Memorandum

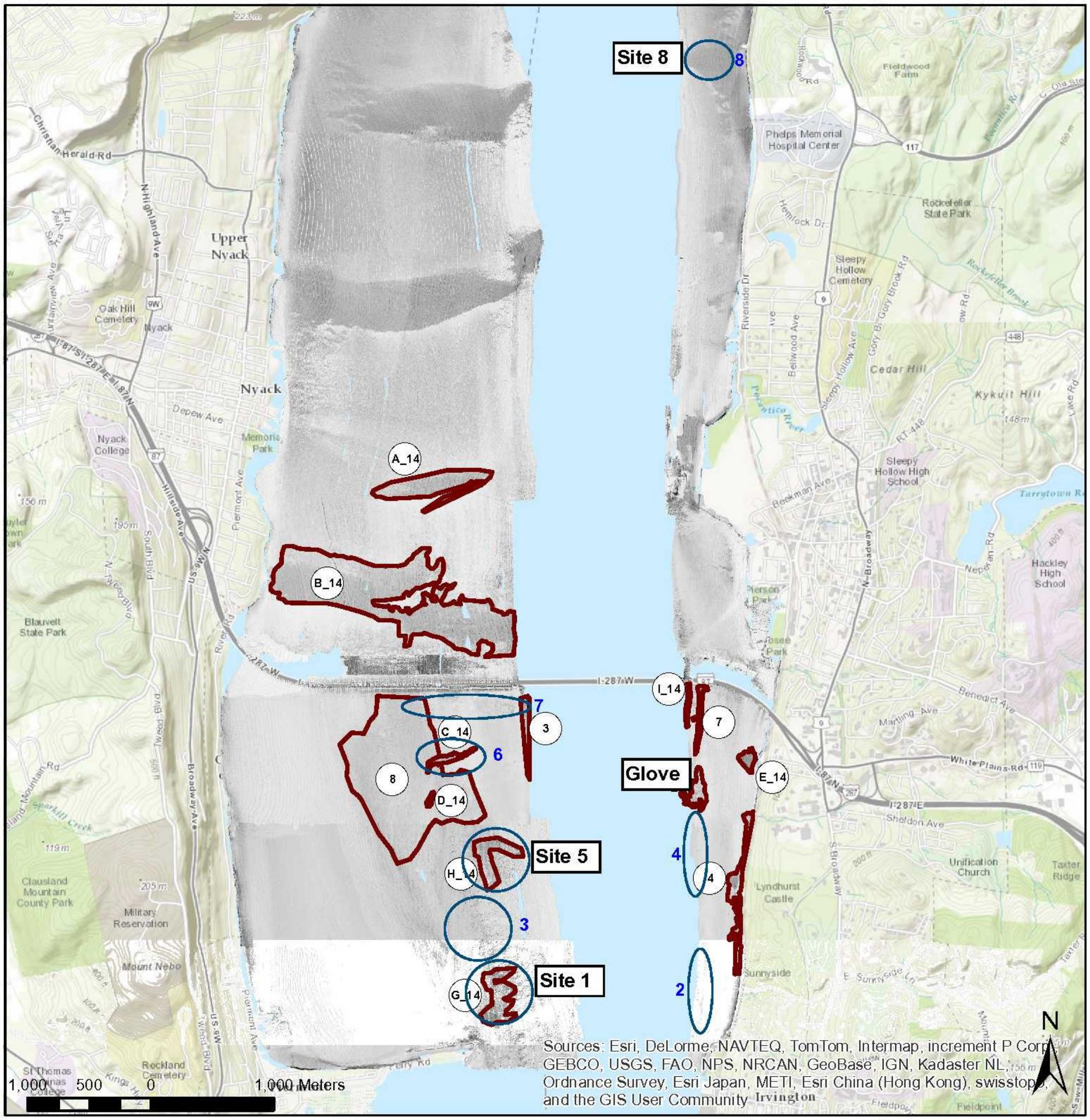
To: Oyster Work Group
From: Chad Seewagen, Fred Jacobs, Christy Stoll
Date: November 30, 2016
Re: Tier 3 Progress Report, Oyster Research and Restoration Plan, New NY Bridge Project
cc:

Tier 3 of the four-tiered oyster research and restoration plan was developed by the Oyster Work Group (OWG) and New York State Department of Environmental Conservation (NYSDEC) for the New NY Bridge Project. This memo presents the results of the second year of measurements of salinity, dissolved oxygen (DO), temperature, and information on the timing and extent of spat-fall at each study site (**Figure 1**). Site-specific salinity and DO data are intended to provide additional context in which to interpret the findings of the substrate comparison study that is being conducted by the Hudson River Foundation also under Tier 3, and the spat collectors are intended to assess larval availability among sites while also providing information on the timing of wild oyster spat-fall in the Tappan Zee region of the Hudson River.

STUDY DESIGN AND SAMPLING FREQUENCY

The study design and sampling frequency during the 2016 season was nearly the same as during the 2015 season. With the exception of Site 0 (“the glove”), one sonde that measures conductivity (later converted to salinity) and temperature (HOBO U24-002-C, Onset, Bourne, MA) was placed at each of the three plots within each study site, and one DO logger (Precision Measurement Engineering miniDOT, Vista, California) was deployed at two of the three plots within each site. Site 0 had a sonde placed at two plots and a DO logger placed at one plot. The sondes and DO loggers were elevated by buoys approximately 2 feet off of the river bottom and were programmed to record at 15 minute intervals. They were deployed on April 28, 2016. Prior to the first deployment and upon each retrieval event, the sondes were calibrated by taking a reading while submerged in a standard solution (5,000 µs/cm at 25° C); the readings were then used in the HOBOware Pro software to adjust the raw conductivity measurements from each sampling period.

The spat collectors used in 2016 were designed the same way as in 2015 and consisted of four segments of corrugated plastic drain pipe (36” wide x 4” diameter) strung together horizontally, anchored by a cinder block, and held upright in the water column by buoys (**Figure 2)**. Each spat collector had a total outer surface area of approximately 1.2 m. The spat collectors were deployed on July 1-6, 2016 and retrieved approximately once a month until removal in early October. During each retrieval event, two of the four segments of drain pipe on each spat collector were scraped clean if they were heavily fouled with other organisms and no oysters were observed. This was done to ensure that the spat collectors were returned with some clean surface area for oyster settlement while avoiding the possibility of removing any recently attached but unseen oysters from the other two segments. When oysters were present, all oysters on both sides of all four tube segments were counted and measured.



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Figure 1. Tier 3 study site locations.

Figure 2. Spat collector prior to deployment.

RESULTS

SPAT COLLECTORS

After deployment in July, the spat collectors were retrieved to the surface and inspected for oyster spat on August 5-8, September 7-8, and October 5-12. As in 2015, oysters were observed on the spat collectors for the first time during the September sampling event; oysters were present on at least one of the three spat collectors at each study site. Densities ranged from 0.3 to 2.4 spat/m^2 among the three study sites during the September sampling event, which were substantially lower than those observed during September 2015. Densities then decreased from September to October at each site except for Site 8 (**Table 1; Figure 3**), suggesting that the oysters observed in September had fallen off and no new recruitment occurred. During 2015, density increased from September to October and a mix of sizes observed during October indicated a second spatfall event had occurred.

Based on the sizes of the spat first observed in September (**Table 1**), they were estimated to have set approximately 1 month prior, shortly after the August sampling event. The sizes were comparable to those in September 2015. At the two study sites where oysters were retained from September to October (Sites 5 and 8), oyster size increased (**Table 1**). No oysters were observed at Sites 0 or 1 in October. While searching for one of the spat collectors at Site 0 on August 5, 2016, a spat collector from the previous year that had been lost was retrieved. Five oysters ranging in size from 25 to 33 mm were present.

While overall densities were much lower in 2016 than 2015, relative differences among sites were somewhat similar. As in 2015, Site 8 had the highest density of oysters and the largest average size oysters by October, followed by Site 5. Sites 0 and 1 had relatively poor recruitment during September, and retained no oysters by the time of the October sampling event.

Table 1
Oyster Spat Density and Size Recorded on Spat Collectors in September and October, 2016

	September			October		
Site-Plot	Abundance	Density (m^2)	Mean size (mm)	Abundance	Density (m^2)	Mean size (mm)
0-1	2	1.62	23.5	0	0.0	
0-2	0	0		0	0.0	
0-3	0	0		0	0.0	
Mean	0.7	0.5	23.5	0.0	0.0	
SD	1.2	0.9	0.7	0.0	0.0	
1-1	0	0		0	0.0	
1-2	1	1	15	0	0.0	
1-3	0	0		0	0.0	
Mean	0.3	0.3		0.0	0.0	
SD	0.6	0.5		0.0	0.0	
5-1	7	6	16.4	3	2.4	22.3
5-2	1	1	15	0	0.0	
5-3	1	1	20	2	1.6	23.5
Mean	3.0	2.4	16.7	1.7	1.4	22.8
SD	3.5	2.8	4.9	1.5	1.2	4.6
8-1	0	0		2	1.6	20.5
8-2	6	5	12.6	11	8.9	20.5
8-3	0	0		2	1.6	19.5
Mean	2.0	1.6	12.6	5.0	4.0	20.3
SD	3.5	2.8	1.5	5.2	4.2	5.0

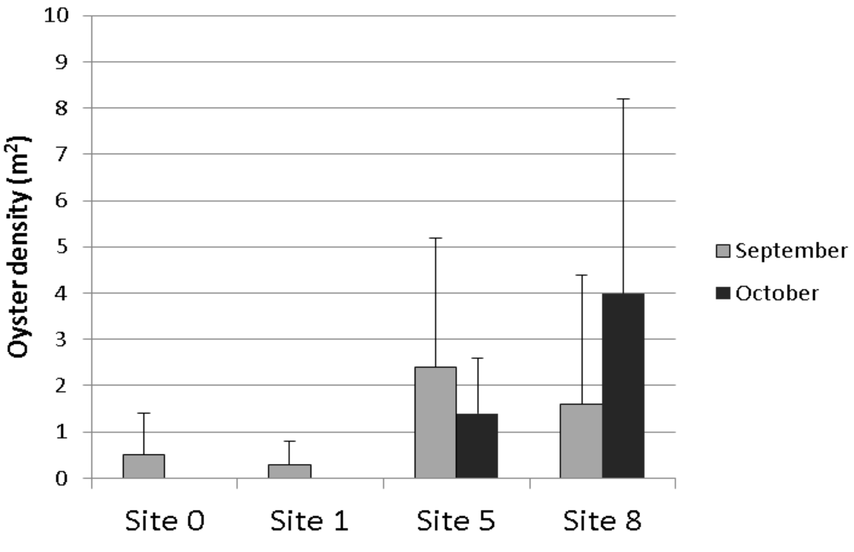


Figure 3. Mean (+ SD) oyster density on spat collectors at each study site during September and October, 2016.

SALINITY, TEMPERATURE, AND DISSOLVED OXYGEN

Sondes and DO loggers were retrieved and downloaded on May 25-June 2, July 1-6, August 5-8, September 7-8, and October 5-12. On a few occasions, a sonde could not be found during a given sampling event and the memory filled up before it was retrieved during the subsequent event, resulting in an incomplete time series. Unlike the Solinst sondes used in 2015, however, none of the HOBO sondes completely failed and none were permanently lost. No DO loggers failed or were lost during the 2016 season. The most complete time series for salinity and DO for each plot within each site are shown in **Appendix A** and **B**, respectively.

Ranges in salinity at each site were compared to one another (**Table 2, Appendix A, Figures A-1 to A-8**). While mean salinities at all sites were fairly similar, a comparison of frequency distributions in salinity indicated that at Site 0 (the glove) salinities were considerably higher on more occasions than other sites, with about 24% of values exceeding a salinity of 12 psu (**Figure A-2**). This can be compared with Site 1 (**Figure A-4**) and Site 5 (**Figure A-6**) where only about 8% and 6% of bottom salinity observations exceeded 12 psu, respectively. Over the study period lower salinities were recorded at Site 8 more frequently than other sites with about 93% of observations occurring in salinities of 8 psu or less (**Figure A-8**). The shaded portion expressed in **FigureA-1** represents a period when the data observed at Site 0 Plot 3 was considered invalid and these salinity data were eliminated as outliers caused by equipment malfunction. Average salinity was lowest at Site 8 as expected because it is the northernmost location, and highest at Site 0 as expected because it is the deepest site (**Table 2**). Minimum levels were lower, and maximum and mean levels were higher in 2016 than in 2015 at every site except Site 8, which may be partly attributable to the fact that different instruments were used in the two years. Temporal trends were also different between 2015 and 2016. In 2015, most sites had a gradual increase in salinity during the course of the study period whereas Sites 0, 5, and 8 each had a gradual decrease in salinity during the study period in 2016. Salinity levels at Site 8 in particular substantially decreased in August and remained under approximately 5 PSU until October. Other sites also experienced low salinity levels of under 5 PSU but for less prolonged periods.

Temperatures during the study period ranged from 12.3-30.7 °C and averaged the lowest at Site 0, which is the deepest study site. Site 0 also had the lowest maximum temperature. As in 2015, average temperatures were highly comparable among Sites 1, 5, and 8, differing by only 1.5 °C (**Table 3**).

The time series of DO from each plot is illustrated in **Appendix B** and the mean, minimum, and maximum values are reported in **Table 4.** DO followed the same general trends at each site, decreasing through June, rising in early July, decreasing again until October, and then starting to rise again. Daily minimum DO levels consistently reached or closely approached 0 mg/L at each site for most of August and September before increasing to above 2 or 3 mg/L towards the end of the study period. Sites 0, 1, and 8 had prolonged periods of up to 2 weeks in mid-August when DO remained under approximately 3 mg/L. A similar trend occurred in 2015, and during both years, these periods likely overlapped with oyster spawning and/or spat settlement. While adult oysters can survive prolonged periods of hypoxic or anoxic conditions by temporarily switching to an anaerobic metabolism, oyster larvae and spat lack this ability and are therefore highly vulnerable to chronically low levels of DO. Multiple, consecutive days of hypoxia can reduce larval settlement as well as feeding ability, development, shell growth, disease resistance, and ultimately, survival and recruitment[1,2,3]. With the exception of Site 1, August and

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[1] Baker, S. M., and R. Mann. 1992. Effects of hypoxia and anoxia on larval settlement, juvenile growth, and juvenile survival of the oyster *Crassostrea virginica*. Biological Bulletin 182: 265-269.

[2] Baker, S.M., and R. Mann. 1994. Feeding ability during settlement and metamorphosis in the oyster *Crassostrea virginica* (Gmelin, 1791) and the effects of hypoxia on post-settlement ingestion rates. Journal of Experimental Marine Biology and Ecology 181: 239-253.

[3] Anderson, R. S., L. L. Brubacher, L. Ragone Calvo, M. A. Unger, and E. M. Burreson. 1998. Effects of tributyltin and hypoxia on the progression of *Perkinsus marinus* infections and host defense mechanisms in oyster, *Crassostrea virginica* (Gmelin). Journal of Fish Diseases 21: 371-380.

September DO levels were generally lower in 2016 than in 2015 at each site and under 3 mg/L for longer periods of time, which may partly explain the poorer recruitment observed on the spat collectors in 2016.

Table 2
Minimum, Maximum and Mean Salinity Levels (PSU), June-October, 2016

Site	Minimum	Maximum	Mean	10th Percentile	90th Percentile
1	0.3	22.8	6.9	1.3	12.2
5	0.3	19.2	6.9	2.0	11.7
8	0.4	15.1	7.0	0.8	8.5
0 (Glove)	1.0	38.1	8.9	2.0	15.7

Table 3
Minimum, Maximum and Mean Temperature (°C), June-October, 2016

Site	Minimum	Maximum	Mean
1	12.3	30.7	22.0
5	12.6	30.0	22.1
8	12.7	30.4	23.5
0 (Glove)	12.4	28.9	21.0

Table 4
Minimum, Maximum and Mean Dissolved Oxygen Levels (mg/L), June-October, 2016

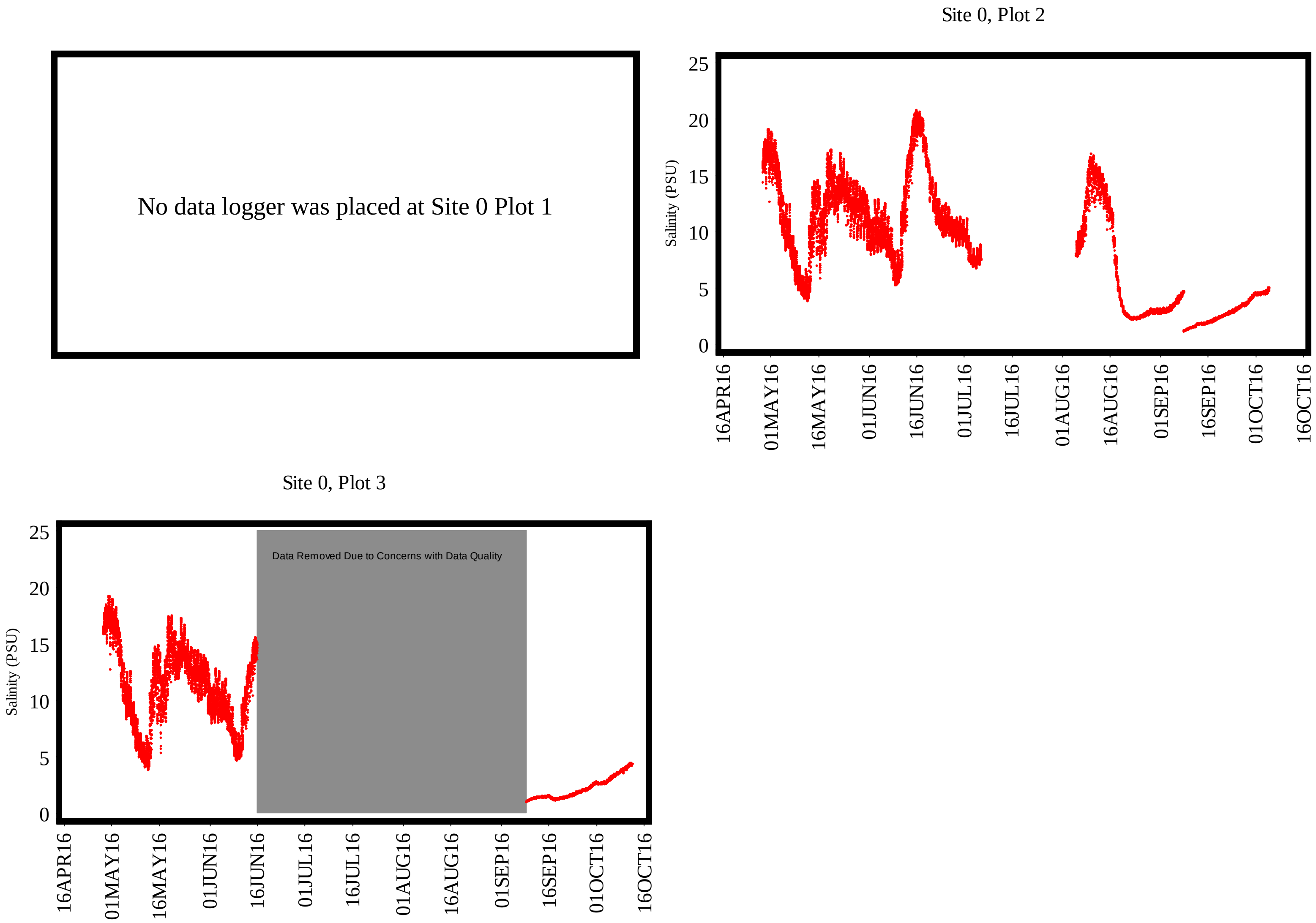
Site	Minimum	Maximum	Mean
1	0.1	12.9	5.2
5	0.0	12.1	5.8
8	0.1	12.5	4.7
0 (Glove)	0.2	11.0	4.7

NEXT STEPS

The results from 2015 and 2016 will be interpreted and discussed by the OWG in conjunction with the results of the Tier 3 substrate comparison study to identify the most appropriate location for the Tier 4 restoration activity. Oyster density during both years was greatest at Site 8, which is the northernmost site and the one with the lowest overall salinity levels. Salinity levels in the Tappan Zee region of the Hudson River already hover for extended periods of time near the extreme low end of oyster tolerance, and climate change models predict more frequent and extreme low-salinity events will occur in the near future (Levinton et al. 2011). The northern limit of suitable oyster habitat within the Hudson River is therefore expected to shift south over time. The OWG will need to consider both present and expected future conditions at each study site to select the area with the greatest likelihood of long-term restoration success.

APPENDIX A

SALINITY FIGURES



No data logger was placed at Site 0 Plot 1

Site 0, Plot 2

Site 0, Plot 3

Data Removed Due to Concerns with Data Quality

Figure A-1. Salinity over time at Site 0 (Glove)

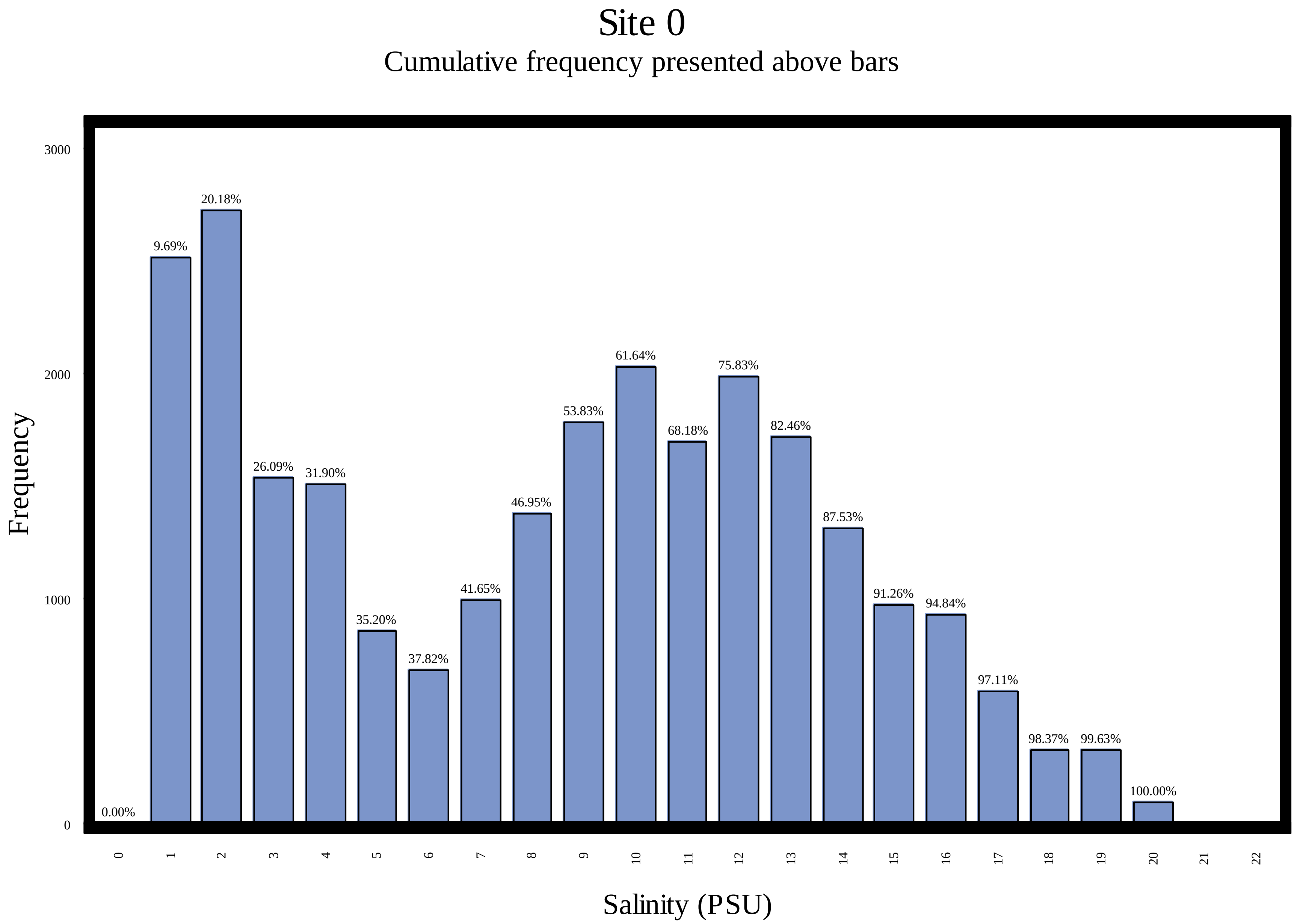


Figure A-2. Salinity frequency distribution at Site 0

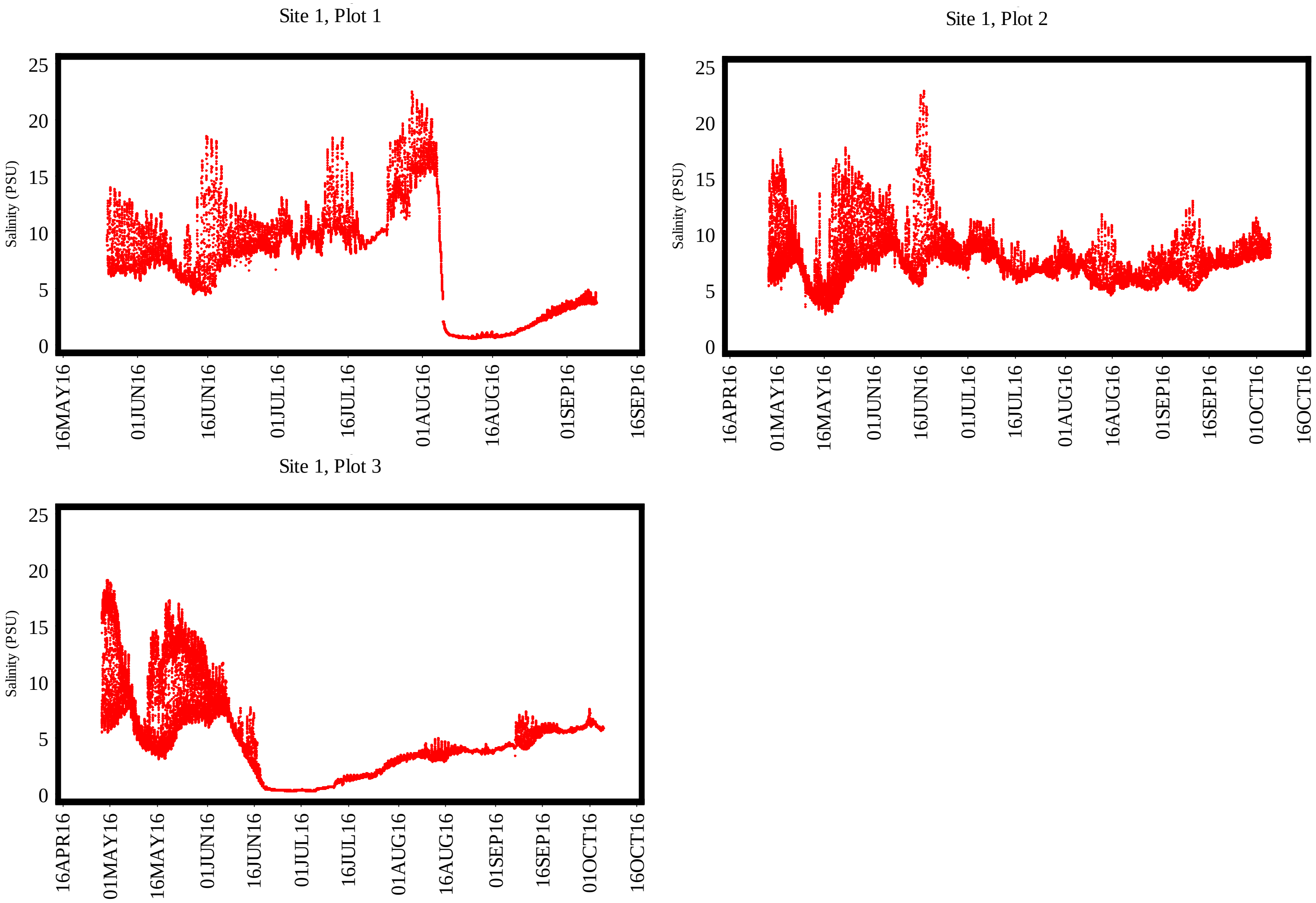
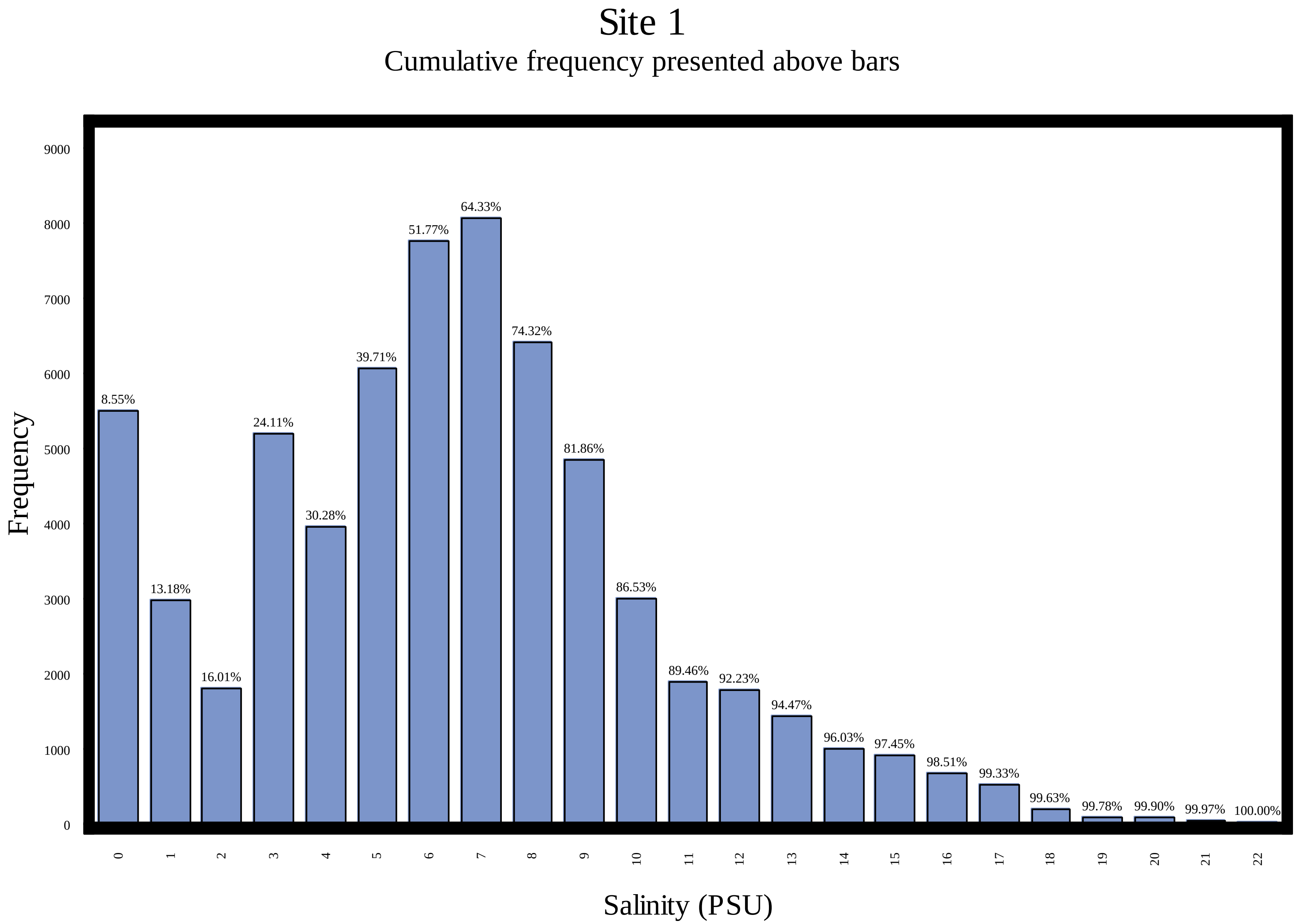


Figure A-3. Salinity over time at Site 1



Site 1

Cumulative frequency presented above bars

Figure A-4. Salinity frequency distribution at Site 1

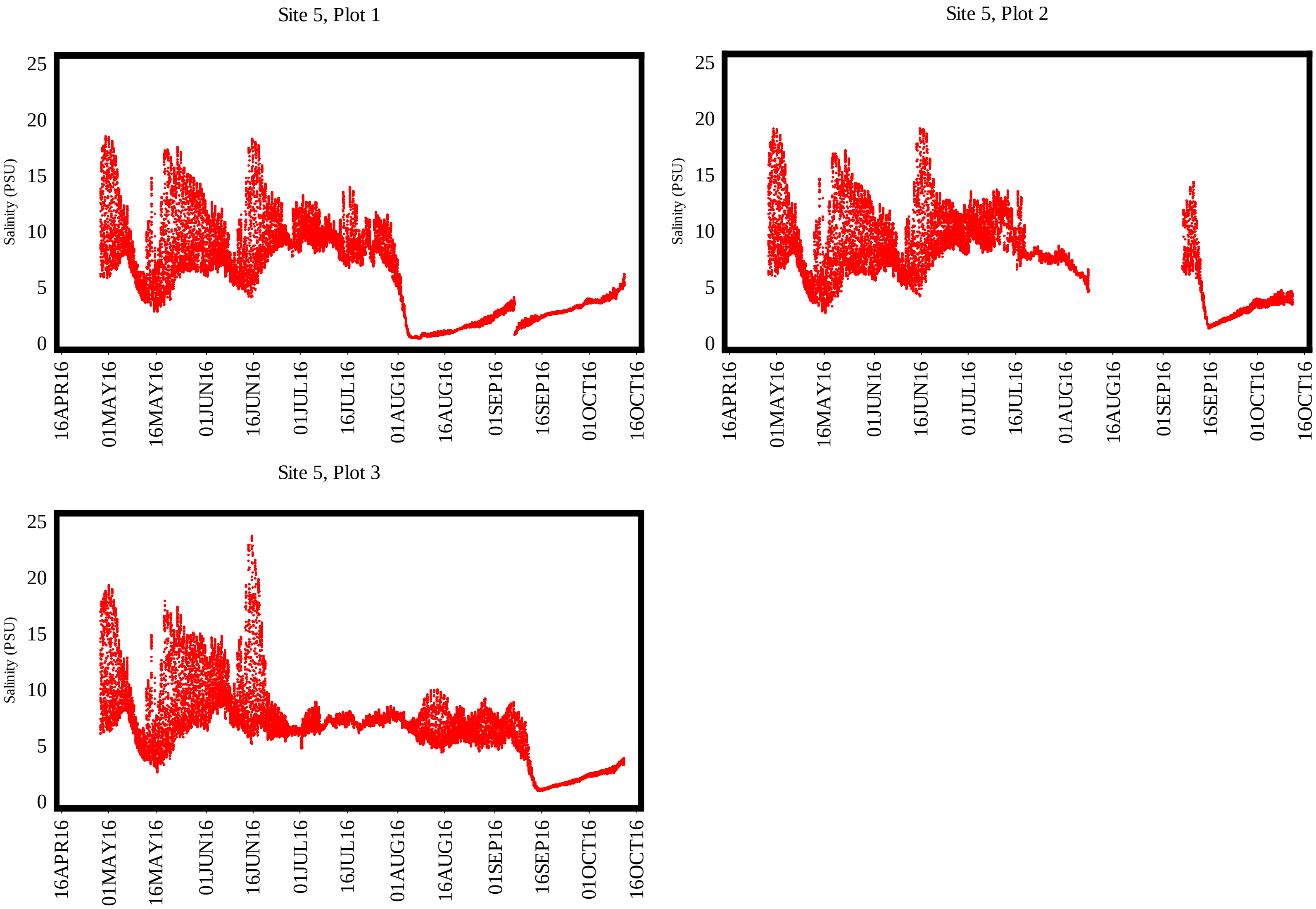


Figure A-5. Salinity over time at Site 5

Site 5

Cumulative frequency presented above bars

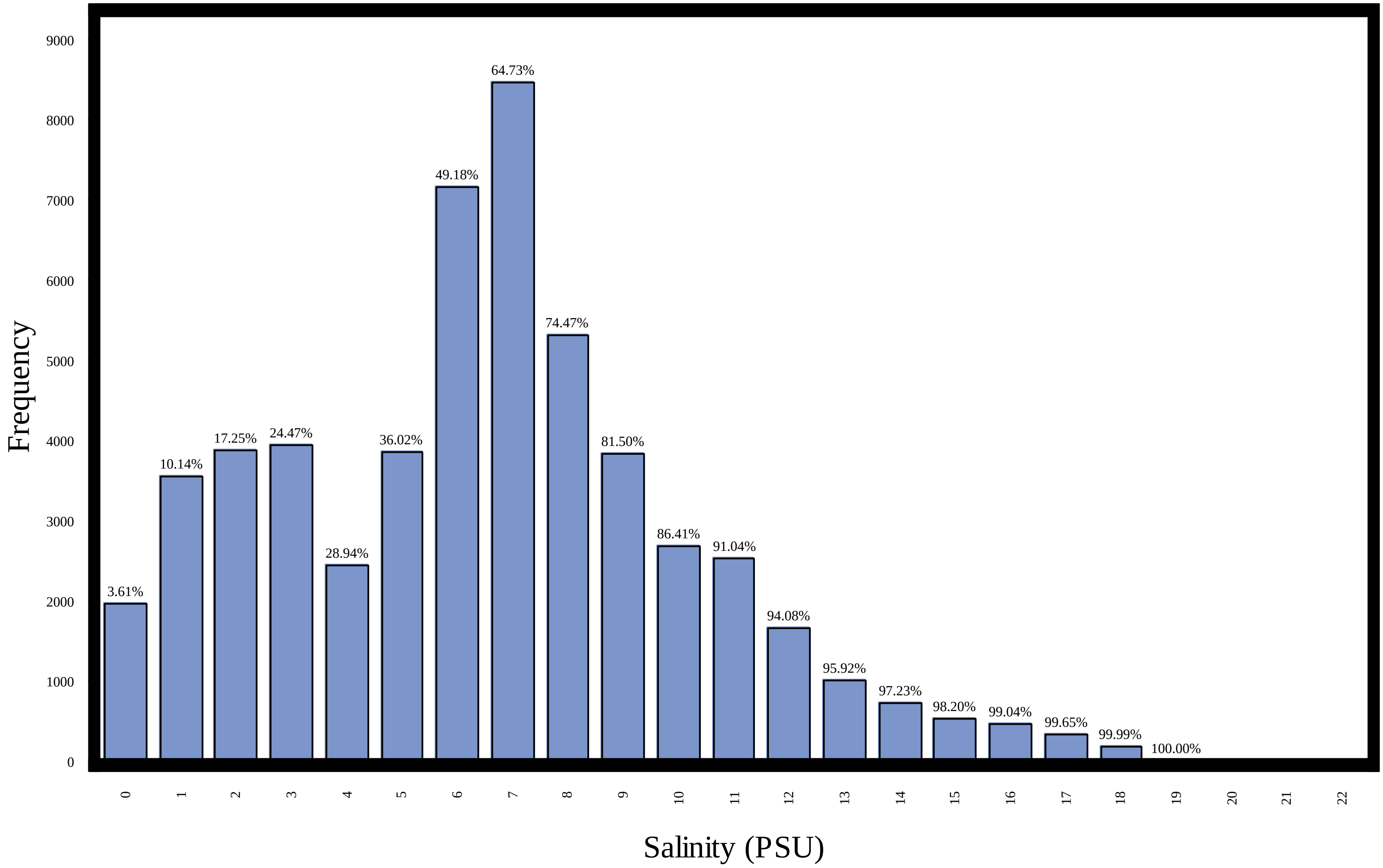
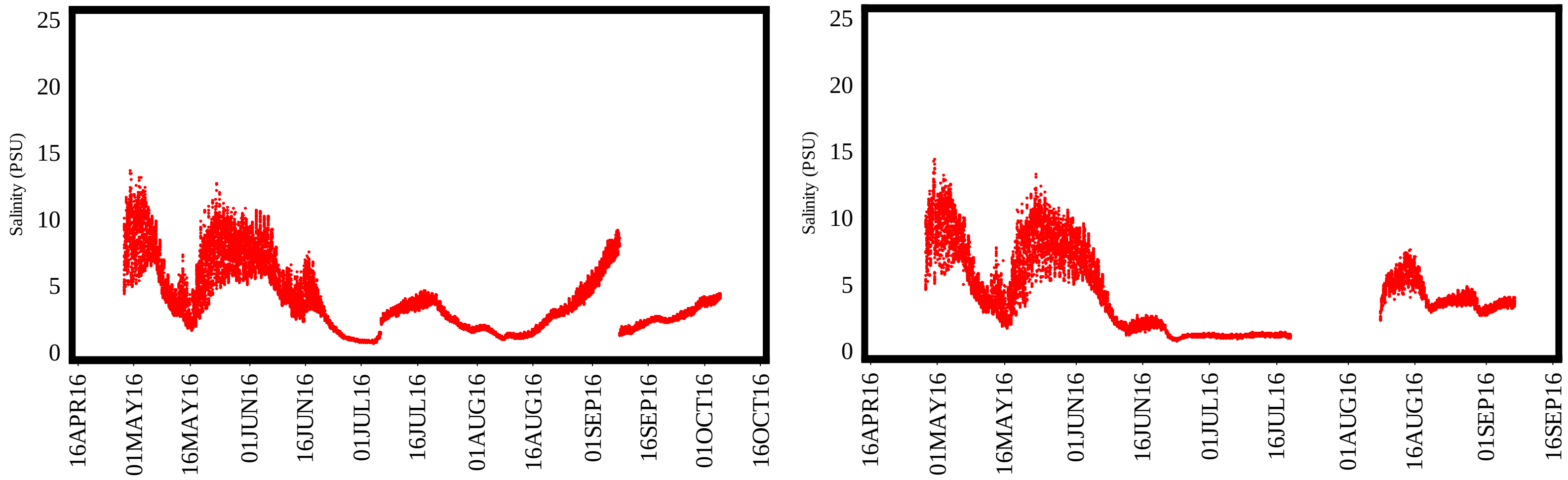


Figure A-6. Salinity frequency distribution at Site 5

Site 8, Plot 1

Site 8, Plot 2



Site 8, Plot 3

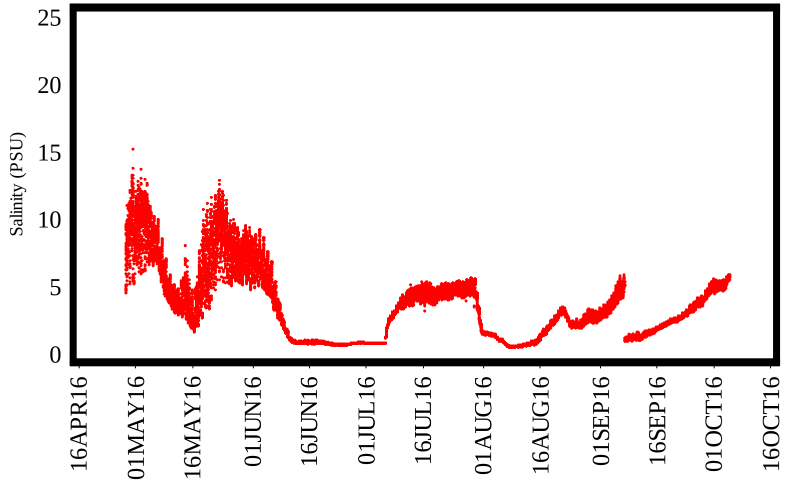


Figure A-7. Salinity over time at Site 8

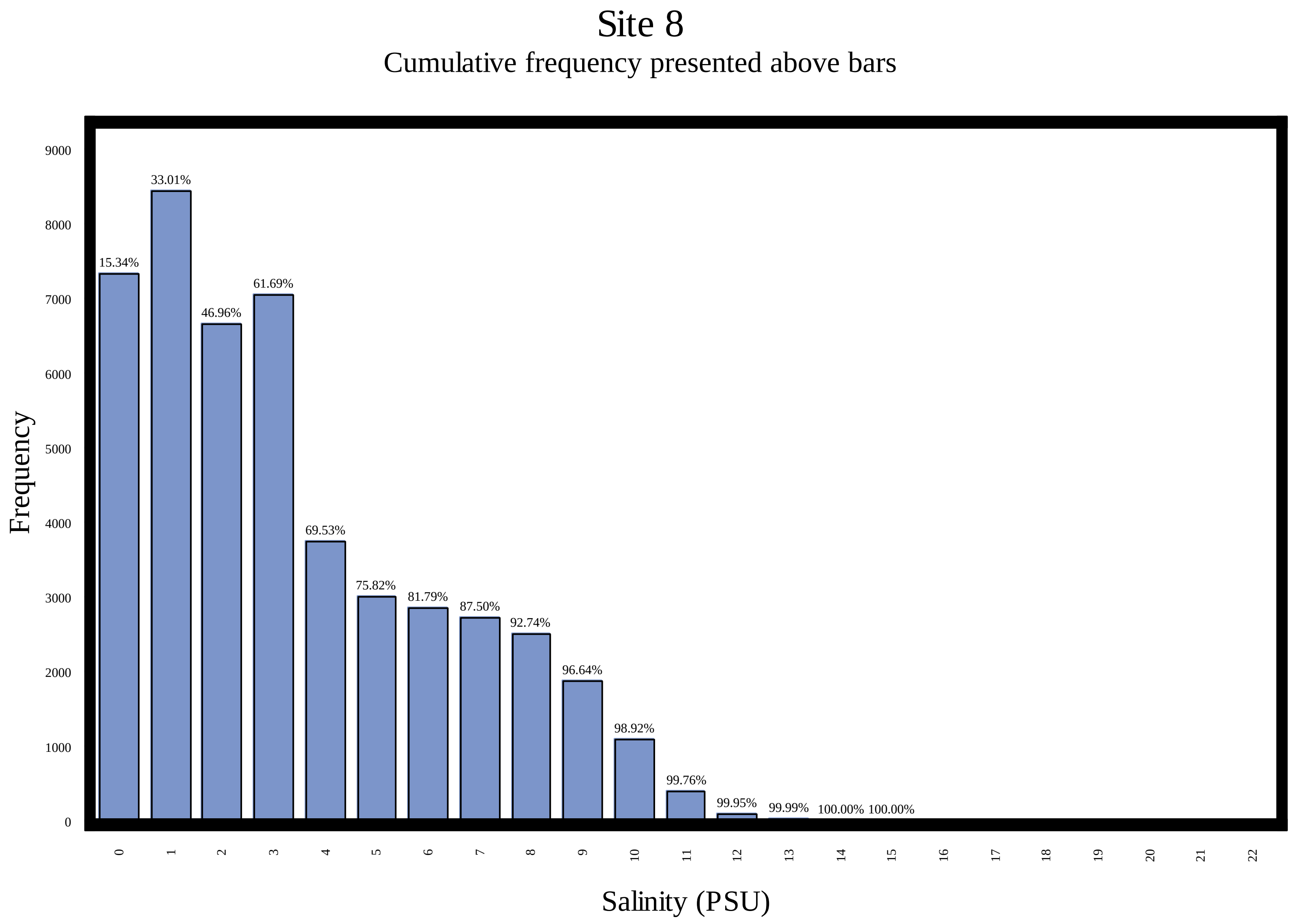
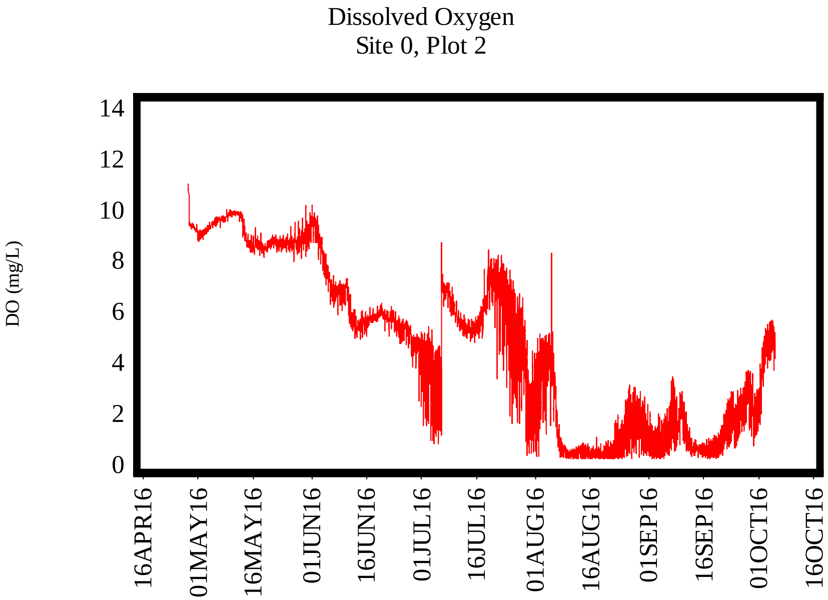


Figure A-8. Salinity frequency distribution at Site 8

APPENDIX B

DISSOLVED OXYGEN FIGURES



Dissolved Oxygen
Site 0, Plot 2

Figure B-1. Dissolved Oxygen over time at Site 0 (Glove)

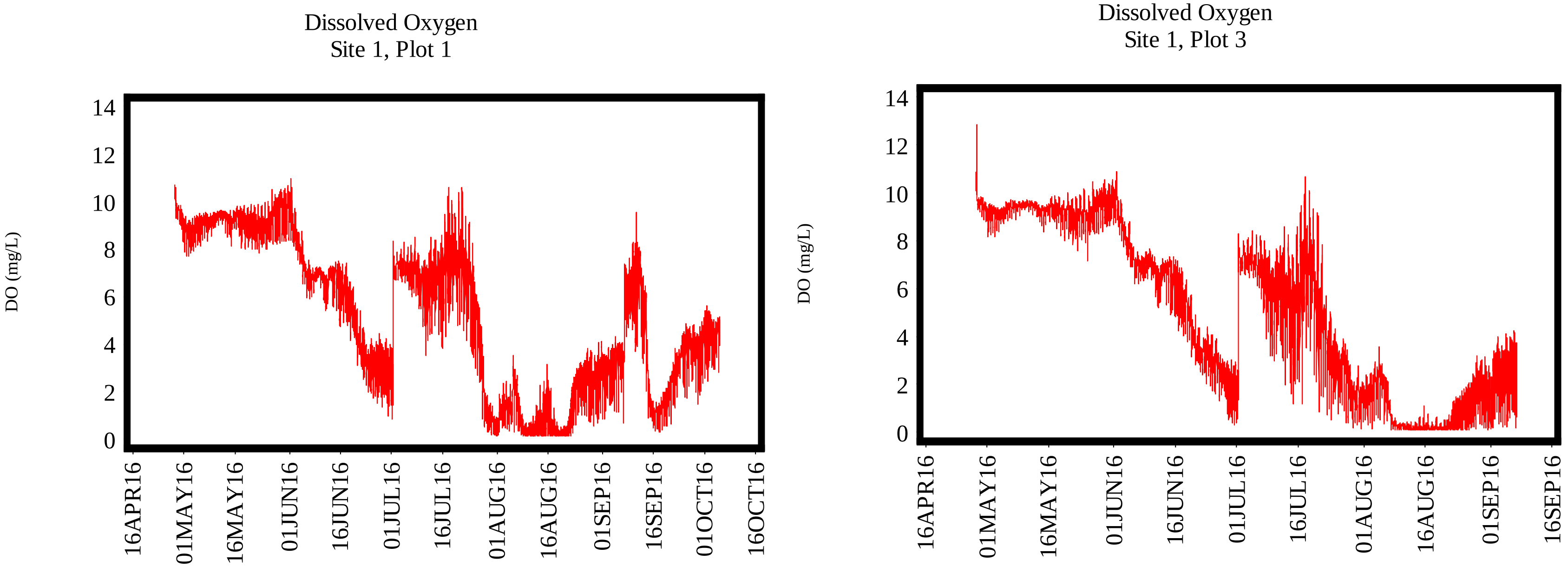
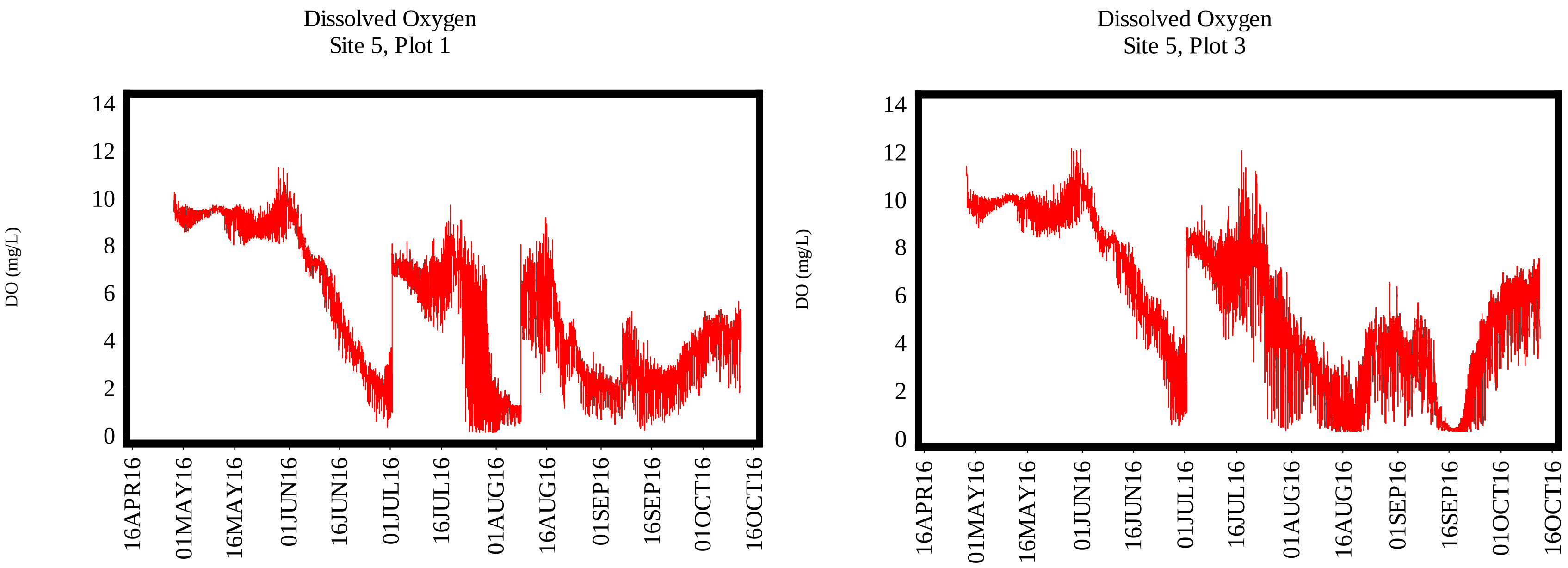


Figure B-2. Dissolved Oxygen over time at Site 1



Dissolved Oxygen
Site 5, Plot 1

Dissolved Oxygen
Site 5, Plot 3

Figure B-3. Dissolved Oxygen over time at Site 5

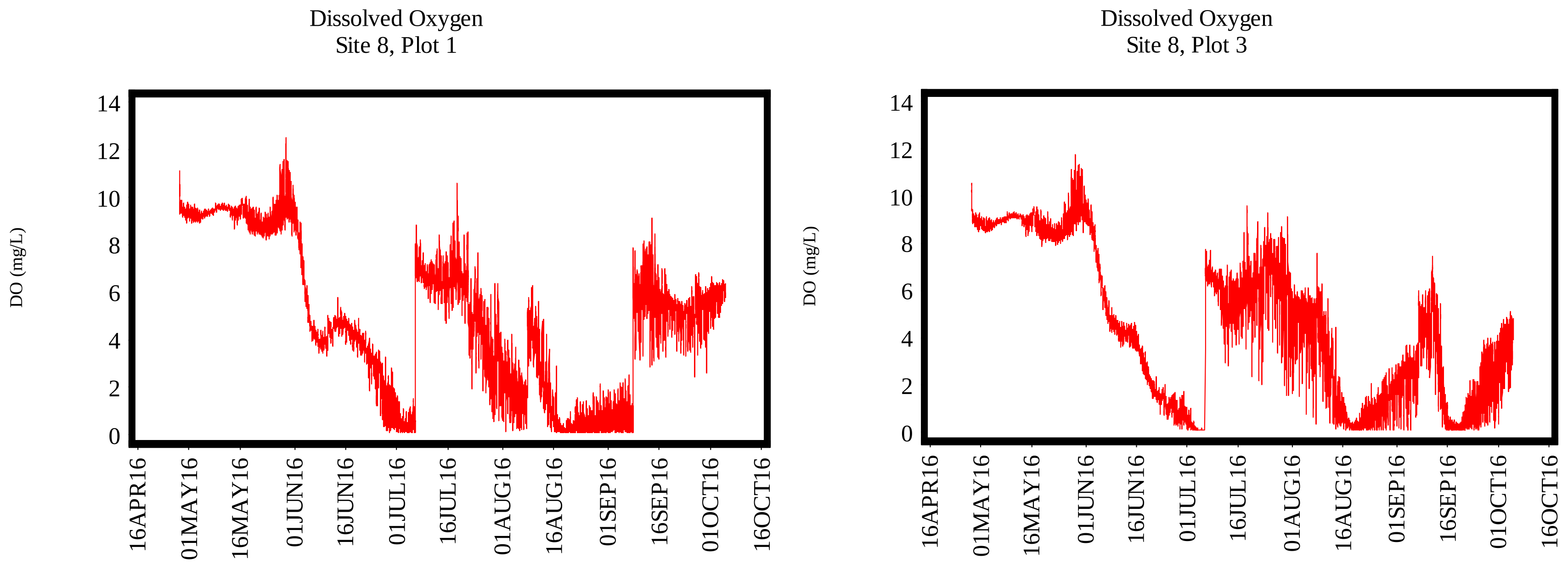


Figure B-4. Dissolved Oxygen over time at Site 8