Gitanyow *Fisheries*
Authority

.

Gitanyow (Kitwanga) Lake Assessment - 2016

Prepared for:

Gitanyow Hereditary Chiefs
Pacific Salmon Commission

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Executive Summary

2015/2016

On November 4 2015, biologists and technicians with Gitanyow Fisheries Authority (GFA) buried 48 egg tubes containing 100 fertilized Kitwanga sockeye eggs in two areas of Gitanyow (Kitwanga) Lake[1]. At each of the two spawning areas selected, three artificial 'redds' were excavated and eight egg tubes were buried / redd, depositing a total of 2400 eggs at each spawning area. The average egg-to-fry survival for the three 'redds' at each spawning area was:

- Area 1 = 88%
- Area 3 = 87%

No statistical difference in survival was noted between Areas 1 and 3 (single factor one-way ANOVA p-value of 0.63 > than significance level of 0.05). Dissolved oxygen and water temperatures monitored in the hyporheic zone over the course of the study provided conditions for adequate egg-to-fry survival at each of the selected spawning areas in Gitanyow Lake (1 year of sampling).

2016/2017

In 2016, the second consecutive year of the study, the primary objectives were to identify potential fresh-water factors that may be hindering egg-to-fry-smolt survival in Gitanyow Lake.

In particular, for 2016, the focus was on:

- Conducting an egg-to-fry survival study;
- Documenting hyporheic conditions at two key spawning locations (dissolved oxygen and water temperature);
- Conducting dissolved oxygen (DO) / temperature profiles in the limnetic area of the lake to see how they could be influencing juvenile sockeye rearing conditions; and
- Collecting sockeye fry in Gitanyow Lake in summer and fall to document summer growth patterns.

Key study findings were:

- Only 11 adult sockeyes were observed frequenting the two areas (1 and 3) during monitoring visits to the lakeshore spawning grounds to collect sockeye broodstock and none had viable eggs for the study; therefore, no egg-to-fry survival was conducted in 2016.
- Dissolved oxygen and water temperature in the hyporheic zone provided conditions for adequate egg-to-fry survival at selected spawning areas in Gitanyow Lake. Area 1 had slightly more variability than Area 3 for both dissolved oxygen and temperature from a minimum of 4.4 mg/l and 3.9^{0}C to a maximum of 7.8 mg/l and 5.3^{0}C (SD – 0.2 and 0.4 respectively). While the dissolved oxygen did dip below 5 mg/l at Area 1 for a short period (~5 hr on January 19, 2017), which is usually the threshold where egg survival is

[1] Will be referred to as Gitanyow Lake for the remainder of the report

affected adversely, similar hyporheic conditions were present in 2015/2016, in which egg-to-fry survival was 88%.

- Dissolved oxygen and temperature profiles showed that there were periods in July of 2016 that the available threshold of dissolved oxygen and water temperatures (i.e. >5 mg/l and < 20⁰C – Bjornn and Reiser 1991) were limited in some parts of Gitanyow Lake. This may have effected growth and survival, but there appeared to be adequate conditions in some parts of the lake for juveniles to seek refuge from unfavorable conditions throughout the study period.
- No sockeye fry were caught during four sinking gill net[2] sets in September of 2016.

[2] Small filament 'Swedish' gillnet

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1 INTRODUCTION

The Kitwanga River, a tributary to the Skeena River, located 250 km from the coast, supports important runs of Pacific salmon. In particular, Kitwanga sockeye (*Oncorhynchus nerka*) are genetically unique and are a distinct conservation unit as described under Canada's *Wild Salmon Policy*. Historically, sockeye returns to the Kitwanga River were in the tens of thousands, supporting a number of sustenance and economic fisheries. In more recent times, the stock has been depressed and in many years' returns are not enough to meet the minimum biological requirements for the stock. In response to this conservation concern, the Gitanyow, with help from organizations such as the Pacific Salmon Commission (PSC) and Fisheries and Oceans Canada (DFO), have initiated rebuilding plans to preserve the genetic uniqueness of the stock and to try and rebuild it to more sustainable, historical levels. Rebuilding efforts have included the creation of spawning platforms in 2006 and 2007 in Gitanyow Lake, the enhancement of the stock through hatchery production in 2006 and 2007 and a reduction in the overall exploitation rate on the stock through the implementation of stricter fisheries management guidelines from 2009 too present. Through this rebuilding plan, stocks have increased considerably in some years from near extirpation a little over ten years ago, and further studies, including those conducted for this report, were added to the recovery process.

Kitwanga sockeye adults begin returning to the Kitwanga River at the start of July, continuing until the middle of October, primarily as four-year-old fish (~80%), with some five-year old's (~19%) and three-year old's (~1%) (Kingston and McCarthy 2016). Returning adults have been observed to spend weeks and even months in Gitanyow Lake, prior to spawning. The peak of spawning, which occurs exclusively on spawning grounds along the shoreline of Gitanyow Lake, occurs from mid to late October, with an overall spawning period occurring from mid-September to the later part of November. Fry emergence occurs in April and May, and juveniles spend their next year in the limnetic zones of Gitanyow Lake. The following April and May, just after ice melt on the lake, smolt outmigration begins. The peak of the smolt run typically occurs during the last week of April and the beginning of May.

In addition to sockeye, the following fish have also been documented in Gitanyow Lake (Fisheries Inventory Data Queries 2016):

Chinook Salmon	*Oncorhynchus tshawytscha*
Coho Salmon	*Oncorhynchus kisutch*
Chum Salmon	*Oncorhynchus keta*
Pink Salmon	*Oncorhynchus gorbuscha*
Steelhead/Rainbow Trout	*Oncorhynchus mykiss*
Cutthroat Trout	*Oncorhynchus clarkii*
Bull Trout	*Salvelinus confluentus*
Dolly Varden	*Salvelinus malma*
Mountain Whitefish	*Prosopium williamsoni*
Pygmy Whitefish	*Prosopium coulterii*
Northern Pikeminnow	*Ptychocheilus oregonensis*
Peamouth Chub	*Mylocheilus caurinus*

Redside Shiner	*Richardsonius balteatus*
Largescale Sucker	*Catostomus macrocheilus*
Longnose sucker	*Catostomus*
White sucker	*Catostomus commersonii*
Prickly Sculpin	*Cottus asper*

1.1 Background and Objective

On November 4 2015, biologists and technicians with Gitanyow Fisheries Authority (GFA) buried 48 egg tubes containing 100 fertilized Kitwanga sockeye eggs in two areas of Gitanyow Lake. These areas were selected because they are known annual sockeye spawning locations and because they were monitored previously leading up to the study period. In addition to monitoring egg-to-fry survival, hyporheic and limnetic zone data (dissolved oxygen (DO) and temperature) was collected. Furthermore, a photosynthesis rate (PR) synoptic survey was conducted on Gitanyow Lake over the study period. The PR survey was conducted by DFO's Cultus Lake group from June 8. 2015 to June 15, 2016 (Beblow 2016).

In 2016, the second year of the study, the primary objectives were to collect an additional year's information on the fresh-water factors that may be hindering sockeye egg-to-fry-smolt survival in Gitanyow Lake.

In particular, for 2016, the focus was on:

- Conducting an egg-to-fry survival study;
- Documenting hyporheic conditions at two key spawning locations (dissolved oxygen and water temperature);
- Conducting dissolved oxygen (DO) / temperature profiles in the limnetic area of the lake; and,
- Collecting sockeye fry in Gitanyow Lake in summer and fall to document summer growth patterns.

Other objectives include fostering aboriginal involvement in fisheries management and creating capacity and employment opportunities to Gitanyow fisheries staff living in and around the communities surrounding the Gitanyow Village.

1.2 Study Area

Gitanyow Lake, the only lake in the Kitwanga River watershed, is located approximately 25 km upstream from the confluence with the Skeena River. It has a surface area of 7.8 km^2 with a drainage basin of 169 km^2 (Shortreed *et al*. 1998). The lake is considered mesotrophic with a mean depth of approximately 5 m and a maximum depth of 15 m, with a euphotic zone that encompasses the entire water column for most of the lake (Cleveland and McCarthy 2003).

Daphnia, a species of macro zooplankton, the primary food source of juvenile sockeye Salmon, are extremely abundant in Gitanyow Lake, making the lake one of the most productive sockeye nursery lakes in all of the Skeena Watershed.

The lake can be delineated into two sub-basins separated by narrows. The sub-basins for the purpose of this report will be referred to as the north and south sub-basins (Figure 1).

Figure 1: Overview of Gitanyow Lake study area showing four limnetic survey stations and two incubation areas

2 METHODS

2.1 Survey Timing

Kitwanga sockeye migrate through the Kitwanga River and hold for weeks and even months in Gitanyow Lake prior to moving to shoreline spawning locations. Typically, spawning occurs from mid-September to the end of the November with peak spawning occurring from mid to late October (Cleveland 2000, Cleveland 2002). A GFA crew of two biologists and three technicians attempted to capture adult sockeye for egg take and milt extraction on October 27 and November 3, 2016 just on the edge of peak sockeye spawning for the year. During weekly monitoring at four long-term monitoring stations (Section 2.4), spawning activity was monitored leading up to the dates selected for brood stock acquisition.

Sockeye in Gitanyow Lake are thought to reach the hatch stage by mid-February and fry emerge by April/May (pers. Comm. Mark Cleveland 2016). To check these timing periods, the intragravel temperature that was gathered as part of the study was used to calculate accumulated thermal units (ATUs), where one ATU is equal to one degree Celsius in one day. Temperatures were averaged for a day and the corresponding ATU was tallied to estimate eyed, hatch and emergence timing. ATU data for these estimations was acquired from the Department of Fisheries and Oceans (DFO 2003).

2.2 Sockeye Spawning Area Monitoring and Locations

Egg-to-fry survival study locations were selected based on historical GFA monitoring of observed sockeye spawning locations and historical spawner densities, as well as monitoring weekly spawning activity in 2016. More specifically, a GFA biologist and technician conducted weekly boat surveys of known spawning areas in September and October of 2016, recording spawning activity and spawner numbers. The two most active areas selected for egg tube studies in 2016, were based on 2015 locations as limited sockeye numbers and spawning activity were observed in 2016. Figure 1 shows the spawning areas that were surveyed (between Area 1 and 3).

2.3 Physicochemical Parameters

In order to assess if DO and/or water temperature were potential limiting egg-to-fry survival at sockeye redd locations, two HOBO® DO loggers (Model U26-001) were buried to a depth of 0.20 m, approximately 15 to17 m from a benchmark point on the lake shore in areas where spawning activity was observed in 2016 (Table 1). Units were buried on October 26, 2016 at Areas 1 and 3. The two data-loggers were calibrated prior to installation and cross-checked with a YSI Pro Plus temperature and DO meter to ensure relative intragravel DO and temperature were comparable to water column DO and temperature. Data points were logged hourly for the entire study period. To capture water temperature on top of spawning gravels two Onset Tidbit® v2 TempLoggers were also installed at Areas 1 and 3 (Table 1).

Table 1: Dataloggers used to record DO and water temperature

Parameter	Accuracy		
	HOBO® U26-001	YSI Pro Plus	Tidbit® v2 TempLogger
Dissolved oxygen	±0.2 mg/L up to 8 mg/L; ±0.5 mg/L from 8 to 20 mg/L	± 2% of the reading or 0.2 mg/l whichever is greater	-
Temperature	±0.2°C	±0.2°C	±0.2°C over 0°C to 50°C

2.4 Dissolved Oxygen/Temperature Profiles

To assess DO and water temperature throughout the water column of Gitanyow Lake, dissolved oxygen and temperature surveys were conducted weekly from July 15, 2016 to October 18, 2016 at four locations. These locations corresponded with the four long-term monitoring stations previously established by GFA (Cleveland 2000, Kingston 2004, Kingston 2006), which were located in the deepest sections of the lake. Figure 1 shows the monitoring stations, two of which were located in the north basin and two in the south basin.

At the onset of the surveys for the year, an anchor (bucket with 10 kg cement block) with a rope and float system was used to mark each station. Prior to taking measurements at a station during any given survey, the survey boat was attached to the station anchor line. A GPS was used periodically to check that each station's anchor location had not moved. Dissolved oxygen and temperatures were taken using a YSI Pro Plus, with one meter increments marked on the probe cable. Near the end of the probe, a weight was added to minimize probe drift when lowering the sensor into the water column and while collecting readings at one meter intervals. Secchi depths to monitor water clarity were also taken during each weekly visit at each of the stations. Weather conditions and the time of surveys were also collected (Appendices I and II). Table 2 shows the UTMs for the four monitoring locations. Photos 2.1 and 2.2 (Figure 2) show representative photos of Secchi disc and the YSI meter used during the study.

Table 2: Location of four monitoring stations on Gitanyow Lake

Station Number	UTM	
	E	N
1 – North bottom	0555875	6137214
2 – North top	0556412	6136334
3 – South top	0556768	6134050
4 – South bottom	0557057	6133300

Figure 2: Representative photos of Secchi depth in process and YSI Pro Plus multimeter

Photo 2.1: lowering Secchi disc at one of the four sampling stations on Gitanyow Lake.

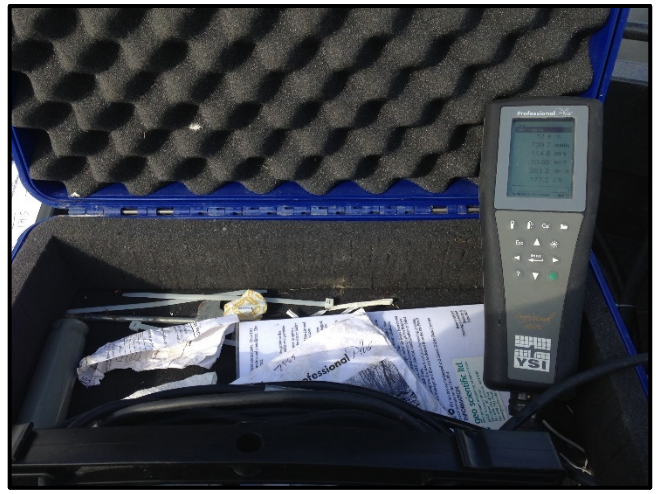


Photo 2.2: YSI Pro Plus used for oxygen and temperature readings at each monitoring site on Gitanyow Lake.

2.5 Acquisition of Broodstock and Egg Tube Installation

On October 26, eleven sockeye males (over half still ripe) and one spawned out sockeye female were captured near the shoreline of Area 3 on Gitanyow Lake. GFA crew on site used a 20 m beach seine along with a GFA boat to assist in closing the loop. Multiple sets were conducted, with the limiting factor being a lack of adult sockeye actively spawning at the site. On October 31 and November 3, 2016, additional visual surveys were conducted to acquire broodstock along the shores at Areas 1 and 3, with a more extensive shoreline reconnaissance conducted of Gitanyow Lake to see if spawning had occurred in alternate areas of the lake. Less than 11 adult sockeyes were observed past October 26 and fish were spread out in areas where they could not be effectively netted; therefore, no egg-to-fry survival was conducted in 2016. Figure 3 shows representative photos of broodstock netting and installation of the dataloggers.

Figure 3: Representative photos of broodstock netting and datalogger installation

Photo 3.1: view of Gitanyow Lake just south of Area 1

Photo 3.2: prepping net for deployment

Photo 3.3: netted adult sockeye male

Photo 3.4: installing dataloggers

2.6 Sockeye Fry Sampling

Two sinking 50 x 8-foot Swedish gill nets (one with 1.5 inch and other with 1-inch mesh) were set near the four long-term monitoring stations (Figure 1) over four sampling times in September, 2017. The first set was planned for 2 hours[3] and the remaining were left overnight, with a plan to reduce the set time, should large numbers of sockeye be caught after the initial overnight set. Lengths, weights and scales samples were to be collected from captured sockeye. Figure 4 shows a representative photo of a sinking gillnet set near long-term monitoring station 3.

[3] Due to boat problems, the initial set ended up being overnight

Figure 4: Representative photo of sinking gillnet set near station 3

3 RESULTS

3.1 Survey Timing

Table 3 shows the predicted sockeye timing to eyed, hatch, and emergence stages (DFO 2003).

Table 3: Predicted ATUs for sockeye to eyed, hatch and emergence stages

Stage	ATUs
Eyed	236-257
Hatch (alevin)	614-694
Emergence (fry)	928-1048

Although broodstock was not obtained to conduct an egg-to-fry survival analysis, spawning sockeye were observed. Figure 5 shows the ATUs calculated from the intragravel water temperature logged over the course of the study period for Area 1. The eyed stage is estimated to have occurred during the last two weeks of December, 2016, hatch from the end of March to the second week of April, 2017 and emergence extrapolated to occur during the first three weeks of June, 2017[4].

[4] The HOBO® logger DO sensor cap life are designed to expire 7 months after initialization, but the sensor caps at both Sites 1 and 3 expired prematurely on April 6, 2017 (~1.5 months earlier than anticipated).

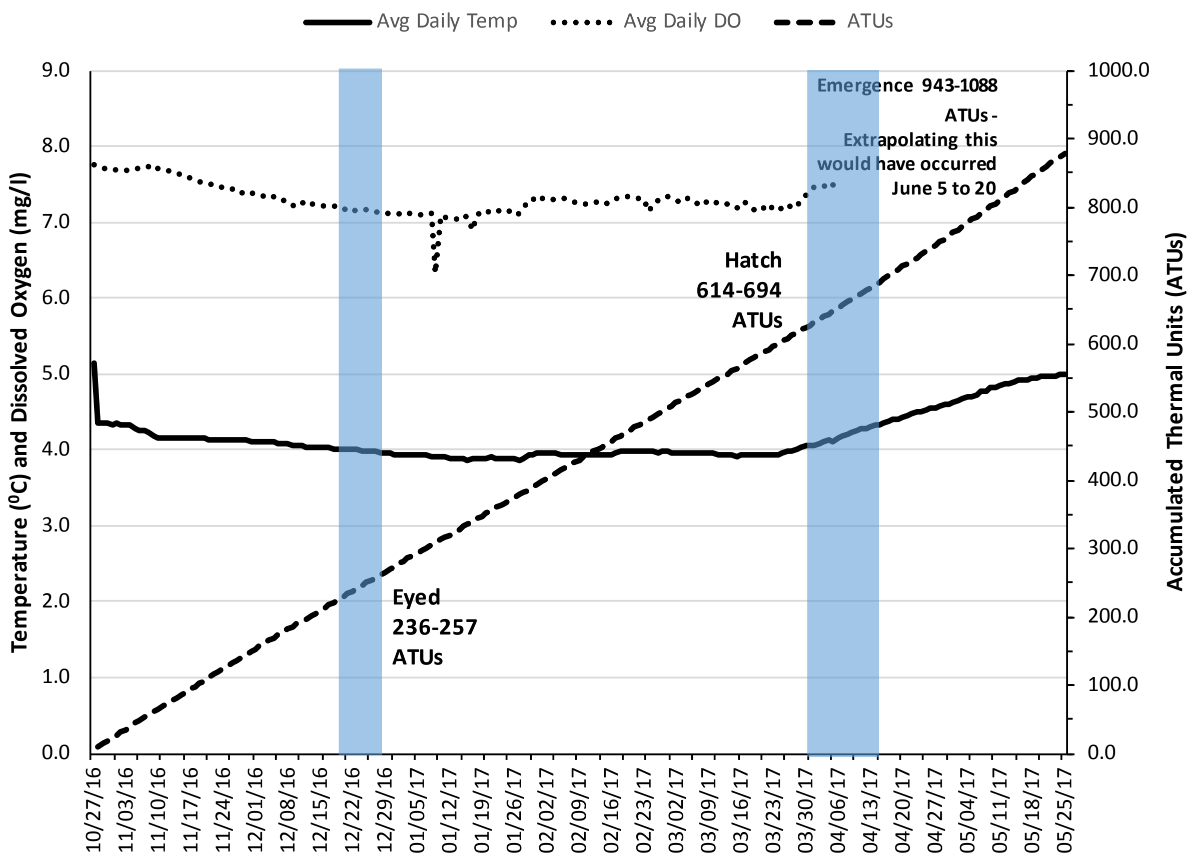


Figure 5: Area 1 - Average daily water temperature, average daily DO, and calculated ATUs

Figure 6 shows the ATUs calculated from the intragravel water temperature logged over the course of the study period for Area 3. The eyed stage is estimated to have occurred during the first two weeks of December, 2016, hatch from the third week in February to the second week of March, 2017 and emergence estimated to occur during May of 2017.

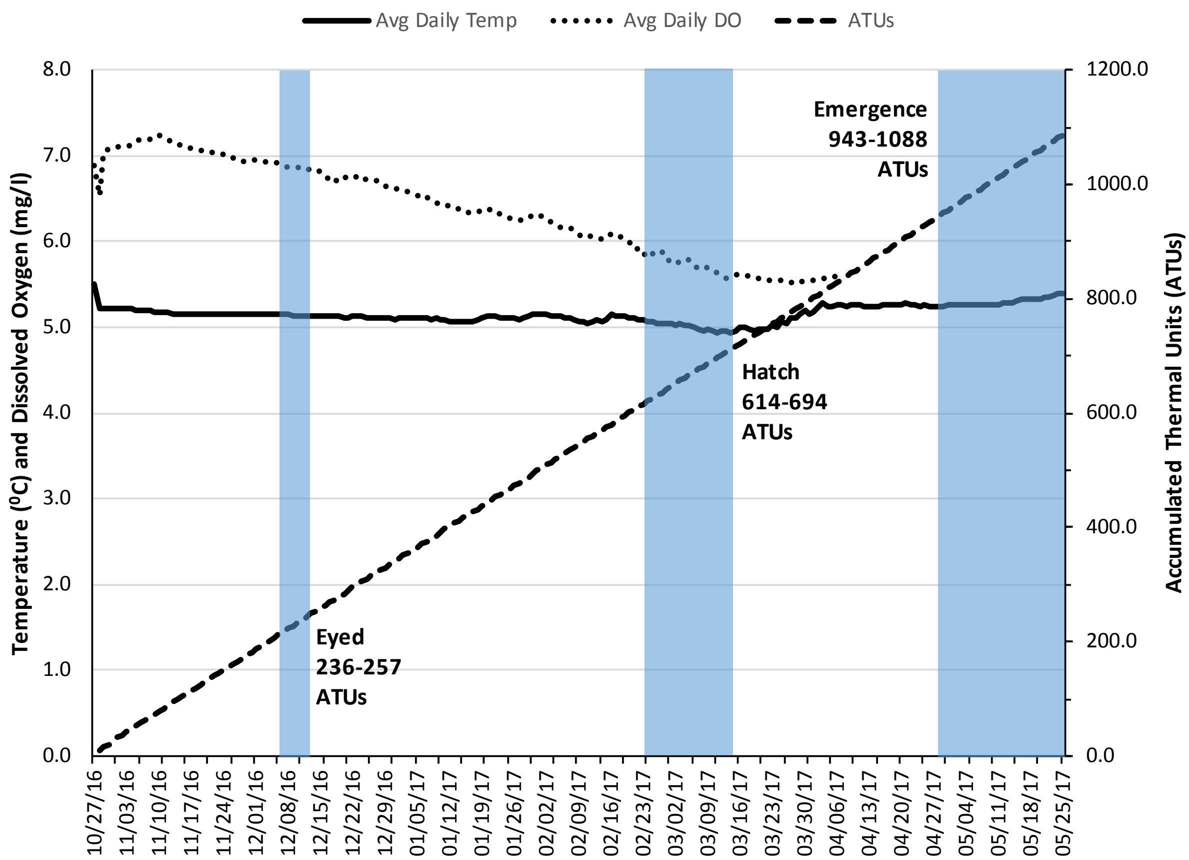


Figure 6: Area 3 - Average daily water temperature, average daily DO, and calculated ATUs

3.2 Sockeye Spawning Area Monitoring and Locations

Sockeye spawning area monitoring was conducted at two locations on a weekly basis starting on August 26, 2016 and finishing on November 3, 2016[5]. Table 4 shows sockeye numbers and activity observed over the monitoring period. Limited sockeyes were observed during their typical spawning period - mid-September to the end of the November with peak spawning occurring from mid to late October (Cleveland 2000, Cleveland 2002). Fifteen adult sockeyes were observed during the survey dates leading up to the brood stock attempts (October 26, 31 and November 3). Table 4 shows the spawning activity by location in 2016.

Table 4: Spawning area monitoring and locations

Date	Area 1	Area 3	Total	Comments
August 26, 2016	0	0	**0**	No redds or spawning observed
September 6, 2016	0	1	**1**	No redds observed. One sockeye observed in Area 3
September 14, 2016	0	0	**0**	No redds or spawning observed
September 26, 2016	0	0	**0**	No redds or spawning observed
September 27, 2016	0	0	**0**	No redds or spawning observed

[5] Due to low numbers observed at Areas 1 and 3 from September to early November, other areas of the lake were surveyed to check for alternate 2016 spawning activity – none were observed.

Date	Area 1	Area 3	Total	Comments
September 29, 2016	0	0	**0**	No redds or spawning observed
October 6, 2016	0	0	**0**	No redds or spawning observed
October 11, 2016	0	0	**0**	No redds or spawning observed
October 18, 2016	0	3	**3**	Spawning activity observed as well as redd locations.
October 26, 2016	0	11	**11**	Spawning activity observed as well as redd locations
October 31, 2016	3	8	**11**	Spawning activity observed as well as redd locations
November 3, 2016	3	5	**8**	Spawning activity observed as well as redd locations
Total	**6**	**28**	**34**	

3.3 Physicochemical Parameters

HOBO® dissolved oxygen loggers and Tidbit® v2 TempLoggers buried on October 26, 2016 at Areas 1 and 3 (between 11:45 and 12:45). were removed on June 19, 2017. The datalogger at Area 1 was removed at 14:15 and was still completely buried. The datalogger buried at Area 3, was removed at 14:00 and was also fully buried. Table 5 shows the maximum, minimum, standard deviation and averaged DO and water temperatures for the study period for each location, as well as 2015/2016 data for comparison.

Table 5: Intragravel DO and water temperatures – October 26, 2016 to June 19, 2017* with November 4/5, 2015 to June 2, 2016 for comparison

	Year	Dissolved oxygen (mg/l)*				Temperature (⁰C)			
		Avg.	Min.	Max.	StDev.	Avg.	Min.	Max.	StDev.
Area 1	2016/2017	7.3	4.4	7.8	0.2	4.3	3.9	5.3	0.4
	2015/2016	6.8	5.8	8.6	0.9	4.8	4.5	5.3	0.2
Area 3	2016/2017	6.4	5.4	7.2	0.1	5.2	4.8	5.9	0.1
	2015/2016	6.4	4.3	10.9	1.3	4.2	1.2	13.5	3.1

* Note, The HOBO® logger DO sensor cap life are designed to expire 7 months after initialization, but the sensor caps at both Sites 1 and 3 expired prematurely on April 6, 2017 (~1.5 months earlier than anticipated).

The BC guidelines for intergravel DO for embryo and alevin stages include an instantaneous minimum of 6 mg/L and a 30-day mean not lower than 8 mg/L. (RIC 1998). Bjornn and Reiser (1991) after conducting a reference review, recommend that DO be no lower than 5 mg/l and should be at or near saturation for successful incubation. The average DO calculated for both areas is on the low side in relation to the thresholds provided in both references, and without follow-up data, is difficult to assess as an issue as overall egg-to-fry survival rates during the 2015/2016 egg-to-fry study were good (Beblow 2016). The U.S. Environmental Protection Agency (1986) noted that at a dissolved oxygen concentration of 6 mg/l that a slight production impairment would occur for salmonids[6].

[6] Referenced in: Carter 2005

In 2006/2007 Kitwanga sockeye salmon culture was used to supplement natural production (Cleveland 2007). Results from the study period showed that Kitwanga sockeye eggs were small with an average weight of only 0.087g ranging from 0.061g to 0.110g (n=20,366). In comparison, eggs from Scully Creek in the Lakelse system, and eggs from the Babine River showed egg weight averages of 0.146g per egg (Groot & Margolis, 1998). Given that Kitwanga sockeye are lake spawners it is quite possible that the smaller egg size observed in 2006 is a local adaptation used to promote embryo survival in the gravel given that the development probably takes place under reduced oxygen conditions (Groot and Margolis, 1998).

In Bjornn and Reiser (1991), Bell (1986) provides a recommended temperature range for incubation intergravel temperature of 4.4 to 13.3 ^{0}C. As noted in Table 4, average water temperatures were at the low end of the recommended threshold for Area 1, but Bell (1986) also notes that survival and development of egg-to-fry does occur at lower temperatures (i.e., < 4,4 ^{0}C), provided initial development has occurred at temperatures > 4,4 ^{0}C. The initial intragravel water temperatures were at or near 4.4^{0}C until the second week of November at Area 1, which may have limited development and/or survival. It should be noted that survival to the fry stage was 88% (from total of 2400 fertilized eggs buried) during the first year of the study (2015/2016) at Area 1 with a similar average water temperature (4.8^{0}C 2015/2016 vs. 4.3^{0}C 2016/2017 - Table 5),

Figures 7 and 8 show the temperature and DO graphed for each area.

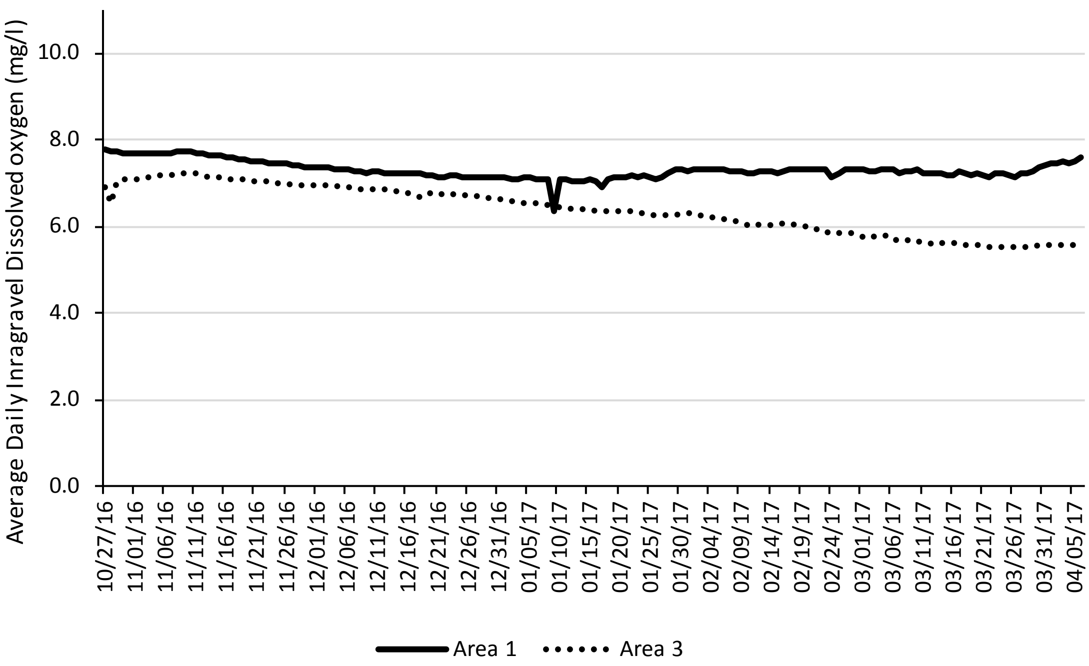


Figure 7: Average daily water intragravel DO Areas 1 and 3

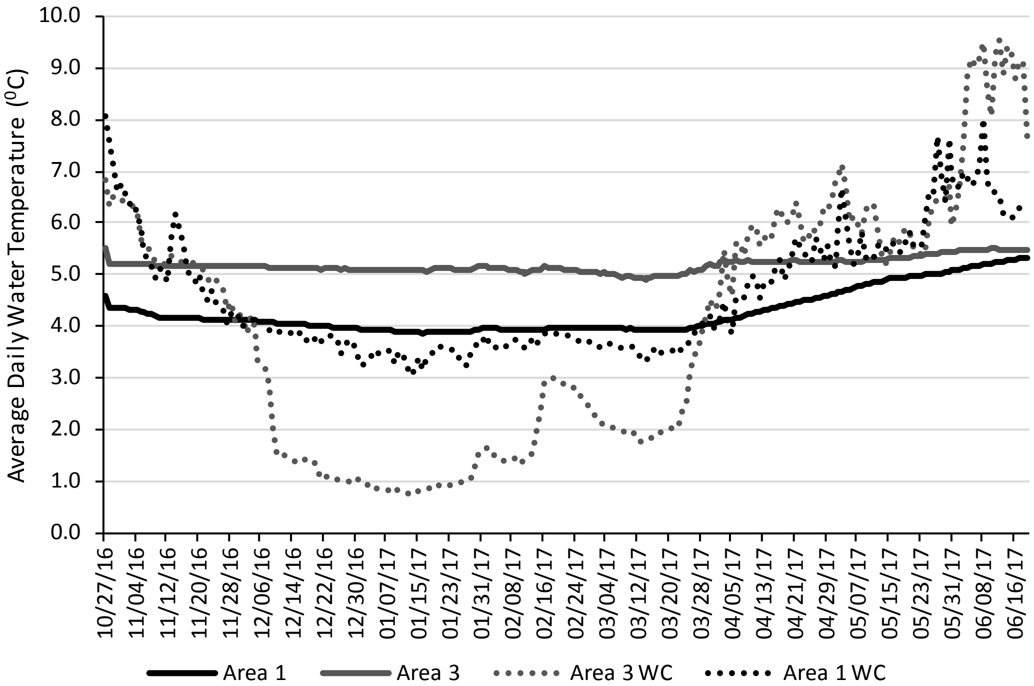


Figure 8: Average daily intragravel and water column (WC) water temperature Areas 1 and 3

In Figure 8, the relative stability of intragravel water temperatures at Areas 1 and 3 is evident, compared to the variances observed in the water column temperatures (surface of gravels) at both sites.

Given that egg-to-fry survival was 88% at Area 1 in 2015/2016 with a similar intragravel temperature range (Table 5), temperature did not appear to be severely limiting egg-to-fry survival at Areas 1 and 3 in 2016/2017.

3.4 Dissolved Oxygen/Temperature Profiles

Over 13 weekly visits from July 15, 2016 to October 18, 2016, DO and temperature profiles were conducted at the four designated long-term monitoring stations. Raw DO and temperature data is presented in Appendix III and profile graphs in Appendix IV.

Figure 9 shows differing lake conditions over the course of the study period, where more optimal DO and temperature conditions, i.e., > 5 mg/l and < 20^{0}C are expanded through the water column and in contrast, limited to a layer of the water column at a given monitoring location. The blue square represents a depth range within the optimal parameters.

Dissolved oxygen and temperature profiles showed that there were periods in July that available threshold DO and water temperatures (i.e. >5 mg/l and < 200C – Bjornn and Reiser 1991) were limited to a depth stratum of:

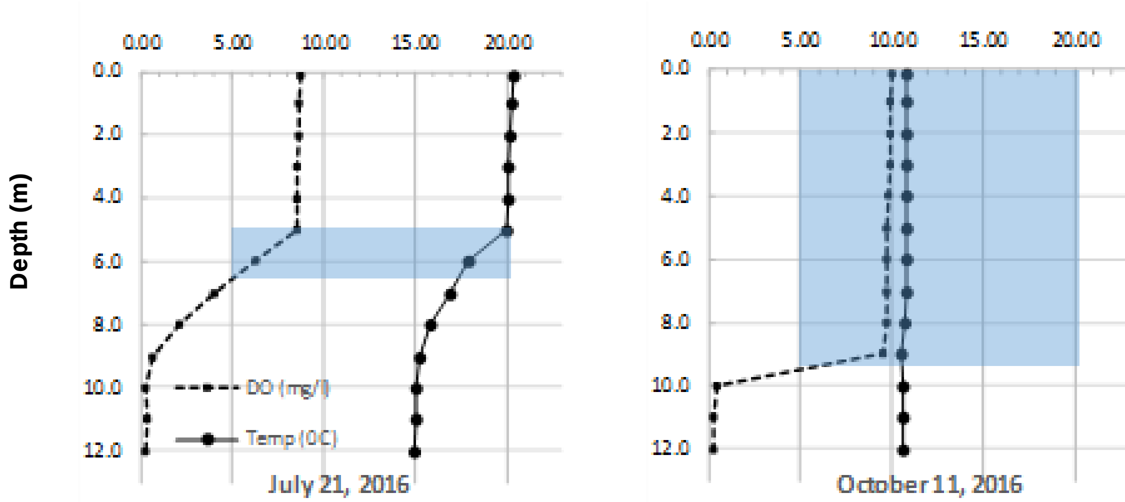
- Between 3 and 7 m at Site 1 and 2 (North Basin) which corresponded to the shallower of the four stations (~12 m depth versus ~15 m depth at sites 3 and 4); and

- Between 4 and 11 m at sites 3 and 4 (South Basin).

Figure 9: Select DO/temp profiles from the four monitoring stations - blue square represents a depth range within the optimal parameters

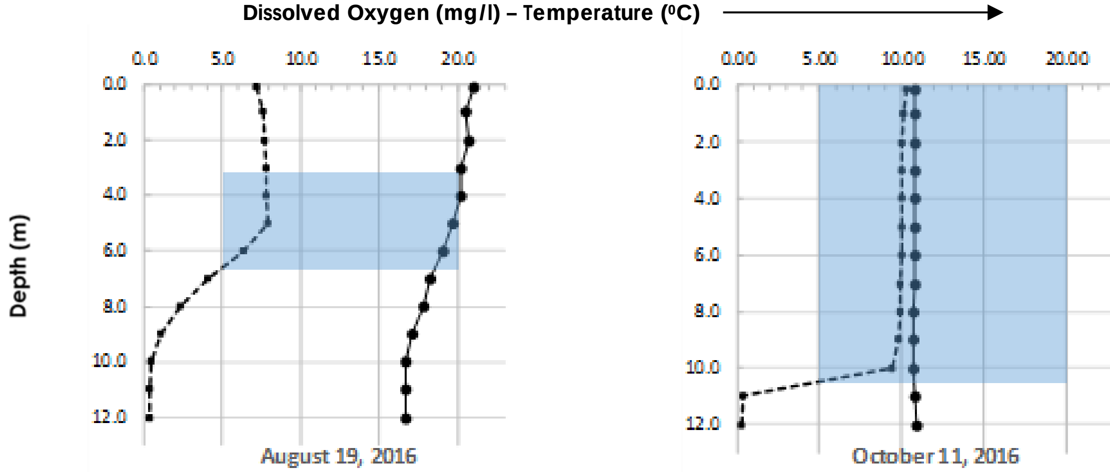
Station 1

Dissolved Oxygen (mg/l) – Temperature (ºC) →



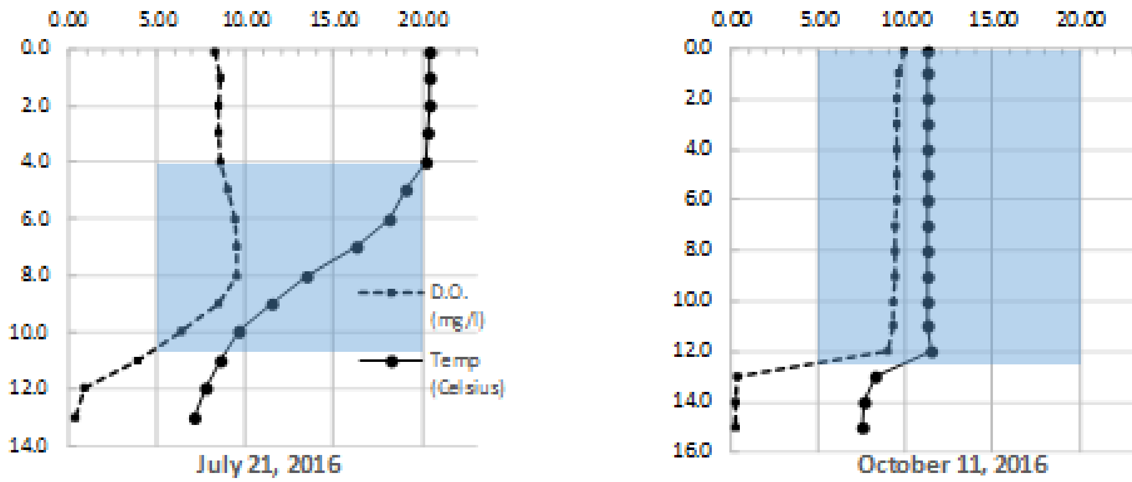
Station 2

Dissolved Oxygen (mg/l) – Temperature (ºC) →



Station 3

Dissolved Oxygen (mg/l) – Temperature (°C)



Station 4

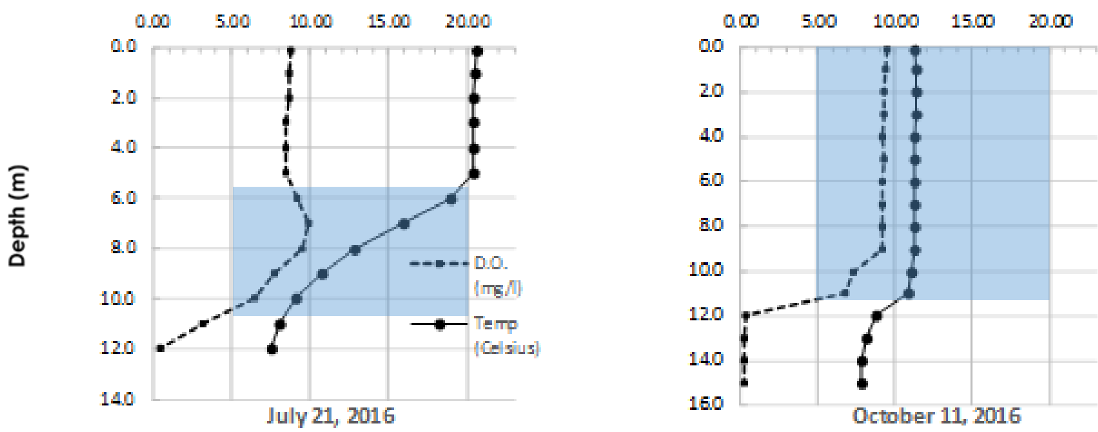


Table 6 and Figure 10 show the Secchi depths observed during weekly visits over the study period. Secchi depths ranged from 20% (2.4 m) to 43% (5.2 m) of the total estimated depth (12 m) at sites 1 and 2 (North Basin). At sites 3 and 4 (South Basin), Secchi depths ranged from 18% (2.7 m) to 61% (9.1 m) of the total estimated depth (15 m). The lowest water clarity at all sites occurred on October 18, 2016 (Table 6 and Figure 10).

Table 6: Secchi depths (m) at four monitoring stations

Date	Station 1	Station 2	Station 3	Station 4
15-Jul-16	4.88	4.88	7.01	7.01
21-Jul-16	5.18	5.18	7.32	7.62
29-Jul-16	4.27	4.27	6.71	6.71
03-Aug-16	3.66	3.66	6.10	6.10
10-Aug-16	4.27	4.27	7.62	7.32
19-Aug-16	4.27	4.27	7.62	7.32
26-Aug-16	4.27	4.57	8.84	8.53

Date	Station 1	Station 2	Station 3	Station 4
06-Sep-16	3.66	3.05	7.92	6.10
14-Sep-16	3.20	2.74	6.55	7.01
26-Sep-16	2.90	3.35	7.62	9.14
06-Oct-16	3.96	3.96	8.23	8.53
11-Oct-16	2.74	3.05	4.88	5.18
18-Oct-16	2.44	2.44	2.74	3.05

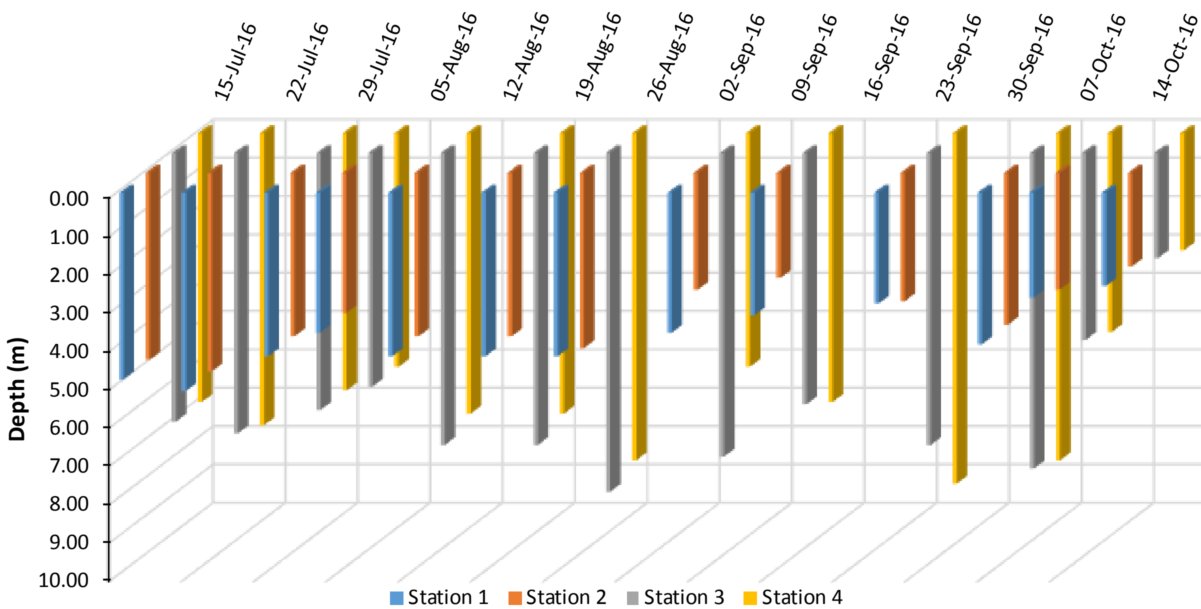


Figure 10: Secchi depths at four monitoring locations

3.5 Sockeye Fry Sampling

No sockeye fry/juveniles were captured during four gillnet sets during sampling periods from September 14 to 29, 2016. The primary species captured were Northern pikeminnow (*Ptychocheilus oregonensis*, n=225), Peamouth chub (*Mylocheilus caurinus*, n=22) and Rainbow trout (*Oncorhynchus mykiss*, n=8), Table 7 shows the numbers by species captured during the gillnet sampling, Figure 11 shows a representative photo of a Peamouth chub and a Northern pikeminnow.

Table 7: Number/species of fish captured gillnet sampling – September 14 to 29, 2017

Peamouth Chub	Northern Pikeminnow	Rainbow Trout	Dolly Varden	Cutthroat Trout	Largescale Sucker	Coho	Bull Trout	Sculpin
225	22	8	4	3	2	1	1	1

Figure 11: Photos of Peamouth chub and Northern pikeminnow

Photo 11.1: Peamouth chub

Photo 11.2: Northern pikeminnow

4 SUMMARY AND RECOMMENDATIONS

For the first year of this study, from November 4, 2015 to June 15, 2016, spawning conditions in the hyporheic zone at Areas 1 and 3, were not deemed to be limiting overall egg-to-fry survival. The average survival to the fry emergence stage at Area 1 was 88% ± 11 and at Area 3, 87% ± 11 (Beblow 2016). These results compare favorably with those found by Kingston (2009) six and seven years earlier, where egg-to-fry survival exceeded 85% from Kitwanga sockeye broodstock cultured at the Kispiox Hatchery under much more controlled conditions.

During weekly surveys on Gitanyow Lake beginning on August 26 and extending to November 3, 2016, which encompassed the historical peak sockeye spawning period, a maximum of 11 adult sockeyes were observed on October 26 and again on October 31; therefore, no egg-to-fry survival was conducted in 2016.

A total of 1,100 sockeyes were estimated to return through the Kitwanga River Salmon Enumeration Facility (KSEF) and the Kitwanga River Smolt Enumeration Facility (KsF) in 2016

The KSEF closed on September 1, 2016, due to extreme high flows, which threatened the safety of the GFA staff and risked damage to the facility. Within 30 hours of the KSEF being shut down, GFA staff were able to set-up and modify the KsF just below Gitanyow Lake to continue to count adult sockeye and coho from September 2nd to November 2nd, 2016. GFA does not believe any sockeye were missed in 2016. However, some may have been double counted and a range of 970 to 1,318 is estimated, with an overall estimated return of 1,100 (Beblow and Cleveland 2016).

The KSEF counting fence is located on the Kitwanga River about 4 Km upstream from the confluence of the Kitwanga and Skeena Rivers and downstream of most Kitwanga salmon spawning areas (Cleveland, 2004). The KSEF operates during the summer and fall months and uses aluminum panels to funnel fish into one of two counting stations located on the left and right banks of the Kitwanga River. From late fall through to the following summer, fence panels and counting boxes are removed allowing fish unimpeded movement past the site when it is not in operation. The Kitwanga River at the KSEF site is about 30m wide and the facility spans perpendicular to the rivers flow.

The operation of the KSEF in 2016 marked the 14th consecutive year the fence was operational. Crews of two fisheries technicians visually enumerated and counted salmon daily as they swam through each counting chute. One GFA technician would work on the right bank counting station and the other on the left during each shift. The hours of operation were during daylight hours only. The KSEF is closed nightly preventing upstream migration between dusk and dawn.

On the Kitwanga River near the mouth at the KSEF, from July 18 to August 29, the 2016 average water levels were only 0.60m, compared to a mean of 0.73m for the 2004-2015 period. The Skeena River was at record low water during this period (Gottesfeld, SFC, Pers. comm., 2016). Furthermore, water levels in the Kitwanga River below Gitanyow Lake were also very low, so low that on August 26, during a stream walk, GFA crews found a 1.2km section of the Kitwanga River, between Gitanyow Lake and Moonlit Creek completely dry (Figure 12).

Figure 12: Photos showing dry section of Kitwanga River

Dissolved oxygen and water temperature in the hyporheic zone provided conditions for adequate egg-to-fry survival at selected spawning areas in Gitanyow Lake. Area 1 had slightly more variability than Area 3 for both dissolved oxygen and temperature from a minimum of 4.4 mg/l and 3.9^{0}C to a maximum of 7.8 mg/l and 5.3^{0}C (SD – 0.2 and 0.4 respectively). While the dissolved oxygen did dip below 5 mg/l at Area 1 for a short period (~5 hr on January 19, 2017), which is usually the threshold where egg survival is affected adversely, similar hyporheic conditions were present in 2015/2016, in which egg-to-fry survival was 88%.

In looking at the DO/temp profiles conducted at four monitoring locations, there are periods where low DO and high water temperatures, defined as < 5 mg/l and > 20^{0}C respectively, are likely limiting where sockeye fry and smolts are able to reside in the water column. However, it should be noted that adequate limnological conditions were present in some parts of both the north and south basins of Gitanyow Lake throughout the summer and fall of 2016.

No sockeye fry/juveniles were captured during four sinking gillnet sets conducted near the four long-term monitoring stations in September of 2016. It is recommended that a smaller mesh size be used for follow-up sampling (1.5 and 1-inch mesh size were used in 2016).

As part of the objectives of follow-up studies, it is recommended that reconnaissance and mapping of aquatic vegetation being undertaken to monitor the encroachment onto sockeye spawning grounds (originally conducted in 2002 – Cleveland and McCarthy 2003). In addition, looking at potential heightened predation pressure by Northern pikeminnow be added to the discussion (gut content analysis), especially in lieu of low smolt numbers seen through the Kitwanga smolt fence (KSF) this past spring and in 2016 and 2015 (n=11,914, 33,423 and 12,165 respectively).

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6 APPENDICES

Appendix I: Blank Lake Data Form

Gitanyow Lake Sampling 2017

Crew: ______________________

Station #1 (North Top)			Station #2 (North Bottom)			Station #3 (South Top)			Station #4 (South Bottom)	
Date:			Date:			Date:			Date:	
Time			Time			Time			Time	
Air Temp:			Air Temp:			Air Temp:			Air Temp:	
Wind Speed			Wind Speed			Wind Speed			Wind Speed	
Direction:			Direction:			Direction:			Direction:	
Cloud Cover			Cloud Cover			Cloud Cover			Cloud Cover	
UTM:	09 0555875		UTM:	09 0556412		UTM:	09 0556768		UTM:	09 0557057
	6137214			6136334			6134050			6133300
Seechi Depth:	ft		Seechi Depth:	ft		Seechi Depth:	ft		Seechi Depth:	ft
Comments:			Comments:			Comments:			Comments:	

Station #1 (North Top)			Station #2 (North Bottom)			Station #3 (South Top)			Station #4 (South Bottom)		
Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)

Appendix II: Time of Survey - Weather

Station 1

Date	Time	Air Temp (^{0}C)	Wind Speed (km)	Wind Direction	Cloud Cover (%)
15-Jul-16	15:38	27	0-3	N/A	20
21-Jul-16	15:21	17	0	N/A	98
29-Jul-16	12:21	20.5	15	S	95
03-Aug-16	14:58	16.1	15-20	S	85
10-Aug-16	15:02	21.9	10-15	S	100
19-Aug-16	12:26	22.1	0	N/A	20
26-Aug-16	14:56	21.9	3	S	100
06-Sep-16	15:38	15.8	0	S	60
14-Sep-16	11:27	18.1	0-3	NW	80
26-Sep-16	14:57	13.7	10-15	SW	90
06-Oct-16	10:04	9.1	0-5	S	100
11-Oct-16	15:05	7.6	10	N	0
18-Oct-16	15:27	9.5	10-15	S	90

Station 2

Date	Time	Air Temp (^{0}C)	Wind Speed (km)	Wind Direction	Cloud Cover (%)
15-Jul-16	15:52	27	0-3	N/A	20
21-Jul-16	15:43	17.6	0-5	S	98
29-Jul-16	12:32	20.5	15	S	95
03-Aug-16	15:24	16	15-20	S	80
10-Aug-16	14:48	21.9	10-15	S	100
19-Aug-16	12:35	22.1	0	S	200
26-Aug-16	14:30	21.9	3	S	100
06-Sep-16	15:15	17.3	0	N/A	60
14-Sep-16	11:59	15.6	0-3	NW	70
26-Sep-16	16:00	11.9	0-5	SW	70
06-Oct-16	10:26	7.3	0-5	S	100
11-Oct-16	14:45	8.3	10	N	0
18-Oct-16	15:14	7.7	10-15	S	80

Station 3

Date	Time	Air Temp (^{0}C)	Wind Speed (km)	Wind Direction	Cloud Cover (%)
15-Jul-16	14:53	27	0-3	N/A	20
21-Jul-16	15:00	16	0	N/A	95
29-Jul-16	11:37	20.5	5	S	99
03-Aug-16	14:22	20.4	15-20	S	99
10-Aug-16	15:17	17.2	1-2	S	100
19-Aug-16	13:00	19.3	30	S	70
26-Aug-16	15:23	22	0	N/A	100
06-Sep-16	16:20	14.6	3	S	90
14-Sep-16	12:23	15.3	0-3	NW	70
26-Sep-16	16:21	12.6	0-5	SW	40
06-Oct-16	10:45	7.2	0.00	N/A	100
11-Oct-16	15:41	7.5	5	N	0
18-Oct-16	14:41	8.5	0-5	S	50

Station 4

Date	Time	Air Temp (^{0}C)	Wind Speed (km)	Wind Direction	Cloud Cover (%)
15-Jul-16	15:15	27	0-3	-	20
21-Jul-16	14:40	16	0	N/A	95
29-Jul-16	11:56	20.5	10	S	99
03-Aug-16	13:53	20.4	15-20	S	99
10-Aug-16	15:33	17.2	5	S	100
19-Aug-16	13:22	19.3	0	N/A	70
26-Aug-16	15:52	22	0	N/A	95
06-Sep-16	16:03	15.3	0	N/A	80
14-Sep-16	12:40	15.1	3-5	NW	70
26-Sep-16	16:33	12.1	0-5	SW	30
06-Oct-16	10:55	8.2	0	NA	100
11-Oct-16	15:30	6.9	2	N	0
18-Oct-16	14:32	8.5	0-5	S	60

Appendix III: Dissolved Oxygen/Water Temperature Raw Data

Date	Station 1			Station 2		
	Depth (m)	DO (mg/l)	Temp (^0C)	Depth (m)	DO (mg/l)	Temp (^0C)
15-Jul-16	0.1	9.20	21.2	0.1	9.40	22.1
15-Jul-16	1.0	9.26	19.9	1.0	9.53	20.5
15-Jul-16	2.0	9.10	19.5	2.0	9.20	20.0
15-Jul-16	3.0	9.16	19.3	3.0	9.22	19.6
15-Jul-16	4.0	9.12	19.3	4.0	8.96	19.4
15-Jul-16	5.0	8.55	18.8	5.0	8.11	18.3
15-Jul-16	6.0	7.42	17.6	6.0	7.37	17.6
15-Jul-16	7.0	5.83	16.6	7.0	5.72	16.6
15-Jul-16	8.0	2.27	15.1	8.0	4.89	16.4
15-Jul-16	9.0	1.39	14.8	9.0	1.75	15.3
15-Jul-16	10.0	0.50	14.8	10.0	0.40	14.9
15-Jul-16	11.0	0.38	14.8	11.0	0.37	15.0
15-Jul-16	12.0	0.35	14.8			
21-Jul-16	0.1	8.76	20.4	0.1	8.81	20.7
21-Jul-16	1.0	8.64	20.3	1.0	8.70	20.6
21-Jul-16	2.0	8.62	20.2	2.0	8.50	20.4
21-Jul-16	3.0	8.58	20.1	3.0	8.54	20.4
21-Jul-16	4.0	8.53	20.1	4.0	8.49	20.2
21-Jul-16	5.0	8.52	20.0	5.0	8.35	19.8
21-Jul-16	6.0	6.28	17.9	6.0	7.91	19.3
21-Jul-16	7.0	4.06	16.9	7.0	4.86	17.3
21-Jul-16	8.0	2.20	15.9	8.0	1.27	15.9
21-Jul-16	9.0	0.68	15.3	9.0	0.44	15.1
21-Jul-16	10.0	0.27	15.1	10.0	0.21	15.1
21-Jul-16	11.0	0.41	15.1	11.0	0.18	15.0
21-Jul-16	12.0	0.32	15.0	12.0	0.17	15.0
29-Jul-16	0.1	9.12	19.0	0.1	9.10	19.3
29-Jul-16	1.0	9.00	19.0	1.0	9.00	19.3
29-Jul-16	2.0	8.90	19.0	2.0	8.95	19.3
29-Jul-16	3.0	8.88	18.9	3.0	8.92	19.1
29-Jul-16	4.0	8.85	18.8	4.0	8.75	19.0
29-Jul-16	5.0	8.78	18.8	5.0	8.72	18.9
29-Jul-16	6.0	8.67	18.8	6.0	8.71	18.8
29-Jul-16	7.0	6.57	17.9	7.0	8.38	18.8
29-Jul-16	8.0	1.67	16.6	8.0	1.41	16.5
29-Jul-16	9.0	0.42	15.6	9.0	0.30	15.9
29-Jul-16	10.0	0.25	15.4	10.0	0.31	15.2
29-Jul-16	11.0	0.20	15.3	11.0	0.33	15.2
29-Jul-16	12.0	0.21	15.4	12.0	0.25	15.3
03-Aug-16	0.1	8.82	19.2	0.1	8.86	19.6
03-Aug-16	1.0	8.88	19.3	1.0	8.73	19.6
03-Aug-16	2.0	8.86	19.2	2.0	8.79	19.7
03-Aug-16	3.0	8.70	18.7	3.0	8.65	19.6

Date	Station 1			Station 2		
	Depth (m)	DO (mg/l)	Temp (^0C)	Depth (m)	DO (mg/l)	Temp (^0C)
03-Aug-16	4.0	8.56	18.6	4.0	8.73	19.3
03-Aug-16	5.0	8.52	18.6	5.0	8.60	19.3
03-Aug-16	6.0	8.22	18.5	6.0	8.50	19.2
03-Aug-16	7.0	8.31	18.5	7.0	8.54	18.8
03-Aug-16	8.0	7.55	18.1	8.0	1.98	16.9
03-Aug-16	9.0	1.14	16.9	9.0	0.74	16.2
03-Aug-16	10.0	0.16	16.1	10.0	0.18	15.9
03-Aug-16	11.0	0.12	16.0	11.0	0.15	15.9
03-Aug-16	12.0	0.12	16.0	12.0	0.13	15.9
10-Aug-16	0.1	8.94	19.9	0.1	8.77	20.4
10-Aug-16	1.0	8.93	19.9	1.0	8.80	20.4
10-Aug-16	2.0	8.89	19.9	2.0	8.83	20.3
10-Aug-16	3.0	8.88	19.9	3.0	8.76	20.3
10-Aug-16	4.0	8.92	19.7	4.0	8.80	20.0
10-Aug-16	5.0	8.96	19.5	5.0	8.80	19.8
10-Aug-16	6.0	8.72	19.0	6.0	8.24	19.2
10-Aug-16	7.0	8.11	18.5	7.0	6.77	18.7
10-Aug-16	8.0	6.48	18.0	8.0	5.73	17.9
10-Aug-16	9.0	1.00	16.7	9.0	2.80	17.1
10-Aug-16	10.0	0.45	16.4	10.0	0.64	16.6
10-Aug-16	11.0	0.37	16.4	11.0	0.44	16.6
10-Aug-16	12.0	0.33	16.4	12.0	0.36	16.6
19-Aug-16	0.1	7.4	20.9	0.1	7.2	21.0
19-Aug-16	1.0	7.5	20.3	1.0	7.6	20.5
19-Aug-16	2.0	7.6	20.0	2.0	7.7	20.7
19-Aug-16	3.0	7.8	19.8	3.0	7.8	20.2
19-Aug-16	4.0	7.7	19.7	4.0	7.8	20.2
19-Aug-16	5.0	7.7	19.4	5.0	8.0	19.7
19-Aug-16	6.0	7.7	19.1	6.0	6.4	19.1
19-Aug-16	7.0	7.6	19.0	7.0	4.1	18.2
19-Aug-16	8.0	3.8	18.0	8.0	2.3	17.8
19-Aug-16	9.0	1.1	17.2	9.0	1.1	17.1
19-Aug-16	10.0	0.6	17.0	10.0	0.5	16.7
19-Aug-16	11.0	0.5	17.0	11.0	0.4	16.7
19-Aug-16	12.0	0.5	17.0	12.0	0.4	16.7
26-Aug-16	0.1	7.61	19.70	0.1	6.72	20.10
26-Aug-16	1.0	7.61	19.70	1.0	6.91	20.10
26-Aug-16	2.0	7.69	19.70	2.0	6.94	19.90
26-Aug-16	3.0	7.72	19.50	3.0	6.95	19.70
26-Aug-16	4.0	7.50	19.30	4.0	6.99	19.60
26-Aug-16	5.0	7.29	19.10	5.0	6.94	19.50
26-Aug-16	6.0	7.26	18.90	6.0	6.02	19.00
26-Aug-16	7.0	7.23	18.80	7.0	4.92	18.50

Date	Station 1			Station 2		
	Depth (m)	DO (mg/l)	Temp (^0C)	Depth (m)	DO (mg/l)	Temp (^0C)
26-Aug-16	8.0	5.52	18.40	8.0	3.64	18.20
26-Aug-16	9.0	0.70	17.60	9.0	3.12	18.10
26-Aug-16	10.0	0.40	17.30	10.0	1.22	17.70
26-Aug-16	11.0	0.34	17.30	11.0	0.60	17.50
26-Aug-16	12.0	0.30	17.30	12.0	0.50	17.50
06-Sep-16	0.1	8.24	17.80	0.1	7.85	17.60
06-Sep-16	1.0	8.09	17.60	1.0	7.58	17.30
06-Sep-16	2.0	8.20	17.30	2.0	7.49	17.20
06-Sep-16	3.0	8.17	17.20	3.0	7.38	17.20
06-Sep-16	4.0	8.11	17.10	4.0	7.47	17.20
06-Sep-16	5.0	8.05	17.10	5.0	7.28	17.20
06-Sep-16	6.0	7.95	17.10	6.0	7.48	17.10
06-Sep-16	7.0	7.74	17.10	7.0	7.26	17.10
06-Sep-16	8.0	6.58	16.90	8.0	7.01	17.10
06-Sep-16	9.0	4.10	16.30	9.0	3.80	16.60
06-Sep-16	10.0	0.17	16.20	10.0	0.19	16.40
06-Sep-16	11.0	0.15	16.20	11.0	0.13	16.40
06-Sep-16	12.0	0.14	16.20	12.0	0.12	16.40
14-Sep-16	0.1	8.81	16.60	0.1	8.56	16.80
14-Sep-16	1.0	8.77	16.30	1.0	8.35	16.40
14-Sep-16	2.0	8.72	16.20	2.0	8.50	16.20
14-Sep-16	3.0	7.74	16.00	3.0	8.28	16.10
14-Sep-16	4.0	7.34	15.90	4.0	7.93	16.10
14-Sep-16	5.0	7.77	15.80	5.0	7.54	16.00
14-Sep-16	6.0	7.78	15.80	6.0	7.74	15.90
14-Sep-16	7.0	7.77	15.70	7.0	6.72	15.60
14-Sep-16	8.0	8.00	15.40	8.0	6.67	15.20
14-Sep-16	9.0	5.11	14.60	9.0	6.18	15.00
14-Sep-16	10.0	0.78	14.60	10.0	0.28	14.90
14-Sep-16	11.0	0.28	14.60	11.0	0.22	14.90
14-Sep-16	12.0	0.21	14.60	12.0	0.20	14.90
26-Sep-16	0.1	9.29	14.10	0.1	9.17	14.10
26-Sep-16	1.0	9.28	14.10	1.0	9.18	14.10
26-Sep-16	2.0	9.21	14.10	2.0	9.17	14.10
26-Sep-16	3.0	9.20	14.10	3.0	9.12	14.10
26-Sep-16	4.0	9.16	14.10	4.0	9.11	14.10
26-Sep-16	5.0	9.15	14.10	5.0	8.99	14.10
26-Sep-16	6.0	9.10	14.10	6.0	9.07	14.10
26-Sep-16	7.0	9.07	14.10	7.0	9.02	14.10
26-Sep-16	8.0	8.96	14.10	8.0	9.00	14.10
26-Sep-16	9.0	8.93	14.10	9.0	9.01	14.10
26-Sep-16	10.0	0.37	14.10	10.0	0.35	14.10
26-Sep-16	11.0	0.23	14.10	11.0	0.23	14.10

Date	Station 1			Station 2		
	Depth (m)	DO (mg/l)	Temp (^0C)	Depth (m)	DO (mg/l)	Temp (^0C)
26-Sep-16	12.0	0.19	14.10	12.0	0.22	14.10
06-Oct-16	0.1	9.55	12.00	0.1	9.45	12.20
06-Oct-16	1.0	9.59	12.00	1.0	9.37	12.20
06-Oct-16	2.0	9.59	12.00	2.0	9.32	12.20
06-Oct-16	3.0	9.54	12.00	3.0	9.27	12.20
06-Oct-16	4.0	9.56	12.00	4.0	9.35	12.20
06-Oct-16	5.0	9.56	12.00	5.0	9.32	12.20
06-Oct-16	6.0	9.56	12.00	6.0	9.46	12.20
06-Oct-16	7.0	9.76	11.90	7.0	9.47	12.20
06-Oct-16	8.0	9.83	11.90	8.0	9.46	12.20
06-Oct-16	9.0	9.81	11.90	9.0	9.32	12.20
06-Oct-16	10.0	0.40	12.00	10.0	0.36	11.80
06-Oct-16	11.0	0.26	12.00	11.0	0.32	11.90
06-Oct-16	12.0	0.24	12.00	12.0	0.26	11.90
11-Oct-16	0.1	10.06	10.80	0.1	10.32	10.80
11-Oct-16	1.0	9.97	10.80	1.0	10.11	10.80
11-Oct-16	2.0	9.91	10.80	2.0	10.08	10.80
11-Oct-16	3.0	9.91	10.80	3.0	10.05	10.80
11-Oct-16	4.0	9.86	10.80	4.0	10.07	10.80
11-Oct-16	5.0	9.79	10.80	5.0	10.03	10.80
11-Oct-16	6.0	9.76	10.80	6.0	10.02	10.80
11-Oct-16	7.0	9.74	10.80	7.0	9.93	10.80
11-Oct-16	8.0	9.77	10.70	8.0	9.96	10.70
11-Oct-16	9.0	9.50	10.50	9.0	9.85	10.70
11-Oct-16	10.0	0.44	10.60	10.0	9.44	10.70
11-Oct-16	11.0	0.32	10.60	11.0	0.34	10.80
11-Oct-16	12.0	0.24	10.60	12.0	0.28	10.90
18-Oct-16	0.1	10.55	8.90	0.1	10.76	8.90
18-Oct-16	1.0	10.47	8.80	1.0	10.69	8.90
18-Oct-16	2.0	10.45	8.80	2.0	10.64	8.90
18-Oct-16	3.0	10.46	8.80	3.0	10.51	8.90
18-Oct-16	4.0	10.38	8.80	4.0	10.44	8.90
18-Oct-16	5.0	10.39	8.80	5.0	10.47	8.90
18-Oct-16	6.0	10.42	8.80	6.0	10.31	8.90
18-Oct-16	7.0	10.45	8.80	7.0	10.40	8.00
18-Oct-16	8.0	10.50	8.70	8.0	10.55	8.90
18-Oct-16	9.0	10.35	8.70	9.0	10.56	8.80
18-Oct-16	10.0	4.60	8.70	10.0	8.00	8.90
18-Oct-16	11.0	0.45	8.70	11.0	0.35	9.00
18-Oct-16	12.0	0.33	8.80	12.0	0.36	8.90

Date	Station 3			Station 4		
	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)
15-Jul-16	0.1	9.80	21.0	0.1	9.04	20.9
15-Jul-16	1.0	9.56	20.4	1.0	9.00	19.9
15-Jul-16	2.0	9.37	20.2	2.0	8.81	19.6
15-Jul-16	3.0	9.34	19.5	3.0	8.69	19.5
15-Jul-16	4.0	9.27	19.4	4.0	8.90	19.1
15-Jul-16	5.0	9.26	19.0	5.0	9.10	18.8
15-Jul-16	6.0	9.68	17.7	6.0	9.20	17.6
15-Jul-16	7.0	9.73	15.9	7.0	9.60	15.8
15-Jul-16	8.0	9.11	11.9	8.0	9.60	13.4
15-Jul-16	9.0	7.40	9.5	9.0	9.10	11.7
15-Jul-16	10.0	3.57	8.7	10.0	8.20	10.4
15-Jul-16	11.0	2.82	7.7	11.0	7.90	9.7
15-Jul-16	12.0	1.73	7.4	12.0	5.60	8.7
15-Jul-16	13.0	0.64	7.0	13.0	2.29	7.9
15-Jul-16	14.0	0.50	6.9	14.0	0.93	7.3
15-Jul-16	15.0	0.50	6.9	15.0	0.72	7.4
15-Jul-16				16.0	0.56	7.4
21-Jul-16	0.1	8.23	20.4	0.1	8.78	20.6
21-Jul-16	1.0	8.53	20.4	1.0	8.70	20.5
21-Jul-16	2.0	8.44	20.4	2.0	8.65	20.4
21-Jul-16	3.0	8.52	20.3	3.0	8.51	20.4
21-Jul-16	4.0	8.54	20.2	4.0	8.45	20.4
21-Jul-16	5.0	9.03	19.1	5.0	8.52	20.4
21-Jul-16	6.0	9.37	18.1	6.0	9.21	18.9
21-Jul-16	7.0	9.52	16.2	7.0	9.95	15.9
21-Jul-16	8.0	9.54	13.4	8.0	9.52	12.8
21-Jul-16	9.0	8.45	11.5	9.0	7.71	10.7
21-Jul-16	10.0	6.43	9.6	10.0	6.54	9.1
21-Jul-16	11.0	3.94	8.6	11.0	3.15	8.1
21-Jul-16	12.0	0.91	7.7	12.0	0.52	7.5
21-Jul-16	13.0	0.33	7.1	13.0		
21-Jul-16	14.0			14.0		
21-Jul-16	15.0			15.0		
29-Jul-16	0.1	8.63	19.3	0.1	8.91	19.3
29-Jul-16	1.0	8.60	19.3	1.0	8.96	19.3
29-Jul-16	2.0	8.69	19.3	2.0	8.95	19.2
29-Jul-16	3.0	8.71	19.2	3.0	8.94	19.2
29-Jul-16	4.0	8.67	19.2	4.0	8.95	19.1
29-Jul-16	5.0	8.73	19.0	5.0	8.92	19.0
29-Jul-16	6.0	8.60	18.8	6.0	8.92	18.8
29-Jul-16	7.0	9.37	16.8	7.0	9.36	17.3
29-Jul-16	8.0	9.01	13.7	8.0	9.85	13.8
29-Jul-16	9.0	8.40	11.5	9.0	9.55	12.8

Date	Station 3			Station 4		
	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)
29-Jul-16	10.0	6.60	9.9	10.0	6.07	9.1
29-Jul-16	11.0	3.60	8.7	11.0	1.58	8.3
29-Jul-16	12.0	3.29	8.3	12.0	0.38	7.7
29-Jul-16	13.0	0.24	7.5	13.0	0.31	7.2
29-Jul-16	14.0	0.16	7.1	14.0	0.17	7.2
29-Jul-16	15.0	0.03	7.2	15.0	0.12	7.2
03-Aug-16	0.1	8.95	19.2	0.1	8.92	19.3
03-Aug-16	1.0	8.66	19.3	1.0	8.86	19.3
03-Aug-16	2.0	8.85	19.1	2.0	8.84	19.3
03-Aug-16	3.0	8.71	19.0	3.0	8.96	19.2
03-Aug-16	4.0	8.72	19.0	4.0	8.86	18.9
03-Aug-16	5.0	8.84	18.8	5.0	8.96	18.9
03-Aug-16	6.0	8.94	18.4	6.0	9.03	18.8
03-Aug-16	7.0	9.21	17.1	7.0	9.05	18.4
03-Aug-16	8.0	8.93	14.4	8.0	9.05	18.1
03-Aug-16	9.0	8.01	11.8	9.0	8.78	11.7
03-Aug-16	10.0	6.61	10.1	10.0	4.48	9.3
03-Aug-16	11.0	3.22	8.6	11.0	1.10	8.2
03-Aug-16	12.0	0.26	7.8	12.0	0.26	7.7
03-Aug-16	13.0	0.15	7.5	13.0	0.21	7.3
03-Aug-16	14.0	0.13	7.1	14.0	0.20	7.3
03-Aug-16	15.0	0.14	7.1	15.0	0.18	7.2
10-Aug-16	0.1	8.55	19.9	0.1	8.29	19.9
10-Aug-16	1.0	8.66	19.9	1.0	8.48	19.9
10-Aug-16	2.0	8.70	19.7	2.0	8.53	19.9
10-Aug-16	3.0	8.65	19.7	3.0	8.55	19.9
10-Aug-16	4.0	8.67	19.6	4.0	8.54	19.9
10-Aug-16	5.0	8.79	19.4	5.0	8.54	19.9
10-Aug-16	6.0	8.79	18.6	6.0	8.64	19.8
10-Aug-16	7.0	8.84	17.7	7.0	8.76	18.8
10-Aug-16	8.0	8.65	14.4	8.0	9.30	15.9
10-Aug-16	9.0	7.70	11.4	9.0	9.57	13.4
10-Aug-16	10.0	5.90	9.6	10.0	7.99	11.5
10-Aug-16	11.0	1.97	8.6	11.0	7.03	9.4
10-Aug-16	12.0	0.83	7.9	12.0	0.91	8.0
10-Aug-16	13.0	0.63	7.5	13.0	0.65	7.7
10-Aug-16	14.0	0.44	7.2	14.0	0.50	7.5
10-Aug-16	15.0	0.42	7.3	15.0	0.50	7.4
19-Aug-16	0.1	7.2	20.6	0.1	7.2	20.7
19-Aug-16	1.0	7.5	20.1	1.0	7.5	20.1
19-Aug-16	2.0	7.6	20.0	2.0	7.6	20.2
19-Aug-16	3.0	7.8	19.9	3.0	7.7	19.4
19-Aug-16	4.0	7.8	19.8	4.0	7.8	19.6

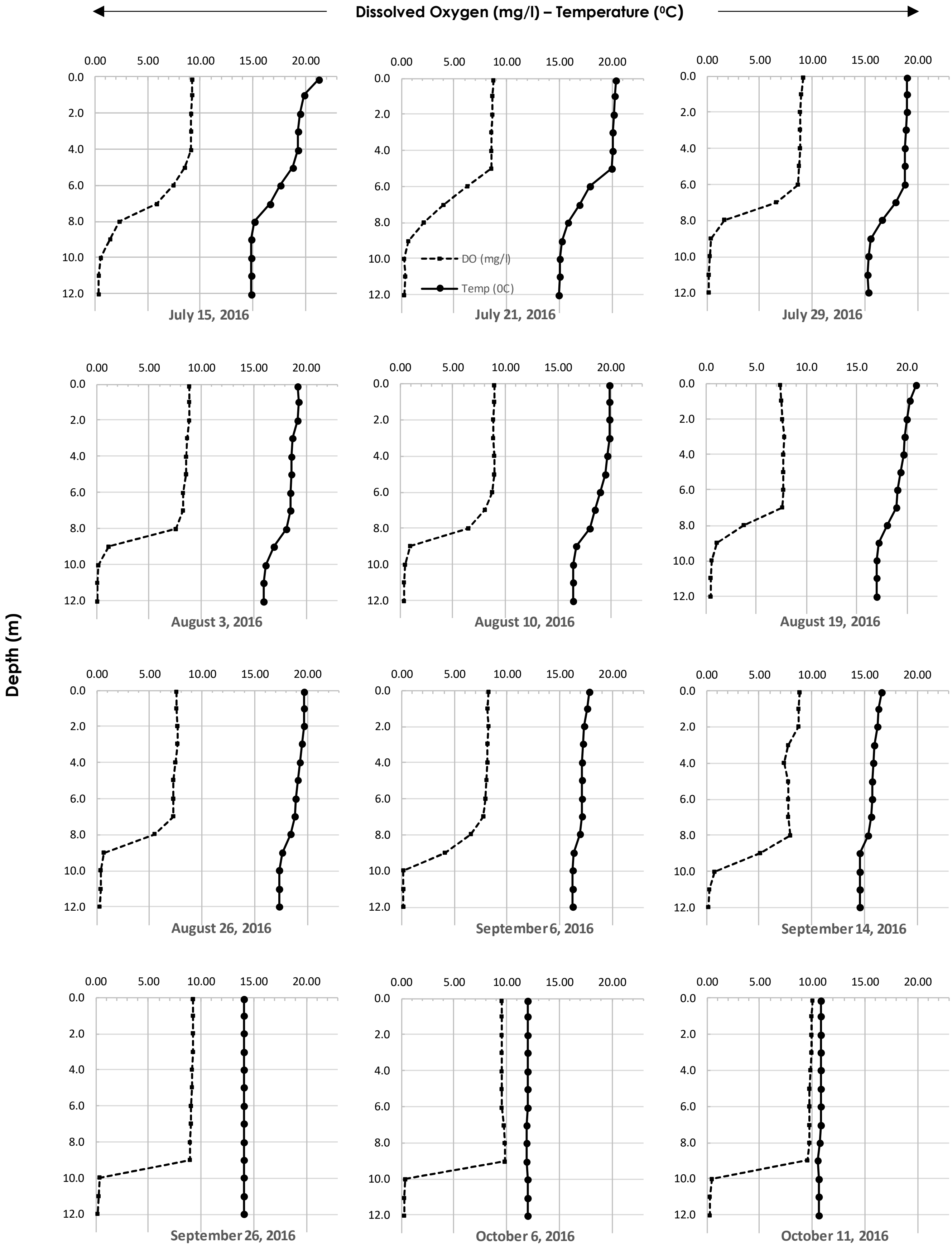
Date	Station 3			Station 4		
	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)
19-Aug-16	5.0	7.9	19.7	5.0	7.8	19.4
19-Aug-16	6.0	7.9	19.4	6.0	7.9	19.4
19-Aug-16	7.0	8.0	18.1	7.0	7.9	19.0
19-Aug-16	8.0	8.3	15.9	8.0	8.1	17.3
19-Aug-16	9.0	7.8	12.6	9.0	8.1	13.4
19-Aug-16	10.0	5.6	10.7	10.0	5.5	9.8
19-Aug-16	11.0	0.8	8.9	11.0	0.5	9.0
19-Aug-16	12.0	0.4	8.1	12.0	0.7	8.2
19-Aug-16	13.0	0.4	7.7	13.0	0.6	7.7
19-Aug-16	14.0	0.4	7.5	14.0	0.5	7.5
19-Aug-16	15.0	0.4	7.4	15.0	0.6	7.5
26-Aug-16	0.1	7.7	19.6	0.1	7.71	19.80
26-Aug-16	1.0	7.8	19.6	1.0	7.71	19.80
26-Aug-16	2.0	8.0	19.5	2.0	7.90	19.70
26-Aug-16	3.0	7.9	19.4	3.0	8.00	19.40
26-Aug-16	4.0	7.9	19.4	4.0	7.95	19.30
26-Aug-16	5.0	7.8	19.1	5.0	8.05	19.20
26-Aug-16	6.0	7.9	18.9	6.0	7.86	19.10
26-Aug-16	7.0	7.9	18.5	7.0	8.01	18.80
26-Aug-16	8.0	7.7	16.8	8.0	8.01	17.90
26-Aug-16	9.0	6.9	13.1	9.0	7.30	13.30
26-Aug-16	10.0	6.0	11.3	10.0	5.81	10.50
26-Aug-16	11.0	0.9	9.0	11.0	1.41	9.30
26-Aug-16	12.0	0.6	8.2	12.0	0.56	8.50
26-Aug-16	13.0	0.4	7.7	13.0	0.48	7.70
26-Aug-16	14.0	0.4	7.5	14.0	0.41	7.00
26-Aug-16	15.0	0.4	7.5	15.0	0.42	7.60
06-Sep-16	0.1	8.8	17.7	0.1	8.43	17.60
06-Sep-16	1.0	8.8	17.6	1.0	8.91	17.60
06-Sep-16	2.0	8.8	17.5	2.0	8.83	17.50
06-Sep-16	3.0	8.8	17.5	3.0	8.86	17.40
06-Sep-16	4.0	8.8	17.5	4.0	8.64	17.30
06-Sep-16	5.0	8.8	17.4	5.0	8.70	17.30
06-Sep-16	6.0	8.7	17.4	6.0	8.72	17.30
06-Sep-16	7.0	8.8	17.3	7.0	8.65	17.30
06-Sep-16	8.0	8.1	17.2	8.0	8.19	17.10
06-Sep-16	9.0	7.2	14.4	9.0	7.03	14.20
06-Sep-16	10.0	4.4	11.2	10.0	5.00	11.70
06-Sep-16	11.0	0.7	9.5	11.0	2.72	10.20
06-Sep-16	12.0	0.3	8.4	12.0	0.35	9.20
06-Sep-16	13.0	0.3	7.7	13.0	0.25	8.60
06-Sep-16	14.0	0.2	7.3	14.0	0.21	7.90
06-Sep-16	15.0	0.2	7.4	15.0	0.20	7.90

Date	Station 3			Station 4		
	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)
14-Sep-16	0.1	9.35	16.60	0.1	9.22	16.70
14-Sep-16	1.0	9.09	16.30	1.0	9.00	16.60
14-Sep-16	2.0	9.05	16.20	2.0	9.00	16.30
14-Sep-16	3.0	8.88	16.20	3.0	8.92	16.30
14-Sep-16	4.0	8.97	16.10	4.0	9.00	16.20
14-Sep-16	5.0	8.95	16.10	5.0	8.92	16.20
14-Sep-16	6.0	8.93	16.10	6.0	8.10	16.10
14-Sep-16	7.0	8.75	16.10	7.0	8.78	16.10
14-Sep-16	8.0	8.75	16.10	8.0	8.48	15.80
14-Sep-16	9.0	7.40	15.10	9.0	6.83	14.40
14-Sep-16	10.0	4.27	11.60	10.0	4.85	12.10
14-Sep-16	11.0	1.44	10.20	11.0	0.57	9.80
14-Sep-16	12.0	0.32	9.00	12.0	0.29	8.50
14-Sep-16	13.0	0.26	8.10	13.0	0.26	7.90
14-Sep-16	14.0	0.24	7.40	14.0	0.23	7.70
14-Sep-16	15.0	0.21	7.40	15.0	0.22	7.80
26-Sep-16	0.1	9.43	14.40	0.1	9.26	14.40
26-Sep-16	1.0	9.43	14.40	1.0	9.33	14.40
26-Sep-16	2.0	9.34	14.40	2.0	9.31	14.40
26-Sep-16	3.0	9.31	14.40	3.0	8.94	14.40
26-Sep-16	4.0	9.28	14.40	4.0	9.23	14.40
26-Sep-16	5.0	9.25	14.40	5.0	9.20	14.40
26-Sep-16	6.0	9.21	14.30	6.0	9.17	14.40
26-Sep-16	7.0	9.23	14.30	7.0	9.12	14.40
26-Sep-16	8.0	9.22	14.30	8.0	9.10	14.40
26-Sep-16	9.0	9.19	14.30	9.0	9.10	14.30
26-Sep-16	10.0	5.25	13.00	10.0	6.31	13.50
26-Sep-16	11.0	0.58	10.50	11.0	0.44	9.90
26-Sep-16	12.0	0.33	9.00	12.0	0.28	8.30
26-Sep-16	13.0	0.28	8.30	13.0	0.27	7.70
26-Sep-16	14.0	0.28	7.80	14.0	0.25	7.70
26-Sep-16	15.0	0.27	7.60	15.0	0.26	7.80
06-Oct-16	0.1	9.47	12.60	0.1	9.34	12.60
06-Oct-16	1.0	9.46	12.60	1.0	9.45	12.60
06-Oct-16	2.0	9.39	12.60	2.0	9.39	12.60
06-Oct-16	3.0	9.36	12.60	3.0	9.34	12.60
06-Oct-16	4.0	9.37	12.60	4.0	9.30	12.60
06-Oct-16	5.0	9.37	12.60	5.0	9.27	12.60
06-Oct-16	6.0	9.28	12.60	6.0	9.28	12.60
06-Oct-16	7.0	9.32	12.60	7.0	9.29	12.60
06-Oct-16	8.0	9.32	12.60	8.0	9.25	12.60
06-Oct-16	9.0	9.24	12.60	9.0	9.24	12.60
06-Oct-16	10.0	9.19	12.60	10.0	9.23	12.60

Date	Station 3			Station 4		
	Depth Readings	D.O. (mg/l)	Temp (Celsius)	Depth Readings	D.O. (mg/l)	Temp (Celsius)
06-Oct-16	11.0	6.40	11.10	11.0	4.92	11.90
06-Oct-16	12.0	0.32	9.10	12.0	0.33	8.70
06-Oct-16	13.0	0.28	8.40	13.0	0.26	7.80
06-Oct-16	14.0	0.27	7.70	14.0	0.25	7.80
06-Oct-16	15.0	0.28	7.50	15.0	0.24	7.80
11-Oct-16	0.1	9.90	11.30	0.1	9.54	11.30
11-Oct-16	1.0	9.59	11.30	1.0	9.44	11.40
11-Oct-16	2.0	9.55	11.30	2.0	9.34	11.40
11-Oct-16	3.0	9.55	11.30	3.0	9.35	11.40
11-Oct-16	4.0	9.48	11.30	4.0	9.24	11.30
11-Oct-16	5.0	9.55	11.30	5.0	9.25	11.30
11-Oct-16	6.0	9.49	11.30	6.0	9.18	11.30
11-Oct-16	7.0	9.41	11.30	7.0	9.21	11.30
11-Oct-16	8.0	9.38	11.30	8.0	9.23	11.30
11-Oct-16	9.0	9.40	11.30	9.0	9.18	11.30
11-Oct-16	10.0	9.27	11.30	10.0	7.33	11.10
11-Oct-16	11.0	9.31	11.30	11.0	6.82	10.90
11-Oct-16	12.0	8.98	11.50	12.0	0.35	8.80
11-Oct-16	13.0	0.42	8.30	13.0	0.27	8.20
11-Oct-16	14.0	0.28	7.60	14.0	0.30	7.80
11-Oct-16	15.0	0.25	7.50	15.0	0.29	7.80
18-Oct-16	0.1	10.05	9.70	0.1	9.54	9.80
18-Oct-16	1.0	9.78	9.70	1.0	9.52	9.80
18-Oct-16	2.0	9.49	9.70	2.0	9.44	9.80
18-Oct-16	3.0	9.40	9.70	3.0	9.24	9.70
18-Oct-16	4.0	8.93	9.70	4.0	9.26	9.70
18-Oct-16	5.0	9.28	9.70	5.0	9.17	9.70
18-Oct-16	6.0	9.33	9.70	6.0	9.24	9.60
18-Oct-16	7.0	9.21	9.70	7.0	9.20	9.70
18-Oct-16	8.0	9.21	9.70	8.0	9.28	9.60
18-Oct-16	9.0	9.20	9.60	9.0	9.33	9.60
18-Oct-16	10.0	9.16	9.60	10.0	9.37	9.60
18-Oct-16	11.0	9.14	9.60	11.0	9.30	9.60
18-Oct-16	12.0	9.12	9.60	12.0	9.34	9.60
18-Oct-16	13.0	8.46	9.60	13.0	0.55	7.80
18-Oct-16	14.0	1.10	9.10	14.0	0.55	7.80
18-Oct-16	15.0	0.37	7.90	15.0	0.43	7.90

Appendix IV: Dissolved Oxygen/Temperature Profiles

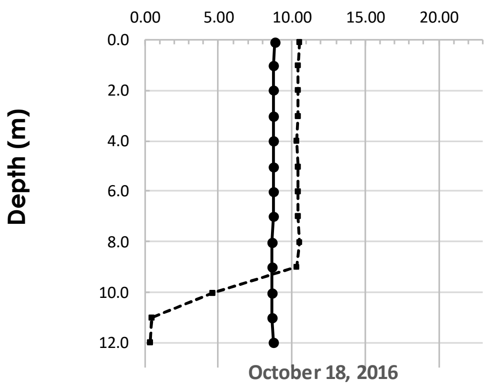
Station 1



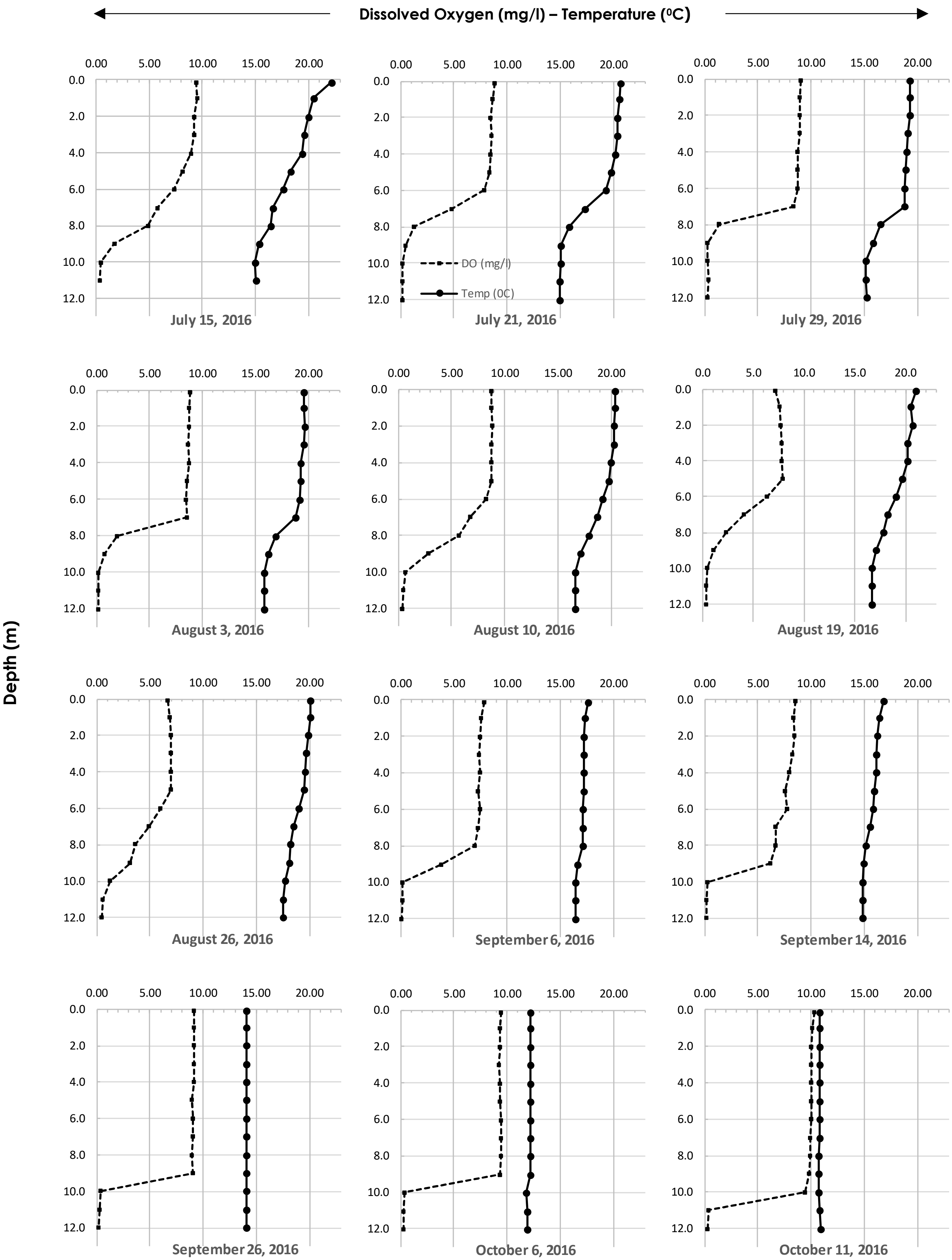
Dissolved Oxygen (mg/l) – Temperature (⁰C)
Depth (m)
DO (mg/l)
Temp (0C)
July 15, 2016
July 21, 2016
July 29, 2016
August 3, 2016
August 10, 2016
August 19, 2016
August 26, 2016
September 6, 2016
September 14, 2016
September 26, 2016
October 6, 2016
October 11, 2016

Station 1

Dissolved Oxygen (mg/l) – Temperature (^{0}C)

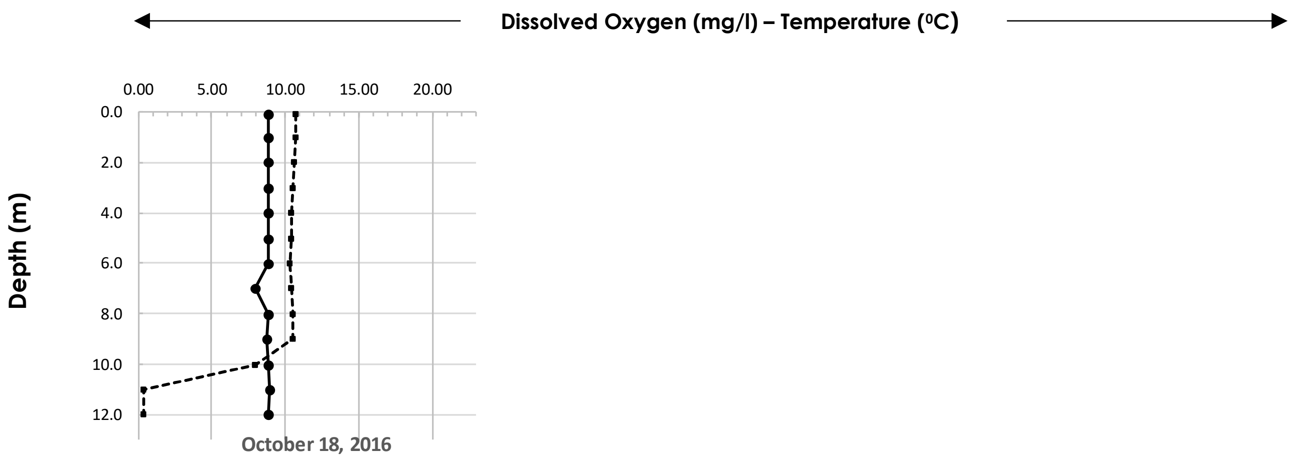


<u>Station 2</u>

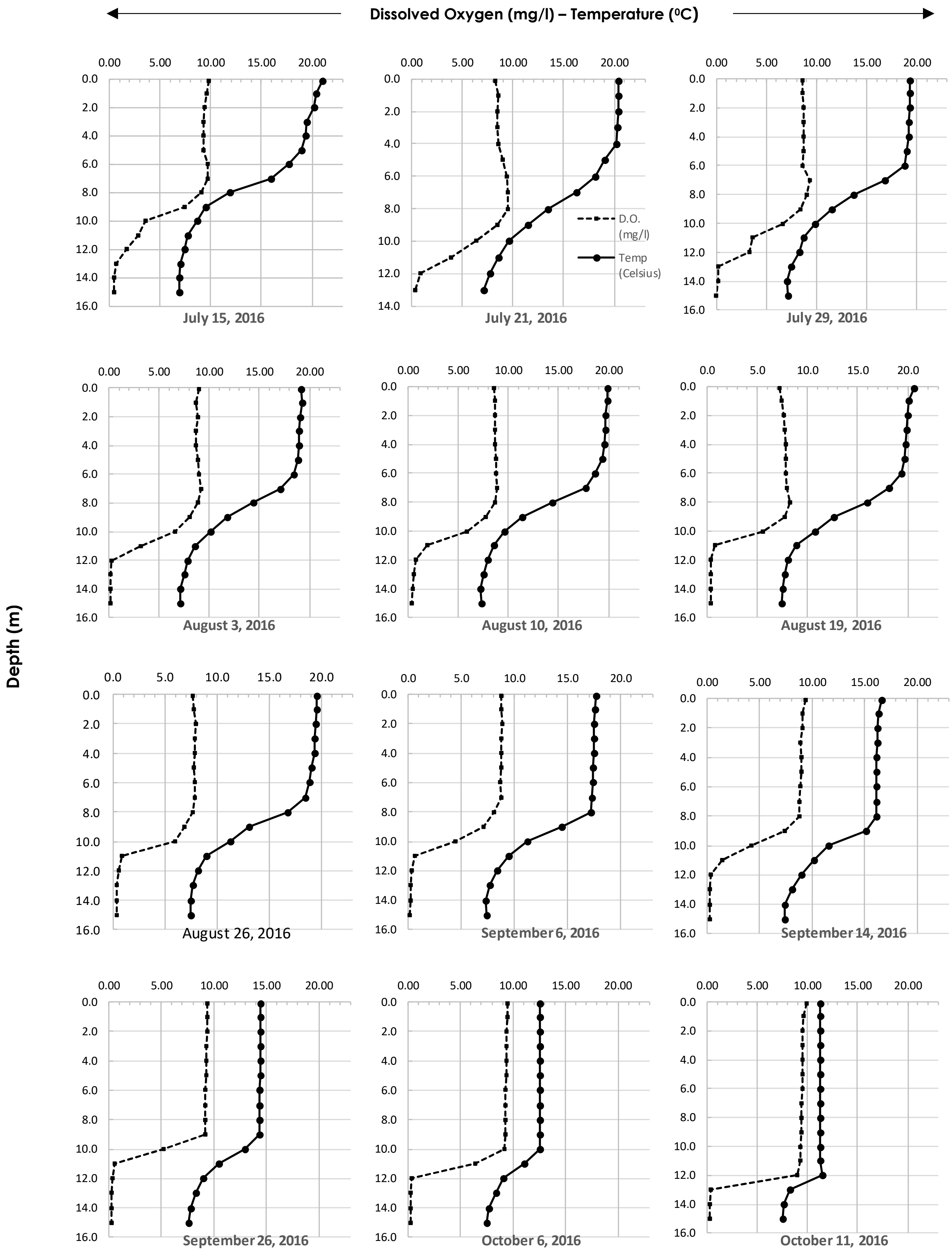


Dissolved Oxygen (mg/l) – Temperature (0C)
Depth (m)
DO (mg/l)
Temp (0C)
July 15, 2016
July 21, 2016
July 29, 2016
August 3, 2016
August 10, 2016
August 19, 2016
August 26, 2016
September 6, 2016
September 14, 2016
September 26, 2016
October 6, 2016
October 11, 2016

Station 2

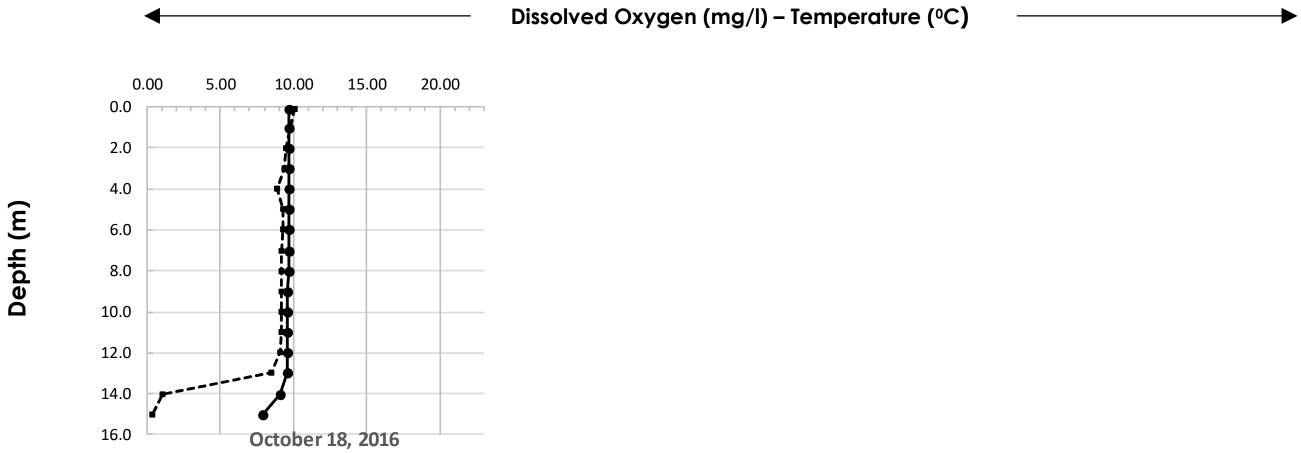

Dissolved Oxygen (mg/l) – Temperature (°C)
0.00
5.00
10.00
15.00
20.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Depth (m)
October 18, 2016

Station 3



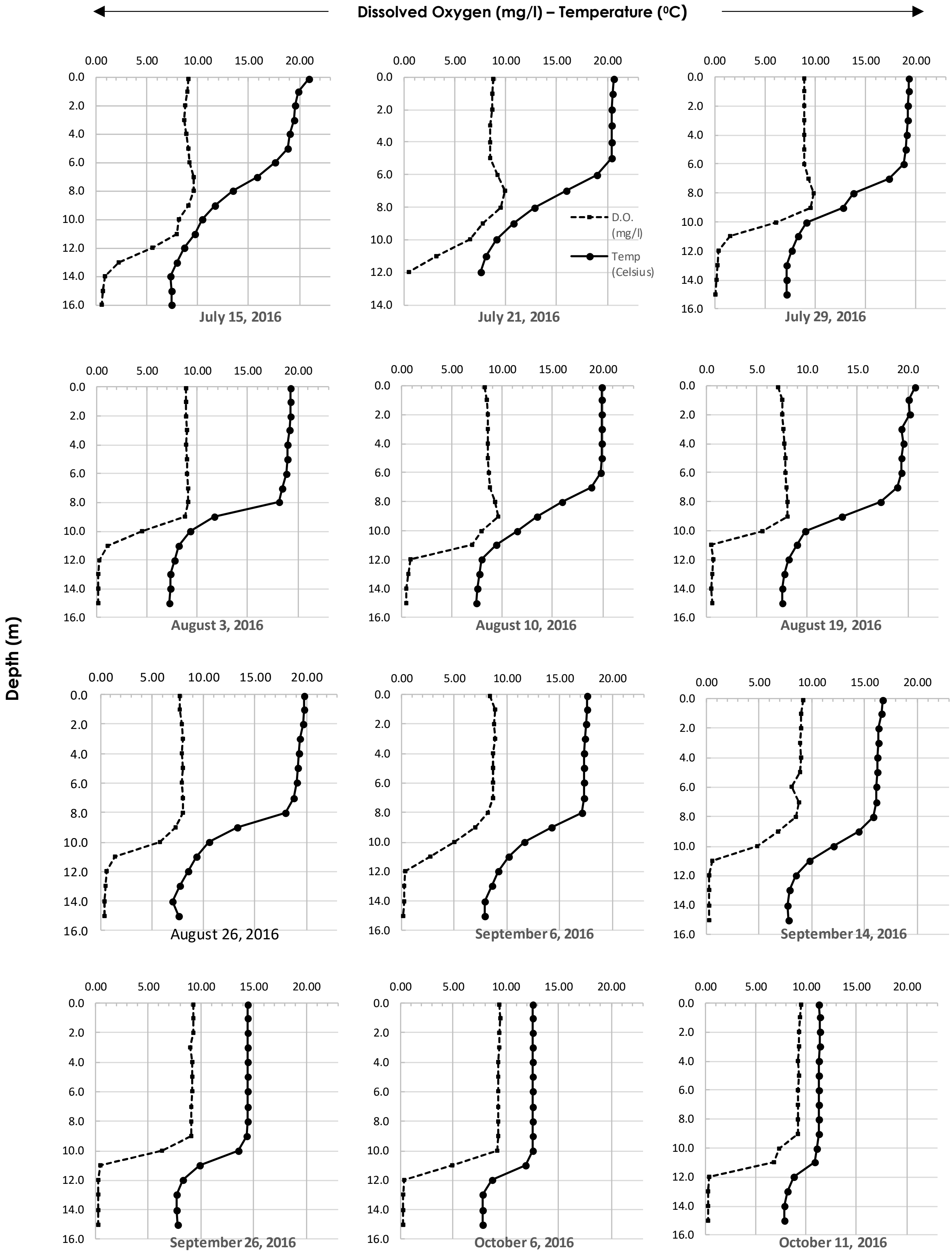
Dissolved Oxygen (mg/l) – Temperature (^{0}C)
Depth (m)
D.O. (mg/l)
Temp (Celsius)
July 15, 2016
July 21, 2016
July 29, 2016
August 3, 2016
August 10, 2016
August 19, 2016
August 26, 2016
September 6, 2016
September 14, 2016
September 26, 2016
October 6, 2016
October 11, 2016

Station 3



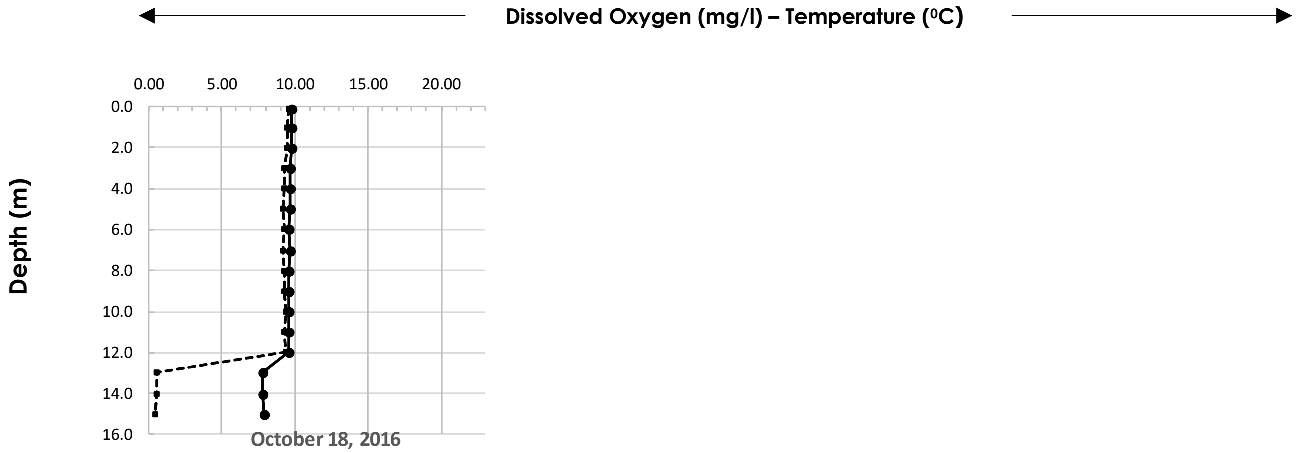
Dissolved Oxygen (mg/l) – Temperature (°C)
Depth (m)
0.00
5.00
10.00
15.00
20.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
October 18, 2016

Station 4



Dissolved Oxygen (mg/l) – Temperature (°C)
Depth (m)
D.O. (mg/l)
Temp (Celsius)
July 15, 2016
July 21, 2016
July 29, 2016
August 3, 2016
August 10, 2016
August 19, 2016
August 26, 2016
September 6, 2016
September 14, 2016
September 26, 2016
October 6, 2016
October 11, 2016

Station 4


Dissolved Oxygen (mg/l) – Temperature (⁰C)
Depth (m)
0.00
5.00
10.00
15.00
20.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
October 18, 2016