Memorandum

To: Oyster Work Group

From: Chad Seewagen, Fred Jacobs, Justin Krebs

Date: March 16, 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. The study discussed in this memo includes the measurement of salinity, dissolved oxygen (DO), depth, and temperature, and information on the timing and magnitude 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. This technical memo presents the results of the first year of salinity, DO, and spat-fall monitoring.

STUDY DESIGN AND SAMPLING FREQUENCY

Three plots were established within each of the three study sites (Sites 1, 5, 8) as well as at "the glove" (**Figure 1**). One sonde that measures salinity, depth, and temperature (Solinst LTC Levelogger Junior, Georgetown, Ontario), and one spat collector were paired together and placed at each of the three plots within each site. A DO logger (Precision Measurement Engineering miniDOT, Vista, California) was deployed at two of the three plots within each site. 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.

The spat collectors consist of four segments of corrugated plastic drain pipe (36" wide x 4" diameter) that are strung together horizontally, anchored by a cinder block, and held upright in the water column by buoys, (**Figure 2)**. Each spat collector has a total outer surface area of approximately 1.2 m. The data loggers and spat collectors were deployed on 4-5 June, 2015 and retrieved once a month until 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. After the October sampling event, the spat collectors, DO loggers, and two of the three sondes at each site were removed from the river for the winter, and will be redeployed in the spring of 2016. One sonde was left at each site to continue recording salinity levels throughout the winter; these remaining sondes were retrieved to download data in December 2015 and will be retrieved again in March 2016.

PRELIMINARY RESULTS

SPAT COLLECTORS

After deployment on June 4-5, 2015, the spat collectors were retrieved to the surface and inspected for oyster spat on July 8-10, August 12-13, September 15-16, and October 12-13. Only two of the three spat collectors at "the glove" could be found in July, only one of the three was found in August, none could be found in September, and then one was found again in October. Otherwise, all three spat collectors from each of the three study sites were retrieved during every monthly sampling event.

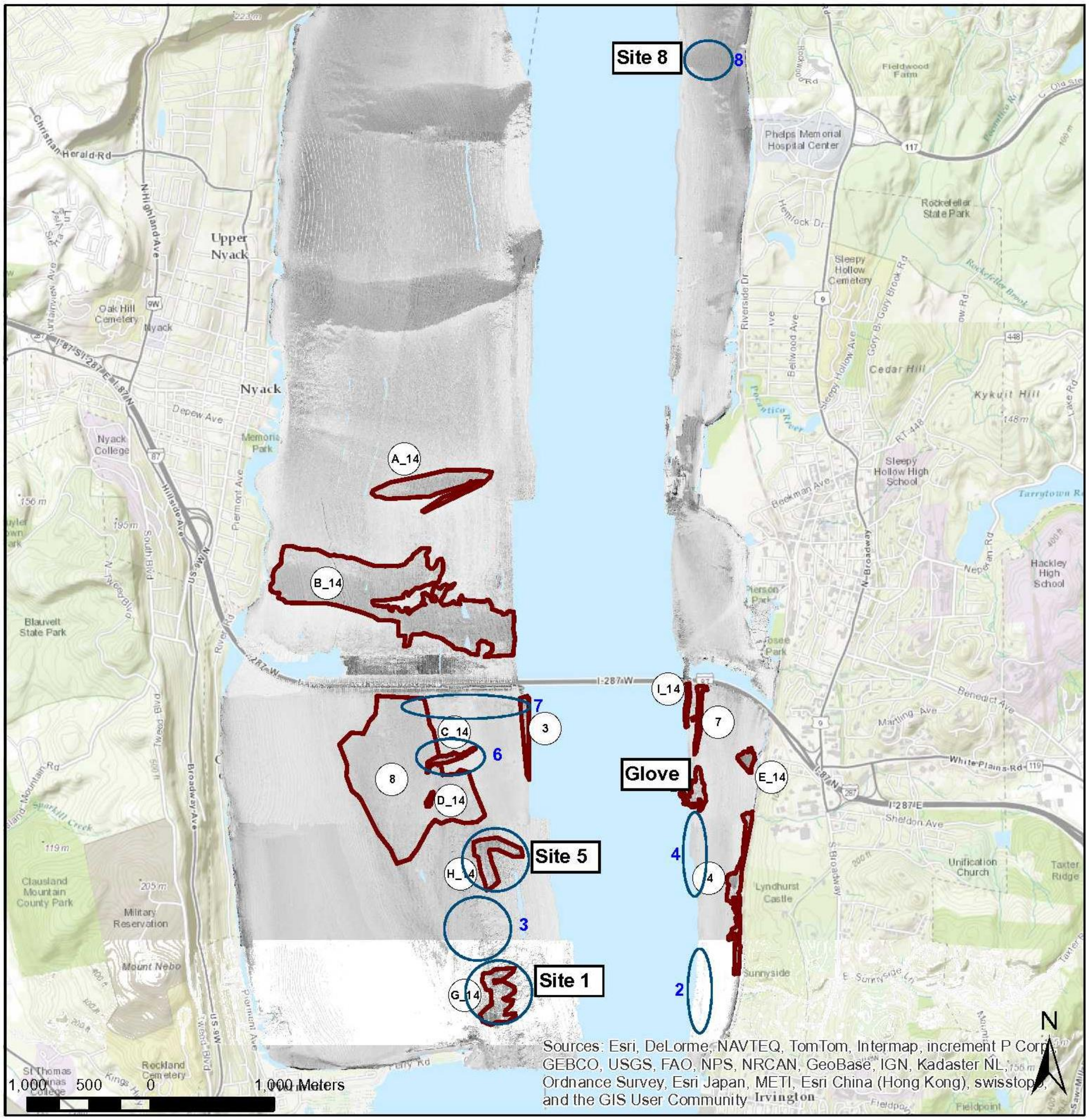

Figure 1. Tier 3 study site locations.

Figure 2. Spat collector prior to deployment.

Oysters were observed on the spat collectors for the first time during the September sampling event; oysters were present on all three spat collectors at all three study sites. The number of individual spat on one randomly selected side of the spat collector (i.e., the front or back side of the four segments of drain pipe) was counted, and 3 to 4 spat were opportunistically measured (shell width at its widest point). Density ranged 9 - 29 spat/m^2 among the three study sites and was highest at Site 8, followed by Site 5 and Site 1 (**Table 1**). Based on the sizes of the spat (**Table 1**), they were estimated to have set approximately 1 month prior, shortly after the August sampling event.

Table 1
Oyster Spat Density and Size Recorded on Spat Collectors in September and October, 2015

	September			October		
Site-Plot	**Spat**	**Density (m^2)**	**Sizes (mm)**	**Spat**	**Density (m^2)**	**Sizes (mm)**
1-1	5	8	13, 16	25	41	29, 25, 22, 13
1-2	9	15		15	24	19, 13, 22, 13
1-3	2	3	13, 13	1	2	19
Mean (± SD)	5 (± 3.5)	9 (± 5.7)	14 (± 1.5)	14 (± 12.1)	22 (± 19.6)	19 (± 5.7)
5-1	12	19	13, 13, 13	19	31	13, 19, 19, 25
5-2	13	21	19, 11	16	26	25, 25, 22, 13
5-3	15	24	6, 6, 11	24	39	19, 13, 19, 22
Mean (± SD)	13 (± 1.5)	22 (± 2.5)	12 (± 4.2)	20 (± 4.0)	32 (± 6.6)	20 (± 4.6)
8-1	28	45	19, 22, 14	34	55	29, 22, 25, 29
8-2	19	31	13, 19, 16	22	36	22, 25, 19, 22
8-3	7	11	16, 16, 13	29	47	25, 29, 16, 29
Mean (± SD)	18 (± 10.5)	29 (± 17.1)	16 (± 3.1)	28 (± 6.0)	46 (± 9.8)	24 (± 4.3)

In October, oyster density increased on all three spat collectors at all three study sites and there was greater size variation among the oysters, suggesting that additional settlement had occurred after the September sampling event. With the new settlement, oyster density remained the highest at Site 8, followed by Site 5 and Site 1 (**Table 1; Figure 3**). The spat collector that was retrieved at "the glove" in October, which was the first spat collector to have been found at this site since the August sampling event, had no oyster spat.

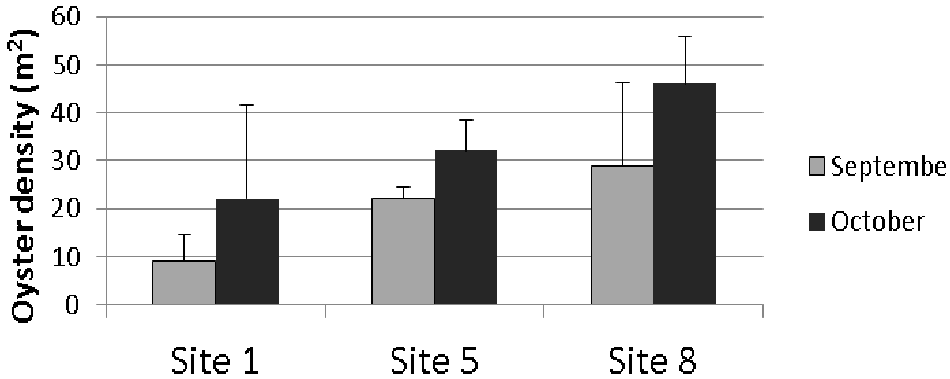

Figure 3. Mean (+ SD) oyster density on spat collectors at each study site during September and October, 2015.

SALINITY, DEPTH, TEMPERATURE, AND DISSOLVED OXYGEN

Sondes and DO loggers were retrieved and downloaded monthly on the same dates as the spat collectors were sampled, until October 2015 when all DO loggers and all but three sondes were removed for the winter. Multiple sondes failed throughout the season possibly as a result of corrosion caused by saline conditions, and two of the three sondes and one of the two DO loggers that were placed at "the glove" could not be found. As such, a complete time series of data was not obtained from every plot within every study site. However, a complete time series of salinity data was obtained from at least one plot within Sites 1 and 8, and a nearly complete time series (June-September) was obtained from one plot at Site 5. Due to the combination of defective and missing sondes at "the glove", salinity, temperature, and depth data were only obtained from one plot from June 5 to August 13. Complete or nearly complete DO data series' were obtained from each of the three study sites. At "the glove", DO data were obtained from June-July at one plot and July-October at the other plot.

After the October retrieval and download of the sondes, one of the three sondes that still functioned properly was placed at each of the three study sites, and the other sondes were removed. The three sondes that were left in the river were last retrieved in December 2015. At that time, only one was still in working condition and downloadable (from Site 5). After downloading the data from the sonde at Site 5, it was returned to continue collecting data through the winter.

Table 2
Minimum, Maximum and Mean Salinity Levels (PSU), June-October, 2015

Site	Minimum	Maximum	Mean
1	1.1	16.6	5.7
5	1.2	16.3	6.4
8	0.6	13.8	5.9
Glove	1.5	16.9	7.4

Table 3
Minimum, Maximum and Mean Depth (m), June-October, 2015

Site	Minimum	Maximum	Mean
1	4.8	6.9	5.8
5	3.6	5.8	4.8
8	4.6	6.7	5.6
Glove	9.5	11.5	10.4

Table 4
Minimum, Maximum and Mean Temperature (°C), June-October, 2015

Site	Minimum	Maximum	Mean
1	16.3	28.5	24.2
5	19.1	27.7	24.9
8	18.1	28.1	24.5
Glove	18.9	26.6	23.6

Table 5
Minimum, Maximum and Mean Dissolved Oxygen Levels (mg/L), June-October, 2015

Site	Minimum	Maximum	Mean
1	0.1	14.1	5.2
5	0.1	11.8	5.3
8	0.1	10.9	4.7
Glove	0.1	9.5	4.7

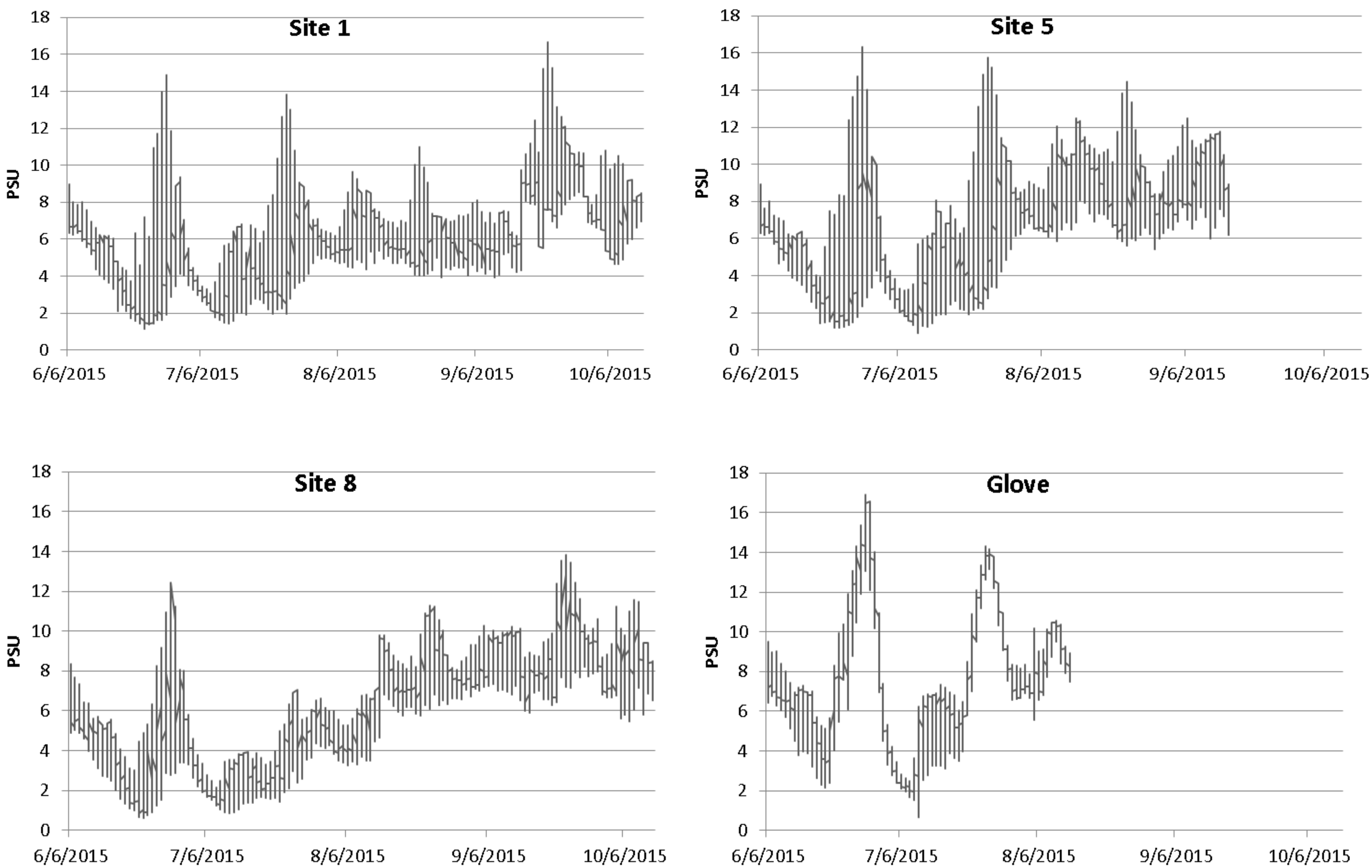

Figure 4. Bottom salinity levels, June-October 2015. The data from the plot with the most complete time series for each site are shown.

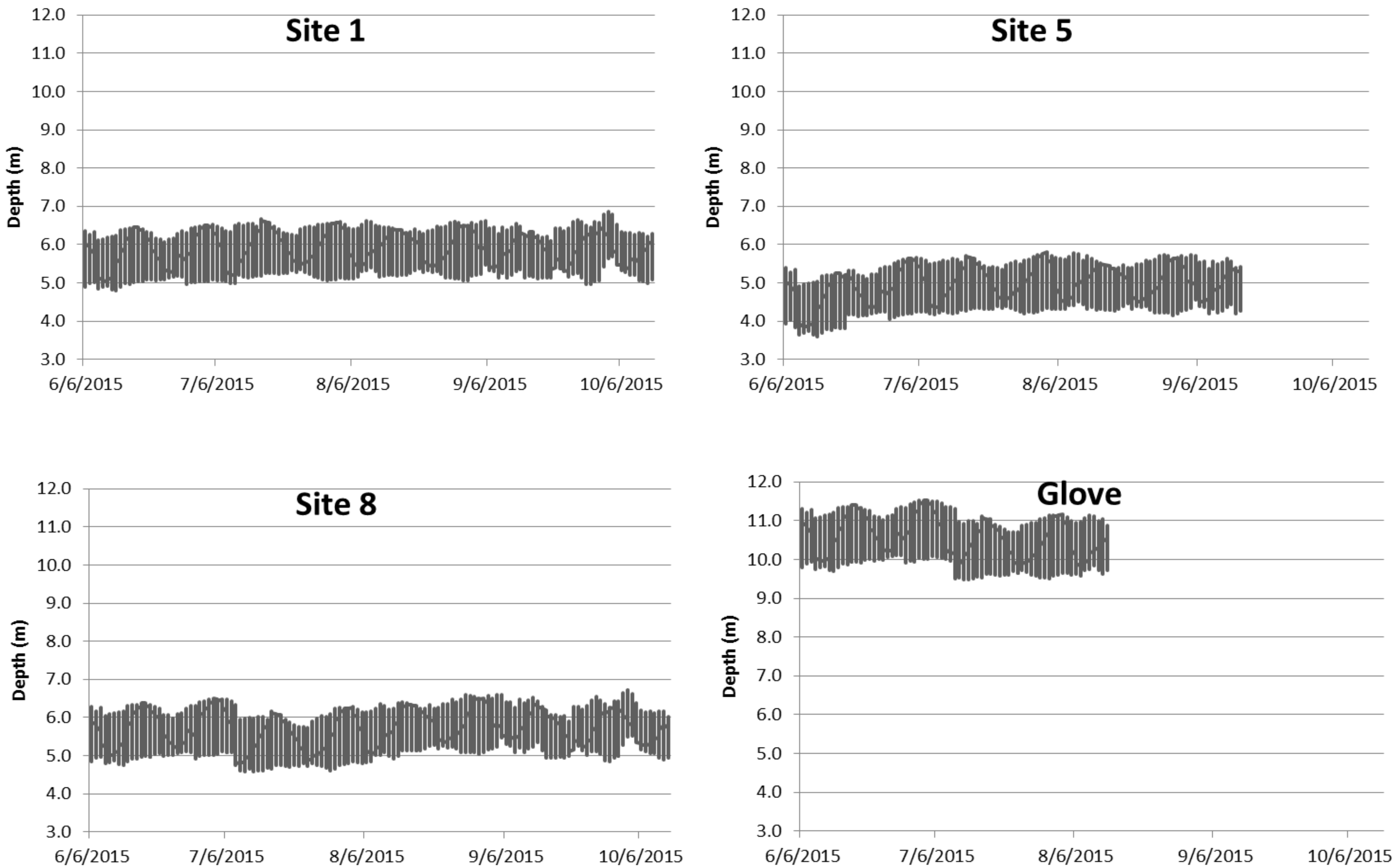

Figure 5. Water depth (meters), June-October 2015. The data from the plot with the most complete time series for each site are shown.

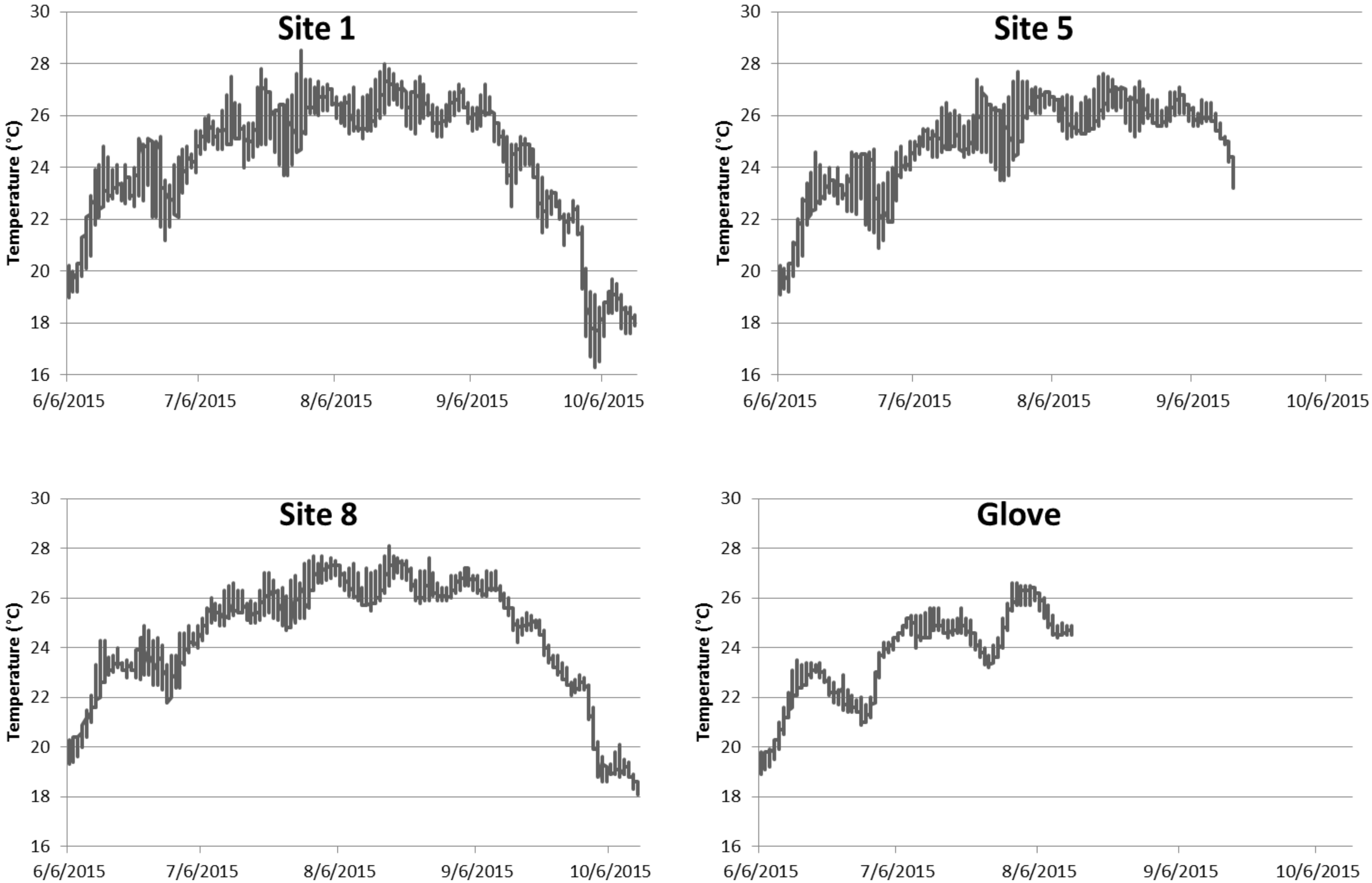

Figure 6. Temperature (°C), June-October 2015. The data from the plot with the most complete time series for each site are shown.

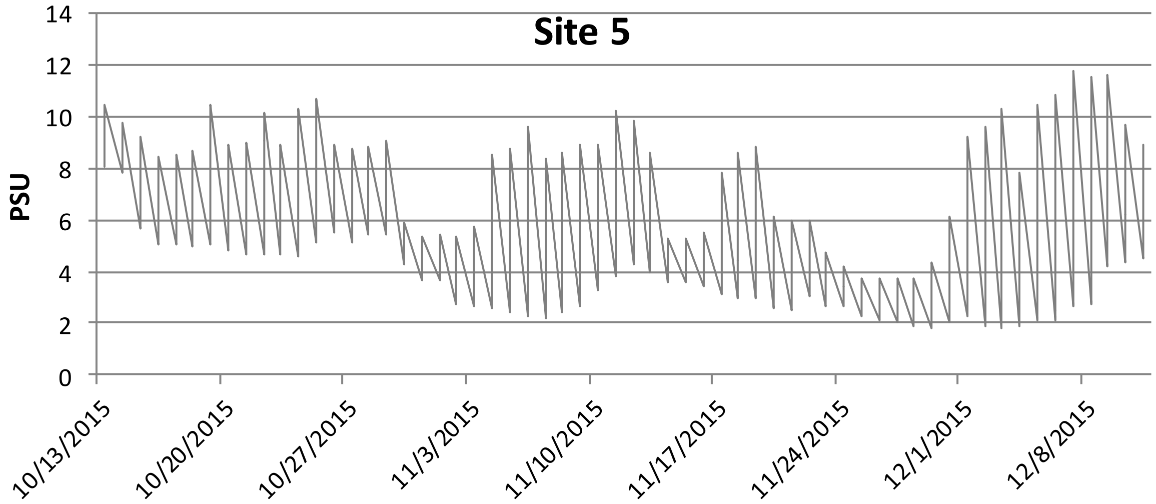

Figure 7. Bottom salinity levels at Site 5 from 13 October to 11 December, 2015. Salinity data were not obtained at Sites 1 and 8 during this time period due to equipment failure.

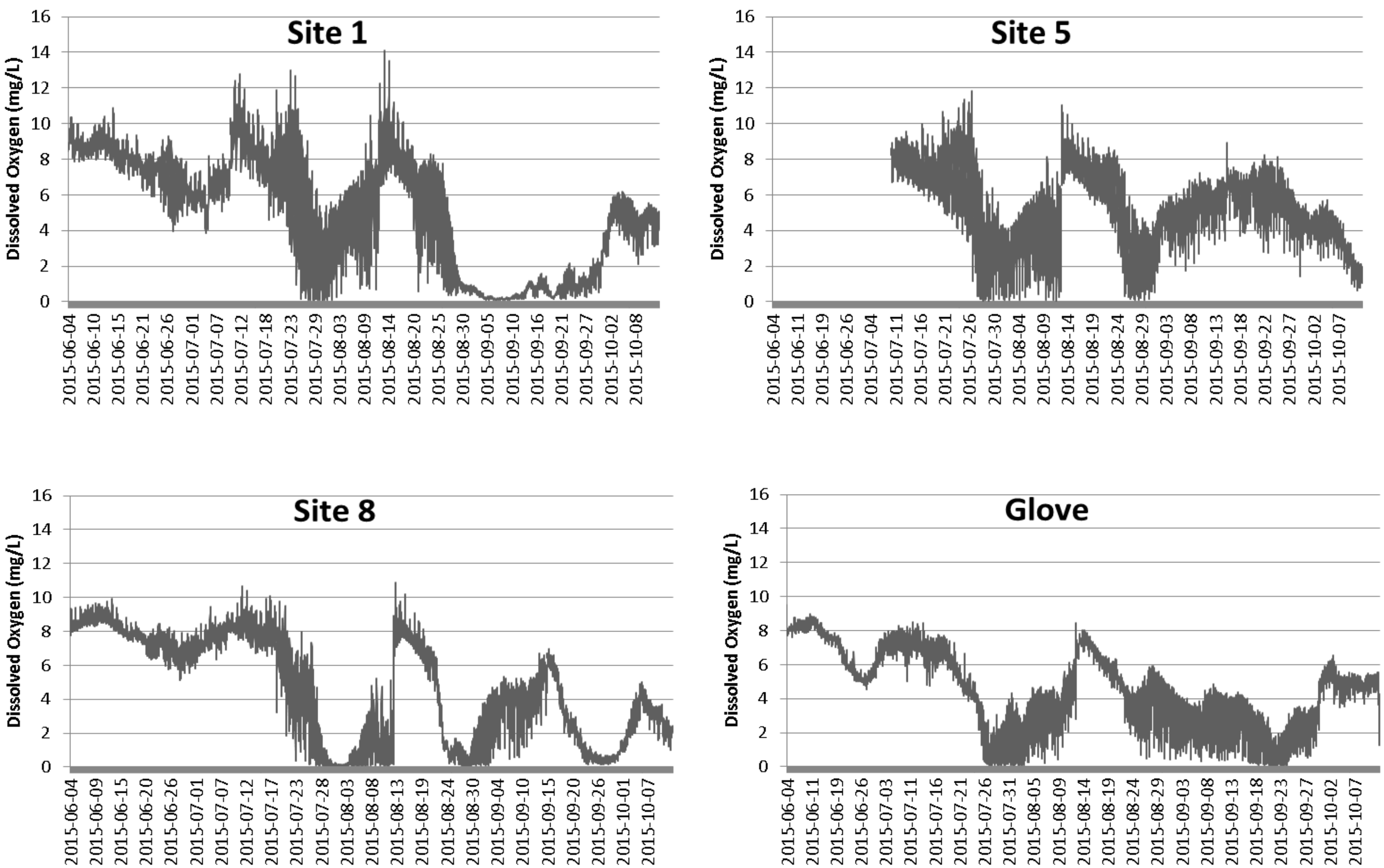

Figure 8. Bottom dissolved oxygen levels, June-October 2015. The data from the plot with the most complete time series for each site are shown.

The most complete time series of salinity, depth, and temperature data for each study site and “the glove” are shown in **Figures 4-6** (excepting the October-December data obtained only from Site 5, shown in **Figure 7**). Temporal trends in salinity were highly similar among sites, although a spike in salinity that occurred in late July at the sites south of the bridge (Sites 1, 5, and “the glove”) did not occur farther north at Site 8. Salinity generally increased at each site as the season progressed from early summer to fall. Salinities ranged 1.1 – 16.6 PSU at Site 1 and 0.6 – 13.8 PSU at Site 8 over the full season. During the portion of the season for which data were obtained at Site 5 and “the glove”, salinities ranged 1.2 - 16.3 PSU and 1.5 – 16.9 PSU, respectively. Average salinity was lowest at Site 1 and highest at “the glove” (**Table 2**), despite the data from “the glove” being limited to the early portion of the season (June 5 – August 13) when salinities in the area were generally lower than later in the season. Salinities consistently fell below 2 PSU at each site besides “the glove” for an approximately 1 week period in late June and mid-July, and the lows in salinity during these periods were more pronounced at the northernmost site (Site 8) than at Sites 1 and 5.

Minimum, maximum, and mean depths were the greatest at the glove, followed by Site 1, Site 8, and Site 5 (**Table 3**). The shallowest depth that occurred during the study period was 3.6 meters, which was at Site 5 during low tide. The greatest depth observed was 11.5 meters at the glove. The time series at each site is illustrated in **Figure 5**. Water depth is an important factor in oyster habitat suitability; waters that are too deep may be too hypoxic, while oysters in shallow waters may receive high amounts of sedimentation and poor nutrient flow. The depth at each study site is within the range in which oysters can thrive and is sufficient for restoration.

Temperatures during the study period ranged from 16.3-28.5 °C and averaged the lowest at the glove, which is the deepest study site. Average temperatures were highly comparable among Sites 1, 5, and 8, differing by only 0.7 C (**Table 4**). At each study site, temperatures climbed steadily from the start of the study period in early June, peaked around early-mid August, and then declined until the end of the study period in October (**Figure 6**).

Data from the only sonde that continued working from October to December showed that salinity levels at Site 5 ranged from 1.8 – 11.8 PSU and averaged 5.4 PSU (± 2.3 SD) over that time period (**Figure 7**). Salinity levels during the last week of November were consistently the lowest and had the least variability. Depth ranged from 4.4-6.4 meters and temperatures continued to decline, reaching a low of 8.2 °C on December 9 and 10.

The most complete time series of DO data for each study site and “the glove” are shown in **Figure 8**, and the mean, minimum, and maximum values are reported in **Table 5**. DO followed the same general trends at each site from June through August, but then differed more substantially among sites during September. DO reached or closely approached 0 mg/L at each site at some point during the study period. Site 8 had several consecutive days with DO levels consistently ≤ 3 mg/L between late July and early August, during late August, and again during the second half of September. DO at Site 8 ranged from only 0.1 – 1.2 mg/L (mean = 0.3 ± 0.3 SD) from July 29 through August 5 and 0.1 – 1.7 mg/L (mean = 0.8 ± 0.4 SD) from August 24 through August 29. These extended periods of hypoxia at Site 8 during August likely overlapped with a portion of the oyster spawning and/or spat settlement period in the area. Site 1 had the most extended period of hypoxia, when DO was consistently ≤ 3 mg/L from late August through September. DO at Site 1 was < 1 mg/L for the majority of the estimated spat settlement period (**Figure 8**), which may partly explain why oyster density on the spat collectors was the lowest at this site. 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].

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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.

NEXT STEPS

The sonde that is remaining at Site 5 will be retrieved in the spring and downloaded if it is still in working condition. The spat collectors, DO loggers, and new sondes will be deployed at each site in June for a second year of data collection. The sondes and DO loggers will be downloaded, and the spat collectors will be sampled, on a monthly basis from June through October, as in 2015. The results will then be communicated to the OWG and used, in conjunction with the results of the Tier 3 substrate comparison study, to identify the Tier 4 restoration site(s).

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[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.