Buzzards Bay Coalition Water Quality Monitoring in Upper Buzzards Bay:

Summary of Four Years of Data Collection

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1. Background

Until 2014, Massachusetts law prohibited the permitting of a new municipal wastewater ocean discharge in state-designated ocean sanctuaries, including Buzzards Bay. The passage of Chapter 259 of the Acts of 2014 allows the Massachusetts Department of Environmental Protection (MassDEP) to approve ocean discharges in ocean sanctuaries if the discharge receives advanced treatment for nitrogen and when robust scientific evidence shows that there will be no adverse impact to ocean water quality. State law requires that twenty-four months of baseline water quality data be collected prior to applying for outfall relocation in an ocean sanctuary.

The Buzzards Bay Coalition expanded its water quality monitoring in Upper Buzzards Bay beginning in 2016 as part of a FY15 Southeast New England Program (SNEP) project and continuing with an additional FY18 SNEP project. The projects joined all of the Head of the Bay communities – Wareham, Bourne, and Plymouth – together with the Massachusetts Maritime Academy and the Buzzards Bay Coalition – to determine the feasibility of a regional wastewater solution that would reduce nitrogen pollution in two of upper Buzzards Bay's most critically nutrient impaired sub-estuaries: the Agawam/Wareham River and Buttermilk/Little Buttermilk Bay.

The data collected are to develop a baseline of information before the potential the relocation of the Wareham Wastewater Treatment Facility's (Wareham WWTF) ocean discharge from the Agawam River to the Cape Cod Canal.

2. Approach

Project partners, the Buzzards Bay Coalition (Coalition) and Massachusetts Maritime Academy (MMA), set out to monitor water quality via bottom automated continuous measurements and discrete surfaces samples in Upper Buzzards Bay. The parameters measured included temperature, salinity, oxygen, pH, and chlorophyll *a*.

Bottom continuous measurements were collected using a YSI EXO sonde that is hung from a davit off the MMA pier. This location had the added benefits of being protected and easily accessible and allowing direct connection to a computer, which allows for real-time monitoring.

For 15 months (Jul 2016 – Sep 2017), monthly grab samples were also collected at this location (MMA1, Figure 1) for a full suite of nutrients and chlorophyll *a* on incoming and outgoing tides at both surface and depth. Additional grab sampling sites included the eelgrass bed to the southwest of the MMA pier (MMA3), the canal dolphins (MMA4), and the MMA Liberty Dock (MMA5). A Quality Assurance Project Plan was developed that described the monitoring procedures and protocols and was approved by the Environmental Protection Agency and the Massachusetts Department of Environmental Protection (Buzzards Bay Coalition et al. 2018).

Based on feedback from state officials and the Coalition's Science Advisory Committee, it was decided additional monitoring through the FY18 SNEP grant should focus on the time period of peak biological activity (May to October) and that additional stations should be monitored. Additional sampling sites include historic Baywatchers stations in Outer Onset Bay (OB10) and Buttermilk Bay (BB4), as well as

new stations near the existing outfall (MMA6) and an "upstream" location near the railroad bridge (MMA7).

With additional funding support from the Town of Wareham and the Southeast New England Program, grab samples were collected each month on both incoming and outgoing tides from June – October 2018, May – October 2019, and May – August 2020. The monitoring was performed following a Quality Assurance Project Plan that were approved by the Environmental Protection Agency and the Massachusetts Department of Environmental Protection (Buzzards Bay Coalition et al., 2016).

Figure 1. Map of stations in Upper Buzzards Bay.

3. Data Collected

Bottom automated continuous measurements -

The sonde was deployed at MMA1 in October 2016. The sonde is positioned at 1 meter above the sea floor. MMA cadets under the supervision of MMA Professor Bill Hubbard have been cleaning the sonde and checking its calibration approximately once a month, though fouling has not been a significant issue. It has generally been collecting data every 15 minutes through September 2020. The exceptions include a few weeks in late November 2017 and in May 2019 when maintenance of the MMA pier required it to be removed. In December 2018, the sonde was sent to the manufacturer for calibration and

preventative maintenance and a second YSI EXO sonde was deployed at the same location while the initial sonde was being serviced. The initial YSI EXO was re-deployed in June 2019 and the second sonde was removed. There were a few periods when data was not recorded due to a failure of the instrument to log data (June 2019), and sonde maintenance (June and August 2020).

Table 1. Summary of sonde measurements.

Number of sonde measurements 1m off bottom at MMA1 as of 9/21/20						
Year	2016	2017	2018	2019	2020	Total
Temperature	8,589	32,518	34,651	29,732	24,443	129,933
Salinity	8,589	32,521	35,591	29,958	24,436	131,095
DO	8,589	32,525	35,592	29,959	24,443	131,108
Chla	8,215	32,519	34,701	25,936	23,495	124,866
pH	8,589	32,525	35,592	29,959	24,443	131,108
TDS	8,589	32,525	35,592	29,959	19,161	125,826

Figures 2 below shows average daily data for the deployment period of October 2016 through September 2020. Long-term temperature data show the annual peaks in bottom water temperature between mid-July and early September and the annual troughs in bottom water temperature from late December to early March. The summertime peak in temperature each year was about 22 °C with the 2018 being the warmest year with the warmest 7 days having an average temperature of 22.8 °C and 2017 having the coolest summer with the average temperature on the warmest 7 days being 21.2 °C. The winters of 2017-2018 and 2018-2019 with the average of the 7 coldest bottom water temperature days of 0.04 °C and 0.50 °C, respectively were colder than the winters of 2016-2017 and 2019-2020 with the average of the 7 coldest bottom water temperature days of 2.19 °C and 2.95 °C, respectively.

The seasonal pattern of dissolved oxygen is a mirror image of that of temperature with highest dissolved oxygen concentrations and percent saturation being highest in the winter when the cold waters are able to hold more gas (Figure 2). The daily average dissolved oxygen concentration ranged from 6 to 13 mg L^{-1}, staying above the 6.0 mg L^{-1} threshold identified for coastal and marine waters classified for use as excellent habitat for fish and other aquatic life and for primary and secondary contact recreation (Massachusetts Department of Environmental Protection, 2013).

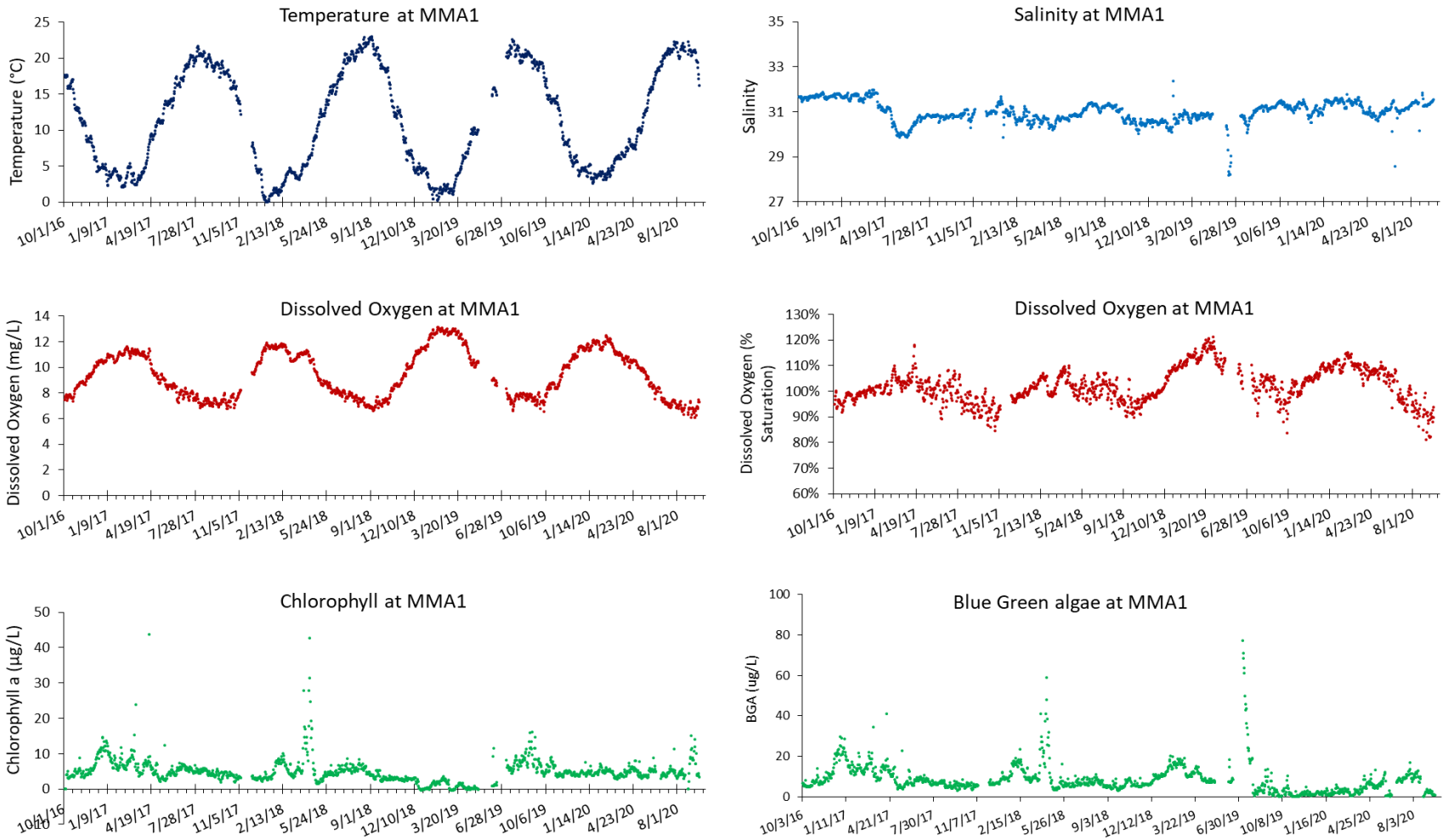

Figure 2. Data collected by the sonde deployed at MMA1 over entire deployment history (average daily: dissolved oxygen concentration, oxygen saturation, temperature, salinity, chlorophyll a, and blue green algae).

There was not a consistent seasonal pattern observed in either the chlorophyll *a* or blue green algae concentrations (Figure 2). In general, the level of chlorophyll *a* was low with a mean of daily average concentration of 5.0 mg L^{-1}. There were periodic blooms of algae where the concentrations of chlorophyll *a* spiked up to 50 mg L^{-1}.

In addition to patterns over the course of a year, there are daily patterns in the data. Figures 3 and 4 show data over the course of a week in the summer (Fig. 3) and in winter (Fig. 4). The time of high and low tide at the Canal Railroad Bridge has been included on these graphs. The water quality parameters at MMA1 are strongly influenced by the tide with waters from Cape Cod Bay pulled into Upper Buzzards Bay with the tide. When it is low tide in Buzzards Bay and at the Canal Railroad Bridge (gray dashed vertical lines), water is flowing through the Cape Cod Canal from Cape Cod Bay to Buzzards Bay.

In the summertime, the signature of the Cape Cod Bay waters is apparent as the colder, more saline, oxygen-rich waters monitored by the sonde at MMA1 (Figure 3). When the tide reverses, the dominant signal observed at the sonde at MMA1 is that of Buzzards Bay with warmer, less saline waters. The concentrations of chlorophyll *a* peak with the high tide at the Canal Railroad Bridge (yellow vertical lines) when the sonde signal is more heavily influenced by Buzzards Bay waters.

In the winter, there are much less pronounced differences between the temperature, dissolved oxygen, and chlorophyll *a* between high and low tides indicating that these parameters are more similar in Cape Cod Bay and Buzzards Bay during the winter (Figure 4).

For one month in summer 2017, a second YSI EXO sonde was deployed 1 m off of the bottom at the central canal dolphin (MMA4, see Figure 1). The data collected at that sonde closely tracked that at MMA1 examined on both the month-long period (Figure 5a) as well as looking at a single week period (Figure 5b). These results indicate that data collected at MMA1 is broadly representative of water quality in Upper Buzzards Bay.

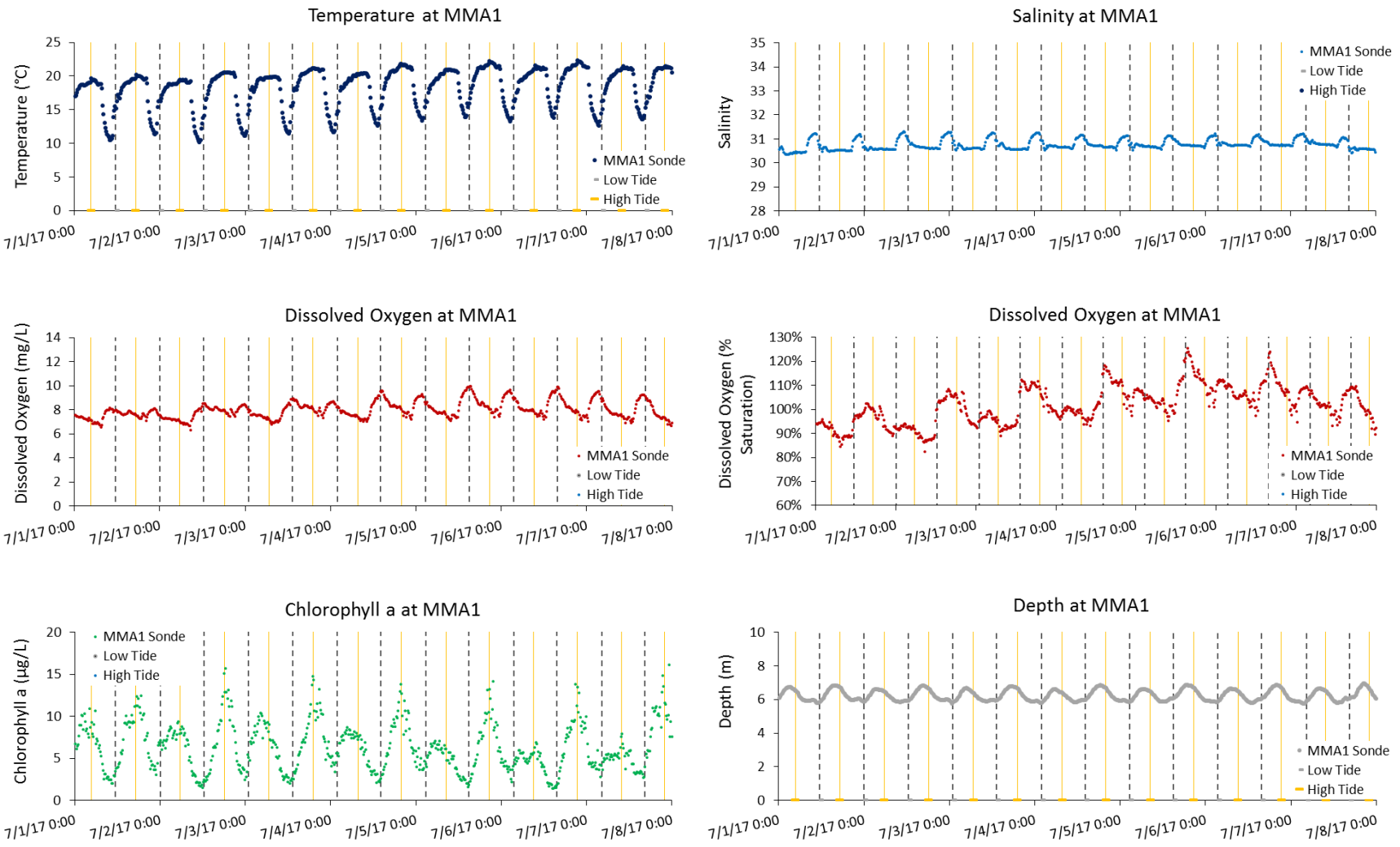

Figure 3. Data collected by the sonde deployed at MMA1 for one week in July 2017.

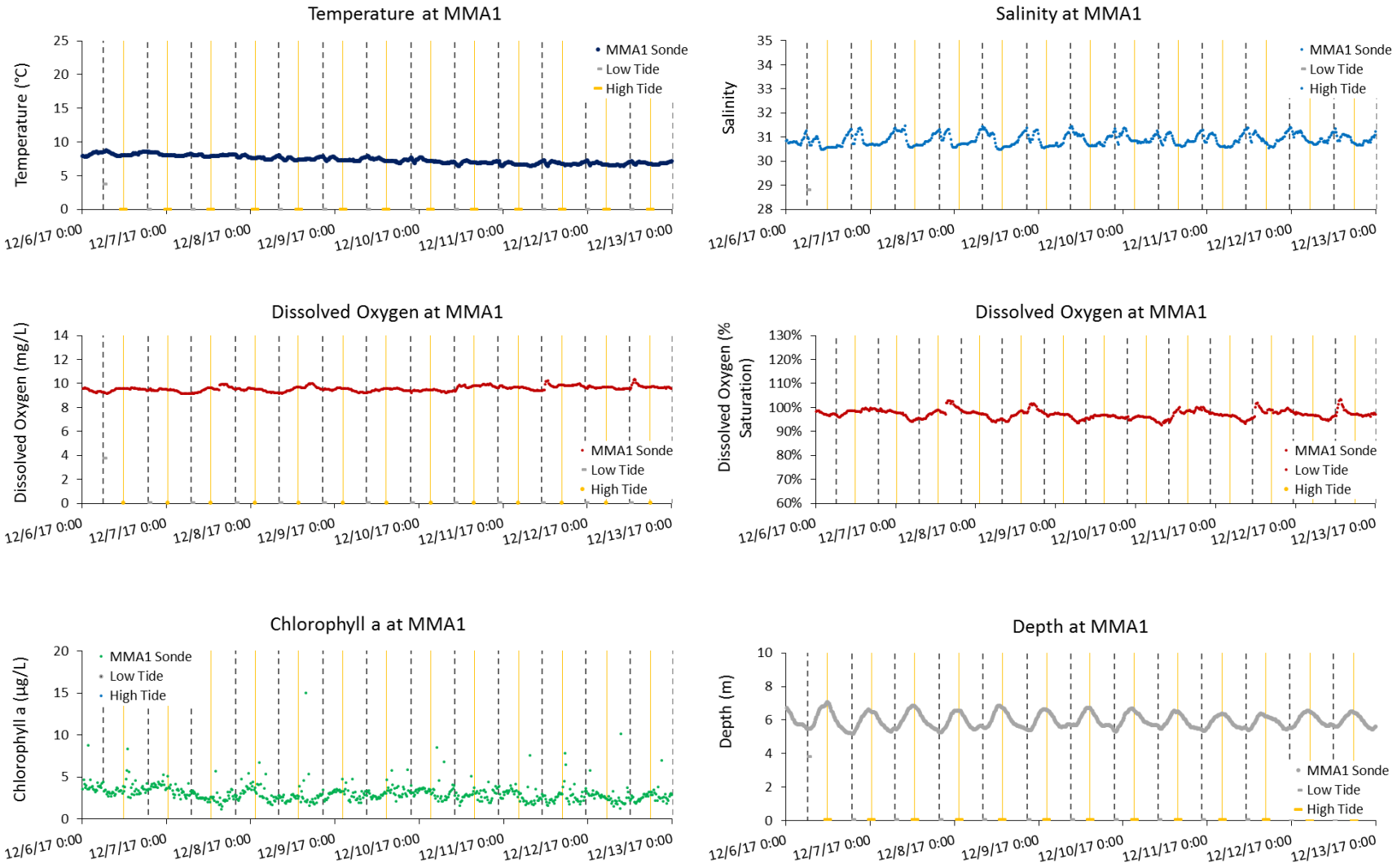

Figure 4. Data collected by the sonde deployed at MMA1 for one week in December 2017.

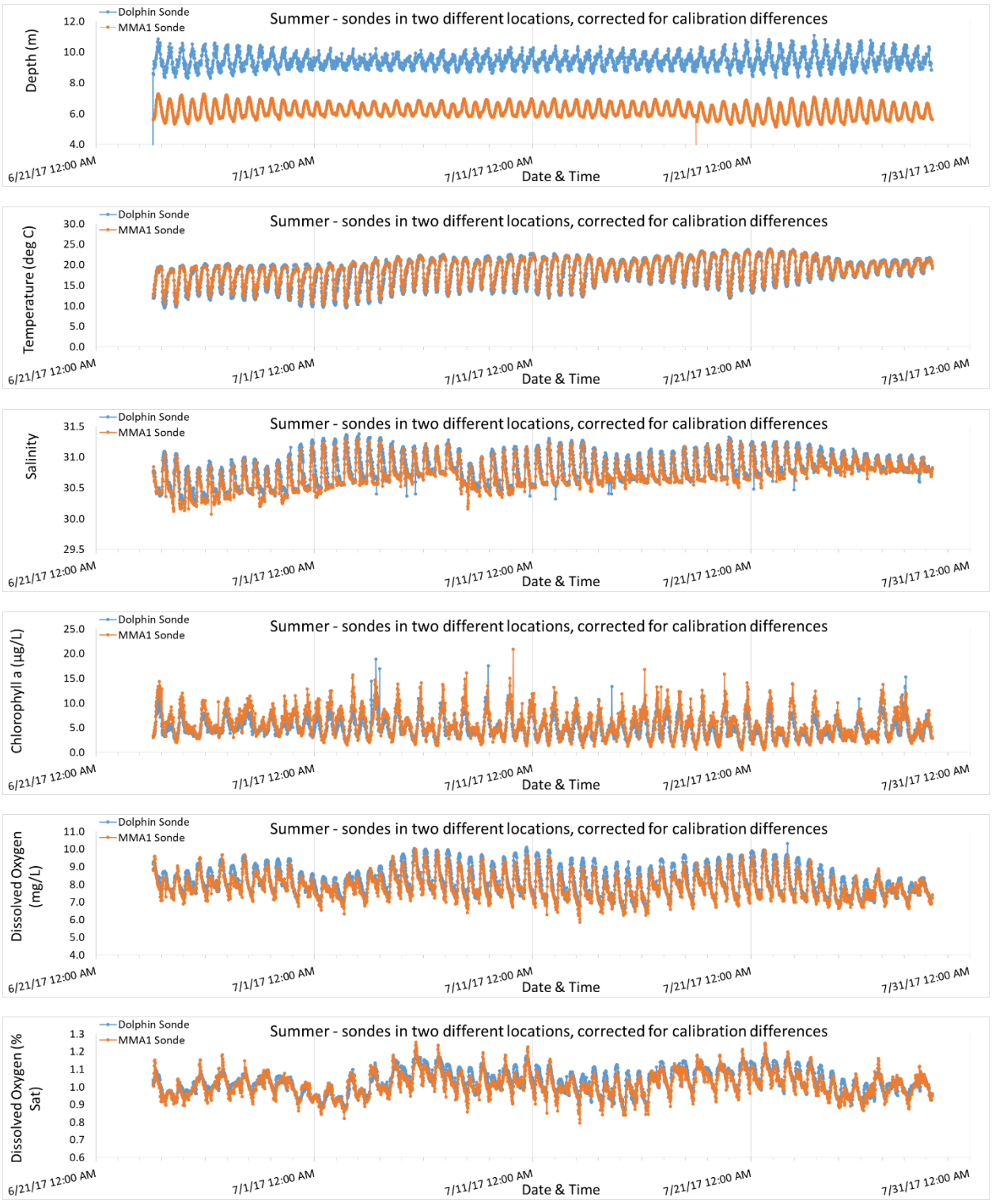

Figure 5a. Data collected by the sondes deployed at MMA1 (orange line) and MMA4 (blue line) for one month in summer 2017.

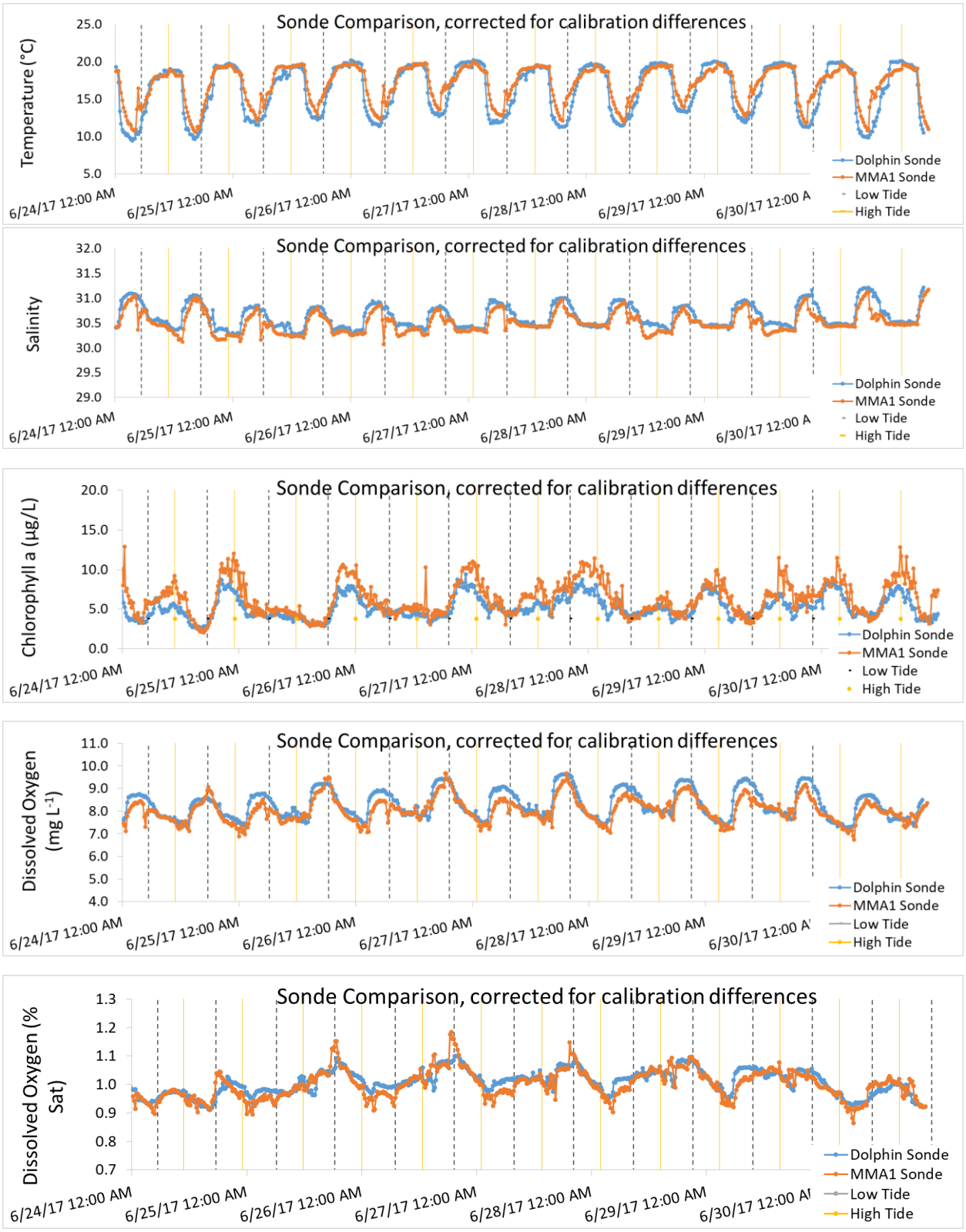

Figure 5b. Data collected by the sondes deployed at MMA1 (orange line) and MMA4 (blue line) for a one week period in June 2017.

Discrete Samples

For the 15 month period between July 2016 and September 2017, discrete grab samples were collected on the ebb tide and flood tide monthly at MMA1. Samples were also collected at either MMA3 (when boat access was possible) or MMA5 (when no boat was available). On a few occasions, samples were also collected at site MMA4, near the middle of the canal dolphins. In addition, in July and August samples were collected on a second date each month on ebb tide only. Beginning in July 2018, discrete grab samples were collected on the ebb tide and flood tide monthly at seven stations (MMA1, MMA3, MMA4, MMA6, MMA7, BB4, OB10) for the months of May to October. Surface samples were collected at all stations and deep samples were also collected at the four stations closest to the proposed outfall (MMA1, MMA3, MMA6, MMA7) for a total of 11 samples per tide. This same sampling scheme was used in 2019 and in May to August 2020.

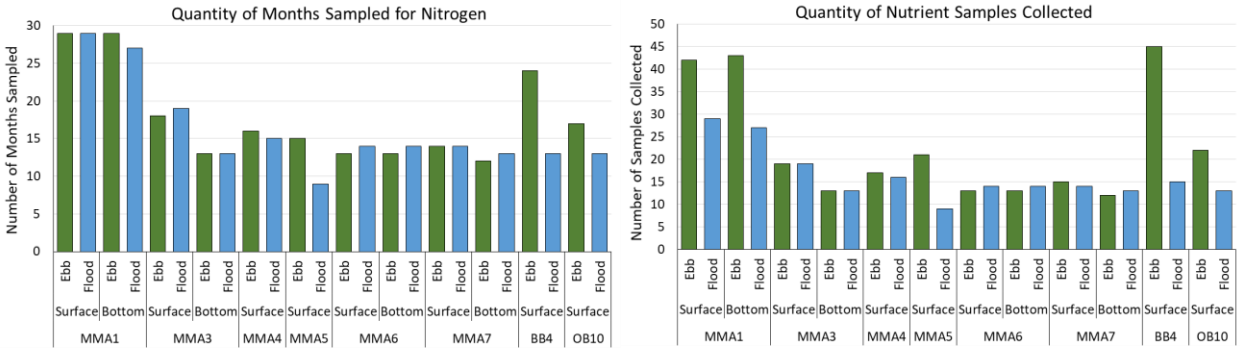

Figure 6. Summary of the number of months sampled (left) and the number of samples analyzed (right).

All stations have been sampled on the ebb tide for at least 12 months and up to 29 months. On the flood tide each station has been sampled for between 9 and 29 months. Including both tides, there have been between 25 and 71 discrete nutrient samples collected per station.

All the nitrogen data from the discrete sampling is presented below; however, the 2020 data has not undergone full quality assurance review and should be considered preliminary.

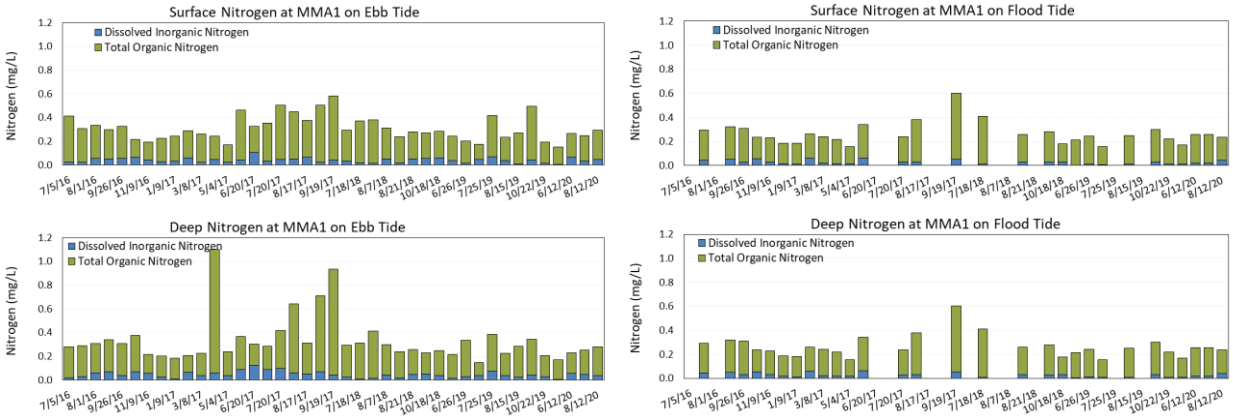

Figure 7a. Nitrogen data collected on ebb and flood tides off the MMA pier (MMA1) near the surface (0.15 m) and deep (1m above the bottom).

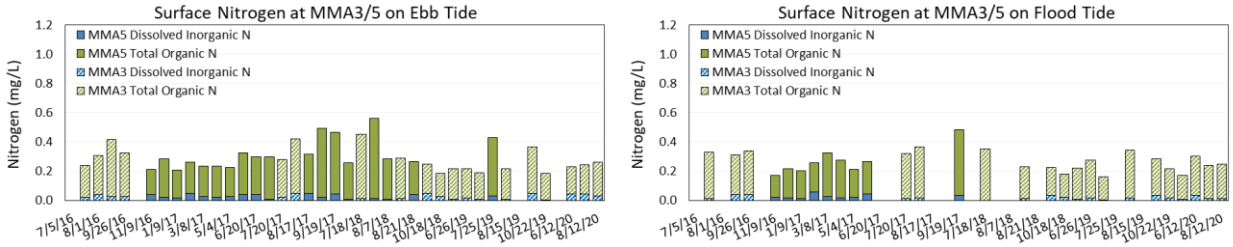

Figure 7b. Nitrogen data collected on ebb and flood tides in the eelgrass beds off of the MMA pier (MMA3) or from a small dock extending off the MMA pier when a boat was not available (MMA5).

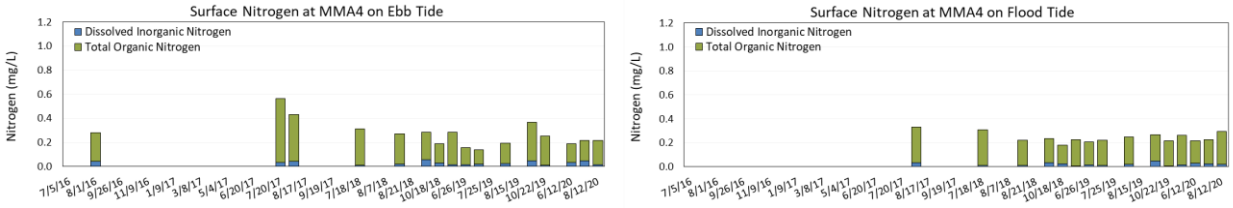

Figure 7c. Nitrogen data collected on ebb and flood tides near the surface (0.15 m) at the center canal dolphin (MMA4).

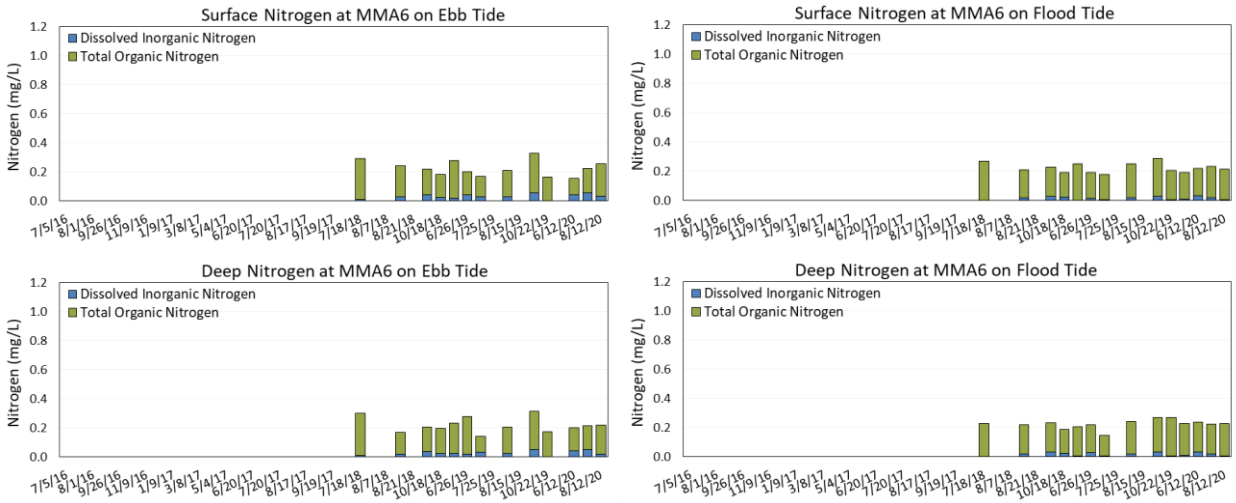

Figure 7d. Nitrogen data collected on ebb and flood tides near the existing MMA outfall (MMA6).

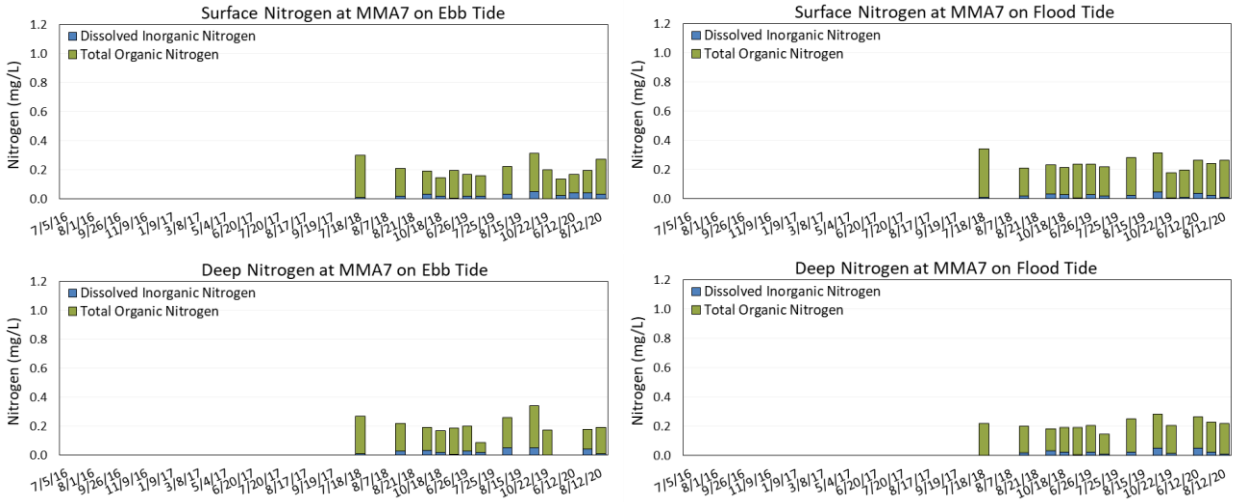

Figure 7e. Nitrogen data collected on ebb and flood tides near the Railroad Bridge (MMA7).

The broad results of the nutrient sampling are that the total nitrogen concentrations are generally low and that the nutrient concentrations across all the stations seem to follow a similar pattern over time. From the available data, it seems that total nitrogen concentrations at these locations tend to be higher in the summer months. The high total nitrogen concentrations 1m off the bottom at MMA1 on some dates are likely an artifact of sampling at this location. The bottom is uneven and sampling may inadvertently disturb the bottom and resuspend sediments.

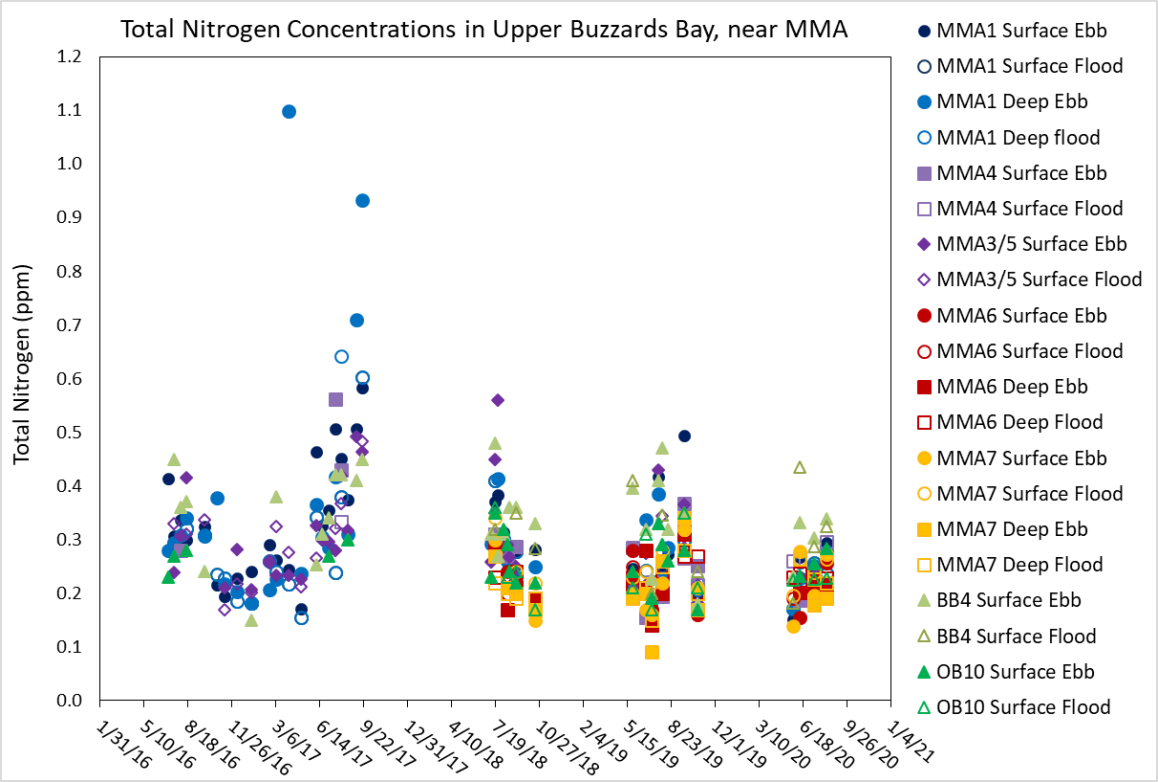

Figure 8. Summary of total nitrogen at all sites.

4. Summary

Water quality parameters were monitored at eight stations in Upper Buzzards Bay between 2016 and 2020. Monitoring with a water quality sonde that collected measurements every 15 minutes from 1 m above the seafloor off of the MMA pier was able to continue year-round. The sonde measurements captured the expected seasonal patterns in water temperature and dissolved oxygen. The measurements also showed how Upper Buzzards Bay is influenced by water coming through the Cape Cod Canal from Cape Cod Bay.

Initial monthly nutrient monitoring year-round at a few locations was modified to include more stations but only focus on the main growing season months (May to October). Total nitrogen concentrations in Upper Buzzards Bay are generally low with station average total nitrogen concentrations between 0.21 and 0.32 mg L^{-1}. These levels are below 0.35 mg L^{-1}, which is the threshold used for many embayments by the Massachusetts Estuaries Project as the concentration below which will support healthy coastal ecosystems.

5. References

Buzzards Bay Coalition, Massachusetts Maritime Academy, and Marine Biological Laboratory. 2016. Quality Assurance Project Plan For Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay. 15 p.

Buzzards Bay Coalition, Massachusetts Maritime Academy, and Marine Biological Laboratory. 2018. Quality Assurance Project Plan For Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay. 14 p.

Massachusetts Department of Environmental Protection. 2013. Massachusetts Surface Water Quality Standards. 314 CMR 4.00.