

Waquoit Bay (WQB) NERR Water Quality Metadata
January – December 2022
Latest Update: August 15, 2024

I. Data Set and Research Descriptors

1) Principal investigator(s) and contact persons –

• Address:

Waquoit Bay National Estuarine Research Reserve
PO Box 3092
131 Waquoit Highway
Waquoit, MA 02536
Website: <http://www.waquoitbayreserve.org>

• Contact persons:

Theophilos (Theo) Collins, Research Associate
E-mail: Theophilos.j.collins@mass.gov
Phone: 774-255-4272; 774-255-4275

Megan Tyrrell, Research Coordinator
Email: Megan.tyrrell@mass.gov
Phone: (774) 255-4265

2) Entry verification –

The data are uploaded in three file formats (each to separate files identified with the same file name but with unique extensions: .CSV, .DAT, .INI) from the YSI 6600-series or EXO data loggers to a PC with the YSI 6600 EcoWatch or KOR software. Raw files are kept on file on the WBNERR archive: one copy is stored on the shared server and one copy is stored on the laboratory computer's hard drive. Initially, file contents are visually examined for anomalies (e.g., sensor malfunction, battery failure, spurious values, etc.), after downloading data following deployment and before post-calibration analysis.

Deployment data are uploaded from the YSI data logger to a personal computer with Windows 7 or newer operating system. Files are exported from EcoWatch in a comma-delimited format (.CDF), EcoWatch Lite in a comma separated file (CSV) or KOR Software in a comma separated file (CSV) and uploaded to the CDMO where they undergo automated primary QAQC; automated Depth/Level corrections for changes in barometric pressure (cDepth or cLevel parameters); and become part of the CDMO's online provisional database. All pre- and post-deployment data are removed from the file prior to upload. During primary QAQC, data are flagged if they are missing or out of sensor range. The edited file is then returned to the reserve for secondary QAQC where it is opened in Microsoft Excel and processed using the CDMO's NERRQAQC Excel macro. The macro inserts station codes, creates metadata worksheets for flagged data and summary statistics, and graphs the data for review. It allows the user to apply QAQC flags and codes to the data, remove any overlapping deployment data, append files, and export the resulting data file for upload to the CDMO. Upload after secondary QAQC results in ingestion into the database as provisional plus data, recalculation of cDepth or cLevel parameters, and finally tertiary QAQC by the CDMO and assimilation into the CDMO's authoritative online database. Where deployment overlap occurs between files, the data produced by the newly calibrated sonde is generally accepted as being the most accurate. For more information on QAQC flags and codes, see Sections 11 and 12.

Copies of all files are retained at the Reserve which includes the raw EXO KOR files (.bin) and raw the 6600-series PC6000 data files (.dat), as well as the quality control spreadsheets (.xlsx) and metadata (.doc) archived at the CDMO site.

3) Research objectives –

For the NERR System-Wide Monitoring Program (SWMP), the YSI EXO data loggers are programmed to record water quality parameters every 15 minutes. A total of four SWMP sites were located in the Waquoit Bay estuarine system during 2015. These four are: 1) Metoxit Point (MP), in operation since 1998, is located in the middle of Waquoit Bay's main basin; 2) Menauhant (MH), in operation since March 2001, is located adjacent to Eel Pond Inlet on Vineyard Sound – one of the two tidal inlets into the Waquoit Bay estuary; 3) Child's River (CR), in operation since May 2002, located near the head of the tidal section of Child's River— one of the two main surface fresh water sources to Waquoit Bay; and 4) Sage Lot (SL), in operation since May 2002, located in Sage Lot Pond—a tidal pond surrounded by salt marsh and barrier beach, possessing one of the bay's few remaining eelgrass stands.

The main purpose of the SWMP water quality monitoring program is to aid Waquoit Bay NERR in one of its priority missions - to perform as a natural laboratory and platform for coastal and estuarine research. The long term, continuous detailed monitoring of the estuary's basic hydro-physical parameters is an essential tool and context for any research activities located here. Besides this overarching mission, there are also several specific research interests. One primary issue for the Waquoit Bay ecosystem is the influence of anthropogenic induced alterations by nitrogen enrichment. Waquoit Bay receives nitrogen from several sources, including but not limited to septic systems (their leachate percolates into groundwater which then enters the bay), run off from roads, run off containing domestic and agricultural fertilizer and animal waste, and atmospheric sources. This elevated nitrogen loading to the bay has resulted in enhanced eutrophication that has contributed to the alteration of the bay's habitats. For example, thick mats of macroalgae now cover the bottom where eelgrass meadows thrived in the 1970's. Unfortunately, there are few definitive records of the bay's water quality conditions during that period, which makes it difficult to evaluate the rates of change. To facilitate future evaluation, long-term records from SWMP can be used to track water column conditions. Of particular interest, in this regard are measurements of dissolved oxygen (DO) and turbidity, as well as dissolved nitrogen and chlorophyll concentration (this data is available by contacting the reserve). Such records will facilitate evaluation of changes which may come about from a continuation of watershed alteration that result from current development patterns (i.e., non-sewered residential areas served by private septic systems typically consisting of septic tanks and leach fields) as well as non-industrial commercial development, such as golf courses, cranberry bogs, and retail shopping outlets. The records will be useful for evaluating the efficacy of remediation efforts intended to reduce the nitrogen loading from these sources to Waquoit Bay.

Another focus of long-term research interest is the detection of climate change and the determination of its effects on the estuarine environment. Characterizing the variability of the various water column parameters, such as their scale, magnitude, and frequency, is an important aspect of the estuarine ecosystem that is affected by climate change. Related to this focus is an interest in the impact of storms (hurricanes and northeasters) and other extreme meteorological events on the estuary. For example, what temperature and wind field thresholds exist that might bring about or trigger certain conditions within the bay? The observations recorded by the SWMP will allow for these types of studies.

4) Research methods –

Multi-parameter YSI EXO2 data loggers, hereafter referred to as sondes, are deployed at each permanent water quality monitoring station at the Waquoit Bay Reserve. Since in-situ instrumentation can only record conditions at a specific location, permanent monitoring stations for SWMP are chosen to be representative of the overall estuary. This is difficult in practice since estuaries by their very definition are coastal regions where large physical, chemical, and biological variations tend to occur in space and time, so that often no particular location within the system is “typical” of the overall system. Establishing several stations can overcome this problem, and as of 2002 four permanent stations were established in the Waquoit Bay estuaries. Our current SWMP stations are situated to represent, as much as possible, the diversity of the estuary and its inputs/outputs. Additional details concerning the station characteristics are discussed in the next section.

The YSI sondes measure and record ambient water temperature, specific conductivity (and calculate salinity), dissolved oxygen (mg/L and % saturated), turbidity (FNU), Chlorophyll-a (ug/L) water level (m), and pH at 15 minute intervals during deployment periods extending for approximately four weeks. Note that the pressure sensors currently in use are non-vented and so variations in atmospheric pressure are recorded as changes in water depth (atmospheric data are available from our SWMP meteorological station (as of January 2002) and other nearby

meteorological observatories), so it is possible to make this correction to the depth data (approximately +1 cm of depth is equal to +1 mb of air pressure), for increased accuracy. Also, at the Metoxit Point site (from 12/2000 to present), Child's River site (from 3/2003 to present), Menauhant site (from 7/2006 to present), and our Sage Lot site (from 6/2006 to present) we have been using an optic chlorophyll fluorescence sensor.

Multi-parameter YSI sondes are deployed and retrieved every four weeks. The "old" sonde is retrieved, and a "new" replacement sonde is deployed immediately so that ideally no record gap occurs. The four-week deployment duration is constrained by a combination of battery life and fouling of the optic sensors during the warm summer months. Prior to deployment (usually within 24 hrs), each instrument is checked and its sensors re-calibrated using standard YSI (Operating Manual) protocols. Similarly, after a deployment, each sonde is brought back to the laboratory for a post-deployment check, data downloading, instrument and sensor cleaning. The conductivity sensors are calibrated with 50.00 mS/cm YSI standard. The pH sensors are calibrated with 7.0 and 10.0 pH standard solutions (2-point calibrations). The turbidity standard used is 126.0 NTU/124.0 FNU, and distilled water (DI) for 0 NTU/FNU. Temperature sensors are checked periodically against a calibrated mercury thermometer. The chlorophyll probe is calibrated on a 2-point calibration with distilled water (DI) and a Fluorescent Red Dye (Rhodamine WT) at a 0.5 mg/L concentration. See the Chlorophyll Qualifier in Sensor Specifications section below regarding chlorophyll fluorescence accuracy. As another check on instrument performance, in-situ measurements of water temperature, DO, salinity, specific conductance, and pH are made using a handheld YSI device (pre-December 2016: YSI 650; post-December 2016: YSI EXO1) at deployment/retrieval times. Deployment/retrieval in-situ data is available at the end of this document.

In July 2016, we upgraded the Metoxit Point site from the 6600-series sondes to the EXO2 sondes. In April 2017, the Childs River site was also upgraded from the 6600-series sondes to the EXO2 sondes. In December 2017, we upgraded the Menauhant site from the 6600-series to the EXO2 sondes. Sage Lot Pond transitioned to the EXO2 in July 2018.

Two types of silos house the YSI sondes during their deployment. One type for dock side stations (Menauhant and Childs River) and the other for open water stations away from shore structures (Metoxit Point and Sage Lot). The Menauhant site, located at a yacht club dock, is adjacent to a tidal inlet, and the Child's River site, located at commercial marina and boat yard, is adjacent to the upper reaches of a tidal river.

For open water, a two-part structure has been designed consisting of a submerged fixed tower and a separate removable silo apparatus that sleeves over the fixed tower. The Metoxit Point and Sage Lot silos are constructed so that the sonde's sensor package is 0.5 m off the bottom. The removable silo apparatus can be lifted on and off the tower for inspection, cleaning or other maintenance. The sondes are deployed into the removable silos consisting of open-ended vertically mounted 4" PVC pipe (each silo is perforated in its lower portion around the business end of the sonde). The fixed tower structure consists of a vertical reinforced concrete filled 3" PVC pipe about 1.3 meters in height extending upward from a 300 lb cast reinforced concrete base (30" in diameter and 6" thickness) anchored into the bottom by a reinforced concrete filled 4" PVC pipe about 1 m in length. The whole structure is somewhat reminiscent of large "child's toy top".

For dock-side locations, the silo apparatuses are a more typical type – a single PVC section (4" ID) mounted vertically onto a pier piling or bulkhead. The base of these silos is also ventilated with large holes (1.0" diameter). All silos are painted with antifouling paint at the beginning of the spring season, and periodically checked and scrubbed during the summer season.

In July of 2006, a transmitter was installed at the Menauhant Yacht Club station which transmits data to the NOAA GOES satellite, NESDIS ID #3B030074. A Sutron Sat-Link2 was installed at the Menauhant site from July 2006 until November 2020 when it was upgraded to a YSI S'TORM3 transmitter system while still using the same NESDIS ID#. The transmissions are scheduled hourly and contain four (4) datasets reflecting fifteen-minute data sampling intervals. Upon receipt by the CDMO, the data undergoes the same automated primary QA/QC process detailed in Section 2 above. The "real-time" telemetry data become part of the provisional dataset until undergoing secondary and tertiary QA/QC and assimilation in the CDMO's authoritative online database. Provisional and authoritative data are available at <https://cdmo.baruch.sc.edu/>.

5) Site location and character –

General description of Waquoit Bay estuarine system:

The Waquoit Bay National Estuarine Research Reserve (WBNERR) is located in the northeastern United States on the southern coast of Cape Cod, Massachusetts. About 8,000 people maintain permanent residency in Waquoit Bay's drainage area, which covers parts of the towns of Falmouth, Mashpee, and Sandwich. During summer months, the population swells 2-3 times with the greatest housing concentrations immediate to the coastline (water views and frontage). In addition, the upper portions of the watershed include a military base, Otis Air Force Base and the Massachusetts Military Reservation, portions of which have been designated by the EPA as Superfund sites due to past practices of dumping jet fuel and other volatile groundwater contaminants.

WBNERR's estuaries are representative of shallow tidal lagoons that occur from Cape Cod to Sandy Hook, New Jersey. WBNERR is within the northern edge of the Virginian biogeographic province, on the transitional border (Cape Cod) with the Acadian biogeographic province to the north and east. Like many embayments located on glacial outwash plains, Waquoit Bay is shallow (< 5 m), fronted by prominent barrier beaches (i.e., those of South Cape Beach State Park and Washburn Island), and backed by salt marshes and upland coastal forests of scrub pine and oak. Two narrow, navigable inlets, reinforced with granite jetties, pass through two barrier beaches to connect Waquoit Bay with Vineyard Sound to the south. A third shallow and generally un-navigable inlet opened through the Washburn Island barrier beach during Hurricane Bob in August 1991. This shallow inlet closed in February 2002.

Bottom sediments in the bay are organic rich (C organic conc. ~ 3-4%) silts and medium sands. Sediment cores obtained in summer of 2002 indicate that the depth of these estuarine sediments is up to 9 m thick in places. Dating work on these sediment cores suggests that the Waquoit Bay basin has been inundated by the sea for about 5000 years, and sediment accumulation rates were estimated to be between 2-10 mm/yr, with higher rates in the upper 1 m of sediments (Maio et al. 2016). Thick (up to 0.3 m) macroalgae mats overlie much of the bottom of the bay, and largely consist of species *Cladophora vagabunda*, *Gracilaria tikvahiae*, and *Enteromorpha* spp. The dominant marsh vegetation in Waquoit Bay is *Spartina alterniflora* and *Spartina patens*. Dominant upland vegetation includes mixed forests of red oak, white oak, and pitch pine, and other shrubs and plants common to coastal New England. Land-use in the bay's watershed is about 60% natural vegetation, but the remaining land is largely residential housing, with some commercial (retail malls) development, and minor amounts of agriculture (~3%; e.g., cranberry bogs).

Dense housing developments cover the two peninsulas that form the western shore of the Waquoit Bay estuarine system. Although the developments are outside of the Reserve boundaries, dissolved nitrogen in discharge from the septic systems (via groundwater) and in fertilizer run-off from lawns has significant effects on the functioning of the Waquoit Bay ecosystem. These impacts have been a primary subject of study at the Reserve since its designation (1988). One outcome of this research has been the delineation of sub-watersheds within the overall drainage area for Waquoit Bay, of which WBNERR is a small part. This knowledge allows for the design of experiments based on the spatial variation of nutrient loading and other land-use related impacts.

At the northern end of the bay, an area comprising a separate sub-watershed, coastal bluffs of glacial till rise 30 feet above sea level. The northern basin of the bay, just below these bluffs, is its deepest area (approximately 3 m MLW), while much of the remainder of the bay is about 1.5 m. Bourne, Bog, and Caleb Ponds are freshwater kettle hole ponds on the northern-most shore of the bay. As components of the same sub-watershed, they have a common albeit minor freshwater outflow into the bay's northern basin via a narrow channel through a brackish marsh. To the east and south, other sub-watersheds surround several tidal and freshwater ponds, including Hamblin and Jehu Ponds, brackish salt ponds that are connected to the main bay by the tidal waters of Little and Great Rivers, respectively. The shorelines of the ponds are developed with residences that are occupied both seasonally and year round. Hamblin Pond and Little River are components of one sub-watershed, and Jehu Pond and Great River are elements of a separate sub-watershed. Further south lies Sage Lot Pond. It is in the least developed sub-watershed and contains a barrier beach and salt marsh ecosystem of the reserve's South Cape Beach State Park. To the east of Sage Lot Pond and within the same sub-watershed, lies the highly brackish Flat Pond. It receives minimal

tidal flows of salt water from Sage Lot Pond through a narrow, excavated, and culverted channel. In the spring of 2008 two (2) channel culverts were replaced, one with a bridge and the second with a wider, less restrictive culvert to increase tidal flushing in the pond. The preponderance of the input to Flat Pond is groundwater and run off, both of which are likely affected (e.g., nutrients, pesticides, bacteria) by an adjacent golf course and nearby luxury residential development.

The largest source of surface freshwater to Waquoit Bay is the Quashnet/Moonakis River. Although named "river", this and Child's River are more appropriately described as "streams" because of their small channels and discharge ~ 1.0 CFS. A component of yet another sub-watershed, the Quashnet River originates in Johns Pond situated north of the bay and traverses forests, cranberry bogs, residential areas, and the Quashnet Valley Golf Course before entering the bay near the southern "boundary" of the northern basin. ("Quashnet" applies to that portion of the river within the town of Mashpee, and "Moonakis" refers to the brackish estuary at the river's mouth, in the town of Falmouth. Quashnet will be used hereafter to refer to the entire river.) The Quashnet River's tidal portion has enough coliform bacteria to cause it to be closed to shell fishing most of the time. The source(s) of these bacteria (human or avian) is currently unknown.

The Childs River is the second largest input of surface freshwater to the bay. A component of another sub-watershed, it runs through densely developed residential areas. The Childs River sub-watershed receives the highest nitrogen loading and is the largest nitrogen contributor to the Waquoit Bay system of all the sub-watersheds. In the upper tidal portions of the river the highest nutrient and chlorophyll levels and the lowest dissolved oxygen readings of any region in the bay have been recorded and so this location represents an end-member for looking at anthropogenic inputs and impacts on the system. Another, albeit smaller, source of freshwater to Waquoit Bay is the discharge of Red Brook through brackish marshlands into Hamblin Pond. Additional freshwater enters the bay elsewhere through groundwater seepage (perhaps up to 50% of all freshwater input into the bay), precipitation, and the flows of smaller brooks. There is relatively little surface water runoff entering directly into the bay due to the high percolation rates of Cape Cod's coarse, sandy soils.

Knowledge of the homo/heterogeneity of the water masses in Waquoit Bay was originally derived from measurements made by reserve staff and from data obtained by the reserve's volunteer water quality monitoring group, the Waquoit Bay Watchers who have collected depth profiles of Waquoit Bay water quality since 1993. Subsequent research by reserve staff has revealed that lateral mixing has considerable influence because tidal currents follow a general course through the bay. This results in an overall structure to horizontal patterns of water quality characteristics. The pattern it produces is a gyre in the central portion of the main bay whereby currents follow a generally counterclockwise flow around a central area that exhibits reduced exchange with the remainder of the bay. The flushing rate within the gyre is diminished when compared with other more peripheral areas of the bay. The location of the gyre meanders slightly, apparently under the influence of tides and wind. Due to the shallow conditions, restricted tidal inlets, and low amplitude tidal forcing of Vineyard Sound here (tides are semi-diurnal with a range ~ 1 m) water levels in the bay are also strongly influenced by wind forcing. Southerly winds increase tidal heights and advance the phase of the flood and retard the phase of ebb. Northerly winds have the opposite effect.

Metoxit Point (MP)

The Metoxit Point station ($41^{\circ} 34' 8.04''$ N $70^{\circ} 31' 17.76''$ W, ~ 2 m deep) initiated in 1998, is located in the main basin of Waquoit Bay and was selected to be within or near the outer regions of the gyre (described above) and more or less represents "typical" water mass conditions and residence times for the bay. Sonde sensors are located 0.5m above the bottom sediments. The location is at least a half mile from shore, well flushed and mixed by tides, and is in an area that is minimally disturbed by routine activities on the bay (e.g. boat traffic, shell fishing, etc.). Bottom sediments at the site are organic rich mud often overlain by thick algal (*Cladophora*) mats. Because of this site's open exposure to the south (greatest fetch over the bay), it has been observed that when sustained southerly winds are greater than about 20 kts, the Metoxit Point site experiences increased turbidity (sediment suspension events).

The tidal range (maximum-minimum water depth; including only the data which pass quality control standards) for Metoxit Point has been calculated using water depth data, corrected for barometric pressure, for 2014-2016. Based on these three years of data, the average tidal range is 0.90 m. Metoxit Point's average relative water depth (distance from water surface to sonde sensor) is 1.23 m. The sonde sits roughly 0.5 m above the bottom sediments. This water depth value has been calculated based on data available through 2016 (corrected for barometric pressure and including only the data which pass quality control standards). The 2014 data was used to calculate salinities (ppt) for this site: the maximum value was 32.1, the minimum value was 13.7 and the average was 30.2.

Menauhant Yacht Club (MH)

The Menauhant station (41° 33' 9.36" N 70° 32' 54.60" W, ~2 m deep), initiated in March 2001, is located within the Eel Pond Inlet at the Menauhant Yacht Club dock. Eel Pond Inlet is the westernmost of the two main tidal inlets into the Waquoit Bay system. The site was chosen because it occupies one of the strategic locations for gauging the system's water mass characteristics. Entering waters represent the marine endmember while outflows represent the final product of estuarine water mass modification and export to shelf waters. The site also has easy walk-in access to a secure private pier that extends into the throat of the inlet.

Due to the turbulent tidal flow within the inlet, conditions are vertically well mixed, and the site can be maintained year-round even through ice-over conditions in the rest of the bay. Bottom sediments at this site are sands and gravels with almost no attached bottom vegetation. Since inception, we have noted that strong south to southeast (onshore) winds tend to produce turbidity events at this site from the wave induced suspension of fine sediments and organic material in the upstream near-shore zone. While we have found that these types of turbidity events are localized to windward near-shore areas in the bay, the transport of these sediments at inlet mouths during such times is perhaps a dominant sedimentation process within the estuarine system. In other words, while the choice of our location may be producing a localized signal in turbidity, the turbidity signal may reflect key processes in the system at large.

The tidal range (maximum-minimum water depth, including only the data which pass quality control standards) for Menauhant has been calculated using water depth data, corrected for barometric pressure, for 2014-2016. Based on these three years of data, the average tidal range is 1.55 m. Menauhant's average water depth (distance from water surface to sonde sensor) is 0.71 m. The sonde sits roughly 0.5 m above the bottom sediments. This water depth value has been calculated based on data available through the end of 2016 (corrected for barometric pressure and including only the data which pass quality control standards). The 2014 data was used to calculate salinities (ppt) for this site: the maximum value was 32.1, the average was 31.3.

Child's River (CR)

The Child's River station (41° 34' 48.47" N, 70° 31' 49.87" W, ~1 m deep), initiated in May 2002, is located on a dock piling at East Falmouth Marina (changed from Bosun's Marina and previously Edward's Boat Yard) a commercial marina near the upper tidal reaches of Child's River—one of the two main surface fresh water sources to Waquoit Bay (see general description of Waquoit Bay watershed above). This location is very strongly stratified, characterized by a salt wedge with fresher river water overlying saline ocean water. Vertical salinity ranges can run from 0-10 ppm at the surface to more than 30 ppm just 1 m below. The 2014 data was used to calculate salinities (ppt) for this site: the maximum value was 30.6, the minimum value was 14.8 and the average was 27.8. The sonde sensors are usually well within the salt wedge portion of the water column (sonde sensors located ~25cm above the sediment), nonetheless this location is also our freshest SWMP site, and is at the opposite end of Child's River from the seaward Menauhant station. Bottom sediments are fine organic rich muds.

This location represents the most terrigenously and anthropogenically-impacted SWMP site. Monthly water quality, collected near this location for the past decade, shows very high chlorophyll concentrations during the warmer months and more recent dissolved nutrient records show very high nutrient-loads. Boat traffic at the marina likely leads to increased turbidity during the boating season as well. As this site is dockside at a private marina,

general security is high and access is easily available. During the winter (generally mid-December through March), the marina staff install aerators at the end of each pier to prevent damage from ice. Until 2021, we did not deploy a sonde during these months due to concern regarding the quality of data being highly altered by the presence of the aerator.

The tidal range (maximum-minimum water depth, including only the data which pass quality control standards) for the Child's River site has been calculated using water depth data, corrected for barometric pressure, for 2014-2016. Based on these three years, the average tidal range is 1.30 m. The Child's River's average water depth (average distance from surface to sonde sensor) is 0.83 m. The sensor sits roughly 0.25 m above the bottom sediments. The water depth calculation is based on data collected through the end of 2016 (corrected for barometric pressure and including only the data which pass quality control standards).

Sage Lot (SL)

The Sage Lot station (41° 33'15.12" N 70° 30'30.20" W, ~1 m deep), initiated in May 2002, is in a deep portion of Sage Lot Pond – a small sub-estuary of Waquoit Bay (20 ha) surrounded by salt marsh and barrier beach. Its small watershed is the least developed of all of Waquoit Bay's sub-watersheds and Sage Lot Pond is its least impacted sub-estuary. Bottom sediments are organic rich muds. Sage Lot Pond possesses one of the few remaining eelgrass beds in the Waquoit Bay system.

The Child's River and Sage Lot Pond sites are considered to represent opposite endmembers of nutrient-loading and human-induced influence. Researchers often locate their experiments in these two locations to take advantage of this difference. However, Sage Lot Pond is hydrologically connected to an upstream brackish source -- Flat Pond – via a series of tidal creeks, drainage ditches and culverts. Flat Pond borders a country club and golf course; such land use may affect the water quality of Sage Lot Pond.

The tidal range (maximum-minimum water depth, including only the data which pass quality control standards) for the Sage Lot Pond site has been calculated using water depth data, corrected for barometric pressure, for 2014-2016. Based on these three years, the average tidal range is 0.99 m. Sage Lot Pond's average water depth (average distance from surface to sonde sensor) is 0.60 m. The sonde sits roughly 0.5 m above the bottom sediments. The average water depth has been calculated based on data available through the end of 2016 (corrected for barometric pressure and including only the data which pass quality control standards). The 2014 data was used to calculate salinities (ppt) for this site: the maximum value was 32.28, the minimum value was 24.22 and the average was 30.26.

Station Code	SWMP Status	Station Name	Location	Active Dates	Reason Decommissioned	Notes
wqbcrwq	P	Child's River	41° 34' 48.47" N, 70° 31' 49.87" W	05/01/2002 00:00 -	NA	NA
wqbslwq	P	Sage Lot	41° 33' 15.12 N, 70° 30' 30.20 W	05/01/2002 00:00 -	NA	NA
wqbmhwq	P	Menauhant	41° 33' 9.36 N, 70° 32' 54.60 W	03/01/2001 00:00 -	NA	NA
wqbmpwq	P	Metoxit Point	41° 34' 8.04 N, 70° 31' 17.76 W	11/01/1998 00:00 -	NA	NA

wqbcbwq	P	Central Basin	41° 33' 55.80 N, 70° 31' 15.96 W	10/01/1995 00:00 - 12/01/1998 00:00	MP was considered more representative of the average water quality dynamics in Waquoit Bay. The MP site is located outside an anti-clockwise gyre, where water exchange is reduced.	
wqbctwq	P	Adjacent to Central Basin	41° 33' 55.80 N, 70° 31' 15.96 W	09/01/1998 00:00 - 10/01/1998 00:00	Considered a “rover” site. Never designed to be long-term	
wqbnbwq	P	North Basin	41° 34' 43.68 N, 70° 31' 25.32 W	10/01/1995 00:00 - 12/01/1997 00:00	Considered a “rover” site. Never designed to be long-term	
wqbnsqw	P	North Basin Surface	41° 34' 43.68 N, 70° 31' 25.32 W	07/01/1997 00:00 - 12/01/1997 00:00	Considered a “rover” site. Never designed to be long-term	

6) Data collection period –

SWMP water quality monitoring in Waquoit Bay was initiated in 1995. Several different pilot sites (i.e., North Basin and Central Basin) were occupied for varying durations before settling on our first permanent long term site at Metoxit Point in summer 1998. The Menauhant site was our second permanent station and began operation in March 2001. Sage Lot and Childs River sites began operation in May 2002.

In 2022, no data were collected at the Childs River station due to active construction at the site. Due to icy conditions during the winter months, the Metoxit Point and Sage Lot stations were not occupied from mid-December 2020 through the last week in March 2021. In preparation for the winter (before the boats are pulled), the Metoxit Point and Sage Lot stations were removed on 12/20/2021 and 12/21/2020, respectively. The deployment dates and times for 2022 are indicated below: The staff at the Childs River marina planned a large construction project for October 2021. All docks and piers were removed while new bulkheads and other structures were built.

Menauhant

DEPLOYMENT

Date/Time

12/30/2021 16:00

02/02/2022 15:30

03/03/2022 12:00

04/05/2022 10:15

05/17/2022 15:30

07/01/2022 14:30

08/03/2022 12:00

*09/09/2022 10:15

10/19/2022 15:30

11/07/2022 20:00

12/15/2022 17:15

RETRIEVAL

Date/Time

02/02/2022 15:15

03/03/2022 11:45

04/05/2022 10:00

05/17/2022 15:00

07/01/2022 14:00

08/03/2022 11:45

09/09/2022 10:00

*10/19/2022 15:15

11/05/2022 16:00

12/15/2022 17:00

01/17/2023 12:45

Metoxit Point

DEPLOYMENT	RETRIEVAL
Date/Time	Date/Time
05/12/2022 11:15	06/24/2022 19:30
06/30/2022 09:30	07/31/2022 11:30
07/31/2022 12:00	09/14/2022 10:15
09/14/2022 10:30	10/19/2022 13:45
10/19/2022 14:00	11/22/2022 14:45
11/22/2022 15:00	12/20/2022 13:30

Child's River

DEPLOYMENT	RETRIEVAL
Date/Time	Date/Time
	10/04/2021 09:45 (removed station due to construction)

Sage Lot

DEPLOYMENT	RETRIEVAL
Date/Time	Date/Time
05/20/2022 16:45	07/06/2022 11:15
07/06/2022 11:30	08/10/2022 12:30
08/10/2022 13:00	09/14/2022 14:45
09/14/2022 16:00	10/21/2022 10:00
10/21/2022 10:15	11/22/2022 10:15
11/22/2022 10:30	12/21/2022 09:45

*Sonde deployment was never initiated, so no data was recorded during this period

7) Distribution –

NOAA retains the right to analyze, synthesize and publish summaries of the NERRS System-wide Monitoring Program data. The NERRS retains the right to be fully credited for having collected and processed the data. Following academic courtesy standards, the NERR site where the data were collected should be contacted and fully acknowledged in any subsequent publications in which any part of the data are used. The data set enclosed within this package/transmission is only as good as the quality assurance and quality control procedures outlined by the enclosed metadata reporting statement. The user bears all responsibility for its subsequent use/misuse in any further analyses or comparisons. The Federal government does not assume liability to the Recipient or third persons, nor will the Federal government reimburse or indemnify the Recipient for its liability due to any losses resulting in any way from the use of this data.

Requested citation format:

NOAA National Estuarine Research Reserve System (NERRS). System-wide Monitoring Program.

Data accessed from the NOAA NERRS Centralized Data Management Office website:

<http://www.nerrsdata.org/>; accessed 12 October 2022.

Also include the following excerpt in the metadata which will address how and where the data can be obtained.

NERR water quality data and metadata can be obtained from the Research Coordinator at the individual NERR site (please see Principal Investigators and Contact Persons), from the Data Manager at the Centralized Data Management Office (please see personnel directory under the general information link on the CDMO home page) and online at the CDMO home page www.nerrsdata.org. Data are available in comma delimited format.

8) Associated researchers and projects –

As part of the SWMP long-term monitoring program, the Waquoit Bay NERR also monitors 15-minute meteorological data. Additionally, Waquoit Bay collects monthly grab and 24-hour diel samples for nutrient data which may be correlated with this water quality dataset. These data are available at www.nerrsdata.org.

Waquoit BayWatchers:

The Reserve has carried out a citizen-based water quality monitoring program since 1993 called *BayWatchers*. Water quality measurements are carried out at 9 sites within Waquoit Bay estuary for the purposes of 1) constructing a long time series of water quality information to determine trends, as well as 2) providing a sentinel role to detect unusual changes and events. Monthly (October-May) and Bi-weekly (June-September) measurements are made year-round on a set schedule. Chl-*a* samples are processed and analyzed using Turner 10AU fluorometer at WBNERR. Dissolved inorganic nutrient samples are currently analyzed by the Provincetown Center for Coastal Studies (pre-2015 data was analyzed at the Woods Hole Oceanographic Institute). All data is processed and archived at WBNERR and is publicly available upon request.

A new field procedure was initiated in July 2007 and a ninth site was added at the south basin of Waquoit Bay at the first inlet buoy in the main channel. A change at this time was made from previous wet chemical measurements to utilizing hand-held YSI 85 meters to measure water temperature, salinity, and dissolved oxygen (‰ and mg/L). Each meter is calibrated each sampling period for dissolved oxygen. Measurements are taken at the surface (0.25m) and the bottom at each site. The bottom depth is recorded. Additionally, due to shallow depths at most sites, water clarity measurements with Secchi discs have been discarded for turbidity measurements.

Two bottles of water are now collected at each site for nutrients analysis, at approximately 0.25m below the surface, by locking the bottles into a hand-held apparatus. This new sampling procedure has helped in standardizing the depth sampled for all sites in our chemical analysis. The bottles are mounted to a pole and capped with rubber stoppers attached to a rope. When the bottles are lowered to a marked level (0.25m) on the apparatus, the rope is pulled and water enters the bottle. The cap is placed on the bottles and returned back to the lab for turbidity, chlorophyll, and nutrient analysis. Physical characterization of the site and sampling period are recorded each sampling date (time of sampling, weather conditions-sun/clouds/rain/fog, name of team members, etc) and any other observations are recorded.

As part of the SWMP long-term monitoring program, XXX NERR also collects 15-minute meteorological data and monthly grab and diel samples for nutrient/pigment data which may be correlated with this water quality dataset. These data are available at www.nerrsdata.org.

II. Physical Structure Descriptors

9) Sensor specifications –

YSI EXO2 non-vented Sonde: *Deployed at all sites in 2022*

Parameter: Temperature

Units: Celsius (C)

Sensor Type: Wiped probe; Thermistor

Model#: 599827

Range: -5 to 50 C

Accuracy: ± 0.2 C
Resolution: 0.001 C

Parameter: Conductivity
Units: milli-Siemens per cm (mS/cm)
Sensor Type: Wiped probe; 4-electrode cell with autoranging
Model#: 599827
Range: 0 to 100 mS/cm
Accuracy: $\pm 1\%$ of the reading or 0.002 mS/cm, whichever is greater
Resolution: 0.0001 to 0.01 mS/cm (range dependent)

Parameter: Salinity
Units: practical salinity units (psu)/parts per thousand (ppt)
Model#: 599827
Sensor Type: Wiped probe; Calculated from conductivity and temperature
Range: 0 to 70 ppt
Accuracy: $\pm 2\%$ of the reading or 0.2 ppt, whichever is greater
Resolution: 0.01 psu

Parameter: Dissolved Oxygen % saturation
Sensor Type: Optical probe w/ mechanical cleaning
Model#: 599100-01
Range: 0 to 500% air saturation
Accuracy: 0-200% air saturation: $\pm 1\%$ of the reading or 1% air saturation, whichever is greater
200-500% air saturation: $\pm 5\%$ or reading
Resolution: 0.1% air saturation

Parameter: Dissolved Oxygen mg/L (Calculated from % air saturation, temperature, and salinity)
Units: milligrams/Liter (mg/L)
Sensor Type: Optical probe w/ mechanical cleaning
Model#: 599100-01
Range: 0 to 50 mg/L
Accuracy: 0-20 mg/L: ± 0.1 mg/L or 1% of the reading, whichever is greater
20 to 50 mg/L: $\pm 5\%$ of the reading
Resolution: 0.01 mg/L

Parameter: Non-vented Level - Shallow (Depth)
Units: feet or meters (ft or m)
Sensor Type: Stainless steel strain gauge
Range: 0 to 33 ft (10 m)
Accuracy: ± 0.013 ft (0.004 m)
Resolution: 0.001 ft (0.001 m)

Parameter: pH
Units: pH units
Sensor Type: Glass combination electrode
Model#: 599701(guarded) or 599702(wiped)
Range: 0 to 14 units
Accuracy: ± 0.1 units within $\pm 10^\circ$ of calibration temperature, ± 0.2 units for entire temp range
Resolution: 0.01 units

Parameter: Turbidity
Units: formazin nephelometric units (FNU)
Sensor Type: Optical, 90 degree scatter

Model#: 599101-01
Range: 0 to 4000 FNU
Accuracy: 0 to 999 FNU: 0.3 FNU or +/-2% of reading (whichever is greater)
1000 to 4000 FNU: +/-5% of reading
Resolution: 0 to 999 FNU: 0.01 FNU, 1000 to 4000 FNU: 0.1 FNU

Parameter: Chlorophyll
Units: micrograms/Liter
Sensor Type: Optical probe
Model#: 599102-01
Range: 0 to 400 ug/Liter
Accuracy: Dependent on methodology
Resolution: 0.1 ug/L chl a, 0.1% FS

Depth Qualifier:

The NERR System-Wide Monitoring Program utilizes YSI data sondes that can be equipped with either vented or non-vented depth/level sensors. Readings for both vented and non-vented sensors are automatically compensated for water density change due to variations in temperature and salinity; but for all non-vented depth measurements, changes in atmospheric pressure between calibrations appear as changes in water depth. The error is equal to approximately 1.02 cm for every 1 millibar change in atmospheric pressure and is eliminated for vented sensors because they are vented to the atmosphere throughout the deployment time interval.

Beginning in 2006, NERR SWMP standard calibration protocol calls for all non-vented depth sensors to read 0 meters at a (local) barometric pressure of 1013.25 mb (760 mm/hg). To achieve this, each site calibrates their depth sensor with a depth offset number, which is calculated using the actual atmospheric pressure at the time of calibration and the equation provided in the SWMP calibration sheet or digital calibration log. This offset procedure standardizes each depth calibration for the entire NERR System. If accurate atmospheric pressure data are available, non-vented sensor depth measurements at any NERR can be corrected.

In 2010, the CDMO began automatically correcting depth/level data for changes in barometric pressure as measured by the Reserve's associated meteorological station during data ingestion. These corrected depth/level data are reported as cDepth and cLevel and are assigned QAQC flags and codes based on QAQC protocols. Please see sections 11 and 12 for QAQC flag and code definitions.

NOTE: Older depth data cannot be corrected without verifying that the depth offset was in place and whether a vented or non-vented depth sensor was in use. No SWMP data prior to 2006 can be corrected using this method. The following equation is used for corrected depth/level data provided by the CDMO beginning in 2010:

$$((1013-BP)*0.0102)+\text{Depth/Level} = \text{cDepth/cLevel}$$

Salinity Units Qualifier:

In 2013, EXO sondes were approved for SWMP use and began to be utilized by Reserves. While the 6600 series sondes report salinity in parts per thousand (ppt) units, the EXO sondes report practical salinity units (psu). These units are essentially the same and for SWMP purposes are understood to be equivalent, however psu is considered the more appropriate designation. Moving forward the NERR System will assign psu salinity units for all data regardless of sonde type.

Turbidity Qualifier:

In 2013, EXO sondes were approved for SWMP use and began to be utilized by Reserves. While the 6600 series sondes report turbidity in nephelometric turbidity units (NTU), the EXO sondes use formazin nephelometric units (FNU). These units are essentially the same but indicate a difference in sensor methodology. For SWMP purposes they will be considered equivalent. Moving forward, the NERR System will use FNU/NTU as the designated units for all turbidity data regardless of sonde type. If turbidity units and sensor methodology are of concern, please see the Sensor Specifications portion of the metadata.

Chlorophyll Fluorescence Disclaimer:

YSI chlorophyll sensors (6025 or 599102-01) are designed to serve as a proxy for chlorophyll concentrations in the field for monitoring applications and complement traditional lab extraction methods; therefore, there are accuracy limitations associated with the data that are detailed in the YSI manual including interference from other fluorescent species, differences in calibration method, and effects of cell structure, particle size, organism type, temperature, and light on sensor measurements.

10) Coded variable definitions –

Station Codes:

<u>Sampling Station</u>	<u>Sampling Site Code</u>	<u>Station Code</u>
Metoxit Point	MP	wqbmpwq
Menauhant	MH	wqbmhwq
Child's River	CR	wqbcrwq
Sage Lot	SL	wqbslwq

File definitions: NERR Reserve/YSI deployment site/data type code/year

Example: wqbmpwq2008 (designates 2008 water quality data for the Metoxit Point site)

11) QAQC flag definitions –

QAQC flags provide documentation of the data and are applied to individual data points by insertion into the parameter's associated flag column (header preceded by an F_). During primary automated QAQC (performed by the CDMO), -5, -4, and -2 flags are applied automatically to indicate data that is missing and above or below sensor range. All remaining data are then flagged 0, passing initial QAQC checks. During secondary and tertiary QAQC 1, -3, and 5 flags may be used to note data as suspect, rejected due to QAQC, or corrected.

- 5 Outside High Sensor Range
- 4 Outside Low Sensor Range
- 3 Data Rejected due to QAQC
- 2 Missing Data
- 1 Optional SWMP Supported Parameter
- 0 Data Passed Initial QAQC Checks
- 1 Suspect Data
- 2 *Open - reserved for later flag*
- 3 Calculated data: non-vented depth/level sensor correction for changes in barometric pressure
- 4 Historical Data: Pre-Auto QAQC
- 5 Corrected Data

12) QAQC code definitions –

QAQC codes are used in conjunction with QAQC flags to provide further documentation of the data and are also applied by insertion into the associated flag column. There are three (3) different code categories, general, sensor, and comment. General errors document general problems with the deployment or YSI datasonde, sensor errors are sensor specific, and comment codes are used to further document conditions or a problem with the data. Only one general or sensor error and one comment code can be applied to a particular data point, but some comment codes (marked with an * below) can be applied to the entire record in the F_Record column.

General Errors

GIC	No instrument deployed due to ice
GIM	Instrument malfunction
GIT	Instrument recording error; recovered telemetry data
GMC	No instrument deployed due to maintenance/calibration
GNF	Deployment tube clogged / no flow
GOW	Out of water event
GPF	Power failure / low battery
GQR	Data rejected due to QA/QC checks
GSM	See metadata

Corrected Depth/Level Data Codes

GCC	Calculated with data that were corrected during QA/QC
GCM	Calculated value could not be determined due to missing data
GCR	Calculated value could not be determined due to rejected data
GCS	Calculated value suspect due to questionable data
GCU	Calculated value could not be determined due to unavailable data

Sensor Errors

SBO	Blocked optic
SCF	Conductivity sensor failure
SCS	Chlorophyll spike
SDF	Depth port frozen
SDG	Suspect due to sensor diagnostics
SDO	DO suspect
SDP	DO membrane puncture
SIC	Incorrect calibration / contaminated standard
SNV	Negative value
SOW	Sensor out of water
SPC	Post calibration out of range
SQR	Data rejected due to QAQC checks
SSD	Sensor drift
SSM	Sensor malfunction
SSR	Sensor removed / not deployed
STF	Catastrophic temperature sensor failure
STS	Turbidity spike
SWM	Wiper malfunction / loss

Comments

CAB*	Algal bloom
CAF	Acceptable calibration/accuracy error of sensor
CAP	Depth sensor in water, affected by atmospheric pressure
CBF	Biofouling
CCU	Cause unknown
CDA*	DO hypoxia (<3 mg/L)
CDB*	Disturbed bottom
CDF	Data appear to fit conditions
CFK*	Fish kill

CIP* Surface ice present at sample station
 CLT* Low tide
 CMC* In field maintenance/cleaning
 CMD* Mud in probe guard
 CND New deployment begins
 CRE* Significant rain event
 CSM* See metadata
 CTS Turbidity spike
 CVT* Possible vandalism/tampering
 CWD* Data collected at wrong depth
 CWE* Significant weather event

13) Post deployment information –

Red text in the tables below indicates a post-calibration that is outside of normal range. The drift could be caused by biofouling or diluted/contaminated standard. The red highlight is merely to acknowledge that the numbers were cause for further investigation and does not necessarily mean the entire deployment was of poor quality.

Childs River (*EXO2 deployed at this site*)

Date Checked	DO	Baro.	Depth	Depth	SpCond	pH 7	pH 10	Turbidity	Turbidity	Chl 0	Chl	Rhodamine
dd/mm/yyyy	100%	Pres.		Offset	50.00	7.00	10.00	DI	124.0	DI	Rhodamine	Std value
	%	mmHg	m	m	mS/cm			FNU	FNU	µg/L	µg/L	µg/L

Menauhant (*EXO2 deployed at this site*)

Date Checked	DO	Baro.	Depth	Depth	SpCond	pH 7	pH 10	Turb	Turb	Chl 0	Chl	Rhodamine
dd/mm/yyyy	100%	Pres.		Offset	50.00	7.00	10.00	DI	124.0/126.0	DI	Rhodamine	Std value
	%	mmHg	m	m	mS/cm			FNU	FNU	µg/L	µg/L	µg/L
02/02/2022	Post-deployment readings for this deployment all read as NAN.											
03/03/2022	101.4	758.31	-0.39	-0.023	42.12	7.03	10.17	3.49	130.5	0.05	75.8	72.4
04/05/2022	100.5	763.56	0.12	0.048	50.03	7.11	10.13	2.73	123.38	-0.7	72.68	72
05/17/2022	99.2	759.06	0.07	-0.013	49.943	7.18	10.33	-1.14	122.7	-0.33	73.47	-
07/01/2022	99.6	761.31	0.07	0	49.724	7.02	9.97	1.12	123.06	15.97	64.37	63.3
08/03/2022	86.8	761.24	-0.02	0	49.317	7.08	10.0	1.12	119.42	1.71	59.44	60.4
09/12/2022	101.5	758.95	-0.04	0	49.538	7.08	10.08	3.95	122.7	0.0	63.1	60.9
10/19/2022	This deployment was never initiated, so no data was ever recorded. No post-deployment readings to measure.											
11/08/2022	102.6	772.67	0.199	0.172	49.999	7.13	10.30	0.03	123.46	-0.05	59.3	70.6
12/16/2022	100.0	757.68	-0.117	-0.032	49.810	6.89	10.07	0.3	125.6	0.33	81.27	71.8
01/17/2023	Post-deployment readings for this deployment all read as NAN.											

Metoxit Point (*EXO2 deployed at this site*)

Date Checked	DO	Baro.	Depth	Depth	SpCond	pH 7	pH 10	Turbidity	Turbidity	Chl 0	Chl	Rhodamine
dd/mm/yyyy	100%	Pres.		Offset	50.00	7.00	10.00	DI	124.0	DI	Rhodamine	Std value
	%	mmHg	m	m	mS/cm			FNU	FNU	µg/L	µg/L	µg/L
06/24/2022	94.1	-	0.31	-	47.878	7.05	-	0.03	102.4	0.08	59.19	-
07/31/2022 disappeared	Post-deployment readings for this deployment log were erased and lost.											
09/15/2022	97.3	763.524	0.05	0	50.119	7.28	10.38	0.6	125.46	-0.12	67.2	67.1
10/19/2022	100.1	757.682	0.057	-0.032	49.515	7.27	10.59	-4.55	123.4	LOST	306.3	94.8

11/22/2022	100.5	768.1	0.188	0.11	49.910	7.14	10.16	0.14	122.8	0.34	71.96	71.7
12/20/2022	100.6	768.858	0.054	0.12	49.95	6.77	10.21	-0.1	123.82	0.12	60.1	71.2

Sage Lot (EXO2 deployed at this site)

Date Checked	DO	Baro.	Depth	Depth	SpCond	pH 7	pH 10	Turbidity	Turbidity	Chl 0	Chl	Rhodamine
dd/mm/yyyy	100%	Pres.		Offset	50.00	7.00	10.00	DI	126.0	DI	Rhodamine	Std value
	%	mmHg	m	m	mS/cm			FNU	FNU	µg/L	µg/L	µg/L
07/06/2022	Post-deployment readings for this deployment log were erased and lost.											
08/10/2022	106.3	765.063	0.043	0	51.659	6.98	10.24	0.86	121.26	0.08	62.63	60.8
09/14/2022	99.3	765.048	0.068	0.069	49.51			0.62	116.68	0.03	67.19	-
10/21/2022	99.9	765.81	0.027	0.079	49.44	6.87	9.80	1.14	123.75	-1.13	196.82	71.1
11/22/2022	101.4	769.62	0.155	0.131	25.274	6.93	9.94	-0.09	121.4	-0.14	70.13	71.8
12/21/2022	101.1	773.43	0.081	0.183	49.794	6.96	10.04	-0.03	123.9	0.0	80.56	72.9

*Note: pH post-deployment readings are temperature dependent and minor variations are expected as a result.

14) Other remarks/notes –

NOTE 1: SMALL NEGATIVE TURBIDITY ANOMALIES:

Slight negative turbidity values sometimes occur because of small calibration offsets. Often these turbidity minimum values are between 0 and -2 NTU. All these small negative turbidity values (the minimum for a given deployment) should be considered to be within 2 NTU of the true datum for correction purposes. This data has been given a Flag Code of <1> and retained.

NOTE 2: BIOLOGICAL-RELATED TURBIDITY ANOMALIES:

This type of anomaly includes turbidity readings that are either outside of the normal range or spikes way above background and unrelated to increased sediment suspension or decreased water column clarity. We believe these records are real (and not sensor malfunction), although not reflective of actual water column turbidity. These extreme values are likely due to biological factors (such as small fish, crabs, or other marine organisms). Our criteria for flagging these data are single spikes (above rather constant background) over 50 NTU that are more than 10 times surrounding values. These readings were rejected <-3>[SQR].

NOTE 3: SUSPENSION EVENT RELATED TURBIDITY ANOMALIES:

This type of anomaly includes turbidity readings that were either outside the normal range, or spikes way above background that are related to elevated turbidity levels indicative of wind wave-induced suspension (at the Menauhant site typically where vegetation often re-circulates due to wind and tidal currents or gets caught on the sonde guard) or prop wash-related suspension events (at the Childs River site typically). We believe these are real (and not sensor malfunction), though not reflective of actual water column turbidity. These extreme values are likely due to large floating particles (i.e., seaweeds, detritus, etc.) suspended in the water column during storm events usually from strong southerly winds in the Waquoit Bay area (see end of section 5 for more detail on these events at this site). Our criteria for flagging these data are values over 100 NTU that are more than 5 times the magnitude of surrounding values and linked to high winds. These readings were rejected <-3>.

NOTE 4: SMALL NEGATIVE DEPTH ANOMALIES:

This type of anomaly occurs due to barometric pressure differences between time of calibration and the reading and ice conditions. In all such cases, barometric pressure differences are checked as well as comparison with other parameters for indications of aerial exposure to verify that all data are valid submerged readings.

NOTE 5: MISSING DATA

Data are missing due to equipment or associated specific probes not being deployed, equipment failure, time of maintenance or calibration of equipment, or repair/replacement of a sampling station

platform. Any NANs in the dataset stand for “not a number” and are the result of low power, disconnected wires, or out of range readings. If additional information on missing data is needed, contact the Research Coordinator at the reserve submitting the data.

NOTE 6: ELEVATED CHLOROPHYLL FLUORESCENCE ANOMALIES

Due to interference from biofouling or floating detritus, the chlorophyll fluorescence optic sensors will record values which are above the normal environmental range. Sporadic values which only occur for one or two 15-minute readings, exceed 25 ug/L, and/or go over five times the magnitude of surrounding values are flagged as suspect <1> and given the code [SCS] indicating a chlorophyll spike. Sporadic values which only occur for one or two 15-minute readings, exceed 40 ug/L, and/or go over ten times the magnitude of surrounding values are flagged as rejected <-3> and given the code [SCS] indicating a chlorophyll spike.

Additionally, values > 100µg/L should be given special consideration when analyzing chlorophyll fluorescence data. Extremely high and sustained chlorophyll fluorescence data impacted by detritus, biofouling, and/or dissolved forms of fluorescent interference (e.g., colored dissolved organic matter) are rejected and flagged as <-3>[SQR].

NOTE 7: HYPOXIC EVENTS AND SMALL NEGATIVE D.O VALUES

Many prolonged periods of hypoxia and even anoxia occurred at the Sage Lot and Metoxit Point stations during the summer months (particularly July and August, but also into September). These hypoxic events often began in the evening (usually around or after 1800, but occasionally earlier), and would last into the morning (as late as 1000), sometimes with a prolonged period of small negative D.O values sandwiched in between during the night hours. This pattern occurred most notably at Metoxit Point, with similar events at Sage Lot not lasting quite as long, not occurring quite as often, and mostly missing the small negative values. Since these events formed a consistent pattern and schedule throughout the summer, the data was flagged as <0> (CDA). Small negative D.O values are automatically flagged as suspect, but since they are thought to represent valid anoxic events and not an issue with the sensor, they are coded with comments as <1> [SNV] (CDA).

FIELD and “CSM” NOTES:

All times reported in Eastern Standard Time (EST).

During 2022 depth was not calibrated correctly at MP, MH or SL. The offset used in KOR was not changed during this time, the same offset used in 2021 was used for all of 2022 on each sonde. This data is suspect.

Childs River (CR)

General (CR)

- Sonde removed from water on 10/04/2021 due to construction at Child’s River site. Pilings and dock where sonde stationed were removed entirely. As of 10/04/2021, Sonde is still out of the water.

Menauhant (MH)

General (MH)

- 07/01/02 14:15 <-2>: Missing data because sonde was out of the water at 14:15 and new sensor was not deployed and in place at that exact time.
- 09/01/2022 09:30 – 09:45: Nearly all parameter readings (except Turbidity) are significantly different than surrounding values. Unknown cause.
- 09/09/2022 10:15 – 10/19/2022 15:30: Sonde was in place but deployment was not initiated, so no data was collected.

- 11/05/2022 16:15 – 11/07/2022 20:00: Sonde ran out of battery power on Saturday, 11/05. A new sonde was calibrated and in place by 2000 on 11/07. Missing data during this period.
- 11/12/2022, 0845 – 12/15/2022, 1715: Conductivity/Temperature sensor on sonde fails, ending the deployment. Sensor failure is undetected until a new sonde is put in place on 12/15/2022 at 1700. Missing data during this period.

Chlorophyll (MH)

- 01/01/2022 – 01/16/2022, <-3> [SQR] – Prolonged issues affecting chlorophyll sensor. Further isolated spikes of chlorophyll in this deployment. Values suspiciously high for January.
- 02/02/2022 – 02/16/2022 00:00, <-3> [SCS] – More issues affecting chlorophyll sensor. Several of these events occur throughout the whole deployment. Values are suspiciously high for February.
- 05/16/2022 – 05/17/2022, <-1> [SQR] (CSM) – Prolonged issues affecting chlorophyll sensor. Many other similar events like this as well as isolated spikes of chlorophyll in this deployment. A hemigrapsus crab was found in the sonde guard at the end of the deployment.
- 05/17/2022 15:45 – 16:15, <-1> [SQR] – Isolated chlorophyll spikes. Several of these throughout the deployment.
- 07/12/2022 22:30, <-3> [SCS] Isolated chlorophyll spike
- 07/15/2022 13:00, <-3> [SCS] Isolated chlorophyll spike
- 12/15/2022 17:15 – end of 2022: Chlorophyll sensor, which records during pre-deployment calibration, does not record data for reasons unknown. During winter maintenance, this sensor passes tests.

Salinity and Specific Conductivity (MH)

- 01/24/2022 06:15, <-3> [SQR] – Isolated dip in salinity/specific conductivity.
- 02/02/2022 15:30 – 03/03/2022 10:15, <1> [SPC] – Post-deployment readings suspiciously low.
- 03/05/2022 16:15, <-3> [SQR] – Isolated dip in salinity/specific conductivity.
- 03/25/2022 04:30, <-3> [SQR] – Isolated dip in salinity/specific conductivity.
- 07/06/2022 15:00, <-3> [SQR] (CCU) – Isolated dip in salinity/specific conductivity.
- 7/15/2022 22:00, 23:30, <-3> [SQR] (CCU) – Isolated dip in salinity/specific conductivity.
- 08/10/2022 22:00, <-3> [SQR] – Isolated dip in salinity.
- 09/05/2022 05:45 – 06:00, <-3> [SQR] (CCU) – Isolated dip in salinity/specific conductivity.
- 11/08/2022 05:45, <-3> [SQR] (CCU) – Isolated dip in salinity/specific conductivity.

Turbidity (MH)

-
- 01/04/2022 16:15, <-3> [STS] – Anomalous turbidity spike.
- 02/02/2022 15:30 – 03/03/2022 10:15, <1> [SPC] – Post-deployment readings suspiciously high.
- 03/04/2022 04:00, <-3> [STS] – Anomalous turbidity spike. Many of these occur throughout the year. Only a few are pointed out here.
- 03/08/2022 04:00, <-3> [STS] – Anomalous turbidity spike.
- 04/07/2022 04:30 and more, <1> (CAF) – Small negative turbidity values, which triggers this flag code to be automatically added.
- 07/08/2022 11:00 <1> [STS] – Anomalous turbidity spike.
- 08/11/2022 00:15, <-3> [STS] – Anomalous turbidity spike.
- 09/03/2022 22:00, <-3> [STS] – Anomalous turbidity spike.
- 09/05/2022 05:45, <-3> [STS] – Anomalous turbidity spike
-

Depth (MH)

- 02/02/2022 15:30 – 03/03/2022 10:15, <1> (CSM) – Initial depth calibration not recorded. Unknown if calibrated or not. Depth values are shifted lower than either of surrounding deployments.

Sage Lot (SL)

General

- The general time period starting 09/14/2022 to 11/22/2022 is full of drastic fluctuations along with periods of obvious sensor drift in Specific Conductivity and Salinity, along with Dissolved Oxygen. Everything in these time periods is marked as suspect, unless otherwise rejected for reasons mentioned below.
- 09/27/2022 13:45 – 10/21/2022 10:00 <-3> [SSD] – Sensor drift in several parameters that becomes very apparent in how the values do not match up with the new deployment values. All parameters were assumed compromised since both Temperature and Specific Conductivity/Salinity values seemed to be affected.
- 11/15/2022 18:45 – 11/22/2022 10:15 <-3> [SSD] – Sensor drift in several parameters that becomes very apparent in how the values do not match up with the new deployment values. All parameters were assumed compromised since both Temperature and Specific Conductivity/Salinity values seemed to be affected.
- 11/22/2022 10:30 <1> [CSM] – This is to bring attention to how different these values at the beginning of the new deployment are vastly different than the previous deployment. This discrepancy is likely due to sensor drift in the previous deployment.

pH (SL)

- 07/06/2022 – 08/10/2022 <1> [GSM] (CCU) – pH values in this deployment were markedly less than the surrounding deployments, and we are unsure what caused this.

Salinity and Specific Conductivity (SL)

- 07/06/2022 – 09/14/2022 <1> (CCU) – Salinity and Specific Conductivity values are suspiciously flat through this time period.
- 09/15/2022 06:15 – 09/27/2022 13:45 <1> (CSM) – Previously stable readings start dropping precipitously and then stabilize around a lower level. Unknown cause.
- 09/27/2022 14:00 – 10/21/2022 10:15 <-3> [SSD] – Sensor drift very apparent in Salinity values
- 11/15/2022 18:45 – 11/22/2022 10:15 <-3> [SSD] – Sensor drift that becomes very apparent in how the values do not match up with the new deployment values.
- 11/22/2022 10:30 <1> [CSM] – This is to bring attention to how different these values at the beginning of the new deployment are vastly different than the previous deployment. This discrepancy is likely due to sensor drift in the previous deployment.
-

Turbidity (SL)

- 07/29/2022 10:45, <-3> [STS] – Isolated turbidity spike
- 07/31/2022 00:15, <-3> [STS] – Isolated turbidity spike
- 08/05/2022 10:15, <-3> [STS] – Isolated turbidity spike
- 08/07/2022 05:45, <-3> [STS] – Isolated turbidity spike
- 11/10/2022 23:00 – 11/11/2022 23:30 <1> [STS] and <-3> [STS]: Prolonged period of higher turbidity values. Values in this prolonged spike less than 400 FNU were kept but flagged as suspect (<1> [STS]). Values greater than or equal to 400 FNU were rejected (<-3> [STS]).
- 11/15/2022 00:45 – 11/22/2022 10:15 <-3> [SSD] – Values remain suspiciously constant for long periods of time for several occurrences over this period, and then do not match up with new sonde data around the new deployment.
- 11/22/2022 10:30 <1> [CSM] – This is to bring attention to how different these values at the beginning of the new deployment are vastly different than the previous deployment. This discrepancy is likely due to sensor drift in the previous deployment.

Dissolved Oxygen (SL) mg/L and % Sat

- 07/14/2022 04:30 to 07/15/2022 07:00, <0> (CDA) – Hypoxic event lasting through the early hours of the morning. A few examples exist of this, although not nearly as many or as persistent and repeating as hypoxic/anoxic events at Metoxit.
- 08/11/2022 03:45 to 06:30, <0> (CDA) – Hypoxic event lasting through the early hours of the morning. A few examples exist of this, although not nearly as many or as persistent and repeating as hypoxic/anoxic events at Metoxit.
- 09/06/2022 16:00 to 18:00, <0> (CDA) – Afternoon and evening hypoxic event, observed several times throughout this deployment
- 09/15/2022 21:00 to 09/27/2022 13:00, <0> (CDA) or <-3> [SNV](CCU) – Multi-week prolonged and consistent hypoxia readings. Rejected in most cases when negative D.O. values are seen. Other entries left as <0> (CDA).
- 09/27/2022 13:15 – 10/21/2022 10:00 <-3>[SDO] – Rejected because of negative D.O. values as well as the sensor drift seen in other parameters over this same time period.
- 10/21/2022 10:15 to 11/15/2022 22:30 <-3>[SNV](CCU) Rejected because of negative D.O. values and the sensor drift apparent in other parameters. See general notes for the rejected values after this time.
- 12/01/2022 0300 <0> (CDA), - Isolated and seemingly valid hypoxic event.
- 12/08/2022 19:30 – 12/09/2022 00:30 <0> (CDA), - More prolonged hypoxic event, with two isolated readings slightly above 3mg/L.

Chlorophyll Fluorescence (SL)

- 08/08/2022 00:30, <-3>[SCS] Isolated chlorophyll spike
- 09/14/2022 – 10/21/2022, <1> [SPC] (CSM), Post deployment checks on chlorophyll readings were excessively high, so all chlorophyll values from this deployment are considered suspect.
- 09/22/2022 17:30, <-3>[SCS] Isolated chlorophyll spike

Metoxit Point (MP)

General (MP)

- 4/15/2022: Station deployment delayed from usual date due to staffing restrictions and slight station re-design.
- 5/12/2022: Installed a different type of mooring for Metoxit Point sonde station in same location.
- 6/24/2022: Successfully retrieved sonde, but weather conditions prevented deployment of new sonde until 6/30/2022. Missing data between 19:30 on 06/28/2022 until 09:30 on 6/30/2022.
- The 6/30/2022 – 7/21/2022 deployment depth, pH, D.O., and Specific Conductivity/Salinity values are shifted from the rest of the year's values. Depth values were marked as <1> [SIC] to indicate that these values are suspect. All other values were marked as <1> (CCU) to indicate that the cause was unknown.
- 07/18/2022 18:45 we believe the sonde was pulled up here for maintenance at the site.
- 7/29/2022 Discovered that tagline for sonde was fouled around the mooring station.
- 7/31/2022: Dive down on sonde station to shorten tagline, add more weights to mooring, and deploy new sonde.
- 07/30/2022 13:30 we believe the sonde was pulled up here for maintenance at the site.
- 7/31/2022: Dive down on sonde station to shorten tagline, add more weights to mooring, and deploy new sonde. Data missing at 11:45. Data from 7/31/2022 12:00 – 14:00 most likely impacted by this work.
- 09/14/2022: Retrieve sonde with two people diving down on the mooring station. Agitate bottom sediments, seaweeds, and algae during retrieval and deployment process.

Chlorophyll Fluorescence (MP)

- 07/17/2022 19:30, <-3> [SCS] – Isolated chlorophyll spike
- 07/18/2022 18:45, <-3> [SCS] – Isolated NAN, for missing data at this point.
- 07/24/2022 12:30, <-3> [SCS] – Isolated chlorophyll spike
- 07/24/2022 12:45, <-3> [SCS] – Isolated chlorophyll spike

Dissolved Oxygen (MP) mg/L and % Sat

- 06/01/2022 04:30 to 10:00, <0> (CDA) – Prolonged morning hypoxic event. Several of these events occurred throughout the deployment. See below for more.
- 06/30/2022 09:15 to 06/30/2022 22:15, <1> (CCU) or <1> (CDA)
- 06/30/2022 18:15 to 06/30/2022 22:15, <0> (CDA) – Hypoxic to anoxic event. These events repeated most evenings throughout the whole deployment, starting at earliest 18:15 and lasting into mid-morning (latest 11:15). They usually co-occur with data flagged as mentioned below.
- 06/30/2022 22:30 to 07/01/2022 09:00, <1> [SNV] (CDA) – Small negative DO values indicating a hypoxic event. These are usually accompanied by the above-mentioned flagged data as well, as part of the same cycle on most nights throughout the whole deployment.
- 08/02/2022 05:00 to 08/02/2022 09:00, <0> (CDA) – More hypoxic events usually at nights until early or mid-mornings. They are fewer and not as long-lasting as the ones occurring throughout July.
- 09/21/2022 06:00 to 10:00, <0> (CDA) – A hypoxic event. A few other instances of this occur during the deployment between 09/14 and 10/19.

Turbidity

- 09/14/2022 10:30 to 10/19/2022 13:45, <1> [SIC] or <1>[SIC](CAF)– The whole deployment is labeled as suspect because of negative turbidity values at various times (<-2). Occasionally the negative values are within acceptable calibration error (between -2 and 0), and those carry the (CAF) comment.

Depth

- The 6/30/2022 – 7/21/2022 deployment depth values are shifted to deeper values than the rest of the year's values. Marked as <1> [SIC] to indicate that these values are suspect.

YSI EXO1 In-Situ Comparison Data

A handheld YSI EXO1 was used for field calibration and data were recorded at approximate sonde deployment depths (influenced by tide). The handheld measurements are shown below in Tables 1-4. They represent another form of post-check on retrieved sonde data as it is assumed that the recently calibrated sonde is highly accurate on its initial measurement at deployment. If the assumption holds true, we should expect last / first readings to be quite similar within the usual 15 minute time difference between readings if the retrieved instrument was still reading accurately. Large differences indicate potential problems.

Table 1: Menahant (MH) Deployment/Retrieval EXO1 Data.

Table 1: Menahant (MH) Deployment/Retrieval EXO1 Data

	Date	Time	Temp	SpCond	Salinity	DO %	DO Conc.	pH	Depth
MH	M/D/YY	hh:mm	C	mS/cm	ppt	%	mg/L		m
Deploy	12/30/21	04:10	5.30	46.62	34.78	105.6	10.61	8.07	0.35
Retrieve	02/02/2022	15:25	0.165	46.67	34.58	102.5	11.71	8.08	1.359
Deploy	02/02/2022	15:25	0.165	46.67	34.58	102.5	11.71	8.08	1.359
Retrieve	03/03/2022	10:27	3.49	46.46	34.65	106.1	11.15	8.14	0.71
Deploy	03/03/2022	10:27	3.49	46.46	34.65	106.1	11.15	8.14	0.71

Retrieve	04/05/2022	09:09	9.17	44.95	33.28	106.4	9.89	8.08	1.14
Deploy	04/05/2022	09:09	9.17	44.95	33.28	106.4	9.89	8.08	1.14
Retrieve	05/17/2022	15:10	16.06	47.99	35.88	107.8	8.57	8.57	1.0
Deploy	05/17/2022	15:10	16.06	47.99	35.88	107.8	8.57	8.57	1.0
Retrieve	07/01/2022	13:09	24.02	48.28	34.96	114.9	7.91	8.15	1.1
Deploy	07/01/2022	13:09	24.02	48.28	34.96	114.9	7.91	8.15	1.1
Retrieve	08/03/2022	10:45	25.91	53.43	35.23	110.2	7.35	8.18	0.04
Deploy	08/03/2022	10:45	25.91	53.43	35.23	110.2	7.35	8.18	0.04
Retrieve	09/09/2022	09:09	22.20	53.709	35.53	94.4	6.69	8.07	0.04
Deploy	09/09/2022	09:09	22.20	53.709	35.53	94.4	6.69	8.07	0.04
Retrieve	10/19/2022	14:12	16.35	52.445	34.59	104.7	8.32	8.19	1.032
	Sonde deployment was never initiated, so no data was recorded during this period.								
Deploy	10/19/2022	14:12	16.35	52.445	34.59	104.7	8.32	8.19	1.032
Retrieve	11/07/2022	15:42	17.68	52.381	34.56	104.6	8.10	8.20	1.134
Deploy	11/07/2022	15:42	17.68	52.381	34.56	104.6	8.10	8.20	1.134
Retrieve	12/15/2022	17:15	5.428	53.972	34.95	99.2	9.93	8.04	0.981
Deploy	12/15/2022	17:15	5.428	53.972	34.95	99.2	9.93	8.04	0.981
Retrieve	01/17/2023	12:58	4.059	49.674	31.70	102.1	10.79	7.85	0.962

No sonde deployed at Child's River after 10/04/21 due to construction.

Table 2: Metoxit Point (MP) Deployment/Retrieval EXO1 Data

	Date	Time	Temp	SpCond	Salinity	DO %	DO Conc.	pH	Depth
MP	M/D/Y	hh:mm	C	mS/cm	ppt	%	mg/L		m
Deploy	05/12/2022	10:57	11.57	47.14	34.97	103.1	9.0	7.98	1.5
Retrieve	06/24/2022	19:45	23.08	46.83	33.86	142.5	10.04	8.32	0.4
Deploy	06/30/2022	09:13	24.25	45.43	32.63	109.9	7.64	8.17	0.9
Retrieve	07/31/2022	10:47	27.96	47.27	33.79	108.3	7.03	8.31	0.4
Deploy	07/31/2022	10:47	27.96	47.27	33.79	108.3	7.03	8.31	0.4
Retrieve	09/14/2022	09:16	22.86	51.30	33.73	101.5	7.19	8.09	1.3
Deploy	09/14/2022	09:16	22.86	51.30	33.73	101.5	7.19	8.09	1.3
Retrieve	10/19/2022	12:58	16.03	49.737	32.59	112.4	9.09	8.24	1.03
Deploy	10/19/2022	12:58	16.03	49.737	32.59	112.4	9.09	8.24	1.03
Retrieve	11/22/2022	15:00	5.63	51.48	33.20	106.0	10.72	8.39	1.09
Deploy	11/22/2022	15:00	5.63	51.48	33.20	106.0	10.72	8.39	1.09

Retrieve	12/20/2022	13:45	3.366	52.245	33.41	103.5	10.96	8.36	1.00
----------	------------	-------	-------	--------	-------	-------	-------	------	------

No sonde deployed at Metoxit Point after 12/20/2022 due to winter conditions

Table 3: Sage Lot Deployment/Retrieval EXO1 Data

	Date	Time	Temp	SpCond	Salinity	DO %	DO Conc.	pH	Depth
	M/D/Y	hh:mm	C	mS/cm	ppt	%	mg/L		m
Deploy	05/20/2022	16:45	18.42	45.43	33.09	99.2	7.63	7.76	1.2
Retrieve	07/06/2022	11:15	22.81	40.67	28.91	83.8	6.03	7.44	1.0
Deploy	07/06/2022	11:15	22.81	40.67	28.91	83.8	6.03	7.44	1.0
Retrieve	08/10/2022	11:41	26.41	53.04	34.64	47.7	2.63	7.32	1.3
Deploy	08/10/2022	11:41	26.41	53.04	34.64	47.7	2.63	7.32	1.3
Retrieve	09/14/2022	14:45	23.94	51.54	33.87	115.7	8.03	8.11	1.3
Deploy	09/14/2022	14:45	23.94	51.54	33.87	115.7	8.03	8.11	1.3
Retrieve	10/21/2022	10:03	13.21	50.634	33.17	87.2	7.44	8.04	1.0
Deploy	10/21/2022	10:03	13.21	50.634	33.17	87.2	7.44	8.04	1.0
Retrieve	11/22/2022	10:16	4.96	52.223	33.63	94.7	9.67	8.24	1.1
Deploy	11/22/2022	10:16	4.96	52.223	33.63	94.7	9.67	8.24	1.1
Retrieve	12/21/2022	09:48	2.364	50.930	32.27	97.0	10.68	8.10	1.03
No sonde deployed at Metoxit Point after 12/20/2022 due to winter conditions									

Literature Cited:

Maio, C.V., J.P. Donnelly, R. Sullivan, S.M. Madsen, C.R. Weidman, A.M. Gontz and V.A. Sheremet. 2016. Sediment dynamics and hydrographic conditions during storm passage, Waquoit Bay, Massachusetts. *Marine Geology*. 381: 67-86.