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Technical Memorandum

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

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Date: November 12, 2021

RE: Cedar Pond Adaptive Management Monitoring Program: 2021 Semi-Annual Report (Activities between January 2021 and August 2021)

This Technical Memorandum, 2021 Semi-Annual Report, on the status of water quality monitoring of Cedar Pond, as 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 2021 Annual Report will be prepared in following completion of 2021 monitoring and barring any additional COVID delays. The 2021 Annual Report will include more monitoring results, a more refined assessment of all 2021 data, a comparison to 2018-2020 monitoring data and adaptive management actions, and a review of potential modifications of management activities for consideration for implementation in 2022.

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) nutrient assessment of Rock Harbor[1] and regular monitoring by town volunteers,[2] the impaired water quality of Cedar Pond has been well documented.[3] Although it was impaired, MEP measurements also 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.

[1] 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. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 132 pp.

[2] Eichner, E. 2007. Review and Interpretation of Orleans Freshwater Ponds Volunteer Monitoring Data. Cape Cod Commission. Barnstable, MA. 80 pp.

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

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.

Portions of the Cedar Pond system have been subject to a various management actions over the past 150 years, mostly without comprehensive assessments of potential impacts. These actions have included filling a portion of the pond for the construction of Route 6, siting regional power lines over the pond that were subsequently used by a large summer cormorant population for roosting, and changes to the stream channel connecting the pond to Rock Harbor. The significant changes to the stream channel 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 during at least one summer caused the pond to export more nitrogen than was added by the watershed. The significant increase in salinity has magnified nutrient-related water quality impairments within the pond, degraded a potential pond herring habitat, and threatened the Atlantic White Cedar wetland adjacent to Cedar Pond.

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 Atlantic White Cedar wetland.[4] The 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, and the Town was then required to complete a Massachusetts Environmental Policy Act (MEPA) filing for the project. Subsequently, MEPA approved the Plan and added a condition to develop a Fishway Operations and Maintenance Plan (Fishway Plan). The Fishway Plan was developed in coordination with MassDMF to provide potential fish 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 would have recommendations for any management changes to better achieve the Management Plan goals.

This Technical Memorandum is the 2021 Semi-Annual Report and focuses on 2021 data collection completed between January 2021 and July 2021. The 2021 Annual Report will complete a more in-depth review and presentation of all 2021 data, along with comparison to previous monitoring results. It is anticipated that the 2021 Annual Report will be completed

[4] 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.

during the first quarter of 2022 unless the COVID pandemic causes further disruptions in field data collection, completion of lab assays, or data review.

II. Management of Board Height, Pond Elevation, and Fish Movement

One of the strategies in the Management Plan adaptive approach 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 natural watershed groundwater inputs to gradually lower pond salinities. CSP/SMAST developed the initial board elevation in 2014 based on previously collected data.[5] It was acknowledged at the time that future adjustments would occur as additional monitoring data was collected and reviewed.

Goals in the Fishway Plan led to the initial alterations in planned board heights. In the Fishway Plan, 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, 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. The Town, MassDMF, and CSP/SMAST would also work to identify any fish noted during monitoring or board adjustment visits.

In order to measure the water elevations over the boards and assess the impacts of management activities in Cedar Pond, CSP/SMAST initially installed shallow and deep sondes with multiple sensors in the center of the pond. These sondes have been collecting continuous readings since November 2017. CSP/SMAST added another water level recorder at the pond outlet in May 2019 after review of the monitoring results from 2018 (*i.e.*, the first year of monitoring). The continuous data collection at two locations was complemented by approximately monthly water column samples and dissolved oxygen and temperature profiles at the deep basin and streamflow readings and water quality samples downstream of the pond at a station that has been periodically monitored since 2002. Town and CSP/SMAST staff also have noted no fish entering or leaving the pond during over 30 visits to adjust the boards or collect water quality readings.

During the annual review of the 2018 monitoring results, it was noted that water quality improved, but pond water salinity increased after the boards were lowered. Town, DMF, and CSP/SMAST staff discussed options to better attain the Management Plan goal of reduced salinity while also addressing Fishway Plan goals. As a result, 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-

[5] Howes, B., E. Eichner, R. Samimy, J. Ramsey, and S. Kelley. 2014. CSP/SMAST 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.

sectional area exposed to tidal water inputs. It was hoped that this board configuration change would retain the lower salinity that occurs in the winter and early spring throughout the summer.

Review of the 2019 data showed that 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 (~6 ppt) just above the 1 to 4 ppt range targeted in the Management Plan.[6] Because 2019 began at a lower salinity level, salinity levels throughout 2019 were lower than 2018. However, 2019 salinity levels increased at the same rate as in 2018 once the notch was added. In the 2019 lower salinity setting, pond water quality improvements were measured with higher dissolved oxygen levels, lower nitrogen and phosphorus levels, and less nitrogen and phosphorus transferred from the pond to Rock Harbor. Subsequent review of the 2019 water level data at the inlet showed that boards could be raised 4 inches higher while still attaining the goals for fish entrance and exit.[7]

In 2020, the notch elevation was increased and water quality incrementally improved, but salinity rates again increased at the same rate as in 2018 and 2019 after the notch elevation was lowered to address the Fishway Plan goals. Water quality conditions in 2020 showed a greater proportion of the water column in the pond achieving the MassDEP minimum dissolved oxygen concentrations, lower TN and TP water column concentrations, and lower export of TN and TP out of the pond to Rock Harbor but, overall, the pond continued to have impaired conditions.[8]

Data collected in 2021 to date show continued improvement from 2020, along with a mix of other results. Continuous 2021 readings from the center of the pond through July 21 showed shallow 2021 temperatures were generally lower than corresponding 2020 readings (Figure 2). Average monthly 2021 shallow salinity readings were higher in January through May 2020, but were lower in June and July 2021 (Table 1). Monthly average shallow dissolved oxygen readings in all 2021 months (January through July) were greater than the MassDEP 5 mg/L minimum limit (Figure 3). In 2020, shallow monthly average DO in June, July, and August were less than the MassDEP minimum. Improvement in DO may be due to a number of factors, including lower temperatures and larger phytoplankton populations. Further review of precipitation, groundwater levels, tides, DO saturation levels, etc. in the 2021 Annual Report will help to provide context for these 2021 water quality improvements.

Continuous 2021 water elevations at the pond outlet through July were generally consistent with 2020 levels (Figure 4). Monthly average elevations in January through March 2021 were 1 to 3 cm higher than 2020, but average elevations in April through July were 2 to 4 cm lower than

[6] 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.

[7] CSP/SMAST 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.

[8] Eichner, E., B. Howes, and D. Schlezinger. *In review*. 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.

2020. Monthly 2021 maximum elevations tended to be lower than in 2020 (-14 cm to +2 cm) and minimum elevations tended to be similar (-2 cm to +6 cm).

Water column profile readings from 2021 to date (Figure 5) generally agree with the continuous readings for salinity (slightly higher) and shallow DO (higher) than spring/early summer 2020, but 2021 temperature profiles were slightly warmer than 2020, while continuous monthly reading averages were cooler. While April and May 2021 shallow temperature profile readings were 2 to 3°C greater than corresponding profiles in 2020, monthly averages from the continuous record at 1.2 m depth showed that April and May 2021 had lower temperatures than the same months in 2020. This difference reinforces the benefits provided by continuous readings, although profiles continue to provide more complete measurement throughout the whole water column. Review of salinity showed that 2021 monthly profiles readings tended to be slightly greater (+1 ppt) than the same months in 2020. DO profiles showed that shallow readings in April 2020 and 2021 were similar with both having DO concentrations in waters deeper than 2.25 m below the MassDEP minimum (5 mg/L). In May and June 2021, there was a clear improvement compared to prior years with a greater proportion of the upper water column having acceptable DO. July 2020 and 2021 DO profiles had similar concentrations. Preliminary review of assay results from water column samples suggest that higher phytoplankton populations (*i.e.*, higher pigment concentrations) may play a significant role in increased 2021 shallow DO concentrations especially considering the warmer 2021 temperatures. Further review of the integrated data from profiles, lab results, and continuous readings will occur in the 2021 Annual Report.

III. Summary/Discussion

The Town of Orleans Cedar Pond Management Plan focused on effective stewardship of pond resources through three key goals: 1) restore water quality, 2) restore the historic herring run, and 3) protect the adjacent Atlantic White Cedar wetland. At the time of the management plan approval, Cedar Pond was clearly significantly impaired. As with all adaptive management plans, management steps are planned, implemented, and the response of the system is monitored. If monitoring results show that management steps should be modified to better reach the goals, restoration actions are adjusted and the process continues.

The first step in the Cedar Pond Management Plan was to return the pond to more brackish, less saline conditions that had previously existed in the pond; a brackish salinity range of 1 to 4 parts per thousand (ppt) was set as a goal. Other steps recommended in the Management Plan, to be completed sequentially or concurrently, included addressing nutrient inputs from the large number of cormorants roosting during the late summer (*i.e.*, move the electrical lines from over to pond) and reducing regenerated loads from the sediments within the pond.

Adaptive management changes have been implemented during each of the previous three years of Cedar Pond monitoring. The boards were reinstalled at the pond inlet in 2018, the regional electrical lines were removed over the pond in late 2018, and the inlet board configurations have been adjusted in 2019, 2020, and 2021. Adjusting the tidal exchange to reach salinity goals through the board configuration is the main remaining action, before addressing the sediments.

Monitoring results have shown that the management changes have resulted in improved water quality and better understanding of key factors for sustaining acceptable water quality. Monitoring in 2018 showed improvements in water quality as a result of reinstallation of weir boards at the pond outlet. Review of the 2018 monitoring data led to changes in the pond inlet board configuration in 2019. The 2019 water quality results were the first to include impacts of removing the electrical wires and Cedar Pond water quality improved substantially along with less nutrients exported from the pond to Rock Harbor, but substantial impairments remained. In 2020, water quality continued to improve with average shallow continuous DO in August/September 2020 exceeding the MassDEP minimum (5 mg/L) and the June/July average was 2 mg/L greater than in 2019. Preliminary water quality results in 2021 show continued shallow DO improvements, but due to the continuing salinity stratification the deep waters continue to be anoxic and significantly impaired.

The collected data show the importance of lowered salinity, but its regular annual increase due to board lowering means that it is difficult to attain the management goals of the Cedar Pond Management Plan, including the restoration of a sustainable herring spawning habitat that is also the goal of the Fishway Plan. Pond water quality has improved and continues to make small improvements each year, but the annual lowering of the boards during the summer specified by the Fishway Plan, make water quality improvements difficult to sustain or increase in a substantial way.

The Fishway Plan was adopted as a condition of the EOEA approval of the Management Plan and was developed in consultation with MassDMF. The goal of the Fishway Plan was to provide sufficient water flow between Rock Harbor and Cedar Pond to allow herring to spawn in Cedar Pond between March and June and for juvenile herring to leave between July and November. Water level monitoring in each year showed that water levels were sufficient to meet the Fishway Plan goals. MassDMF staff regularly worked with the Town and CSP/SMAST to adjust board configurations and elevations to better meet water quality salinity goals, while also meeting the water level goals for herring movement.

Monitoring during 2018, 2019, and 2020 has shown, however, that the seasonal lowering of the boards causes a regular summer-long increase in pond salinity. Continuous measurements showed that the rate of salinity increase was similar each year even with changes in the board elevations and the addition of the board notch. In addition, none of the board elevation changes seemed to encourage herring to enter or exit Cedar Pond; no fish have been noted during more than 30 visits by Town and CSP/SMAST staff to the pond outlet during expected herring movement periods.

In light of the existing data, we propose that the boards be placed at a winter elevation for the whole of 2022. Implementation of this strategy would provide monitoring information on the expected conditions if lower winter salinities are achieved and sustained. Groundwater inputs would have greater relative impact to sustain lower water column salinities. Regular monitoring would continue and measure how water quality changes respond to lower salinity. This approach could track the rate of salinity changes just as we have as the boards were regularly lowered and provide a more comprehensive understanding of what water quality improvements are possible in notably lower salinity conditions. Since no herring have been noted in three

years, this change could also create improved water quality conditions that would favor fish spawning in Cedar Pond in 2023.

This proposed change would need to have contingencies to address rises in pond levels. Given that Orleans groundwater levels during 2021 to date have been average to below average, it is anticipated that pond levels should be relatively stable or even lower than usual. If pond levels rise to unacceptable levels, contingencies would be in place to lower board elevations. Regular reporting on water levels could be incorporated into current reporting requirements.

We are making this proposal recognizing that these proposed changes will need to be reviewed and accepted by MassDMF. Details of the board elevations and potential adjustments in 2022 will be discussed among MassDMF, Town and CSP/SMAST staff. A more in-depth review of all 2021 data, including stream water quality and flows and water column sample results, will be completed in the 2021 Annual Report. The 2021 Annual Report will be completed during the first quarter of 2022 barring any additional COVID-related delays.

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. Autonomous recording devices were installed at shallow and deep depths at the deep sampling location (green circle), the inlet (orange diamond), and the creek stream north of Route 6 (yellow triangle). Modified from Figure 1 in Cedar Pond Management Plan (2013).

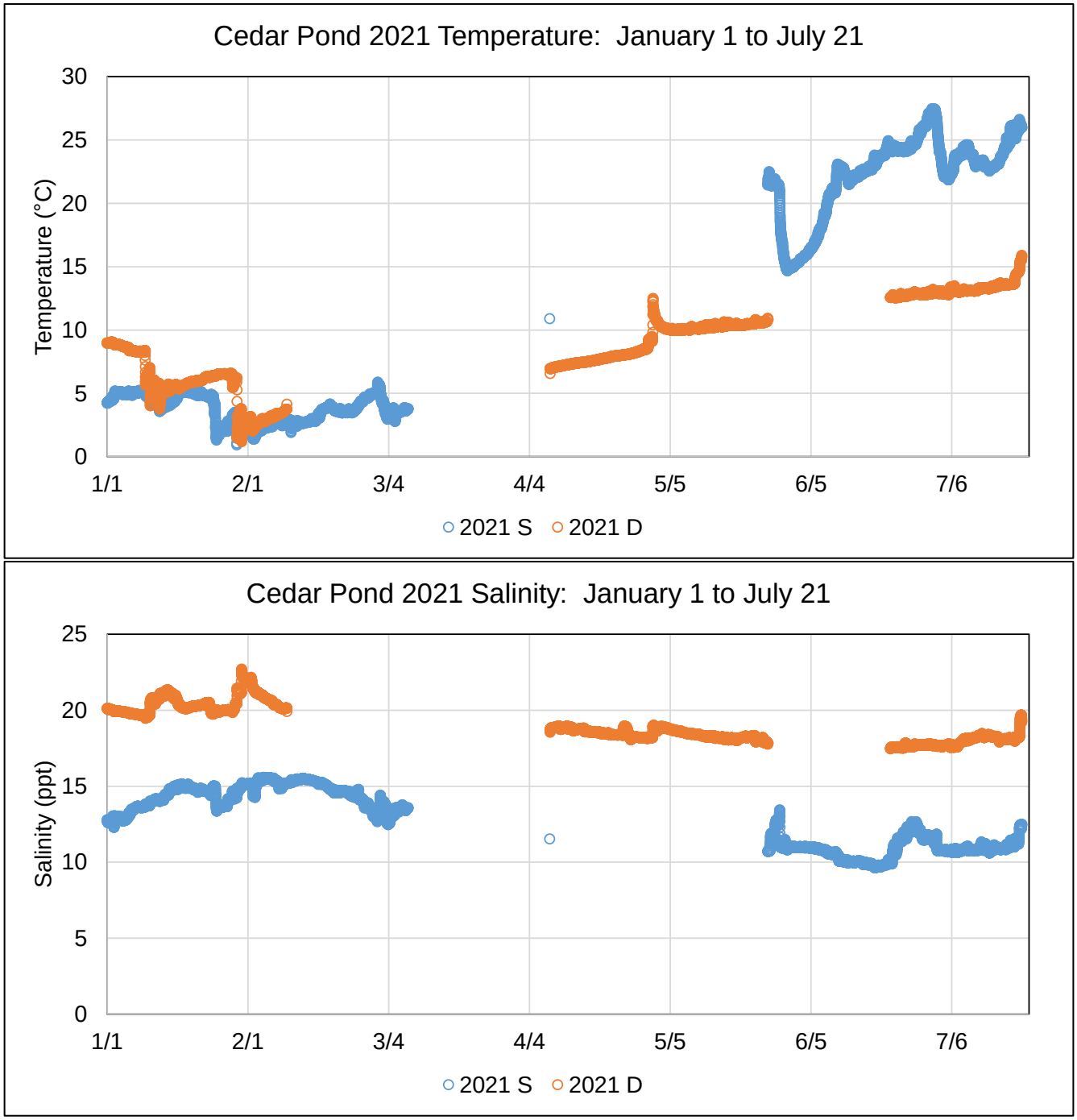


Figure 2. Cedar Pond 2021 Shallow and Deep Continuous Temperature and Salinity (January 1 to July 21). Temperature and salinity readings generally showed strong separation between shallow and deep waters, especially in June and July. Average depth of sensors were: 1.21 m and 3.53 m, respectively. Shallow and deep 2021 temperatures were cooler than 2020 readings in all months with sufficient readings; gaps in the record are due to instrument failure. Average monthly shallow salinities were higher than 2020 readings in first two months, but similar in June and less than 2020 in July; average deep salinity were generally higher than in 2020. Salinity readings had significant enough differences that the shallow waters would mix separately from deeper waters during January to July 2021.

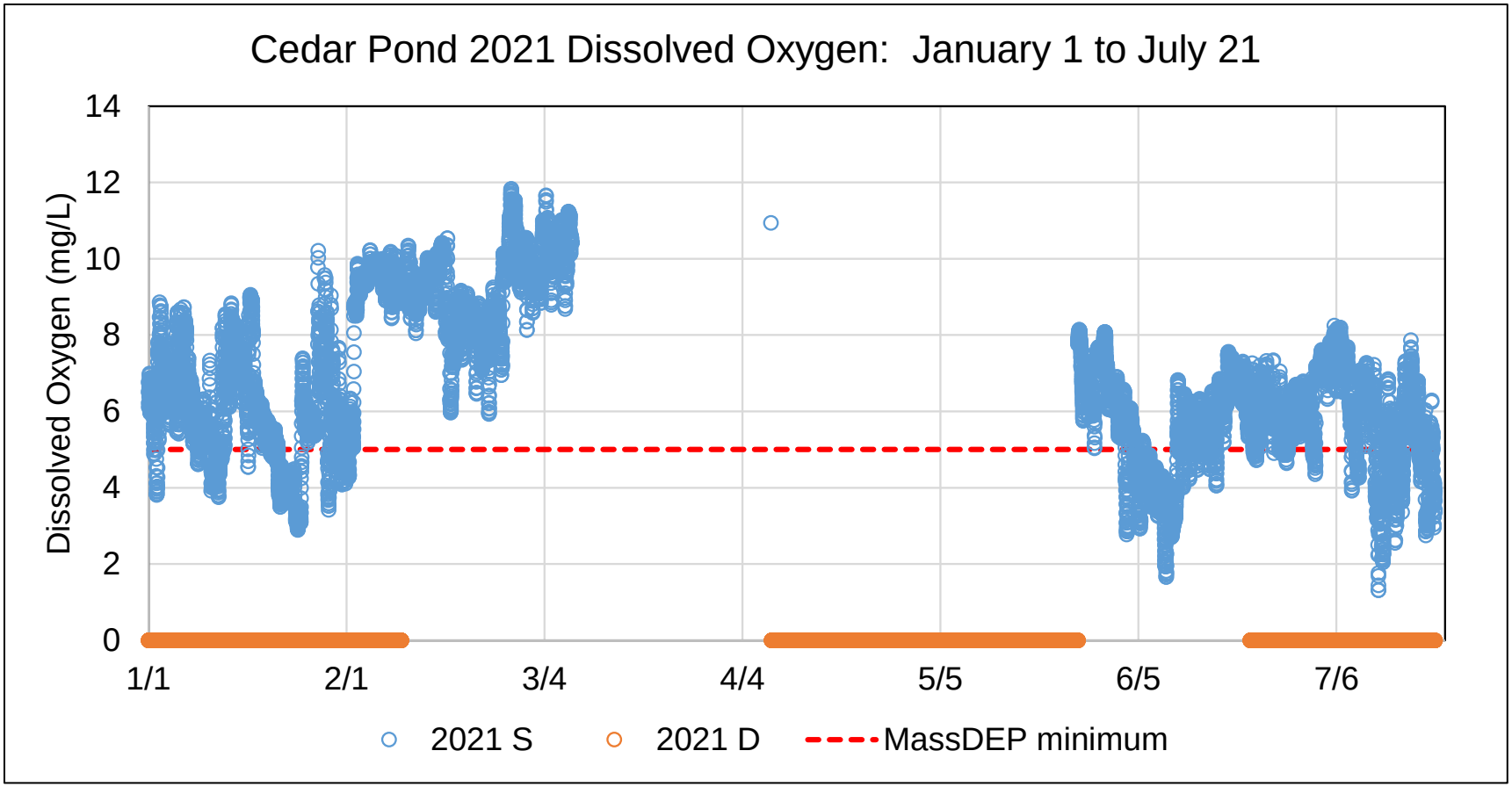


Figure 3. Cedar Pond 2021 Shallow and Deep Continuous Dissolved Oxygen (January 1 to July 21). Shallow DO readings during the recording period averaged 6.7 mg/L (*i.e.*, greater than the MassDEP 5 mg/L minimum), while Deep DO readings were consistently 0 mg/L. Continuous monthly DO readings are somewhat limited in the January to July time period, but among these May 2020 was the only previous monthly average above 5 mg/L. Average shallow DO concentrations in June and July 2020 and April, May, June and July 2019 were less than the MassDEP minimum. All monthly averages of 2021 shallow DO readings were greater than the MassDEP minimum.

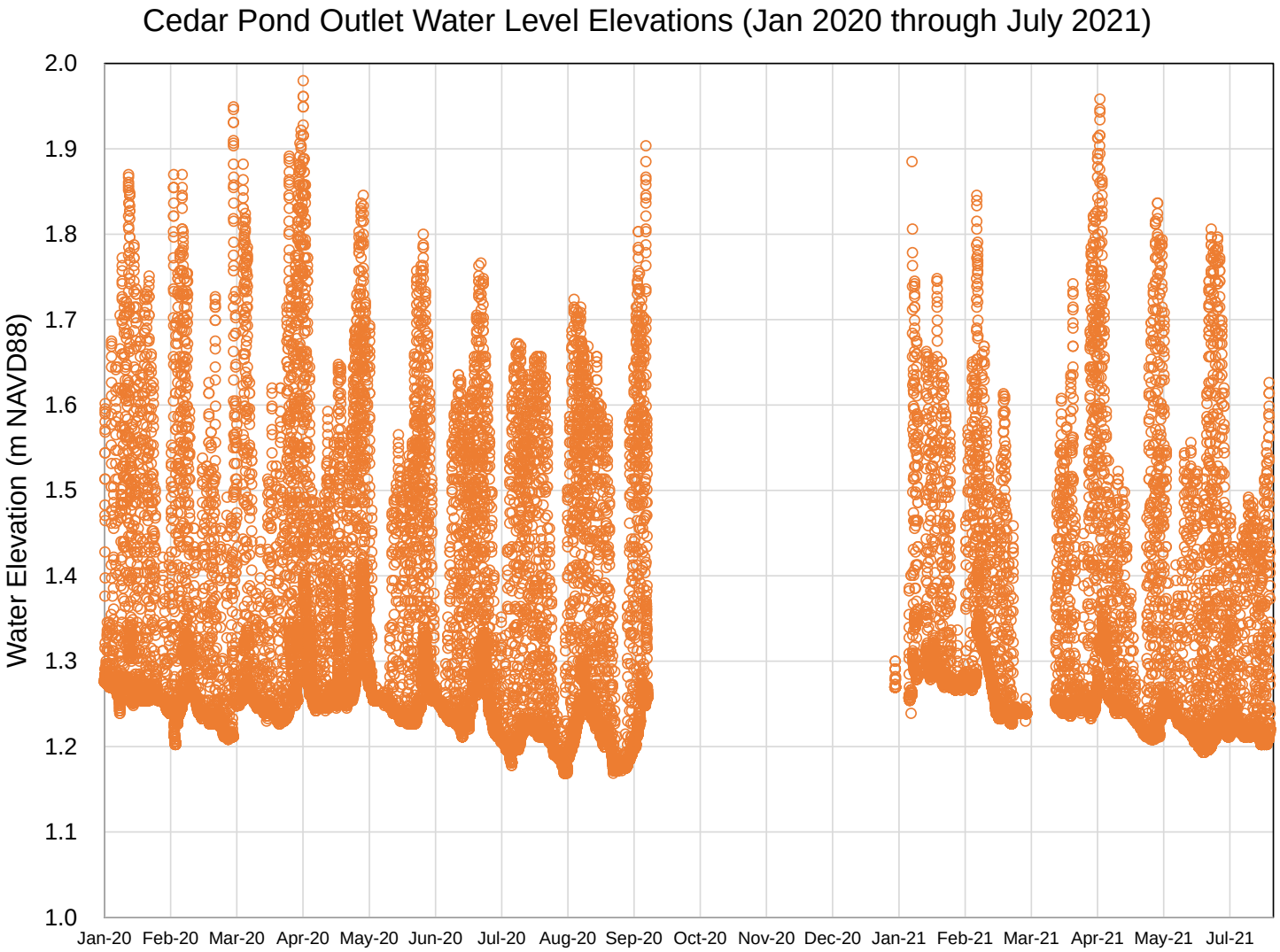
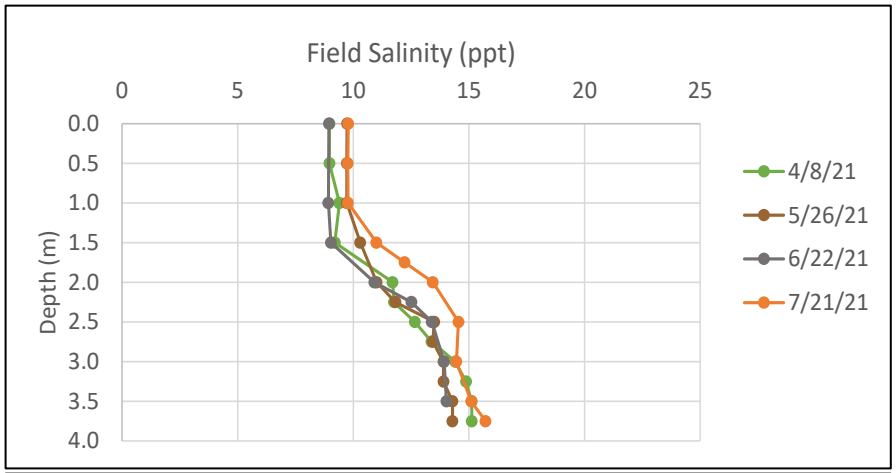
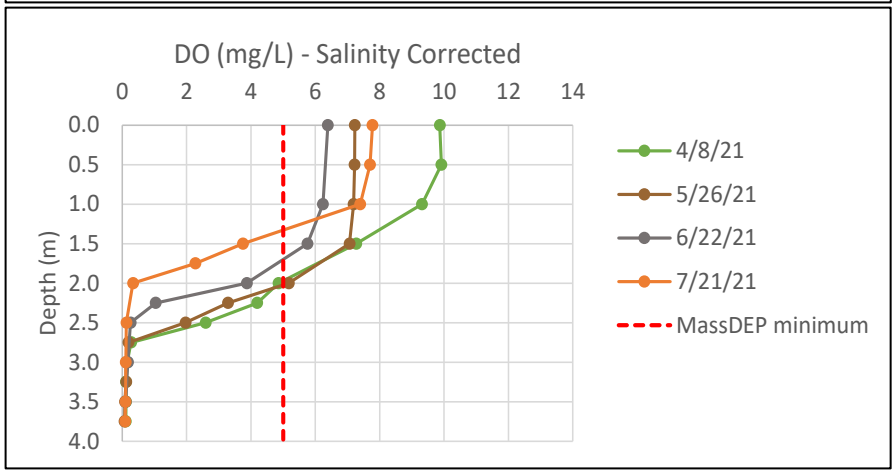


Figure 4. Cedar Pond Inlet Continuous Water Level Elevation (January 2020 to July 2021). Continuous water elevations at the Cedar Pond inlet were similar in 2020 and 2021 to date. Monthly average elevations in January through March 2021 were 1 to 3 cm higher than corresponding monthly averages in 2020, but average 2021 elevations in April through July were 2 to 4 cm lower than 2020. Monthly 2021 maximum elevations tended to be lower than in 2020 (-14 cm to +2 cm) and minimum elevations tended to be similar (-2 cm to +6 cm).





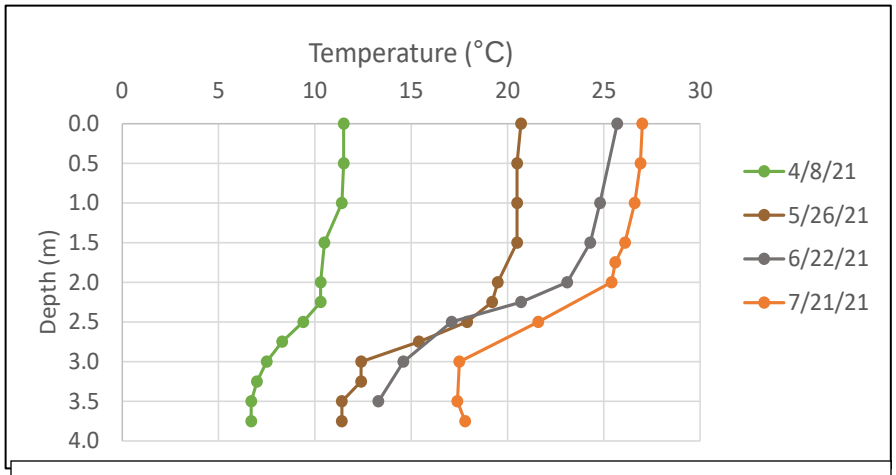


Figure 5. 2021 Cedar Pond Water Column Profiles: Salinity, Temperature, and Dissolved Oxygen. 2021 water column profile readings to date show the pond was slightly warmer, slightly saltier, and had greater shallow DO than in the spring/early summer of 2020. These findings are generally consistent with continuous readings except for temperature, which generally had cooler temperatures in 2021. 2021 monthly salinity profiles readings tended to be slightly greater (+1 ppt) than the same months in 2020. DO profiles showed that shallow readings in April 2020 and 2021 were similar including DO concentrations deeper than 2.25 m below the MassDEP minimum (5 mg/L). In May and June 2021, more of the shallow water column had acceptable DO than in 2020, consistent with the continuous readings. July 2020 and 2021 DO profiles had similar concentrations.

Table 1. Cedar Pond Monthly Averages from Shallow and Deep Continuous Records in Deep Basin (January through July, 2021 and 2020). Comparison of 2020 and 2021 monthly averages for temperature, salinity, and dissolved oxygen (DO) show that shallow and deep temperatures tended to be cooler in 2021 compared to 2020 and shallow and deep salinity tended to be higher in 2021. However, in June and July 2021 shallow temperatures and salinities were notably lower than 2020 and DO was higher. Shallow DO monthly averages in all 2021 months were above the MassDEP regulatory minimum, while deep DO monthly averages continued to be anoxic. The number of temperature readings in each year are shown for comparison purposes, while any table cells without available data are colored gray.

	Shallow								Deep							
	Temp °C		Temp n		Salinity ppt		DO mg/L		Temp °C		Temp n		Salinity ppt		DO mg/L	
	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020
Jan	4.26	4.74	2,976	2,976	14.13	8.93	5.94		6.41	8.26	2,976	2,971	20.33	18.06	-	-
Feb	3.20	5.13	2,688	2,784	14.93	8.42	8.94		3.02	7.88	825	2,784	20.81	16.99	-	-
Mar	3.93	6.21	700	505	13.42	6.37	10.07			7.96	0	1,390		16.28		0.25
Apr	10.90	9.77	1	820	11.54	8.38	10.94		7.76	9.52	2,152	816	18.56	14.95	-	-
May	18.55	15.66	527	2,976	11.45	9.18	6.98	6.06	10.33	10.84	2,440	2,973	18.37	14.96	-	0.08
Jun	21.72	22.86	2,880	2,880	10.74	11.46	5.45	2.81	12.77	15.08	813	2,877	17.64	17.22	-	-
Jul	24.05	25.71	1,964	2,976	11.00	13.57	5.76	2.42	13.33	17.19	1,964	2,974	18.04	19.20	-	-