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## Technical Memorandum

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To: George Meservey, Director of Planning & Community Development, Town of Orleans  
Nate Sears, Natural Resources Manager, Town of Orleans

From: Ed Eichner, Principal Water Scientist, TMDL Solutions/Adjunct Professor, CSP/SMAST  
David Schlezinger, Sr. Research Associate, CSP/SMAST, UMASSD  
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Date: September 26, 2024

RE: Cedar Pond Adaptive Management Monitoring Program: 2024 Semi-Annual Report  
(Status of field activities between January 2023 and August 2023)

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This Technical Memorandum, 2024 Semi-Annual Cedar Pond Report, on the status of water quality monitoring is required under the 2017 Certificate of the Secretary of Energy and Environmental Affairs, the Massachusetts Department of Environmental Protection (MassDEP) Superseding Order of Conditions, and the Massachusetts Division of Marine Fisheries (MassDMF) Fishway Operations and Maintenance Plan. A 2024 Annual Report will be prepared following completion of 2024 calendar year monitoring. The 2024 Annual Report will include: a) a more refined assessment of all 2024 data, including data collected during the last four months of 2024, b) a comparison of 2024 data to 2018-2023 monitoring data, c) discussion of past adaptive management actions, and d) a review of potential modifications of management activities for consideration for implementation in 2025.

### I. Background

Cedar Pond is a heavily manipulated kettle pond located at the headwaters of a tidal creek that discharges to the innermost portions of the Rock Harbor estuary (**Figure 1**). Through water quality monitoring conducted for the 2008 Massachusetts Estuaries Project (MEP) ecosystem assessment of Rock Harbor<sup>1</sup> and regular monitoring by town volunteers,<sup>2</sup> the impaired water quality of Cedar Pond had been well documented.<sup>3</sup> Although it was impaired, 2002/2003 stream measurements for the Rock Harbor MEP assessment showed that the pond was removing 58% of the watershed nitrogen flowing through it and, therefore, was preventing it from reaching the estuarine basin of Rock Harbor. The MEP assessment also determined that the Rock Harbor estuary was impaired by nitrogen enrichment and in need of nitrogen reduction to restore its impaired resources.

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<sup>1</sup> Howes B.L., S.W. Kelley, J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, E.M. Eichner. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, MA. SMAS/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 132 pp.

<sup>2</sup> Eichner, E. 2007. Review and Interpretation of Orleans Freshwater Ponds Volunteer Monitoring Data. Cape Cod Commission. Barnstable, MA. 80 pp.

<sup>3</sup> *e.g.*, failing to meet state surface water regulatory standards, regular low or anoxic dissolved oxygen concentrations, high nitrogen, phosphorus, and chlorophyll concentrations.

Portions of the Cedar Pond system have been subject to various management actions over the past 150 years, mostly without comprehensive assessments of potential impacts. These actions have included: a) filling a portion of the pond for the construction of Route 6, b) siting regional power lines over the pond that were subsequently used by a large summer cormorant population for roosting, and c) changes to the stream channel connecting the pond to Rock Harbor. The significant changes to the stream channel in 2007 were the most recent action and occurred after the completion of the MEP stream monitoring. The stream changes increased tidal saltwater inflows to the pond and gradually increased salinities in the pond. The pond ecosystem was altered from a brackish, slightly salty condition with surface salinity of 6.9 parts per thousand (ppt) to a coastal salt pond with 21.8 ppt surface water salinity. This shift in pond ecology also eliminated the watershed nitrogen attenuation the pond provided for Rock Harbor and subsequent monitoring showed that, during at least one summer, caused the pond to add additional nitrogen to the nitrogen exported to Rock Harbor, increasing the overall export to greater than the load added solely by the watershed. The significant increase in salinity magnified nutrient-related water quality impairments within the pond, degraded the potential pond herring habitat, and threatened the adjacent Atlantic White Cedar wetland.

In 2011-2012, the Town asked the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) to develop a management plan for Cedar Pond with three goals: 1) restore water quality, 2) restore the historic herring run, and 3) protect the adjacent Atlantic White Cedar wetland.<sup>4</sup> The 2013 Management Plan was reviewed and approved by appropriate Town Committees, the Board of Selectmen and the Conservation Commission. However, the Conservation Commission approval was appealed by some Orleans citizens, and the Town was then required to complete a Massachusetts Environmental Policy Act (MEPA) filing for the project. Subsequently, MEPA approved the Plan in 2017 and added a condition to develop a Fishway Operations and Maintenance Plan (Fishway Plan). The Fishway Plan was developed in coordination with MassDMF with the goal to provide potential herring/alewife passage into the pond for spawning and out of the pond for the young of the year.

The Cedar Pond Management Plan included an adaptive management approach, where regular review of monitoring data would be used to guide adjustments in plan implementation. State regulatory approvals confirmed and formalized a requirement to have regular reporting of monitoring results. Monitoring results are to be reviewed annually in two reports: 1) a Semi-Annual Report focused on the status of data collection efforts from January to July and 2) an Annual Report reviewing a whole year of data results. The Annual Report will have recommendations for any management changes to better achieve the Management Plan goals.

This Technical Memorandum is the 2024 Semi-Annual Report and focuses on 2024 dissolved oxygen (DO) and temperature profile data collected from March 2024 through August 2024. Laboratory assay results for water column samples collected during this period are still being compiled. The 2024 Annual Report will complete an in-depth review and presentation of all 2024 data, along with comparison to previous monitoring results. It is anticipated that the 2024 Annual Report will be completed during the first quarter of 2025.

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<sup>4</sup> Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 54 pp.

## II. Management Plan Implementation: Historical Water Quality Improvements (2018-2023)

One of the adaptive strategies in the Management Plan has been to gradually return Cedar Pond to its historically lower salinity/brackish conditions by reinstalling the tidal boards in the pond outlet. The boards would only allow the highest tides into the pond, while also allowing freshwater from natural watershed groundwater inputs to gradually return the pond to lower salinities. Based on historical data at the time, it was expected that this return back to brackish conditions would improve the impaired 2011-2012 water quality conditions that had developed due to removal of the boards and the changes in the stream between Rock Harbor and Cedar Pond. CSP/SMASST developed an initial board elevation in 2014 based on previously collected data.<sup>5</sup> It was acknowledged at the time that future adjustments would occur as additional monitoring data was collected and reviewed.

Through discussion among Town, MassDMF, and CSP/SMASST staff, the Fishway Plan was developed to try to balance tidal inflows, pond water levels, and fish passage. Board elevations at the outlet were to be adjusted throughout the year to allow spawning fish to enter in the spring and juvenile fish to leave in the summer and fall. The initial recommendation in the Fishway Plan was to have the boards set from March 15 to June 30 at an elevation to allow at least 6 inches (0.15 m) of water depth to flow over the top of the board. This elevation was thought to facilitate entry into the pond by river herring migrating upstream from Cape Cod Bay/Rock Harbor for spawning within the pond. On July 1, when water levels have historically decreased, the board elevation would be adjusted to allow at least 2 inches (0.05 m) of outflowing water over the top board. This adjustment would last until November 15 and would be designed to allow juvenile herring (spawn of the year) to leave the pond. All staffs would also work to identify any fish noted during visits to the pond for monitoring or board adjustment.

In order to measure the water elevations over the boards and assess how water quality conditions changed, CSP/SMASST initially installed shallow and deep sondes with multiple sensors in the center of the pond. This monitoring was accompanied by approximately monthly water column samples and dissolved oxygen and temperature profiles at the deep basin and streamflow readings and water quality samples. These mid-pond sondes have been collecting continuous readings since November 2017. In May, 2019, CSP/SMASST added a water level recorder at the pond outlet after review of the 2018 monitoring results (*i.e.*, the first year of monitoring) and subsequent discussions with MassDMF and Town staff.

During this 2018 first annual review of monitoring results, it was noted that the pond water quality improved, but salinity increased after the boards were lowered. Town, DMF, and CSP/SMASST staff discussed options to better attain the Management Plan goal of reduced salinity while also addressing Fishway Plan goals. As a result of the discussions, it was agreed that board elevations would be maintained in 2019, but the opening in the boards would be limited to a 6 inch notch. The goals of this configuration would allow fish passage, but reduce the cross-sectional area exposed to tidal water inputs. It was hoped that this change in the board configuration would help to retain the lower salinity concentrations of winter/early spring throughout the summer.

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<sup>5</sup> Howes, B., E. Eichner, R. Samimy, J. Ramsey, and S. Kelley. 2014. CSP/SMASST Technical Memorandum: Board Height Recommendation for Cedar Pond Outlet. To: Town of Orleans (George Meservey, Director of Planning & Community Development and Carolyn Kennedy, Chair, Marine and Fresh Water Quality Task Force). Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 13 pp.

Review of the annual data in 2019, 2020, and 2021 showed shallow salinity was low at the beginning of the monitoring period in March/April, but typically increased at the same rate during the summer once the board notch was added. In 2019, winter and early-spring salinity in the pond was significantly reduced and the pond began March (the beginning of Fishway Plan board lowering) at a low salinity just above (~6 ppt) the 1 to 4 ppt range targeted in the Management Plan.<sup>6</sup> Salinity levels throughout 2019 were lower than 2018, because initial 2019 salinity levels were low. In 2020, the elevation of the bottom of the notch was increased slightly following discussion of water level monitoring results<sup>7</sup> among MassDMF, CSP/SMASST, and Town staff. Following this change, water quality improved incrementally, but salinity rates again increased at the approximately the same rate as in 2018 and 2019 once the notch was added. In 2021, spring salinity levels were slightly lower than 2020, but increased at the approximately the same rate as previous years once the board notch was added. In 2022, the rate of salinity increase was lower, largely because spring salinity concentrations were higher, but the late summer peak salinity was similar to 2019-2022 levels. In 2023, salinity levels were lower than 2022. Shallow salinities were relatively low throughout 2023 (average = 7.3 ppt; peak = 8.6 ppt) and deep readings were higher, but relatively stable (average = 13.1 ppt; peak = 14.9 ppt).<sup>8</sup> Review of some of the 2023 data suggested that there were lower tidal inputs to Cedar Pond.

Water quality during 2019-2023 improved each year. In the 2019 lower salinity setting, pond water quality improvements included higher dissolved oxygen levels, lower nitrogen and phosphorus concentrations, and less nitrogen and phosphorus transferred from the pond to Rock Harbor. Water quality conditions in 2020 showed an even greater proportion of the pond water column achieving the MassDEP minimum dissolved oxygen concentrations, further decreases in TN and TP water column concentrations, and lower pond export of TN and TP to Rock Harbor.<sup>9</sup> Water quality conditions in 2021 were again incrementally better with: 1) all shallow DO profile concentration readings above the MassDEP minimum for the first time and 2) shallow TN concentrations were approximately the same as 2020, but shallow TP concentrations were the lowest measured 2018-2021. Water column dissolved oxygen (DO) concentrations in 2022 were incrementally better than 2021 with acceptable DO concentrations throughout a greater portion of the water column than in any of the previous monitoring years.<sup>10</sup> Deep conditions continued to be impaired, but stronger salinity stratification in the water column generally reduced their impact on the shallower waters. In 2023, DO improvements were sustained, TN and TP export was the

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<sup>6</sup> Eichner, E., B. Howes, and D. Schlezinger. 2020. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2019 to December 2019. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 38 pp.

<sup>7</sup> CSP/SMASST Technical Memorandum: Cedar Pond Board Adjustment. October 21, 2020. From: E. Eichner, Howes, B., and D. Schlezinger. To: G. Meservey, Director of Planning & Community Development and N. Sears, Natural Resources Manager, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 6 pp.

<sup>8</sup> Eichner, E., D. Schlezinger, and R. Samimy. 2023. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2023 to December 2023. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 52 pp.

<sup>9</sup> Eichner, E., B. Howes, and D. Schlezinger. 2021. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2020 to December 2020. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 44 pp.

<sup>10</sup> Eichner, E., D. Schlezinger, and R. Samimy. 2023. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2022 to December 2022. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 58 pp.

lowest among the six years of monitoring, and TN export from the pond was lower than it had been during the MEP assessment (2002/2003 monitoring).

The improved ecosystem conditions in Cedar Pond have encouraged herring to return to the pond. Prior to 2022, no fish were observed entering or leaving Cedar Pond during more than four years of Management Plan monitoring and over 80 visits to the pond outlet and Cedar Pond Creek by Town, CSP/SMASST, and MassDMF staff. Through adaptive management discussions among these staff, MassDMF assisted the Town with installing fyke nets in Cedar Pond Creek during the primary alewife/herring spawning period to see if any herring were returning. During this deployment (March/April 2022), 30 alewife were trapped and released. This monitoring was not repeated in 2023, but their presence was an additional encouraging sign about improved water quality and ecosystem conditions in Cedar Pond and provides some hope that future alewife visits will increase due to fish returning to the stream were they were born.

### III. Status of 2024 Cedar Pond Water Quality Data Collection

In order to continue to meet the terms of the MassDEP regulatory approval of the Cedar Pond Management Plan, CSP/SMASST staff are again collecting the water quality data in 2024, including:

- 1) water column profile measurements and water quality samples at selected depths approximately monthly at the deepest location in the pond,
- 2) deployed continuous monitoring devices at shallow (~1.3 m) and deep (~3.7 m) depths at the deep sampling location (measuring DO, temperature, chlorophyll, and depth every 15 minutes),
- 3) deployed a continuous water level recorder at the pond outlet to record elevations relative to the board/notch height, and
- 4) collected stream water quality samples, streamflow readings, and deployed a continuous water level recorder in Cedar Pond Creek at the same location used since 2002/2003.

Water column sampling and profile data has been collected on seven dates so far in 2024: March 4, April 16, May 2, May 30, June 27, July 31, and August 27. Additional future planned sampling dates are: September 25, October 24, November 26, and December 23. Streamflow and water quality sample collection has occurred on 15 dates through mid-August (approximately every two weeks).

Sampling is continuing throughout 2024, but early water column profile data generally is consistent with recent monitoring. The data collected to date shows that the pond had shallow temperatures of approximately 8°C in March and then warmed rapidly to approximately 25°C by June and sustained that level in July and August (**Figure 2**). The water column had weak temperature stratification beginning in April, but had developed strong stratification at 2 m by the end of May. This is slightly different than in 2023 when no stratification was present until strong stratification was measured in the June 15 profile. Individual salinity profiles showed that at least the upper 1.5 m had similar levels and deeper readings were 3 to 4 ppt higher. Shallow salinity readings in March to July varied between 7.5 and 10 ppt, while deep readings varied between 11 ppt and 13 ppt. In August, salinity readings at both shallow and deep depths increased by ~ 2 ppt, while at the same time temperature stratification weakened. Salinity readings prior to August

generally matched 2023 readings, which had a maximum shallow reading of 8.6 ppt and deep readings averaged 13.1 ppt.<sup>11</sup> The 2024 Annual Report will evaluate the whole record and look at potential causes of the August salinity increases.

To date in 2024, temperature and salinity stratification within the water column created separate shallow and deep conditions. This setting is similar to what has been measured in previous years. In March, the water column was not temperature or salinity stratified. But beginning in April, temperature and salinity differences created separate shallow and deep layers that have only limited mixing between the two layers. In the warmer, lower salinity, shallow portion of the water column, DO concentrations were all greater than the MassDEP minimum (5 mg/L) (**Figure 3**). In the cooler, higher salinity, deep portion of the water column, DO concentrations tend to be anoxic (*i.e.*, <1 mg/L). Some of the shallow DO readings suggest high phytoplankton levels (*i.e.*, DO saturation >110%). Shallow 2023 DO concentrations at 0.5 m and 1 m were greater than the MassDEP minimum throughout the year.

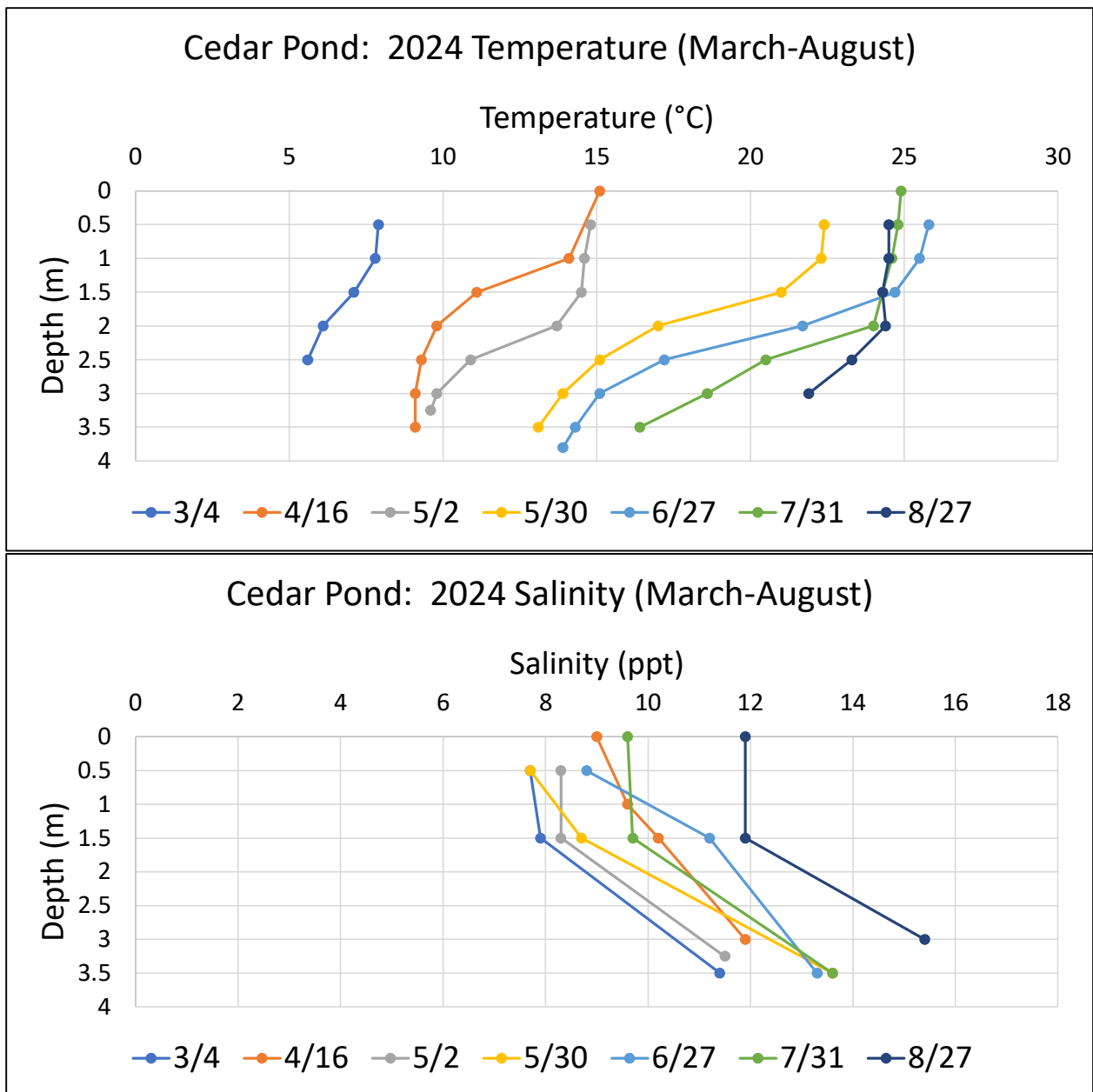
Further review of all factors impacting water quality in Cedar Pond, including precipitation, groundwater levels, tides, DO saturation levels, etc., and results for continuous readings at the mid-pond and outlet monitoring locations will be reviewed in the 2024 Annual Report. The 2024 Annual Report will be completed during the first quarter of 2024.

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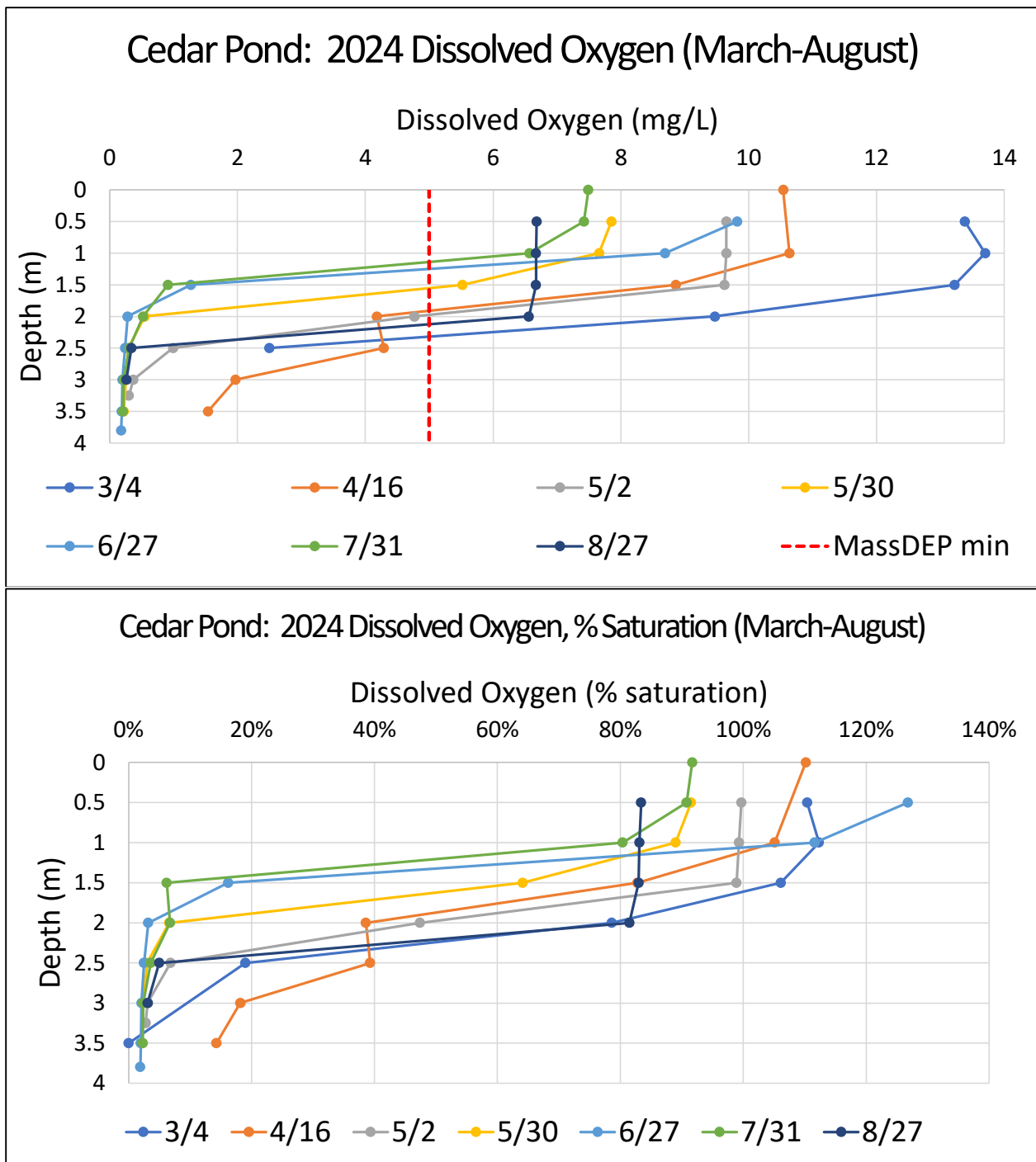
<sup>11</sup> Eichner, E., D. Schlezinger, and R. Samimy. 2023.



**Figure 1. Cedar Pond Locus and Sampling Locations.** Cedar Pond is located in northern Orleans, south of Route 6 and west of Town Cove. A stream outlet from Cedar Pond flows under Route 6 and discharges into the Rock Harbor estuary. Water quality samples are collected at the: a) Deep sampling location (multiple depths, green circle) and b) the Creek Stream Gauge (yellow triangle). Autonomous recording devices were also installed at shallow and deep depths at the deep sampling location, the creek stream gauge location and the inlet (orange diamond). Modified from Figure 1 in Cedar Pond Management Plan (2013).



**Figure 2. Cedar Pond March to August 2024 Temperature and Salinity Profile Readings.** To date, water column profile data has been collected on seven dates in 2024: March 4, April 16, May 2, May 30, June 27, July 31, and August 27. Temperature readings show increasing shallow temperatures until June with relatively similar temperatures in July and August. Deep temperatures increase on each sampling date. Temperature stratification was first measured in April and was measured in each subsequent profile with the shallow layer typically in the upper 2 to 2.5 m of the water column. Salinity profiles also show a similar shallow layer, but readings can only document it to a depth of 1.5 m. Shallow salinity readings generally vary between 7.5 and 10 ppt before the August 27 profile, while deep salinity readings vary between 11 and 13 ppt. In the August 27 profile, both shallow and deep salinity readings increased by approximately 2 ppt and there was only weak temperature stratification at 2.5 m depth.



**Figure 3. Cedar Pond March to August 2024 Dissolved Oxygen Profile Readings.** DO concentrations in shallow waters (0-1 m) were greater than the MassDEP minimum (5 mg/L) in all profiles to date. Water at 1.5 m was greater than the minimum through May, but was less than the minimum in all subsequent profiles. Deeper waters were anoxic in all profiles after the April 16 profile with the anoxia generally rising to 2 m depth after May 2 profile. The depth of temperature stratification (*i.e.*, the top of the transition layer) was the top of the anoxic water in all profiles through June 27. July and August profiles had anoxia in the bottom of the shallow layer.