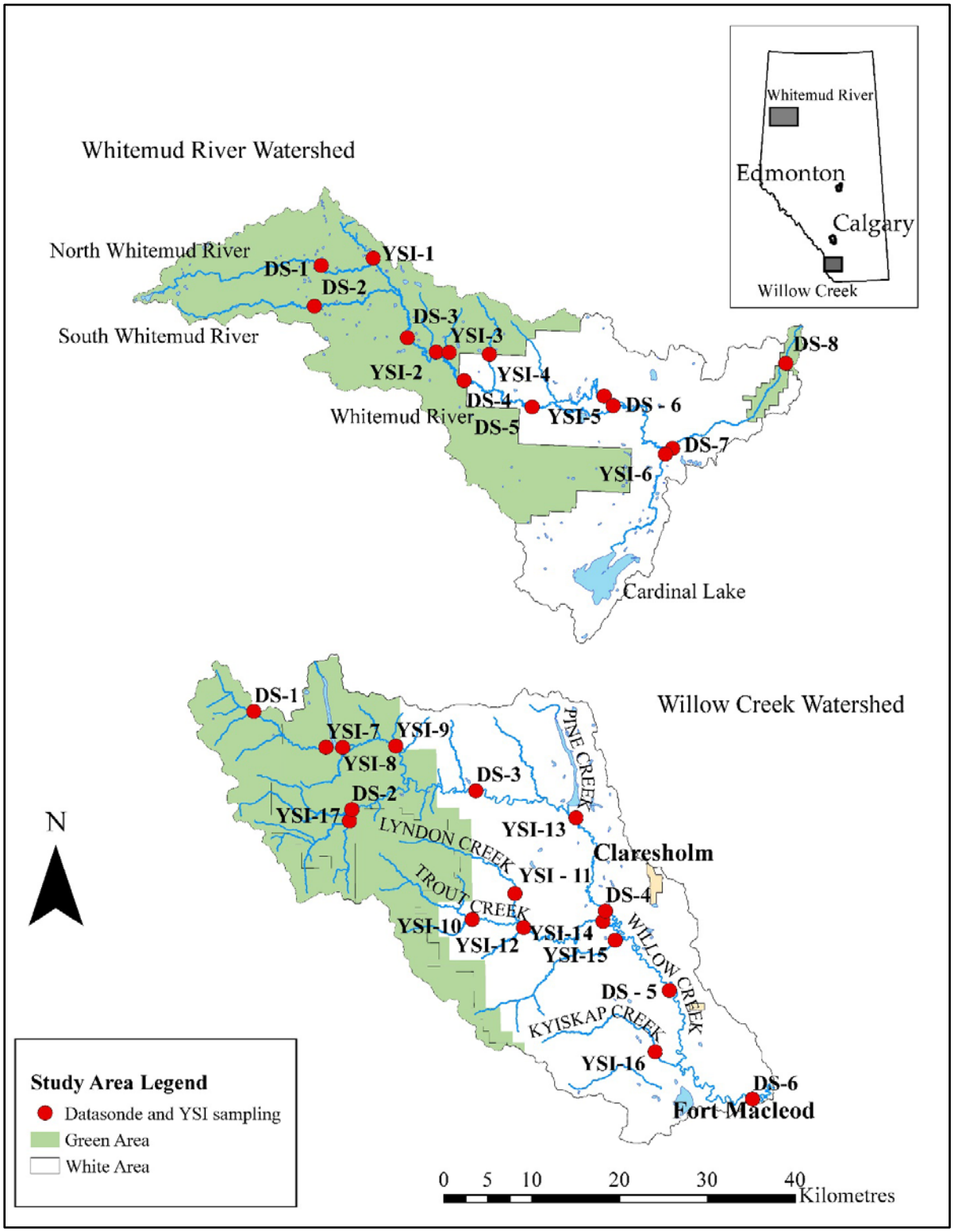

Figure 1. Winter dissolved oxygen and water temperature monitoring sites in the Whitemud River and Willow Creek watersheds, December 2016 to May 2017. Inset map shows the location within the province of Alberta.

3.0 MATERIALS AND METHODS

Using a geographical information system (GIS), we derived a list of candidate sample sites in the Whitemud River and Willow Creek watersheds to investigate access and suitability of overwintering pools within which to monitor winter under-ice DO. In late summer and early fall of 2016, we conducted reconnaissance at candidate sites to determine suitability of water depth and anchor points (i.e., tree trunks) for overwinter DO monitoring sites. We also conducted reconnaissance near the mouths on major contributing tributaries to establish sites for repeat visits for hand-held measurements of winter under-ice DO.

3.1 Winter dissolved oxygen monitoring with datasondes

Prior to ice-over in fall 2016, we installed pre-calibrated PME MiniDOT temperature-oxygen data loggers (datasondes), at intervals between major tributary inputs within the two watersheds. The optode oxygen sensor measures DO through fluorescence with ± 5% accuracy over a range of 0 to 150% oxygen saturation (± 10 μmole/L DO accuracy); and the temperature sensor measures to ± 0.1˚C, over a range of 0 to 35˚C. Datasonde sites spanned the length of both watersheds, with eight sites in the Whitemud River watershed and six sites in the Willow Creek watershed (Figure 1).

We fastened datasondes to a vertical T-bar pounded into the streambed. Where suitable anchor points were unavailable we post-pounded 90 cm sections of T-bar posts into the stream bank to use as anchor points. For safety reasons, we covered the exposed portion of T-bars with a rubber protector. Datasondes were encased in 5 cm diameter flow-through, capped ABS containers, and affixed to the T-bar with quick-links. We anchored datasondes, cases, and T-bars to the shore (i.e., tree trunk, bridge piling, or shore-based T-bar) using airplane cable and u-clamps. Datasondes were positioned within wading distance from shore to facilitate efficient extraction, and mid-way up the water column to avoid exposure to streambed sediments, nutrients, sinking debris, and similarly from surface-ice, ice-over, or floating debris. The datasondes monitored winter DO and water temperature throughout the ice-over period, taking measurements at 15-minute intervals. We retrieved datasondes after spring break-up but prior to spring freshet before flows became too high and unsafe.

3.2 Winter dissolved oxygen monitoring with YSI meters

We conducted biweekly winter DO measurements using a Yellow Springs Instruments (YSI) hand-held Professional Plus Pro with a 30 m Quatro Cable, 5560 temperature/conductivity sensor, and galvanic dissolved oxygen sensor with a 1.25 mil PE membrane. We took DO and water temperature measurements through a hole drilled through the ice with a 10 cm hand auger, at the approximate depth of datasonde sites. Measurements were taken at every datasonde site in both watersheds, and at an additional six sites in the Whitemud River watershed, and 11 sites in the Willow Creek watershed (Appendix 1 and 2). These YSI only sites included stream reaches between datasonde sites and near the mouths of major contributing tributaries (Figure 1), in order to construct a comprehensive winter DO map, examine relationships between snapshot and season-long monitoring techniques, and act as a failsafe to datasonde failure, loss, or theft.

3.3 Data management and analysis

We assessed winter water quality suitability for trout based on DO concentrations <6.5, <5.0, and <3.5 mg/L, which represent the chronic effects threshold for aquatic life, acute effects threshold for aquatic life, and acute effects threshold for salmonids (including Arctic grayling and Westslope cutthroat trout), respectively. We determined the daily mean, minimum, and maximum DO, and water temperature at datasonde sites using RStudio 1.0.153, and determined when, and for how long, DO dropped below established thresholds (RStudio 2015). We plotted datasonde readings from December 1, 2016 to May 1, 2017 in the Whitemud River watershed, and December 1, 2016 to April 1, 2017 in the Willow Creek watershed, coinciding with respective ice-on periods per watershed. We plotted all YSI measurements taken at datasonde and YSI sampling sites in both watersheds to examine trends in the data.

We performed correlation analyses to compare YSI measurements with datasonde measurements for the Whitemud River and Willow Creek watershed datasets separately and plotted the YSI data against datasonde data to illustrate the range of variability encountered in DO measurements by method and location. During comparative analysis we excluded data from time periods when water columns were completely frozen.

4.0 RESULTS

4.1 Winter dissolved oxygen concentrations from datasondes

Winter DO concentrations varied considerably among datasonde sites in both watersheds (Table 1). One of seven datasonde sites in the Whitemud River watershed, and one of five in the Willow Creek watershed recorded DO concentrations that remained above the chronic effects threshold for aquatic life throughout the winter months (Figure 2). No clear spatial pattern was observed between datasonde sites, however winter DO concentrations fell below the lowest thresholds at most of the sample sites in both watersheds (i.e., 5/7 for Whitemud and 3/5 for Willow).

Table 1. Maximum number of consecutive days that winter dissolved oxygen concentrations remained below acute thresholds for salmonids, and acute and chronic thresholds for aquatic life, at datasonde sites, in the Whitemud River and Willow Creek watersheds, December 2016 and May 2017.

		Number of days below dissolved oxygen threshold		
		Salmonids	Aquatic life	Aquatic life
		Acute	Acute	Chronic
Watershed	Datasonde ID	<3.5 mg/L	<5.0 mg/L	<6.5 mg/L
Whitemud River	DS - 1	20	27	35
	DS - 2	0	1	1
	DS - 3	96	97	99
	DS - 4	0	0	0
	DS - 5	105	112	115
	DS - 6 - *Lost due to flood event*			
	DS - 7	17	23	24
	DS - 8	56	58	61
Willow Creek	DS - 1	0	0	0
	DS - 2	14	27	47
	DS - 3	4	4	5
	DS - 4	0	0	1
	DS - 5 - *Lost due to theft*			
	DS - 6	25	26	45

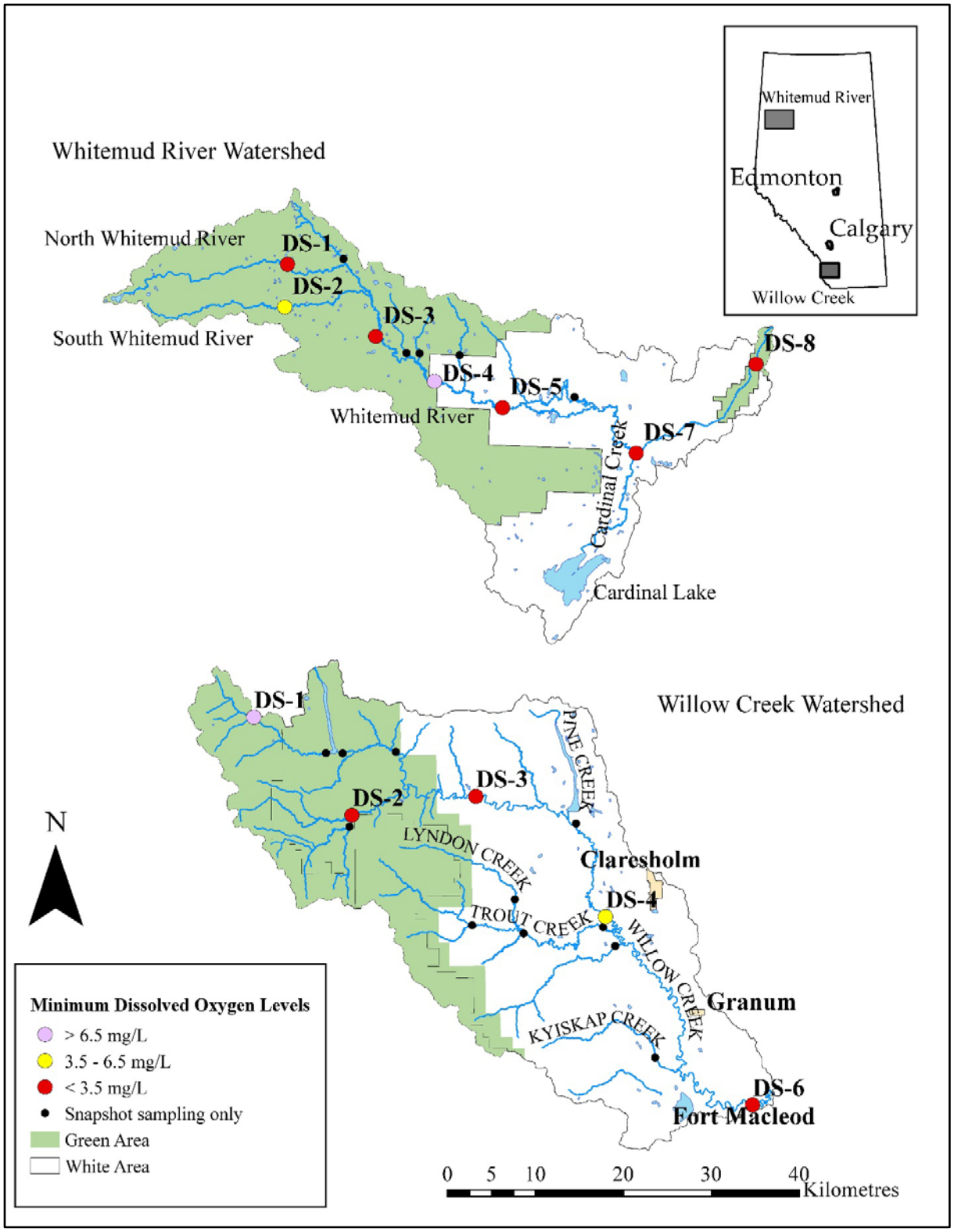

Figure 2. Winter dissolved oxygen concentrations, measured with datasondes, in the Willow Creek and Whitemud River watersheds, December 1, 2016 to April 1, 2017. Inset map shows the location within the province of Alberta.

In the Whitemud River watershed, we recorded the most suitable winter DO concentrations, above all three chronic and acute effects thresholds, at a mid-watershed site (DS-4), however the next downstream site (DS-5) recorded the least suitable concentrations of all sites, and remained below all three threshold limits for a sustained period of three and a half months (Table 1 and Appendix 3). A headwater datasonde site on the South Whitemud River (DS-2) recorded the second most suitable winter DO concentrations, remaining above all three threshold limits for the majority of the winter, but dropped briefly below the acute threshold for aquatic life for periods of less than a day. Conversely, a datasonde site positioned in a similar headwater location on the North Whitemud River (DS-1), recorded DO concentrations that remained above all three threshold limits for the majority of the winter, but dropped below chronic limits for aquatic life for five weeks in late spring. One datasonde site (DS-3) was influenced by the operation of a winter ice-bridge for industrial traffic, built immediately upstream of the datasonde site. Stream-water withdrawal for construction and maintenance of the bridge resulted in reduced stream flows downstream, causing frequent freezing of the water column and the datasonde into the ice (Figure 2 and Appendix 3).

In the Willow Creek watershed, the furthest upstream datasonde site (DS-1) recorded the most suitable winter DO concentrations, above all three chronic and acute effects thresholds, followed by a mid-watershed datasonde site (DS-4), which had concentrations above chronic and acute limits for aquatic life, but dropped below the chronic limits for aquatic life for a one day period (Figure 2 and Appendix 4). Another mid-watershed datasonde site (DS-3) recorded winter DO concentrations above all three threshold limits for the majority of the winter, but dropped below acute limits for salmonids for a four day period in mid-February. The datasonde site that recorded the least suitable winter DO concentrations was near the mouth of Willow Creek (DS-6), and remained below acute threshold limits for salmonids for a sustained period of three and a half weeks (Table 1 and Appendix 4).

4.2 Winter dissolved oxygen concentration from YSI meters

Based on bi-weekly readings, YSI meters recorded winter DO concentrations above the chronic effects threshold for aquatic life at 6 out of 13 sites in the Whitemud River watershed and 8 of 17 sites in the Willow Creek watershed (Figure 3).

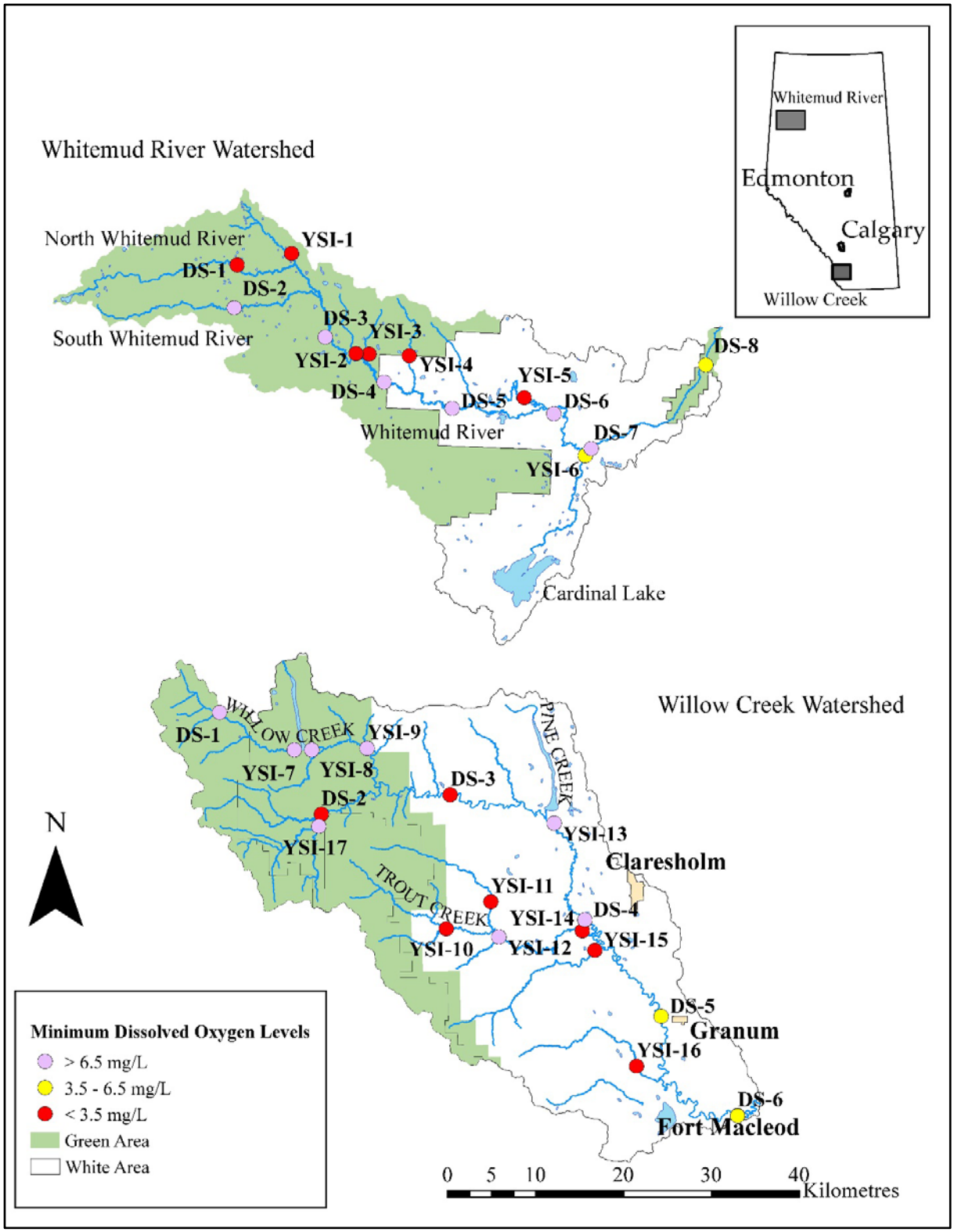

Figure 3. Winter dissolved oxygen concentrations, measured with YSI meters, in the Willow Creek and Whitemud River watersheds, December 1, 2016 to May 1, 2017. Inset map shows the location within the province of Alberta.

4.2.1 Whitemud River

In the Whitemud River mainstem, winter DO concentrations were above the chronic limits for aquatic life, except near the mouth (DS-8) where it fell below the chronic limits for aquatic life, but remained above acute limits for salmonids (Figure 3 and Appendix 5). None of the tributary sites had winter DO concentrations that could support aquatic life except for Cardinal Creek (YSI-6), where while DO concentrations were below the chronic limit for aquatic life, it remained above threshold limits for salmonids (Figure 3 and Appendix 5). Winter DO concentrations below the acute limit for aquatic life occurred on Lightning Creek (YSI-3) for the entire winter, and Wagon Creek (YSI-4) in early spring. Sampling sites on North Whitemud River (DS-1) and Silver Creek (YSI-2) underwent extensive periods of complete freezing. Bi-weekly sampling was terminated at Beaton Creek (YSI-5) and a tributary to the Whitemud River (YSI-1), due to confirmed anoxic conditions, and lack of flowing water, respectively, during late fall open water conditions.

4.2.2 Willow Creek

In the Willow Creek watershed, headwater streams tended to have the most suitable winter DO concentrations (Figure 3 and Appendix 6). DO concentrations in the upper Willow Creek (DS-1, YSI-7, YSI-8 and YSI-9), upper South Willow Creek (YSI-17), Trout Creek (YSI-12) and the middle reaches of Willow Creek (YSI-13) were well above the acute effects threshold for salmonids. All waterbodies with unsuitable winter DO concentrations for aquatic life including salmonids, underwent periods of complete freezing down to the streambed, and included South Willow Creek (DS-2), Willow Creek (DS-3), Trout Creek (YSI-10 and YSI-14), Lyndon Creek (YSI-11), Meadow Creek (YSI-15), and Kyiskap Creek (YSI-16).

4.3 Datasonde and YSI correlation analysis

Correlation analyses between datasonde and YSI winter DO concentration data resulted in low correlation coefficients for both watersheds, 0.49 for the Whitemud River and 0.48 for Willow Creek (Figure 4), indicating consistently weak agreement between the two methods.

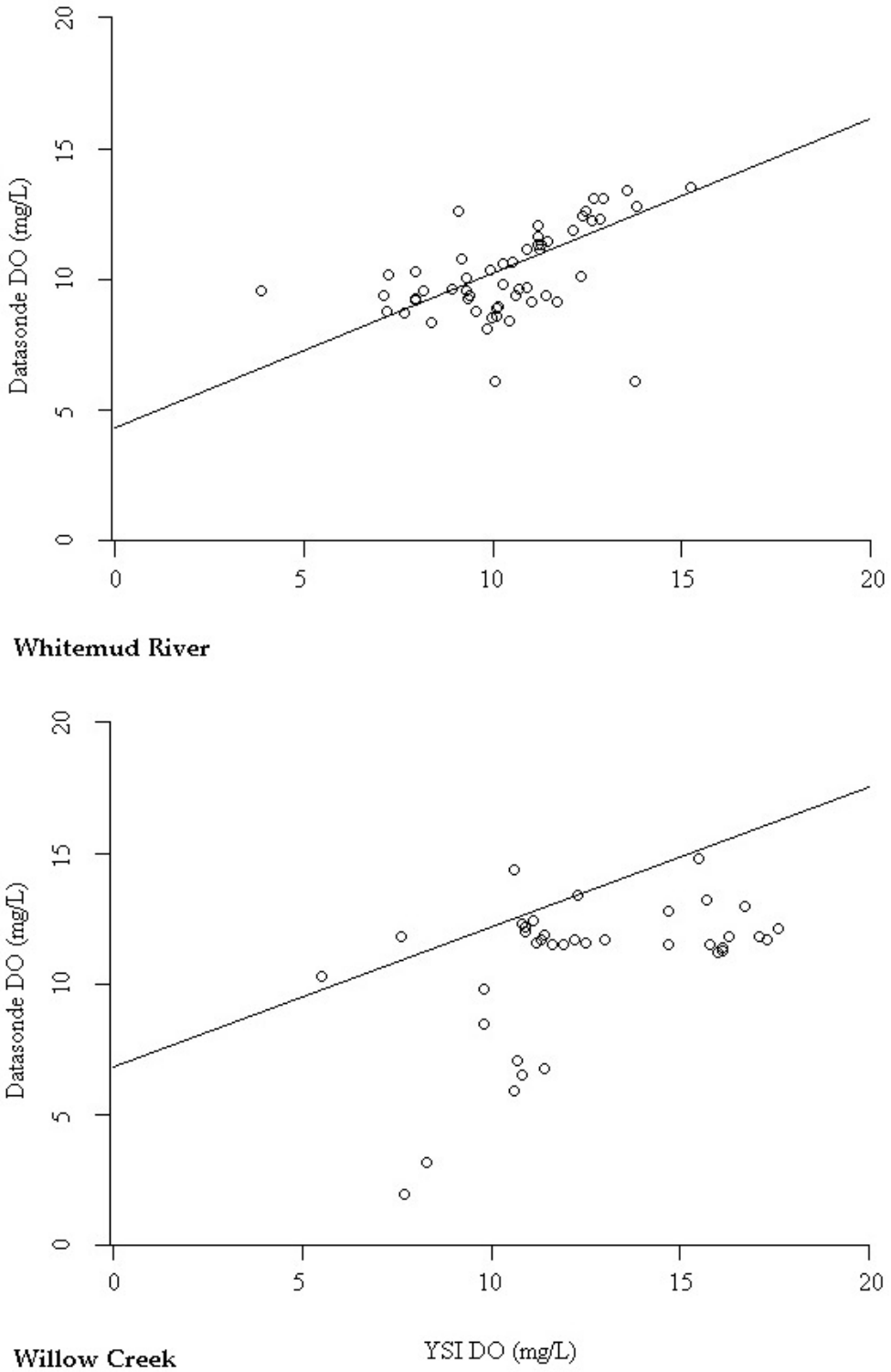

Figure 4. Correlation between datasonde and YSI winter dissolved oxygen measurements on the Whitemud River, and Willow Creek watersheds, December 2016 to May 2017.

The Whitemud River watershed winter DO concentrations varied considerably on a day-by-day and site-by-site basis. Three sites showed modest agreement between methods (DS-2, DS-4 and DS-7), and one was frozen/inaccessible (DS-1) (Appendix 7). Three other sites (DS-3, DS-5 and DS-8) showed a trend in YSI measurements being frequently higher than those of the datasondes, and agreement between methods weakened as the season progressed. Among these sites, one (DS-3) was confirmed as frozen.

In the Willow Creek watershed winter DO concentrations also varied widely throughout the winter between the two methods (Appendix 8). Three of the five sites (DS-1, DS-3 and DS-4) showed relative agreement, one of which recorded the most favorable winter DO concentrations (DS-1), and the other (DS-3) recorded consistent concentrations for most of the winter except for a single brief anoxic period. Where measurements deviated greatly between methods (DS-2, DS-4, and DS-6), we observed a similar trend to the Whitemud River watershed dataset, where YSI measurements were frequently higher than those of the datasondes and agreement between methods weakened at three of the four sites as the season progressed.

5.0 SUMMARY

We observed no clear spatial trends in overwintering DO habitat suitability in either watershed based solely on datasonde results which varied considerably among sites. One of seven datasonde sites in the Whitemud River watershed, and one of five in the Willow Creek watershed recorded DO concentrations that remained above the chronic effects threshold for aquatic life throughout the winter months. However, using combined results between YSI and datasonde DO measurements, we determined that the majority of the Whitemud River mainstem remained suitable for salmonids throughout the winter, whereas the tributaries and North Whitemud River did not, due to low DO concentrations and frozen conditions. In the Willow Creek watershed, sampling sites in upper headwater reaches tended to have suitable winter DO concentrations for salmonids wherever streams did not freeze to the bottom. We observed site-specific freezing, and variable DO concentrations in both watersheds.

Correlation was low between datasonde and YSI datasets, potentially as a result of undetected freezing/frazzle-ice conditions occurring at or on the datasonde beneath the ice surface. Establishment of sites in pre-determined deep run sections of faster flowing water instead of the slower pool habitats used in this study, may improve correlation between DO concentrations taken by YSI and datasonde methods.

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7.0 APPENDICES

Appendix 1. Whitemud River watershed datasonde and YSI sampling sites.

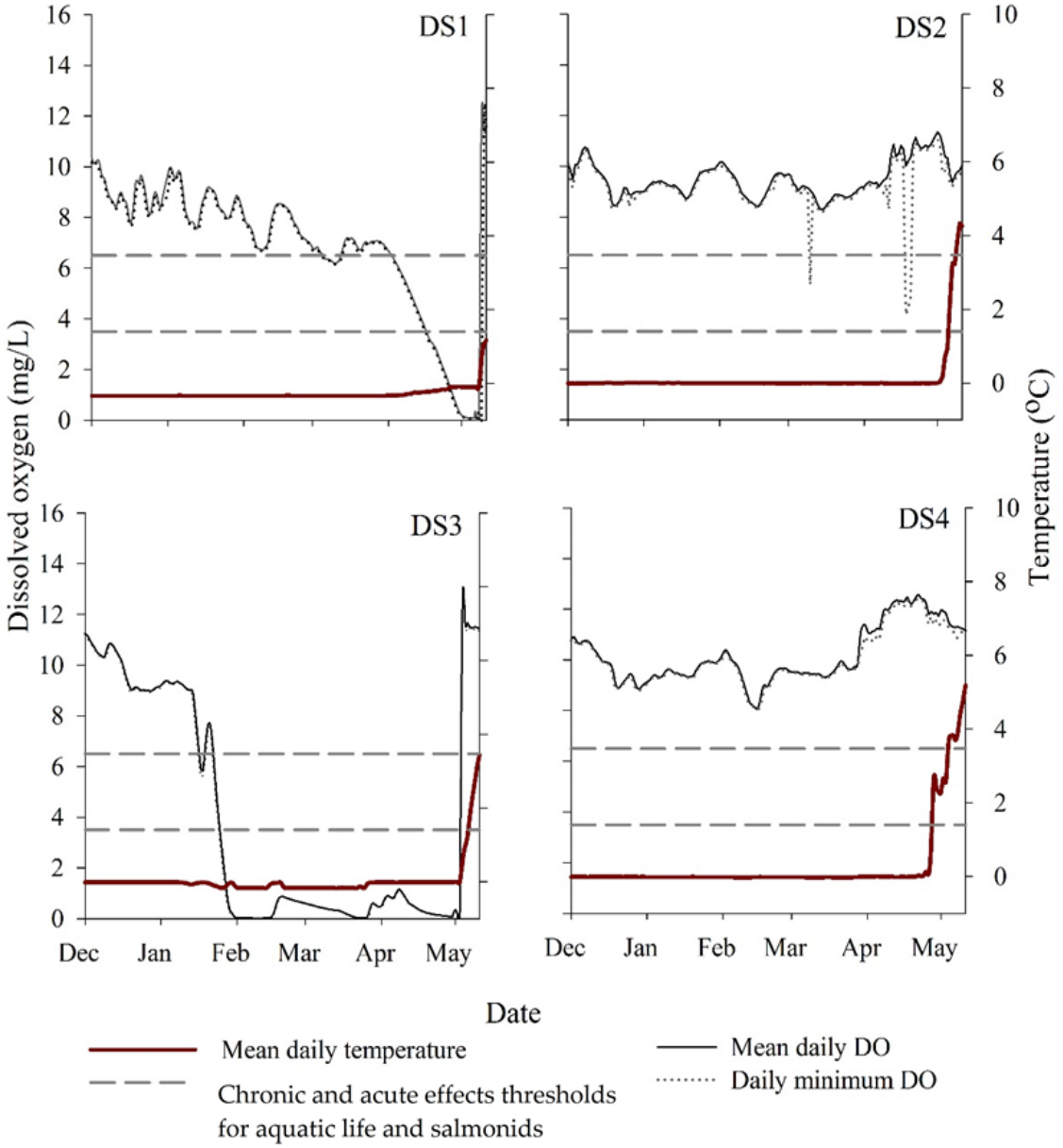
Waterbody	Site ID	Type	NAD 83 Zone	Easting	Northing
Whitemud River	DS-1	Datasonde	11 U	400638	6288643
South Whitemud River	DS-2	Datasonde	11 U	400332	6280802
Whitemud River	DS-3	Datasonde	11 U	417154	6275896
Whitemud River	DS-4	Datasonde	11 U	428129	6268002
Whitemud River	DS-5	Datasonde	11 U	440725	6263544
Whitemud River	DS-6	Datasonde	11 U	459347	6263107
Whitemud River	DS-7	Datasonde	11 U	465411	6255938
Whitemud River	DS-8	Datasonde	11 U	486887	6272870
Unnamed to Whitemud River	YSI-1	YSI Sample	11 U	410861	6289911
Silver Creek	YSI-2	YSI Sample	11 U	422881	6273065
Lightning Creek	YSI-3	YSI Sample	11 U	425266	6273074
Wagon Creek	YSI-4	YSI Sample	11 U	432606	6272955
Beaton Creek	YSI-5	YSI Sample	11 U	453840	6265883
Cardinal Creek	YSI-6	YSI Sample	11 U	465336	6255627

* YSI-1 tributary to Whitemud River was removed from the study due to lack of stream flow.

Appendix 2. Willow Creek watershed datasonde and YSI sampling sites.

Waterbody	Site ID	Type	NAD 83 Zone	Easting	Northing
Willow Creek	DS-1	Datasonde	12 U	688819	5568944
South Willow Creek	DS-2	Datasonde	12 U	702633	5555840
Willow Creek	DS-3	Datasonde	12 U	290893	5558446
Willow Creek	DS-4	Datasonde	12 U	307793	5540985
Willow Creek	DS-5	Datasonde	12 U	317183	5527705
Willow Creek	DS-6	Datasonde	12 U	326586	5514084
Willow Creek	YSI-7	YSI Sample	11 U	698841	5564271
Willow Creek	YSI-8	YSI Sample	11 U	701130	5564323
Willow Creek	YSI-9	YSI Sample	11 U	708433	5564722
Trout Creek	YSI-10	YSI Sample	12 U	289432	5540788
Lyndon Creek	YSI-11	YSI Sample	12 U	295507	5544039
Trout Creek	YSI-12	YSI Sample	12 U	296433	5539288
Willow Creek	YSI-13	YSI Sample	12 U	304430	5553984
Trout Creek	YSI-14	YSI Sample	12 U	307377	5539569
Meadow Creek	YSI-15	YSI Sample	12 U	308920	5536907
Kyiskap Creek	YSI-16	YSI Sample	12 U	313589	5521289
South Willow Creek	YSI-17	YSI Sample	11 U	702341	5554261

Appendix 3. Daily mean and minimum winter dissolved oxygen concentrations, and water temperature of the Whitemud River watershed, December 2016 to May 2017.



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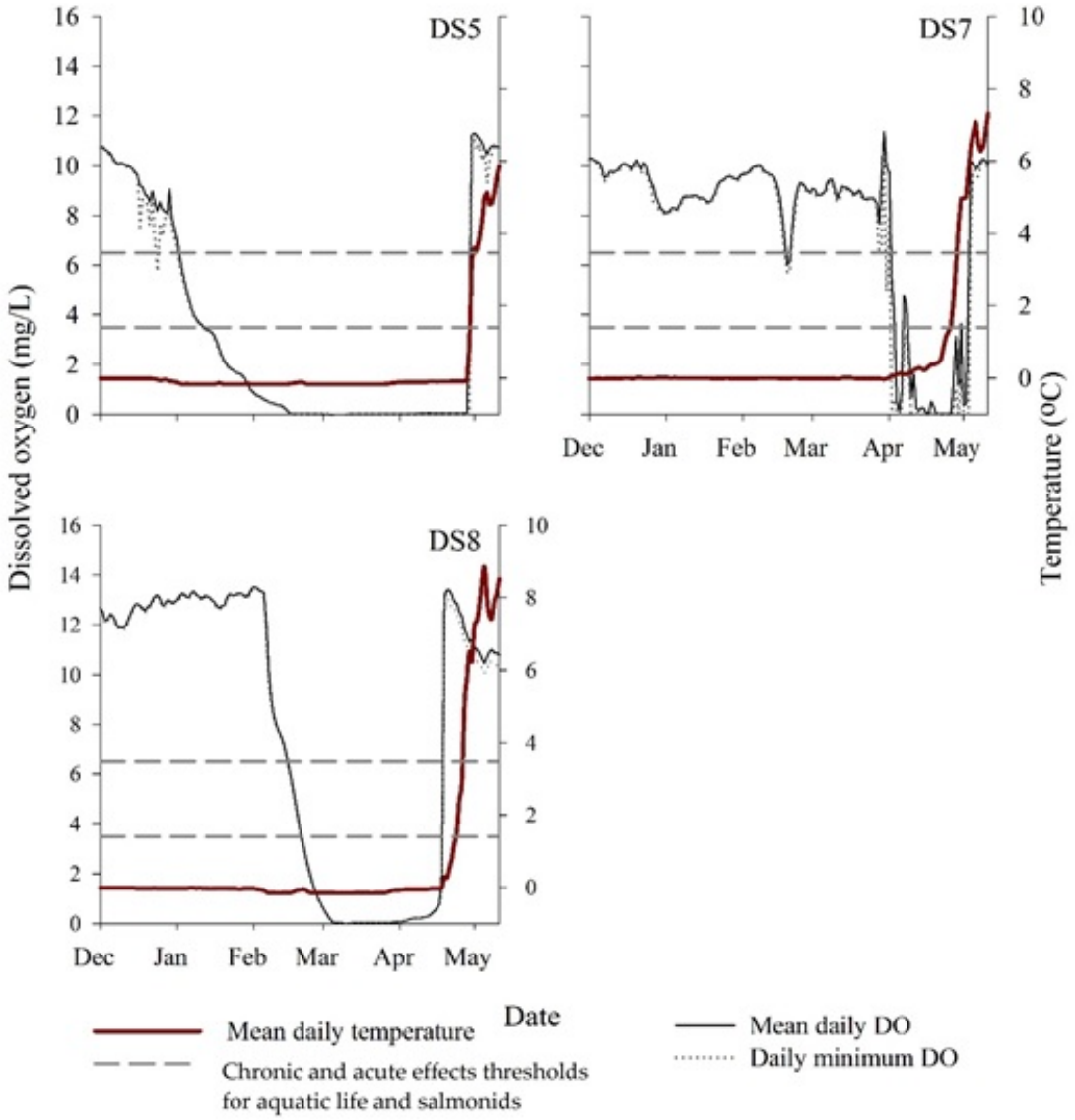
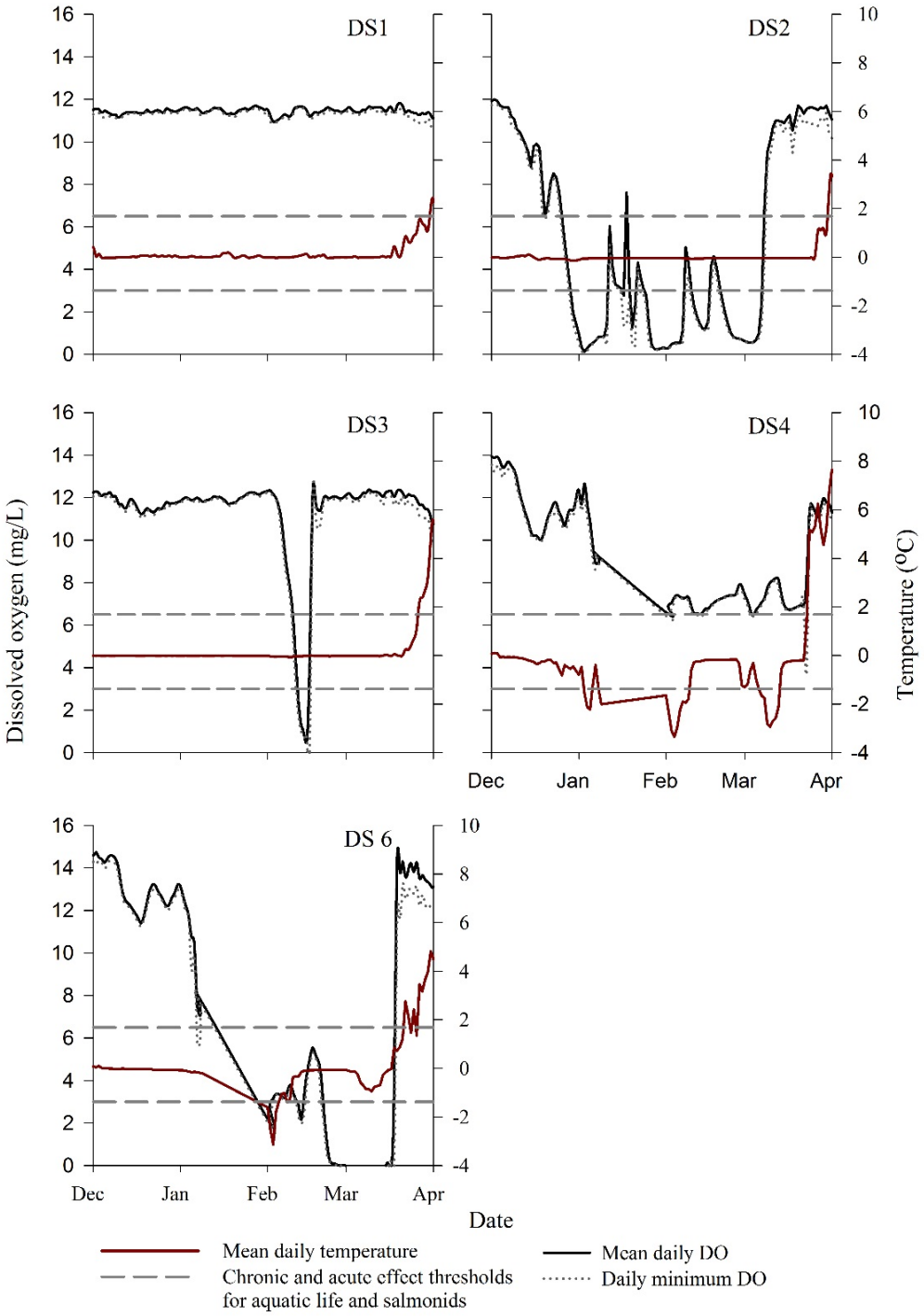
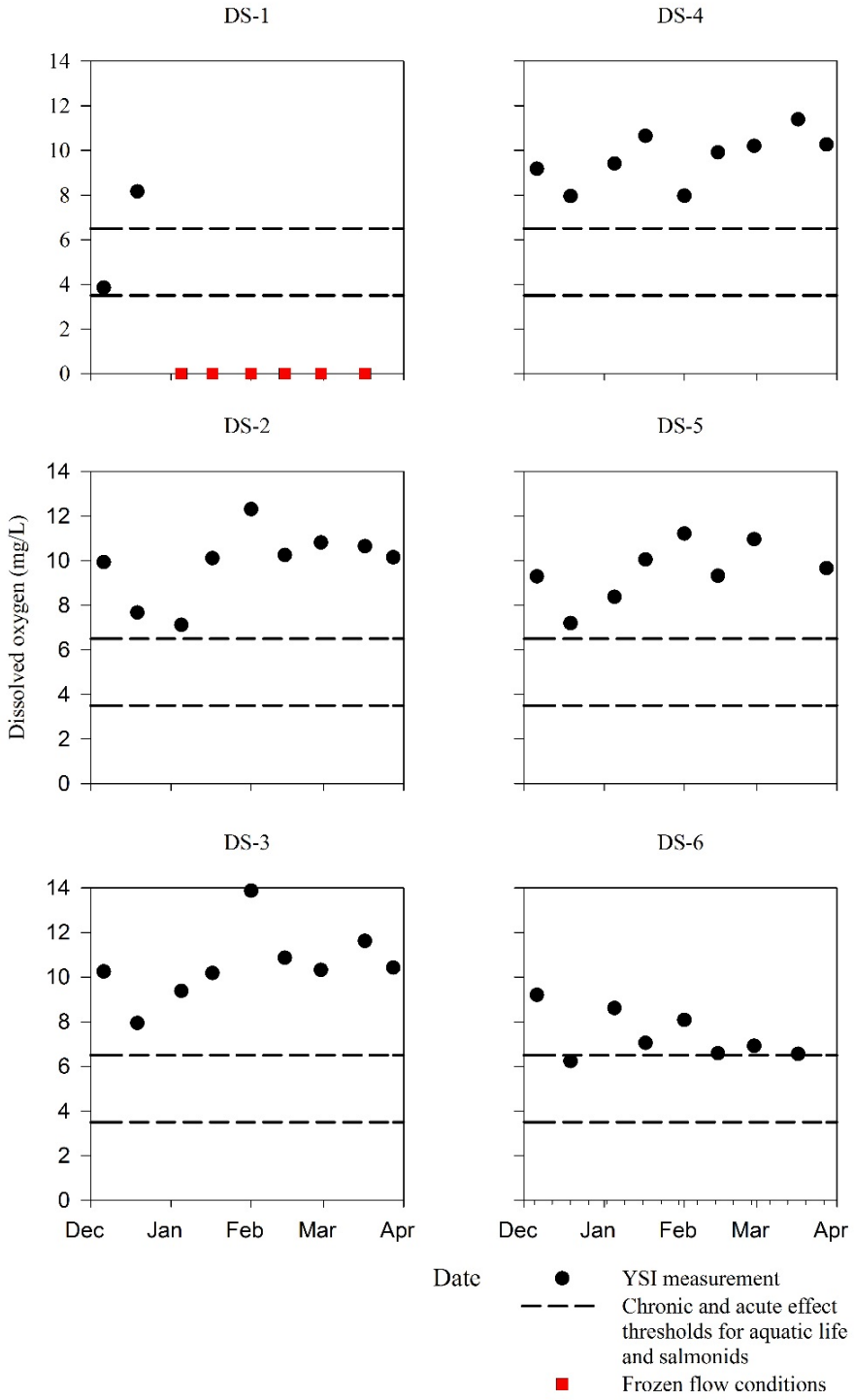


Appendix 4. Daily mean and minimum winter dissolved oxygen concentrations, and water temperature of the Willow Creek watershed, December 2016 to April 2017.



Appendix 5. YSI winter dissolved oxygen concentrations in the Whitemud River watershed, December 2016 to April 2017.



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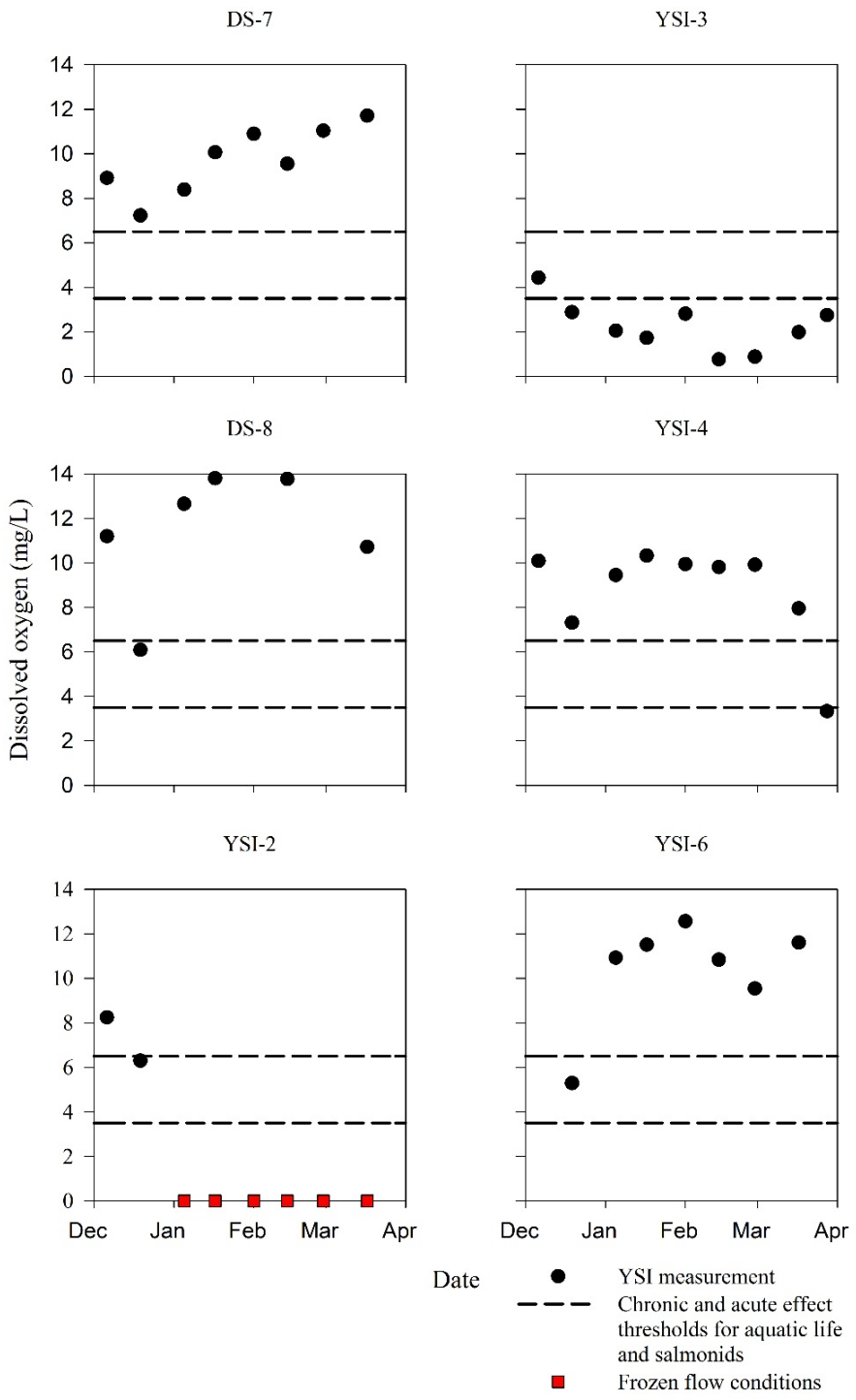
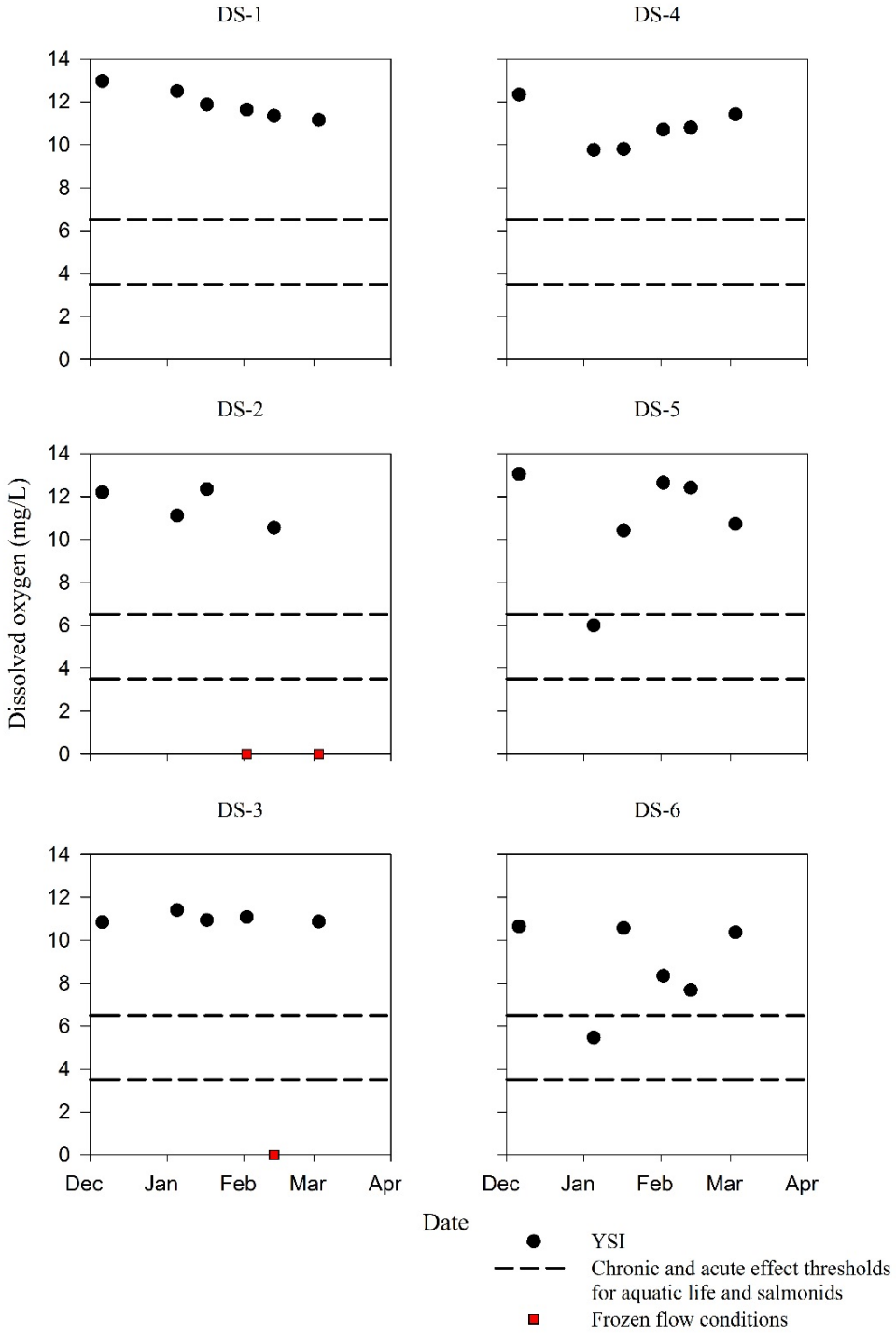


Appendix 6. YSI winter dissolved oxygen concentrations in the Willow Creek watershed, December 2016 to April 2017.



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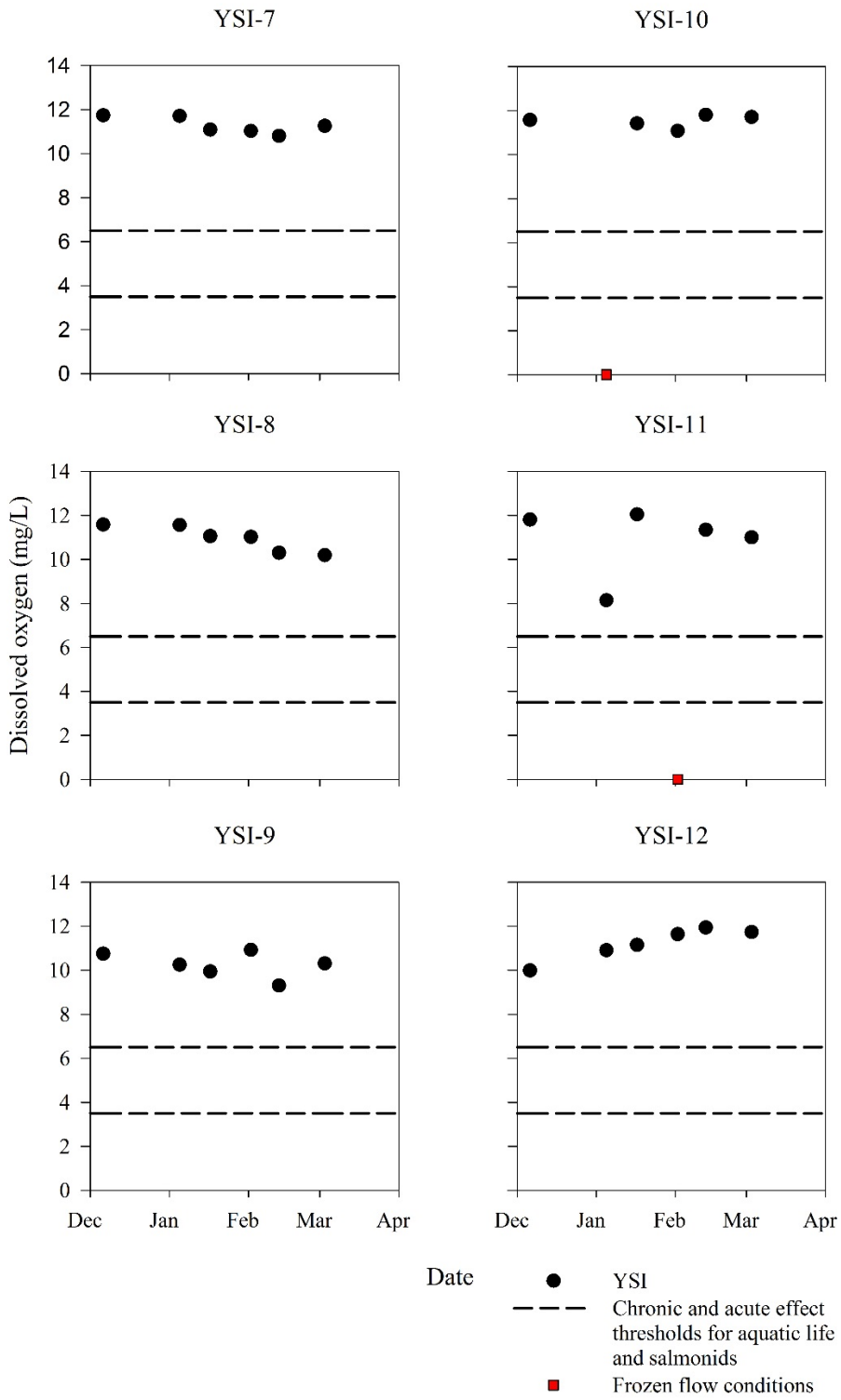
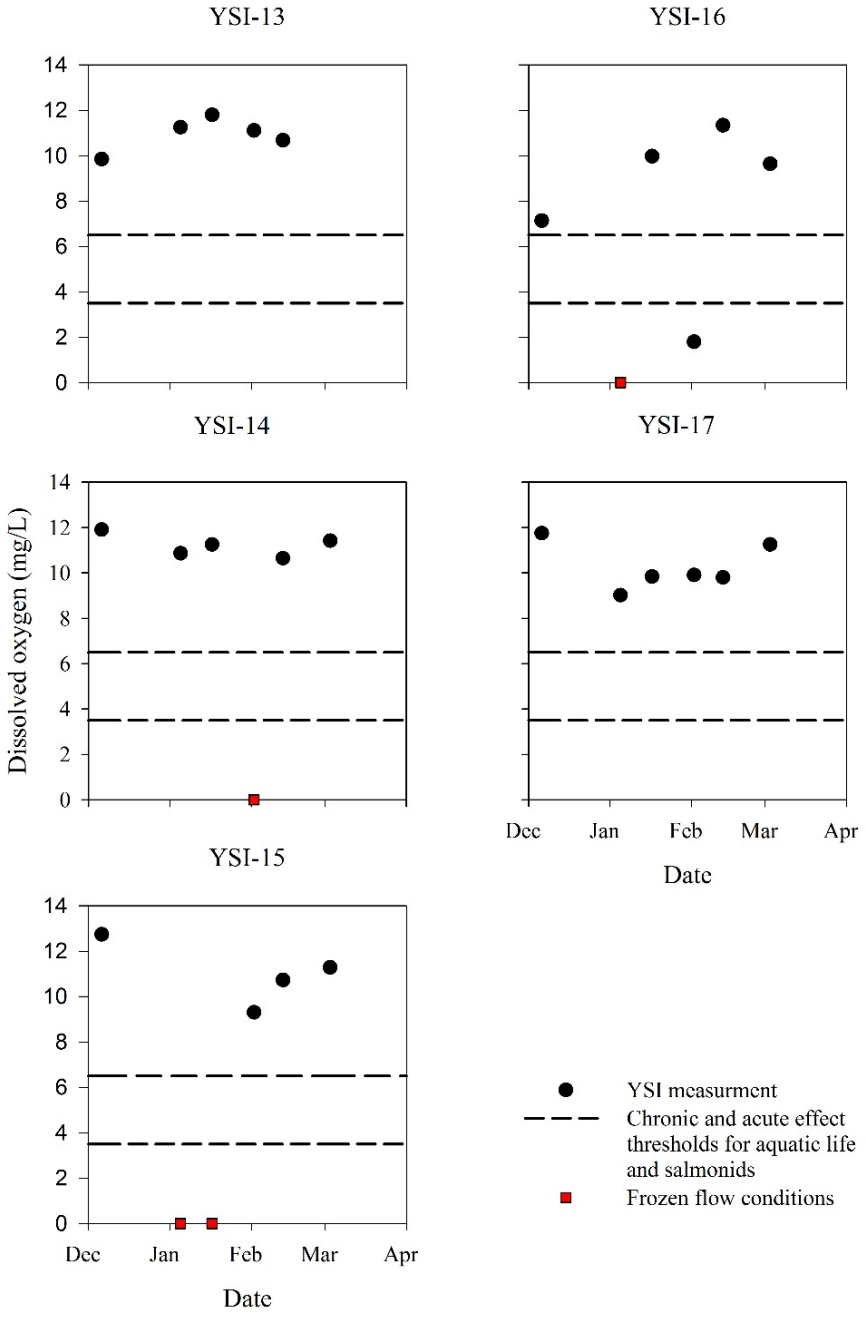
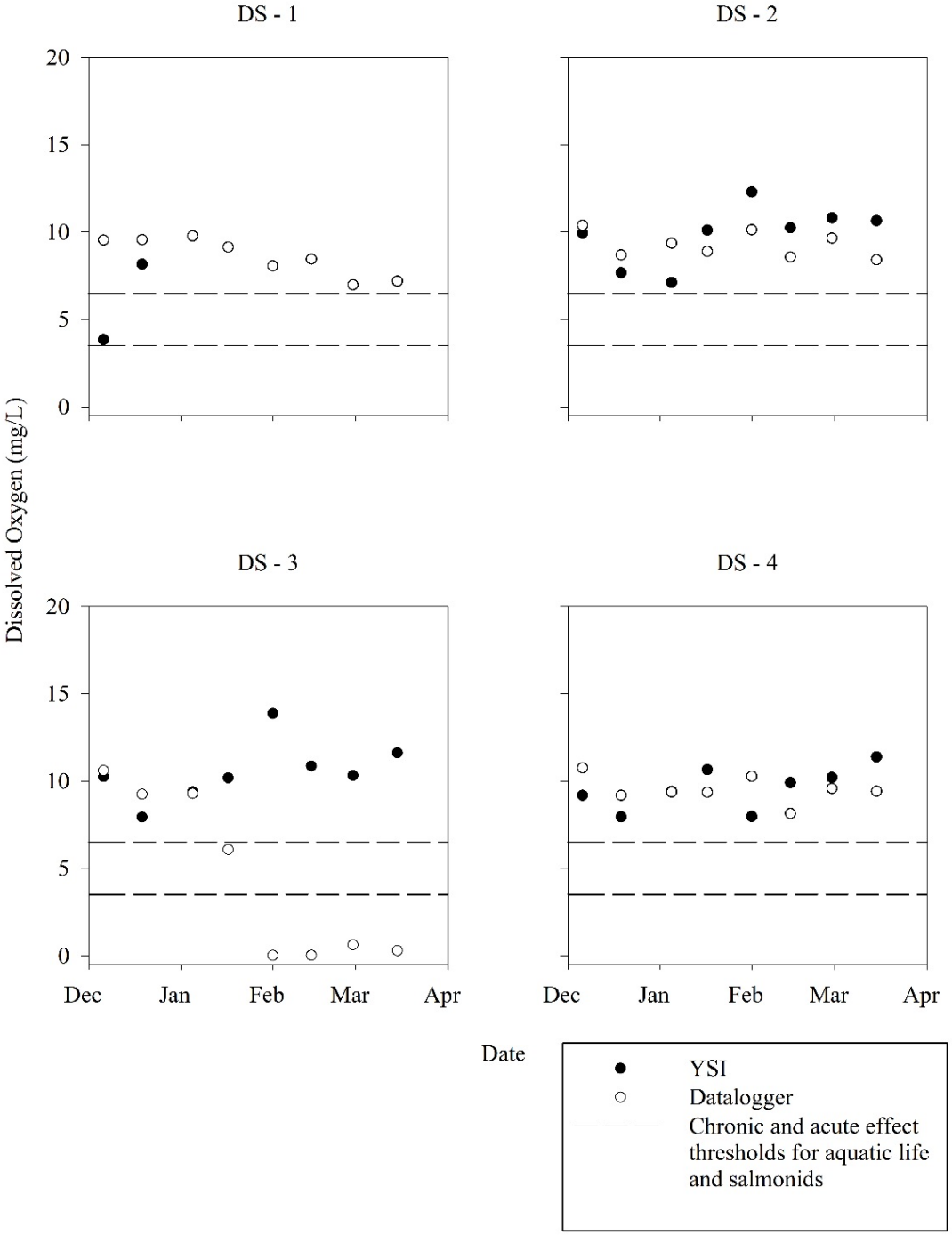


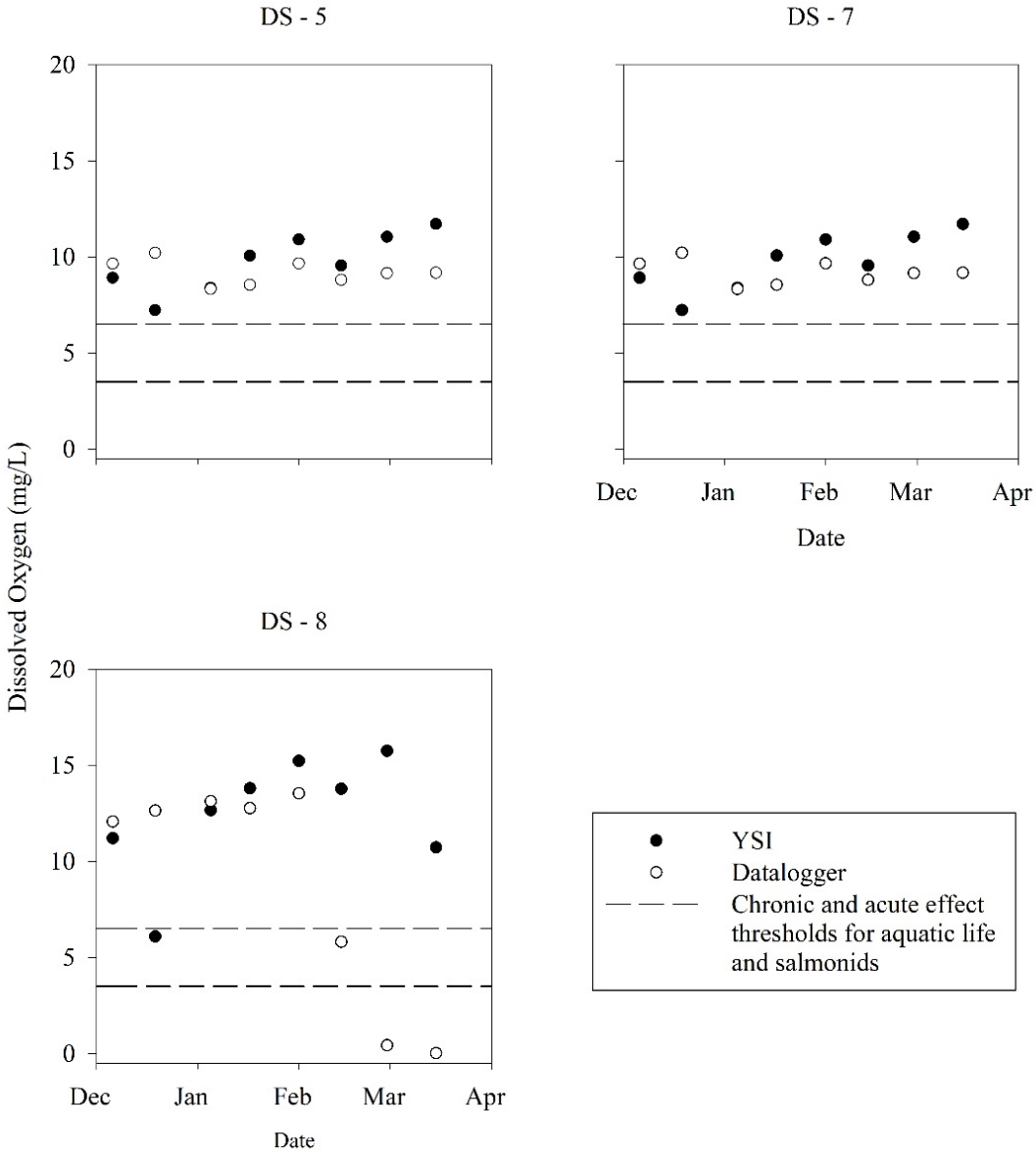
Appendix 6. Continued.



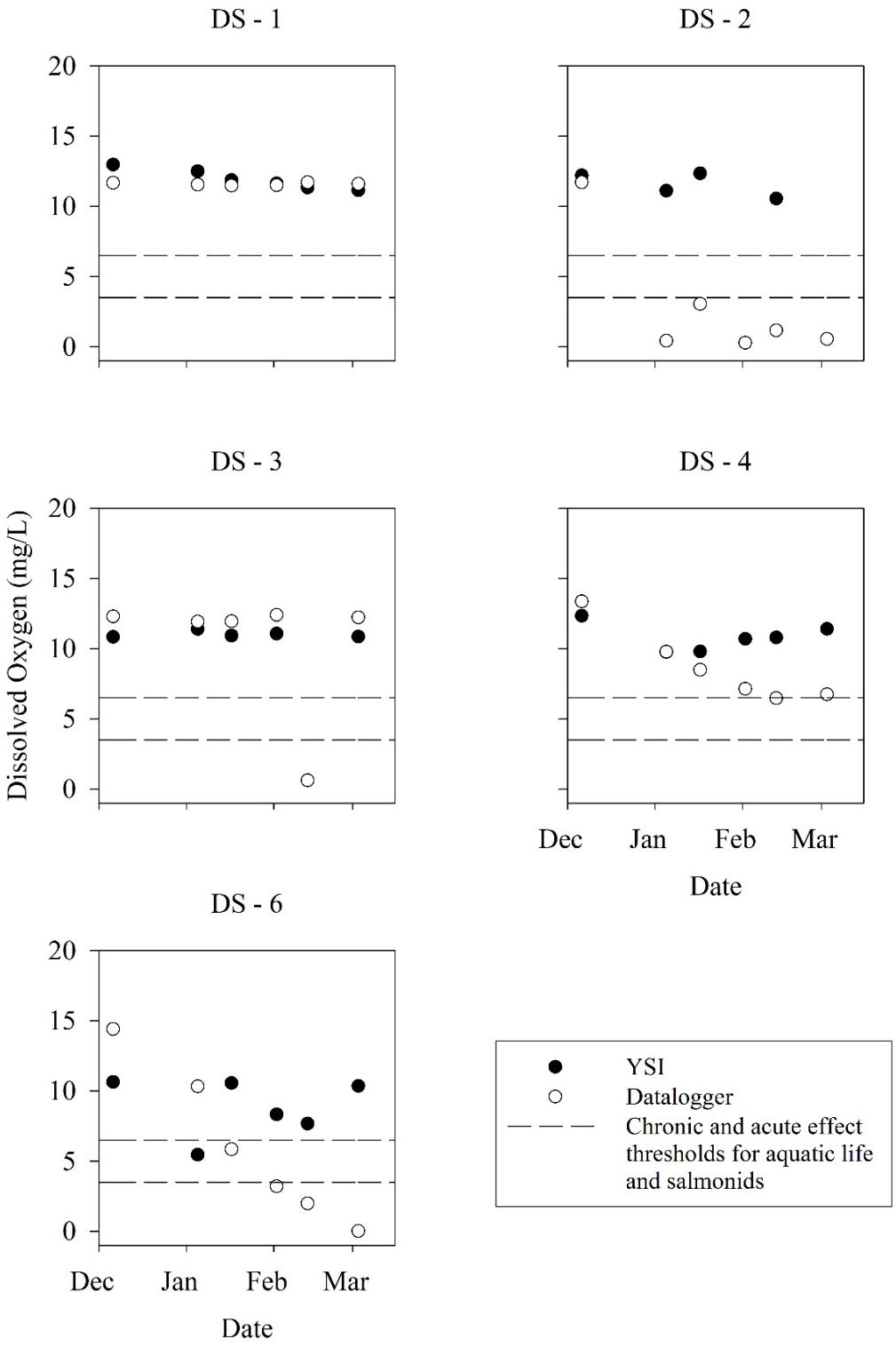
Appendix 7. Comparison of YSI versus datasonde winter dissolved oxygen concentrations in the Whitemud River watershed, December 2016 to April 2017.



Appendix 7. Continued.



Appendix 8. Comparison of YSI versus datasonde winter dissolved oxygen concentrations in the Willow Creek watershed, December 2016 to April 2017.



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