Vertical Profiler Water Quality Monitoring in the Tred Avon River – June 2015 to September 2015

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MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Executive Summary

During June-September 2015, the National Oceanic and Atmospheric Administration (NOAA) deployed a vertical profiler to monitor water quality conditions in the Tred Avon River, an important oyster restoration area in the Chesapeake Bay. The vertical profiler measured salinity, water temperature, pH, dissolved oxygen, chlorophyll, and turbidity at one meter intervals throughout the water column. Profiles were conducted once every hour.

During the 2015 monitoring period, the Maryland Department of Natural Resources (DNR) provided field support for the Tred Avon vertical profiler, monitored profiler operation, downloaded data files, and reviewed the data for quality assurance. Considerable effort was spent in 2015 resolving operating issues with the profiler depth sounder and data logger. The depth sounder often significantly underestimated the depth of the water column, causing the profiler to stop conducting profiles. Additionally, computer malfunctions with the profiler data logger caused the profiler to collect multiple records in rapid succession at a single depth. Following numerous field visits and consultations with the equipment manufacturer, DNR resolved the issues by installing a new operating system on the data logger, disabling the depth sounder, and collecting profile data at pre-determined depths. Once these changes were made, the vertical profiler operated without incident for the remainder of the monitoring season. However, before the vertical profiler is deployed again, the depth sounder as well as several inoperable data sondes should be repaired or replaced.

Vertical profiler data consisted of two types: the readings collected during profile sequences (profile data); and the readings collected when the monitoring sonde was parked in a fixed position awaiting the next profile sequence (hourly data). In late September 2015, the vertical profiler captured a brief, low dissolved oxygen event in the bottom waters of the Tred Avon River, recording dissolved oxygen values as low as 2.95 mg/l. However, overall salinity, pH, water temperature, chlorophyll, turbidity, and dissolved oxygen data from the vertical profiler show that water quality conditions in the Tred Avon River during 2015 were generally suitable for oyster growth and survival.

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Introduction

During June-September 2015, the National Oceanic and Atmospheric Administration (NOAA) deployed a vertical profiler to monitor water quality conditions in the Tred Avon River. The Tred Avon is a tributary of the Choptank River and part of the Choptank Complex that is targeted for oyster restoration activities. Water quality information from the profiler may be used to assess habitat suitability for oyster growth and survival. The 2015 monitoring was a continuation of vertical profile monitoring that NOAA initially began in 2014. This report summarizes monitoring activities of the 2015 season.

In partnership with NOAA, the Maryland Department of Natural Resources (DNR) provided equipment maintenance and data management support for the Tred Avon vertical profiler. DNR currently operates a similar vertical profiler in nearby Harris Creek, and therefore has experience with maintaining of this type of monitoring equipment.

The vertical profiler system deployed in the Tred Avon River consists of a water quality monitoring sonde (YSI Inc., Model 6600 V2) attached by a cable to a CR1000 datalogger (Campbell Scientific, Inc.). The CR1000 is mounted on a floating platform along with a winch mechanism that raises and lowers the sonde in the water column. The Tred Avon profiler is programmed to conduct a profile every hour, with readings taken at 1-meter intervals throughout the entire water column. Profile sequences commence at the top of the hour and take approximately 5 to 8 minutes to complete.

The water quality sonde measures the following parameters: specific conductance/salinity, temperature, pH, dissolved oxygen, turbidity, and chlorophyll. Readings are stored in electronic files on the CR1000. In addition to water quality data, the vertical profiler can also store data files pertinent to instrument operation. Data are retrieved from the CR1000 either by connecting to the unit with a laptop computer, or by communicating remotely via telemetry connection.

Field Support

NOAA installed the profiler platform in the Tred Avon River in late May 2015, and shortly thereafter DNR connected a YSI sonde to the unit to initiate profiler operation. Throughout the monitoring season, DNR conducted regular field visits to the monitoring site to service the vertical profiler. Field visits were generally scheduled at two week intervals during the monitoring period. Routine maintenance tasks primarily included cleaning and recalibration of the monitoring sonde to ensure data integrity. During each field visit, a clean and freshly calibrated sonde was brought out to the site and swapped with the sonde that was already deployed at the profiler. The sonde that was removed was then returned to the DNR field office for cleaning and post-calibration. Post-calibration procedures were necessary to identify any drift in the measurements made by the sonde during deployment.

DNR staff visited the Tred Avon site a total of eight times during the 2015 monitoring season. Dates of field visits are listed in Table 1.

Table 1. Field visits to the Tred Avon vertical profiler by DNR personnel during the 2015 monitoring season.

Date	Activity
May 28, 2015	Initial sonde deployment
June 25, 2015	Swapped sonde
July 13, 2015	Swapped sonde
July 27, 2015	Troubleshoot depth sounder issues; discovered anchor line wrapped around transducer pole
July 30, 2015	Untangled anchor line from transducer; cleaned and reinstalled depth sounder; swapped sonde
August 11, 2015	Attempted to install new operating system; NOAA personnel did not have correct connector to the CR1000.
August 24, 2015	Installed new operating system on CR1000; swapped sonde
September 8, 2015	Swapped sonde
September 22, 2015	Swapped sonde

Profile data collection began on June 1, 2015. The monitoring season concluded on October 1, 2015, when NOAA retrieved the vertical profiling equipment from the Tred Avon River in advance of approaching Hurricane Joaquin.

Operational Issues

In 2015, the vertical profiler experienced some critical operating issues with the depth sounder and the CR1000 datalogger. These issues were a recurrence of equipment malfunctions that initially occurred during the 2014 monitoring season and are described in detail below.

Depth Sounder

The Tred Avon vertical profiler uses a depth sounder to take a water depth reading prior to the start of each profile sequence. This reading determines the maximum depth to which the sonde will descend during a profile sequence. The water depth at the monitoring site is approximately 5m and varies depending on tidal stage. If the initial depth reading was greater than 5m, then a profile was conducted at one meter intervals to a final reading at 5m. If the water depth was less than 5m, the profile sequence concluded with a final reading at 4m depth.

Occasionally, the depth sounder recorded an erroneous initial depth of less than 1m. Since a profile sequence begins with a reading at 1 meter depth, internal checks by the system concluded that there was not enough water to even initiate a profile sequence. This triggered the profiler to

automatically switch into “standby” mode and stop conducting profiles. The problem first occurred in July and was documented in the Event Log file with the error message “Start depth is greater than end depth”. This same operating error occurred multiple times during the 2014 monitoring season. In the past, DNR personnel were able to restart profiling sequences through remote communication with the CR1000. However, this appeared to be a very temporary fix in the 2015 monitoring season. After being restarted remotely, the profiler would often conduct just one or two profiles before switching into “standby” once again.

DNR staff visited the site on July 27, 2015 to further investigate the depth sounder issues. At that time, DNR field personnel noticed that the anchor line for the profiler had become wrapped around the transducer pole for the depth sounder (Figure 1). DNR staff returned to the site on July 30, untangled the anchor line, and moved the point of attachment for the line to the “stern” of the profiler platform to prevent future entanglement. The depth sounder was also found to be heavily fouled (Figure 2), so field staff cleaned and reinstalled the depth sounder. Unfortunately, field efforts to restore operation to the equipment were not successful. The depth sounder continued to malfunction, frequently switching the profiler into “standby” mode.

Figure 1. Tangled anchor line.

Figure 2. Biofouling on depth sounder.

It should be noted that biofouling of the equipment is a major issue at the Tred Avon site. As with the depth sounder, data sondes were often found to be covered in heavy growth when retrieved for cleaning and post-calibration. In addition to possibly impacting the performance of the depth sounder, biofouling may also contribute to inaccurate readings of water quality parameters by the data sondes.

CR1000 Data Logger

The CR1000 data logger stores data and computer programs on board the vertical profiler and also controls operation of the equipment. Under normal operation, the Tred Avon vertical profiler collects 4-5 readings each hour during a single profile sequence. However, in mid-July a computer malfunction within the CR1000 caused the vertical profiler to continuously collect a reading at the same depth every few seconds, quickly filling the data storage files with multiple records. (Any data records that were collected during the malfunction were not included in the final data set.) Attempts to stop and restart the profiler remotely did not correct the problem. A similar problem occurred at the end of the 2014 monitoring season. At that time, YSI technical support was unable to determine the exact reason for the malfunction, but suggested that a computer glitch with the CR1000 datalogger may have been to blame. When consulted on the issue again in 2015, YSI technical support suggested uploading a new setup program to the vertical profiler. However, doing so would first require upgrading the operating system on the CR1000 datalogger. So DNR staff returned to the vertical profiler site on August 24 and, following instructions provided by YSI technical support, installed a new computer operating system on the CR1000.

Following installation of the new operating system and while still on site, DNR staff uploaded a new setup program to the vertical profiler to configure the settings for profiler operation. However, YSI support staff, assisting with the installation through remote communication, had difficulty detecting the depth sounder. Errors with the depth sounder persisted so, after consulting NOAA personnel, DNR staff disabled the depth sounder. Instead, the profiler was programmed to collect data at pre-determined depths of 0.5m, 1.0m, 2.0m, 3.0m, 4.0m, and 4.5m. When not conducting a profile sequence, the data sonde continued to park at 1m depth and hourly readings continued to be collected at 1m depth.

On August 28 and again on September 8, DNR attempted to reactivate the depth sounder. Each attempt was unsuccessful, and the profiler operated at fixed depths for the remainder of the monitoring season.

Data Management

Data Acquisition

In addition to field support and equipment maintenance, DNR also assumed data management responsibilities for the Tred Avon vertical profiler. DNR staff were able to connect to the profiler and perform regular data downloads using Campbell Loggernet software. Connecting remotely with the CR1000 also allowed DNR to troubleshoot issues with profiler operation.

DNR scheduled automatic data downloads to a DNR server daily at 12:00pm. In addition, periodic manual downloads of the data were also performed throughout the monitoring season. Scheduling automatic data downloads helped to minimize the risk of losing data records. Nevertheless, the complete data record for 2015 does include some data gaps, which are listed in Table 2.

Table 2. Time intervals missing profile data records during the 2015 monitoring season**.**

Date of missing records		Time interval			Possible Cause
From	To	Days	Hours	Minutes	
6/25/15 8:06	6/29/15 9:01	4	0	55	Sonde swap
7/10/15 11:06	7/13/15 12:01	3	0	55	Depth reading error; sonde swap
7/14/15 8:05	7/14/15 10:01	0	1	56	Depth reading error
7/14/15 11:01	7/20/15 10:01	5	23	0	Depth reading error
7/20/15 15:07	7/21/15 8:01	0	16	54	Depth reading error; electronic malfunction
7/21/15 8:06	8/24/15 13:01	34	4	55	Electronic malfunction; operating system error
8/28/15 15:07	8/28/15 18:01	0	2	54	Sonde swap
9/8/15 10:07	9/8/15 16:01	0	5	54	Sonde swap
9/8/15 16:05	9/9/15 11:01	0	18	56	Depth reading error

The majority of the missing records were due to the malfunctions with the depth sounder and the CR1000 that were discussed previously. These issues resulted in little or no data records for the period from July 10 to August 24. All remaining data gaps occurred with the sonde swap that took place every 2 weeks for equipment maintenance. When data sondes were exchanged in the field, the interruption in the electronic signal caused the NOAA profiler to switch into "standby" mode and stop conducting profiles. The profiler could only be restarted through communication with the CR1000. Currently, DNR field staff are unable to connect to the NOAA profiler on site, and must therefore rely on remote communication with the CR1000 to restart the profiler. Due to the lag time between swapping sondes in the field and restarting the profiler remotely from the office, some loss of data records (generally a few hours) occurred following field visits.

As data files were downloaded from the profiler (and prior to data quality assurance review), the profile data were posted to the DNR "Eyes on the Bay" website (http://mddnr.chesapeakebay.net/eyesonthebay/noaaprofiler.cfm). Posted files included a data file for download and a graphic displaying the vertical profiler data results. The graphic was a contour plot that interpolated the data through the water column over time. An example of the data plot is shown in Figure 3. Plots and downloadable .csv files were created for each week of data and archived on the web page.

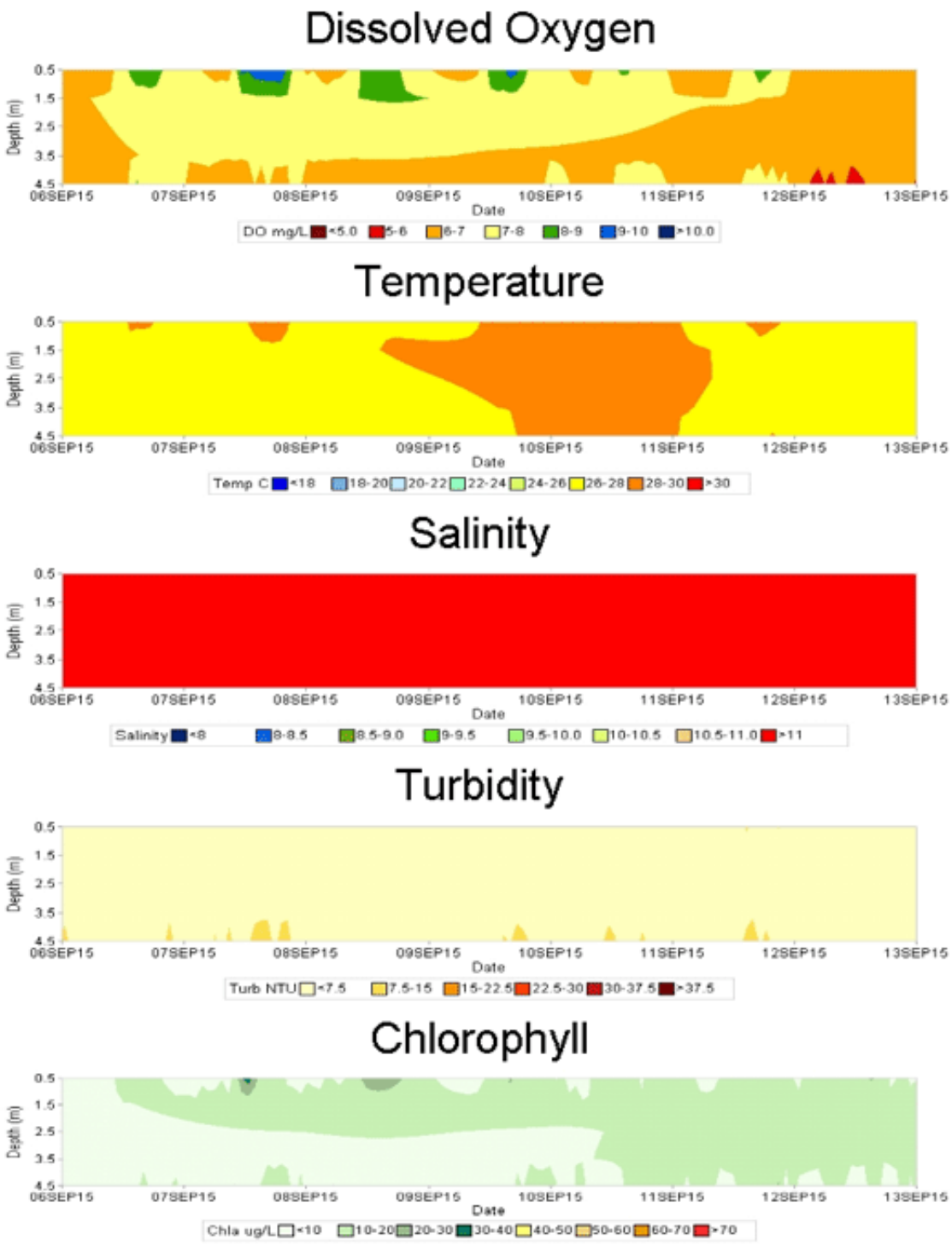

Figure 3. Contour plot of Tred Avon water quality data for the period September 6, 2015 to September 13, 2015.

Data Quality Assurance Procedures

DNR's data quality assurance (QA) procedures for the Tred Avon vertical profiler were modeled after the data management protocols for the Harris Creek profiler and the DNR Shallow Water Monitoring Program. DNR staff analyzed the Tred Avon data using the same Excel macro used to QA similar data collected from the Harris Creek profiler. The macro was run to detect any extreme parameter values that warranted closer examination. Post-calibration results, field notes, and plots of the data were reviewed to judge data validity. Data values determined to be of questionable quality were assigned an error code, but no data were deleted. The file was saved as a "Q-file" which contains parameter values, error codes, and a comment field for additional remarks.

Water Quality Monitoring Results

Two types of water quality data were collected by the vertical profiler: profile readings and hourly readings. Profiles were conducted beginning at the top of each hour. During a profile sequence, the profiler took readings at one meter intervals as the sonde was lowered through the water column. A complete profile took less than 10 minutes to complete. Data collected during a profile sequence were stored as profile readings.

After conducting a profile, the sonde returned to a depth of 1.0m and remained parked there until the next profile sequence. The profiler took an additional reading four minutes before the start of each hour as the sonde was resting in a parked position. Data collected while the sonde was parked were stored as hourly readings.

Profile Readings

Data collected during profile sequences are shown in Figures 4-9. These plots show data values over time with the data at each depth represented by a different line. The sample depths for the profiler data changed slightly beginning in mid-August. This reflects the change from using the depth sounder to determine the depth of the bottom profile reading, to using fixed sample depths that were defined in the profiler setup program. The plots show the entire data record from June through September 2015. Breaks in the line are due to gaps in the data record, either as a result of missing data collection or censoring the data through the QA process.

Other than water temperature, which shows an expected seasonal increase through the summer months (Figure 4), water quality conditions in the Tred Avon River were fairly consistent throughout the 2015 monitoring period. Chlorophyll values generally remained below 20 ug/l, with only a few brief spikes above 40 ug/l (Figure 5). Turbidity values were typically less than 10 NTU, with frequent spikes between 10-40 NTU and occasional spikes over 60 NTU (Figure 6). Salinity values were between 10-12 ppt for most of the monitoring season, but increased rapidly to above 16 ppt near the end of September (Figure 7). Dissolved oxygen, which ranged between 6-10 mg/l for most of the monitoring period dropped below 5 mg/l during this same time (Figure 8). Expanded views of the September data for dissolved oxygen, salinity, and water temperature are shown in Figures 10-12. Bottom water values for dissolved oxygen first

dropped below 5 mg/l on September 24, and reached a minimum value of 2.95 mg/l on September 25 (Figure 10). Salinity and temperature in the bottom waters increased during this time. During September 23 to September 25, salinity rose from 12.5 ppt to 16.7 ppt (Figure 11) and temperature increased from 23.0° C to 23.9° C (Figure 12). Conditions in the water column changed most dramatically between the 3m and 4m depth, suggesting the formation of a pycnocline. These observed changes in oxygen, salinity, and temperature could have been due to a brief influx of saline water from the Choptank River.

Conditions from surface to bottom at the site are fairly uniform, with only slight differences between surface and bottom values. Generally, temperature, oxygen, and chlorophyll values were slightly greater at the surface; and turbidity and salinity were slightly greater near the bottom. Throughout most of the monitoring season, pH values were slightly greater at the surface, with less than a 0.5 difference between surface and bottom values. However, during the month of September, pH values showed an unusual pattern of higher values in the bottom waters, and a range between surface and bottom values of nearly 1 pH unit (Figure 9). Data sonde deployment schedules suggest that this change in data pattern may have been due to a malfunctioning pH probe, although post-calibration results gave no indication of any such problem.

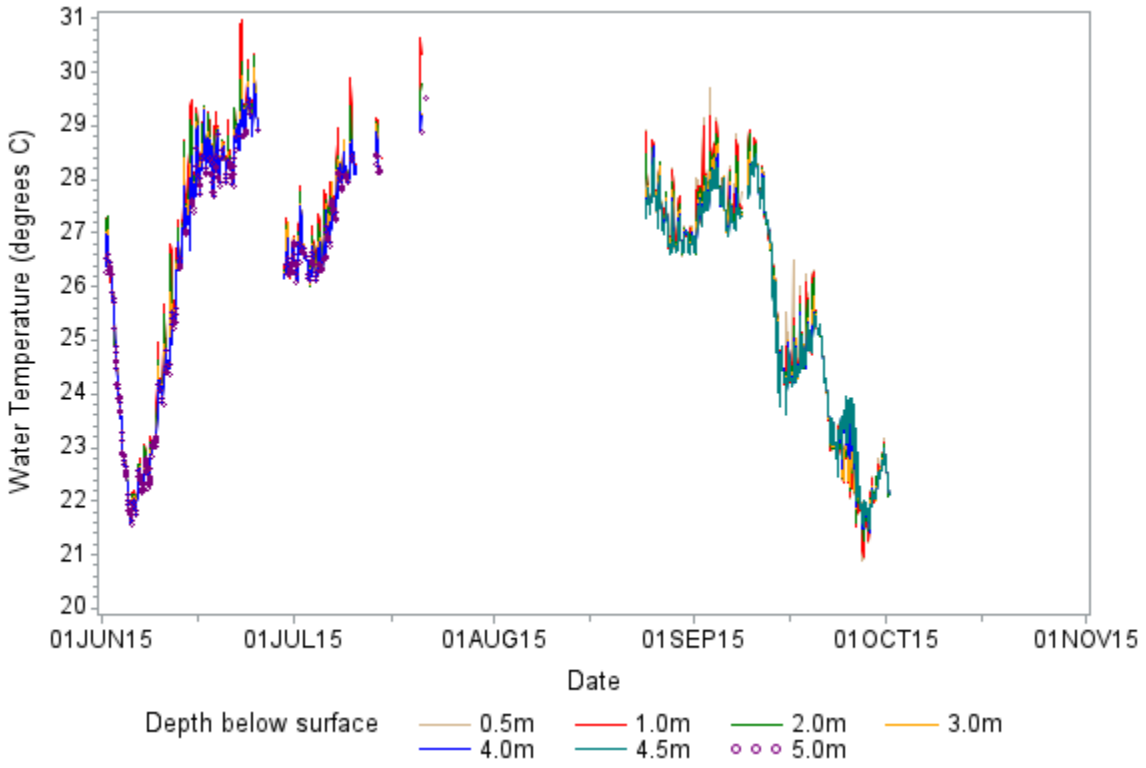

Figure 4. Water temperature in the Tred Avon River during 2015.

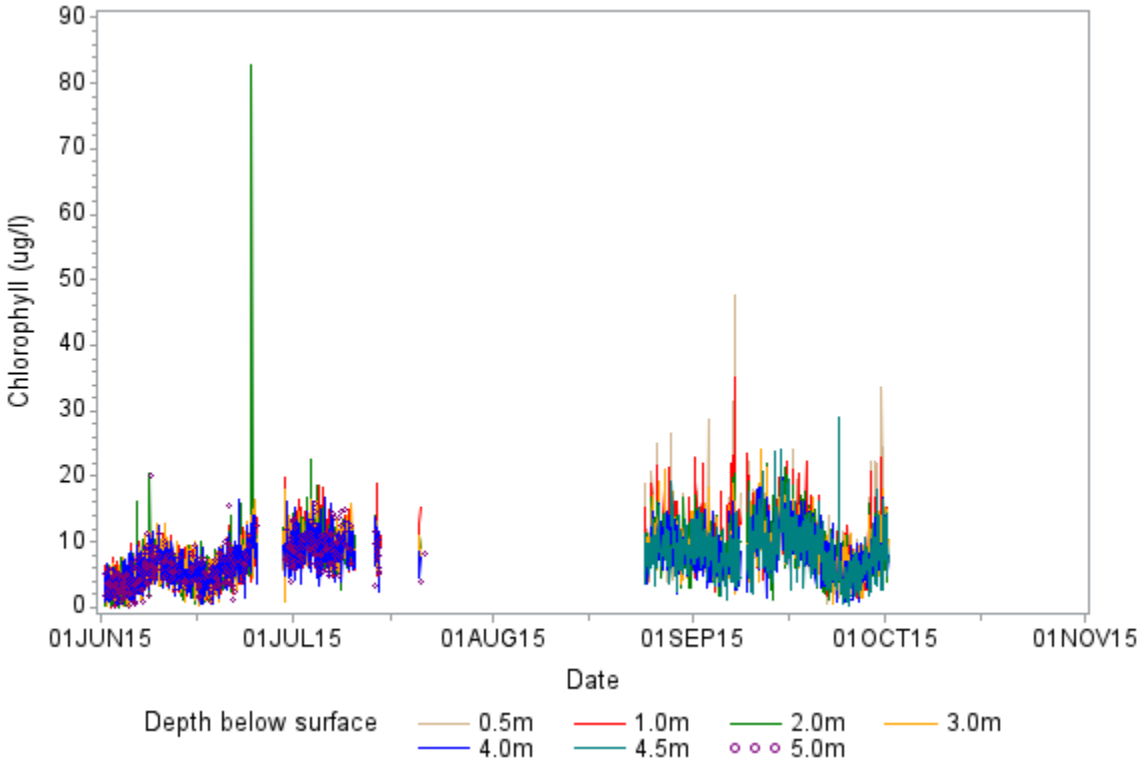

Figure 5. Chlorophyll in the Tred Avon River during 2015.

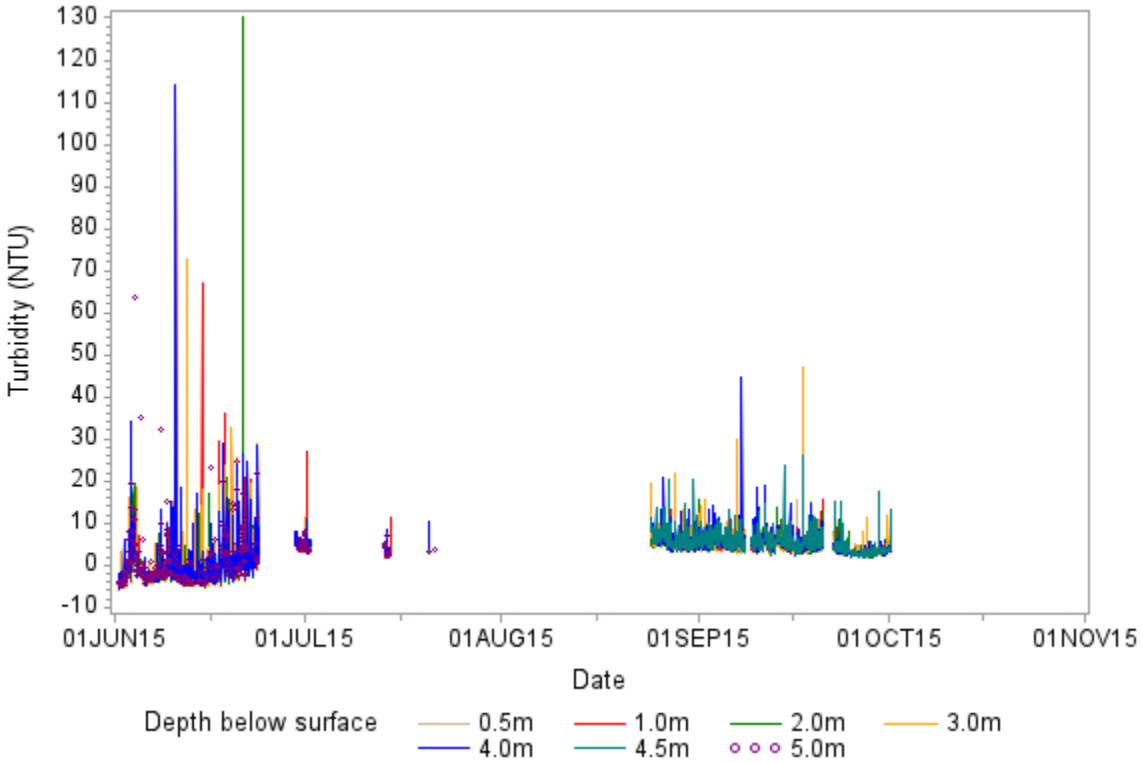

Figure 6. Turbidity in the Tred Avon River during 2015.

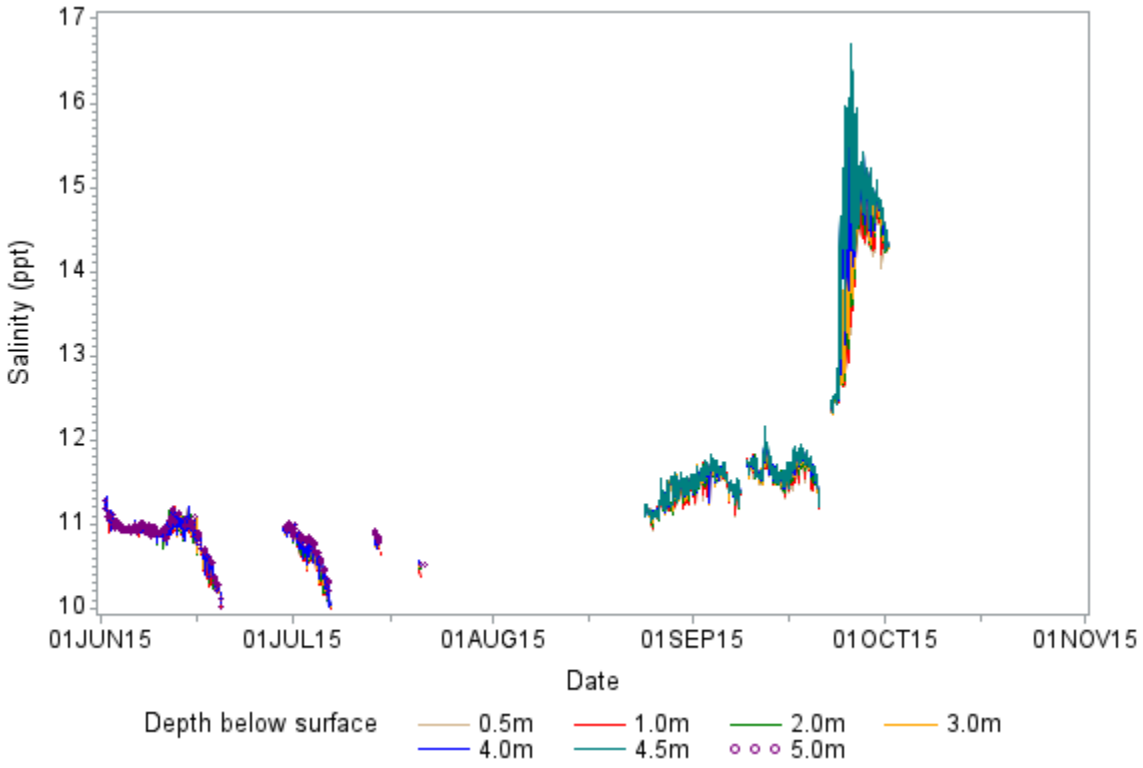

Figure 7. Salinity in the Tred Avon River during 2015.

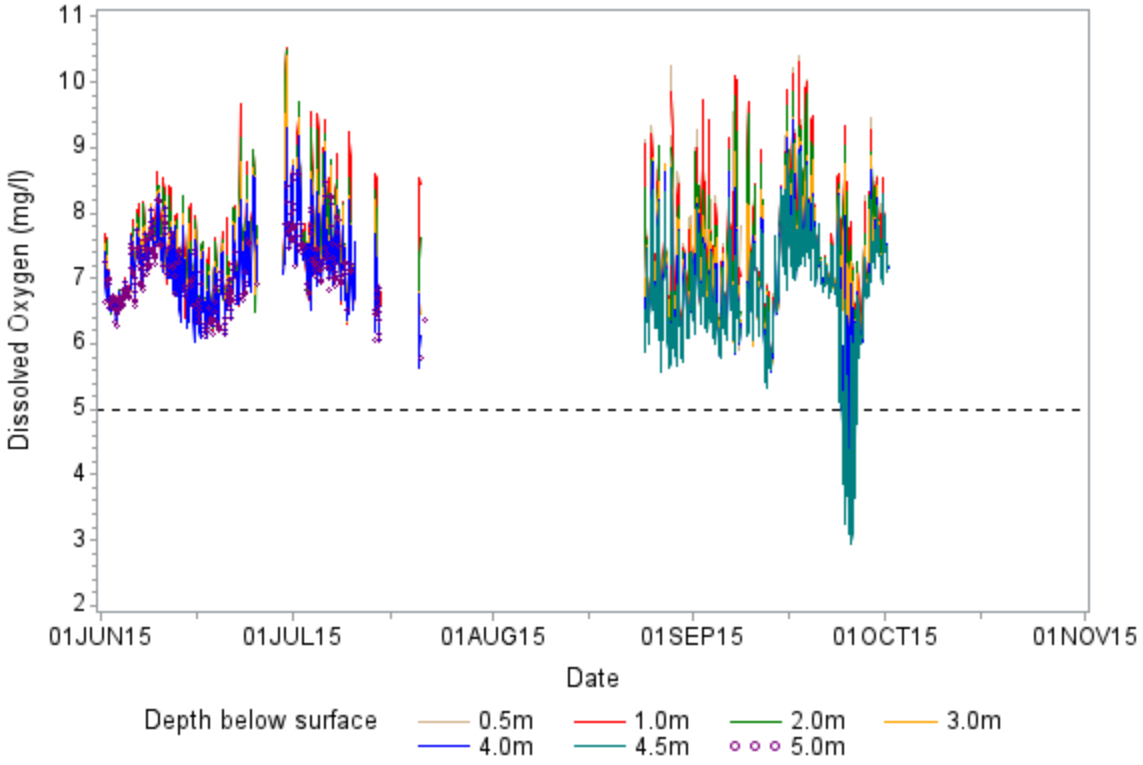

Figure 8. Dissolved oxygen in the Tred Avon River during 2015.

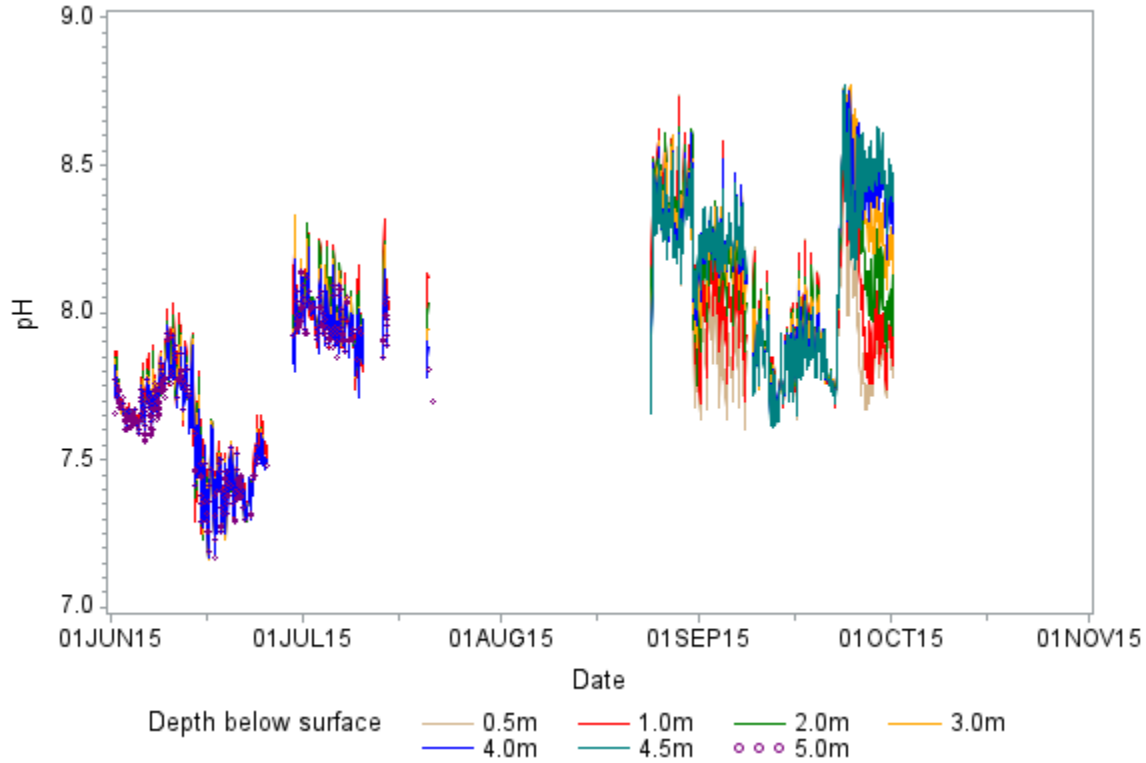

Figure 9. pH in the Tred Avon River during 2015.

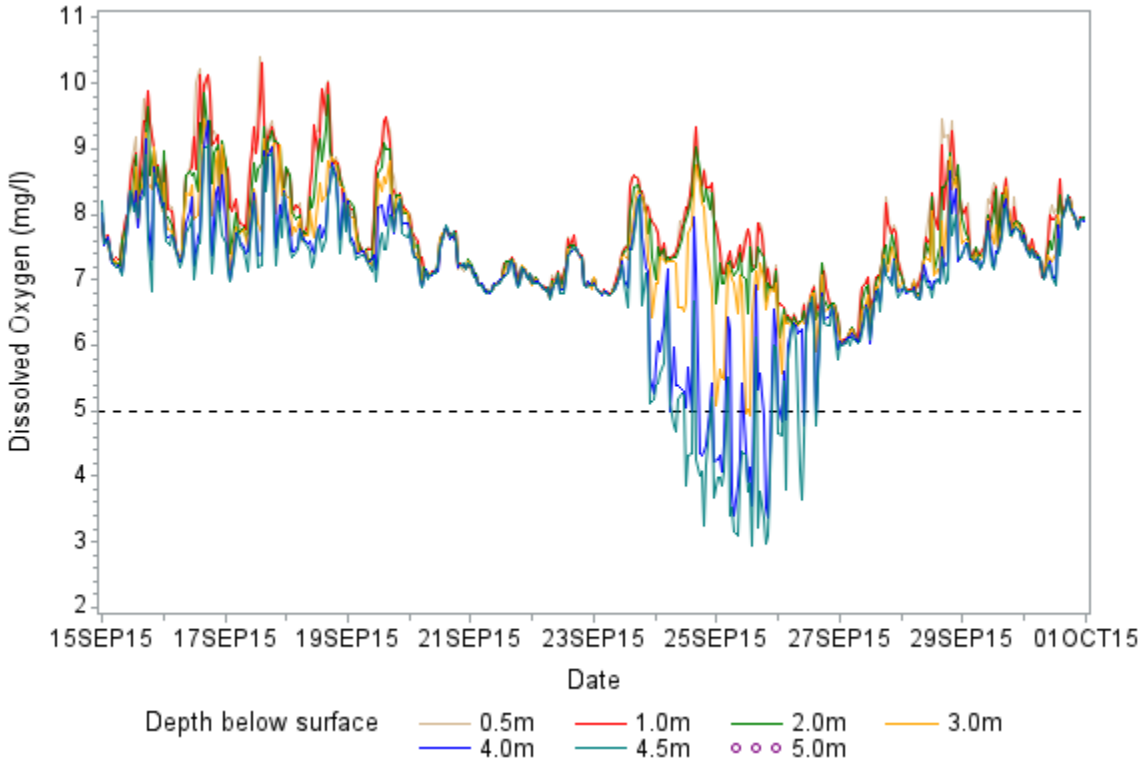

Figure 10. Dissolved oxygen in the Tred Avon River from Sept. 15, 2015 to Oct. 1, 2015.

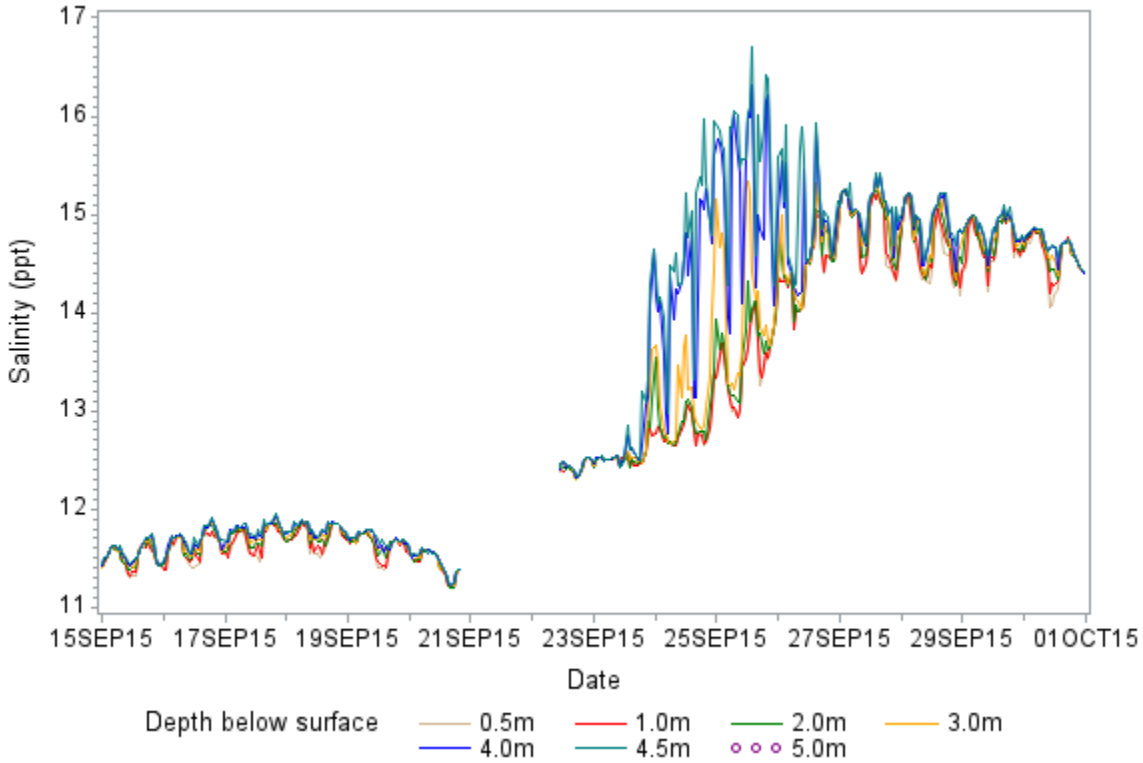

Figure 11. Salinity in the Tred Avon River from Sept. 15, 2015 to Oct. 1, 2015.

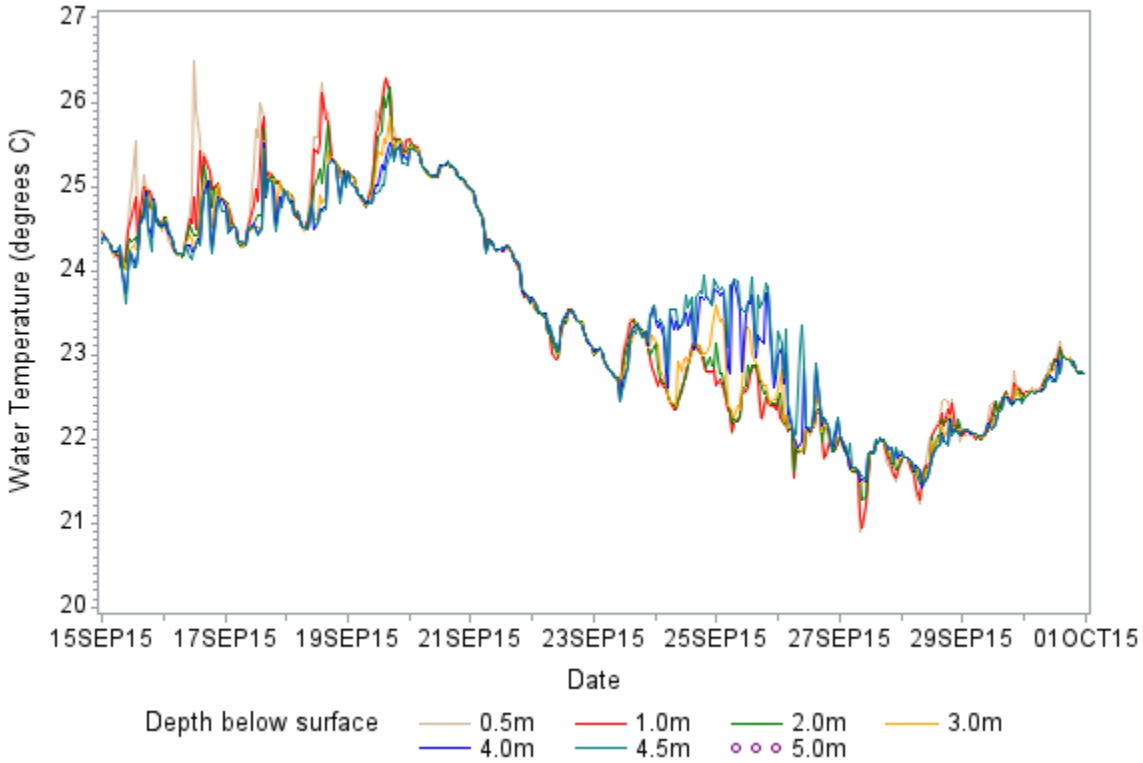

Figure 12. Water temperature in the Tred Avon River from Sept. 15, 2015 to Oct. 1, 2015.

Hourly Readings

The results of the hourly readings are presented in Figures 13-18. When errors caused the vertical profiler to switch to "standby" mode and stop collecting profile readings, the instrument usually continued to collect hourly readings. Thus, the data record for the hourly readings is slightly more complete than the record for profile readings. Collection of hourly data proved to be especially important during the prolonged instrument malfunction in July-August. Hourly readings were collected once per hour at a time when the sonde should have been resting in the 1 meter parked position. As can be seen in the plots, the hourly readings in the Tred Avon River occasionally were measured at depths other than 1 meter, most notably at 3 meters. This occurred if an error caused the profiler to switch to "standby" mode during the middle of a profile sequence. In such an instance, the sonde did not complete the profile and receive a signal to return and park at 1 meter depth, but instead remained at the depth where the error occurred. As a result, the hourly readings were recorded at that same depth until the error was detected, the instrument was restarted, and normal operation resumed.

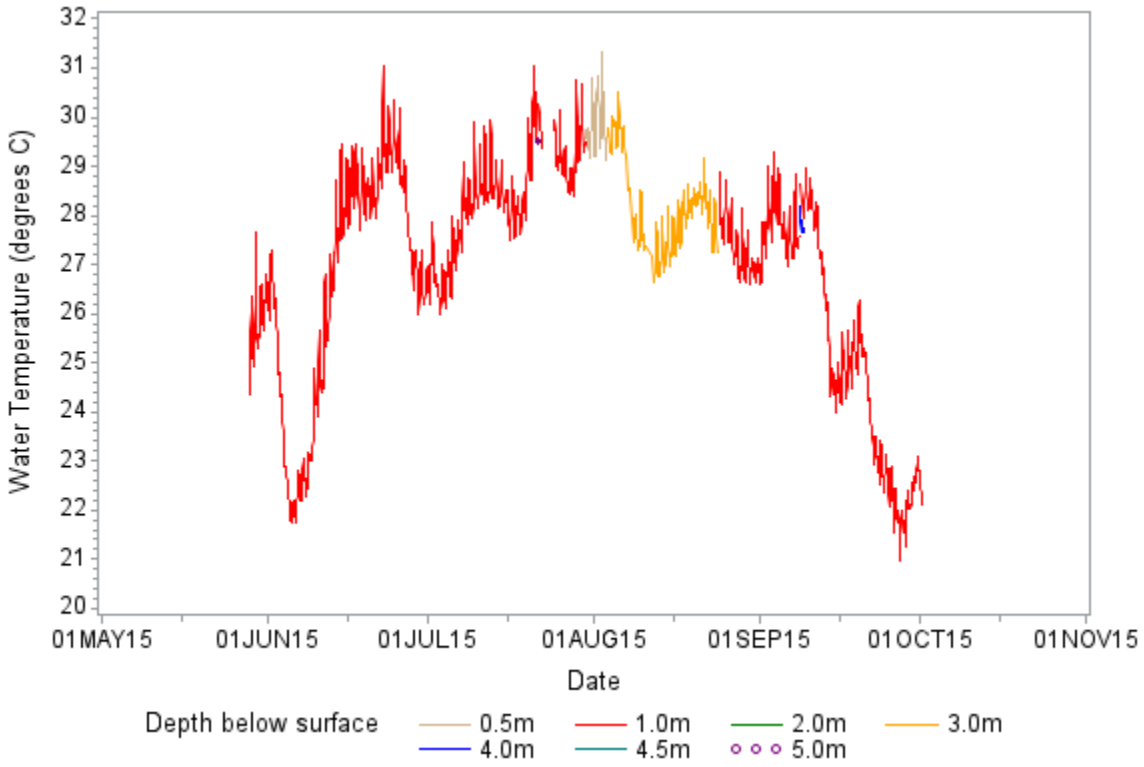

Figure 13. Hourly readings for water temperature in the Tred Avon River during 2015.

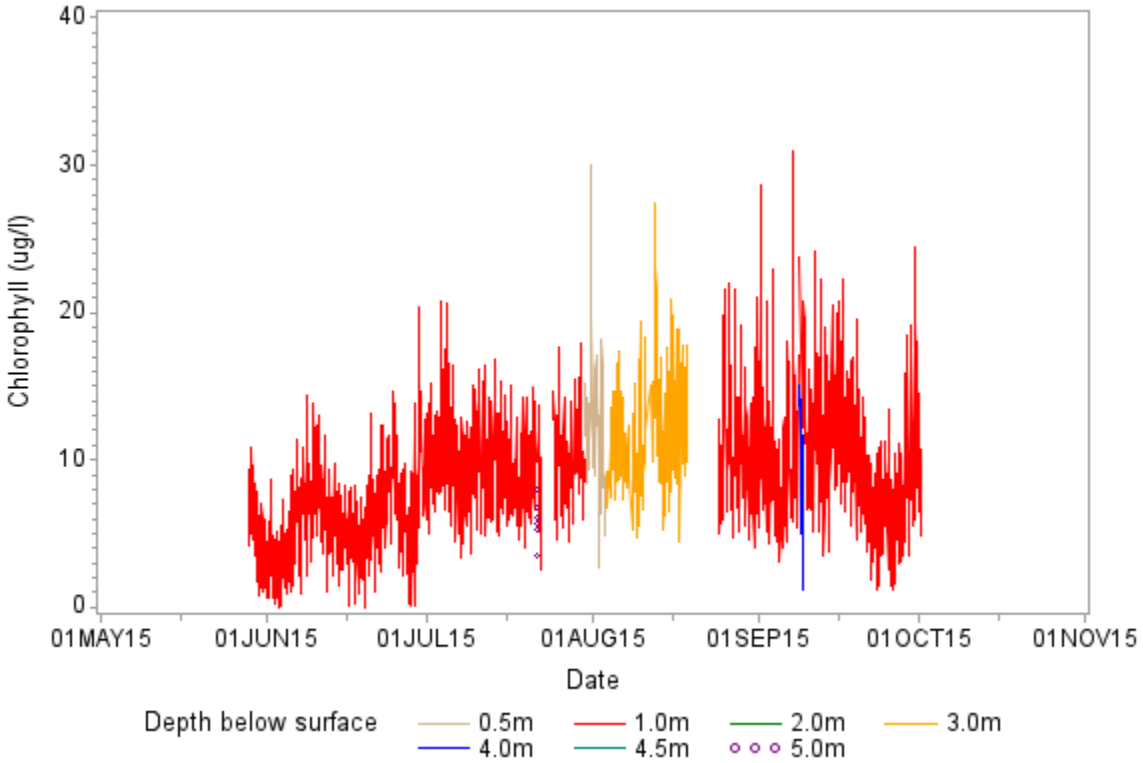

Figure 14. Hourly readings for chlorophyll in the Tred Avon River during 2015.

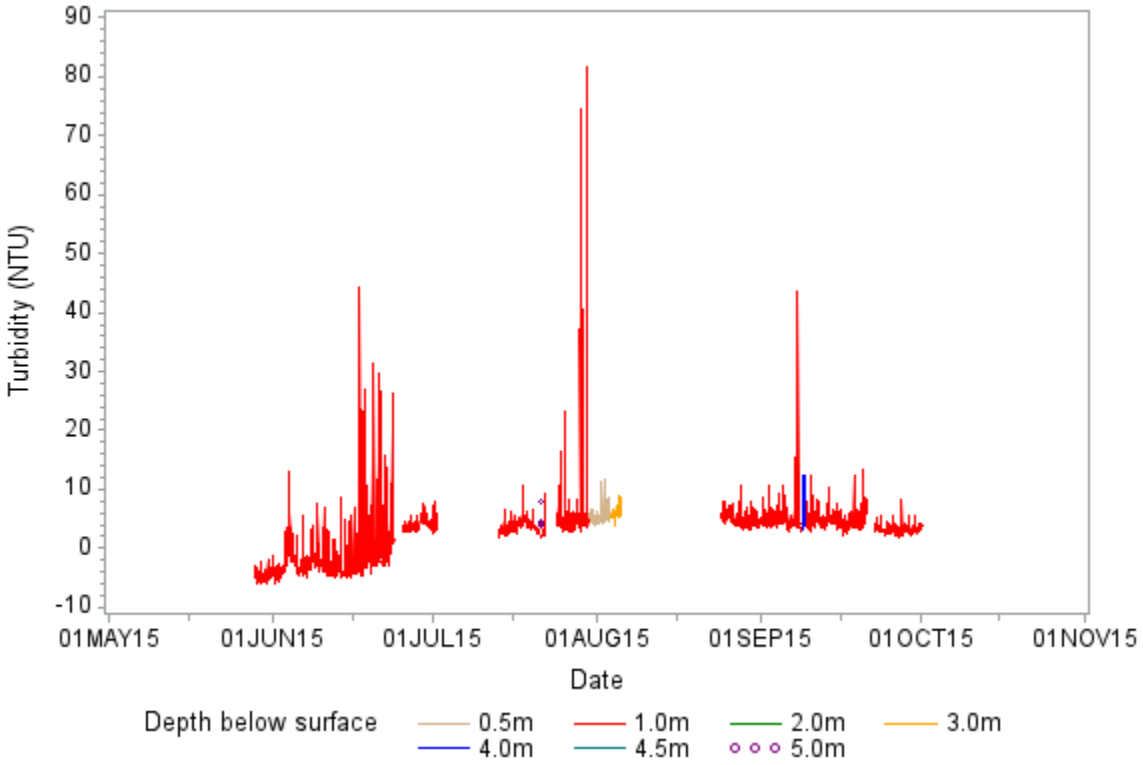

Figure 15. Hourly readings for turbidity in the Tred Avon River during 2015.

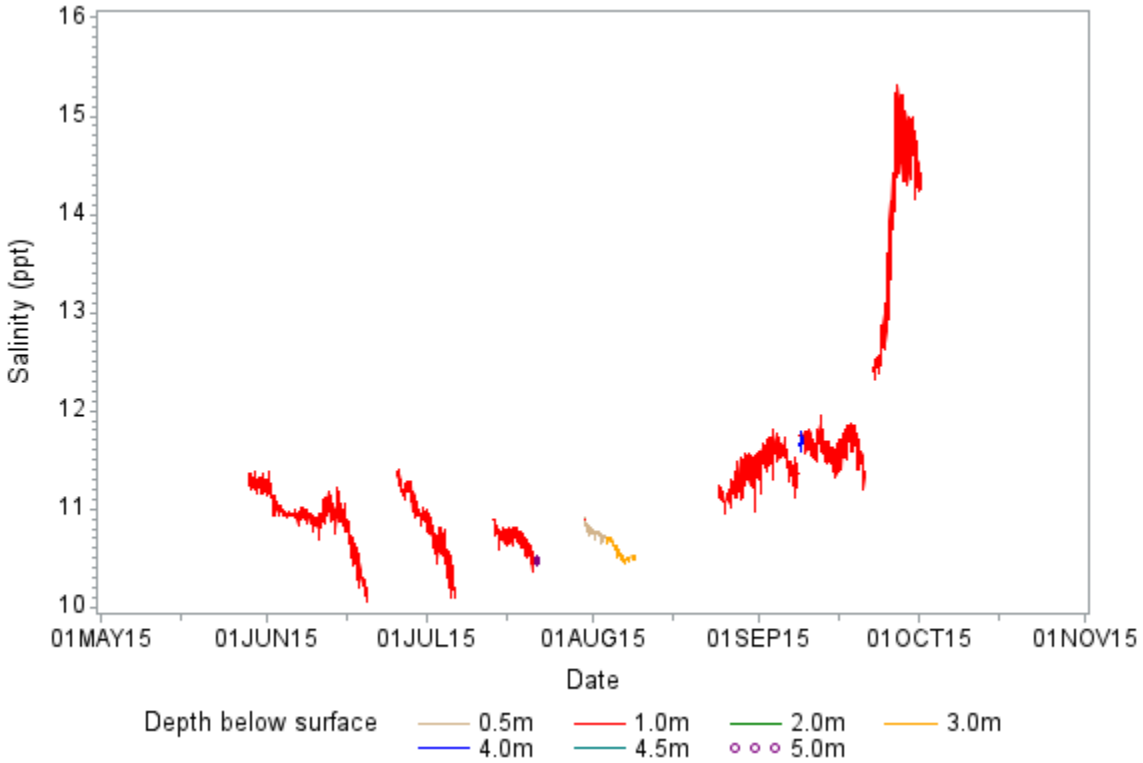

Figure 16. Hourly readings for salinity in the Tred Avon River during 2015.

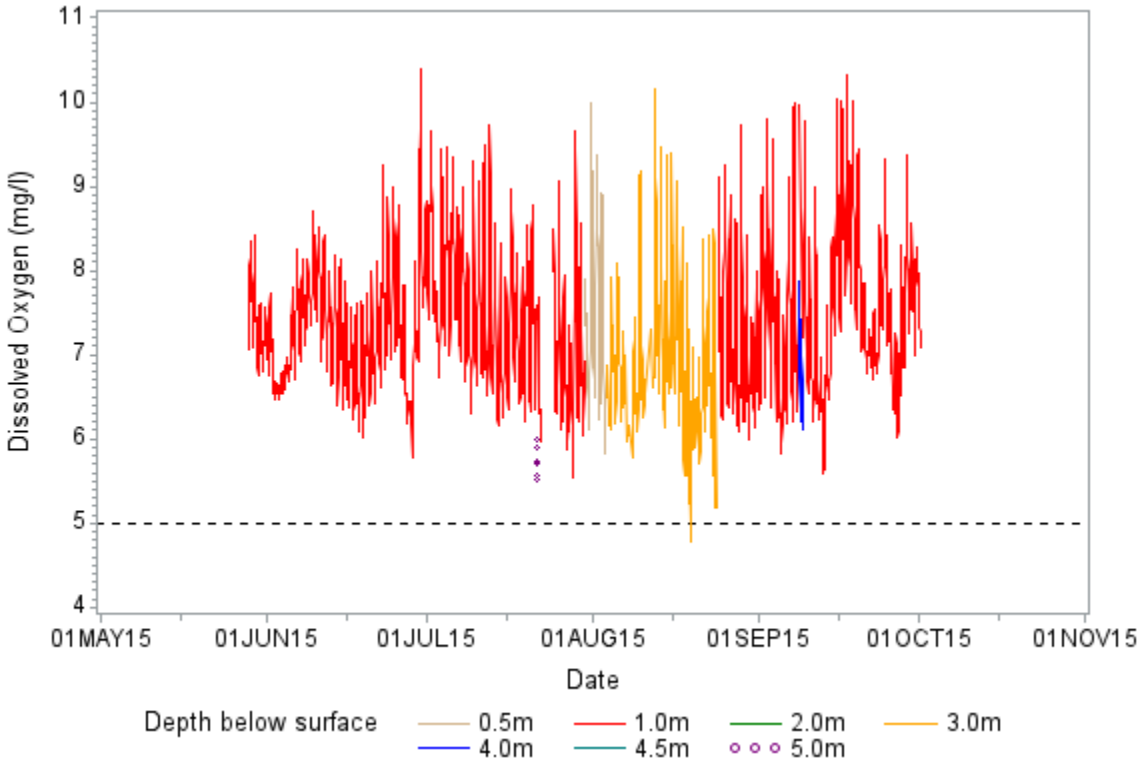

Figure 17. Hourly readings for dissolved oxygen in the Tred Avon River during 2015.

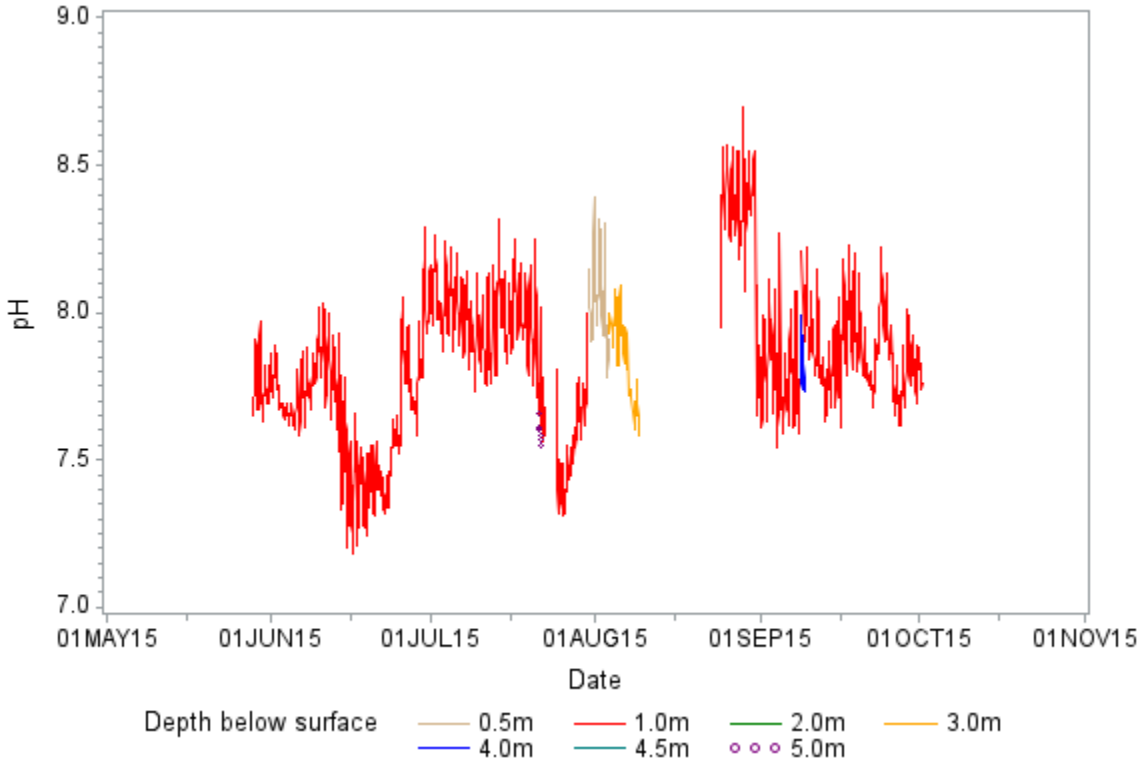

Figure 18. Hourly readings for pH in the Tred Avon River during 2015.

Recommendations

Building on experience gained from the 2014 monitoring season, vertical profiler operation in the Tred Avon River continued in 2015. Profiler operation was interrupted for an extended period from mid-July until the end of August due to issues with the data logger and the depth sounder. DNR staff were able to restore the data logger to working condition by installing a new operating system on the CR1000. However, the depth sounder issues could not be resolved, and the sounder frequently recorded erroneous water depths of less than 1 meter. YSI support staff suggested that possible reasons for erroneous depth readings could include such things as an uneven bottom, underwater vegetation, or debris floating in the water; but it could also be a problem with the sounder itself, such as air bubbles inside of it. Use of the depth sounder was disabled in late August, allowing the profiler to continue operating error-free until the end of the monitoring season. Through the off-season, issues with the depth sounder should be thoroughly investigated if the profiler is to use this feature in the next deployment.

NOAA supplied DNR with three data sondes for use with the vertical profiler in 2015. Collectively, one pH probe, one chlorophyll probe, and one optical dissolved oxygen probe on these sondes were not working properly. In addition, one sonde has a dissolved oxygen probe that uses outdated Clark cell technology, and another sonde has a bad mother board. As a result, of the three NOAA sondes, only one remains fully functional. As necessary, DNR-owned probes were used to replace malfunctioning probes on the working NOAA sonde, thus allowing the profiler to remain operational through the 2015 monitoring season. However, prior to the next deployment of the profiler, NOAA should conduct a complete inventory of data sondes and

probes and should purchase any replacement parts needed to restore all data sondes to good working condition.

In spite of the equipment issues, the vertical profiler collected over 9,100 profile records and 2,900 hourly records in 2015. Scheduled data downloads helped to reduce incidences of lost data records and should continue with future deployments. Some minor loss of data records occurred during field visits to the site. Enabling field staff to connect to the CR1000 while on-site will eliminate those data gaps.

Biofouling of equipment continues to be a major concern in the Tred Avon River and may need to be addressed, either with more frequent visits to the site or with the use of additional anti-fouling techniques. Biofouling contributed to some data values being censored during data quality assurance procedures and may also have been a factor in the poor performance of the depth sounder.