University of Massachusetts Dartmouth
The School for Marine Science and Technology

---------------------------- **Coastal Systems Program Technical Memorandum** -------------

To: George Meservey, Director of Planning Department, Town of Orleans

From: David Schlezinger, Sr. Scientist, Coastal Systems Program, SMAST-UMD
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Date: October 29, 2009

RE: Cedar Pond Autonomous Mooring Results, Summer 2009

Background: The Coastal Systems Program within the School for Marine Science and Technology –UMASS Dartmouth, was contacted by the Town in June of 2009 with a request to deploy continuously recording instruments within Cedar Pond for ~1 month during the summer of 2009. Given the importance of this data to on-going planning and the helpful volunteer field support from individuals associated with Town activities (i.e. J. Scanlon), CSP staff decided to extend the measurements to cover the full summer period, thereby leveraging the Town support.

Cedar Pond has ranged from a fresh pond to a brackish only periodically tidal pond to a micro-tidal salt pond over the past 2 centuries. Until recently it was brackish, until micro-tidal exchange was re-established over the past few years with the clearing of the marsh channel and the removal of the weir restriction.

There are many questions that need to be addressed relative to the proper management of Cedar Pond (fresh vs. brackish vs. saltwater habitat; oxic vs. anoxic bottom waters; fresh/brackish herring spawning vs. salt water; water levels high vs. low; etc.). The present study aimed to address:

- What is the level and variability of salinity of pond waters?
- Is the pond fully stratified throughout the summer?
- What are the oxygen conditions?
- What is the extent of phytoplankton blooms?
- Is the pond tidal, or does it just receive periodic freshwater and saltwater inflows?

Approach: To better understand the physical and biogeochemical characteristics of Cedar Pond in Orleans as they relate to tidal flushing, 2 YSI 6600 sondes were deployed and maintained throughout the summer of 2009. The instruments were moored to the bottom in the deepest part of the Pond (3.5 m), so as to record readings at: (a) 1 meter above the bottom sediments and (b) 2.5 meters above the bottom within the mixed surfical layer of pond waters. Records were collected at 15 minute intervals from June 16 through September 10, 2009. The instruments were calibrated prior to deployment and periodically throughout the deployment (June 16, July 15, September 10). At each depth, salinity, temperature, depth, and chlorophyll fluorescence were measured, additionally dissolved oxygen was recorded by the mixed layer instrument.

Density of surface and bottom water is primarily the result of salinity and to a lesser extent temperature in coastal salt ponds. Water column stratification can be determined by differences in these parameters between surface and bottom waters. Stratification in coastal salt ponds is generally the proximate cause of low oxygen in bottom waters. The ultimate cause of low oxygen is high rates of oxygen uptake in the water column and sediments resulting from high organic matter levels related to nitrogen inputs. This situation is true for Cedar Pond as well as larger basins, such as Pleasant Bay.

Results: At the time of initial deployment, June 16, 2009, the waters of Cedar Pond were stratified[1] and the bottom waters were anoxic. The high rates of production and respiration within pond waters resulted in an upward migration of the low oxygen zone, which combined with an apparent pulse of seawater entering the pond, resulted in hypoxic conditions reaching upward to 1 meter below the surface water. Note that oxygen levels at the 1 meter depth were otherwise generally at or above air equilibration throughout the study (Figure 1). However, very high oxygen levels were frequently observed in the record, particularly during blooms (Figures 1 & 2). These significant exceedences of air equilibration levels indicate a highly nutrient enriched eutrophic salt pond, and are consistent with the finding of anoxic of bottom waters. Similarly, the very high chlorophyll a levels, with blooms in excess of 40 ug/L, are consistent with the low light penetration, periodic hypoxia of surface waters of a eutrophic salt pond.

Sometime after August 15th the depth of anoxia reached the surface sonde (1 meter below the surface). This is evidenced by the dramatic increase in oxygen signal to more than 50 mg/L indicating electrode poisoning by sulfide. Thus, oxygen data beyond August 15 cannot be considered valid. It has been left in the figure for completeness.

Chlorophyll data from both the surface and bottom sensors were extremely high indicating persistent bloom conditions possibly resulting from periodic upward mixing of the nutrient rich bottom waters[2]. Since the pond was stratified and anoxic throughout the study period, the bottom waters accumulate high levels of inorganic nitrogen. Periodic mixing events, where the surface layer mixes slightly deeper into the water column, brings these nutrient rich waters into the euphotic zone and stimulates phytoplankton blooms. In this way having shallow stratification, like in Cedar Pond, sets the stage for highly variable conditions in the surface waters during the summer. Managing these conditions would require a deepening of the surface layer, if possible the creation of a fully vertically mixed pond coupled to a reduction in external loading of “new” nitrogen to pond waters.

Temperature, salinity and depth data present a unified picture of physical processes in Cedar Pond. From the day of instrument deployment, both temperature and salinity indicate the lack of vertical mixing between surface and bottom waters (i.e. stratification). The colder bottom

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[1] Stratification is when the bottom waters are “heavier” than the surface waters and therefore do not mix. In Cedar Pond, stratification results primarily from the higher salt content of the bottom versus surface waters. In nutrient rich (eutrophic) salt ponds, the lack of vertical mixing and high organic matter levels in sediments and bottom waters results in prolonged anoxia during summer months.

[2] It should be noted that since the chlorophyll sensors measure fluorescence as a proxy for chlorophyll, it is likely that the high pigment concentrations measured 1 m above the sediments in the anoxic zone were the result of bacterial pigments.

waters, coupled with their higher salinity, supported a strongly stratified water column throughout the study period. As noted above, this stratification is fundamental to the prolonged anoxia of the bottom waters.

The pond is presently only very weakly tidal, the major stage changes coincide with freshwater inflow events or from only the very highest Spring tide levels in Cape Cod Bay. These latter events can be seen in the bottom water salinity time-series, which showed distinct increases coincident with extreme high Spring tides around June and August 22. Similar increases in salinity may be seen in the surface salinity record, with an additional salinity spike at about July 22 coincident with the intervening Spring tide. Depth sensors support the inundation of Cedar Pond by high Spring tides and also reflect the rain fall record for the region.

The Coastal Systems Program at UMASS-Dartmouth is pleased to support the Town's efforts relative to the management and restoration of Cedar Pond and hopes for a continued collaboration.

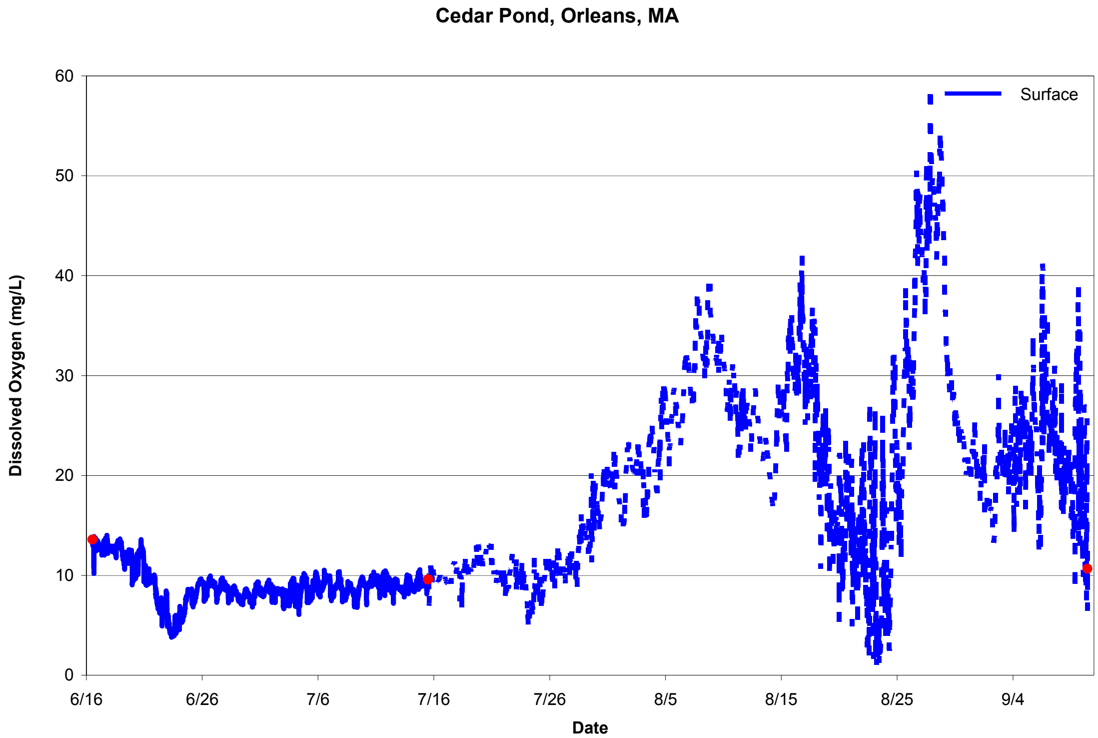

Figure 1. Dissolved Oxygen measured at 1 m (nominal) in Cedar Pond, June – September, 2009 by the SMAST mooring. The late July through late August excess corresponds to a large phytoplankton bloom but likely reflects sensor failure resulting from sulfide poisoning.

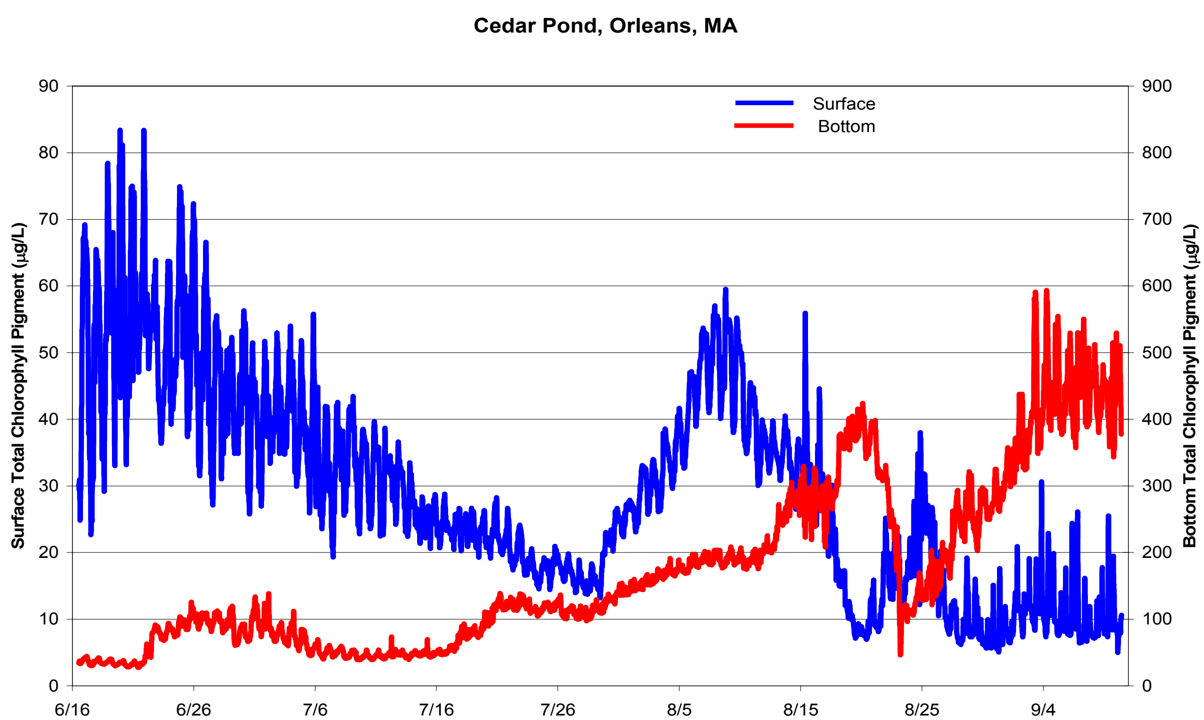

Figure 2. Total chlorophyll a pigment in surface water (blue) and bottom water (red) as measured by fluorescence (SMAST mooring 2009).

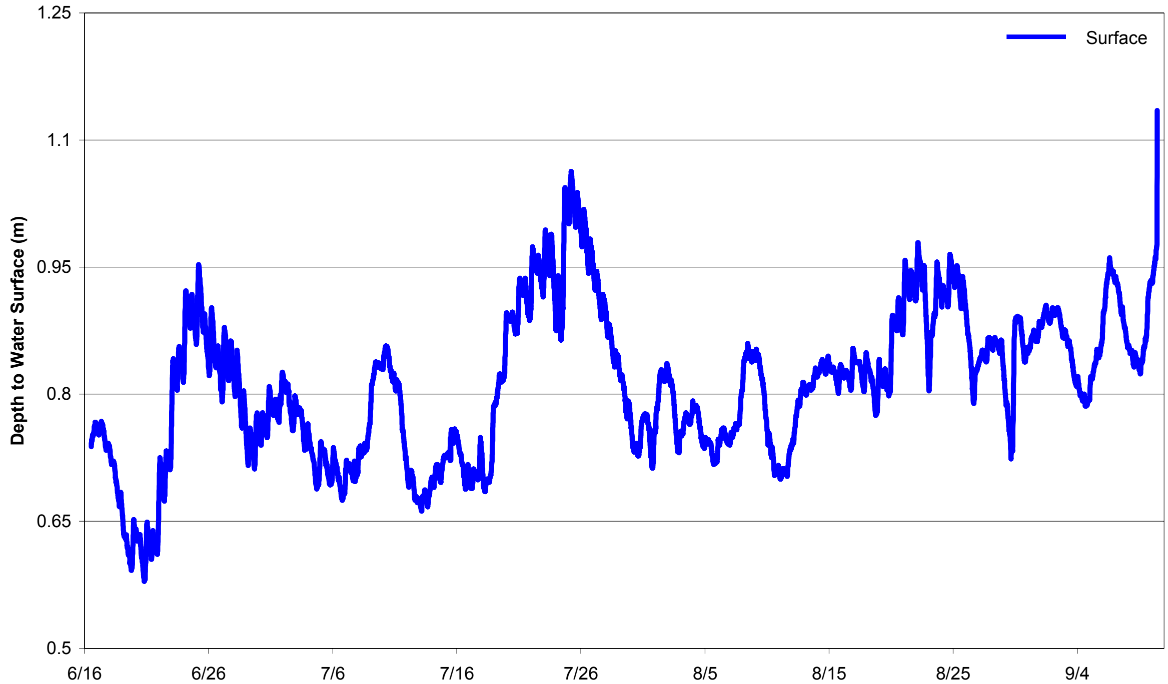

Figure 3. Surface water level (e.g. stage) in Cedar Pond during summer 2009 (SMAST mooring). Note the dominance of periodic in/outflows over daily tidal exchanges.

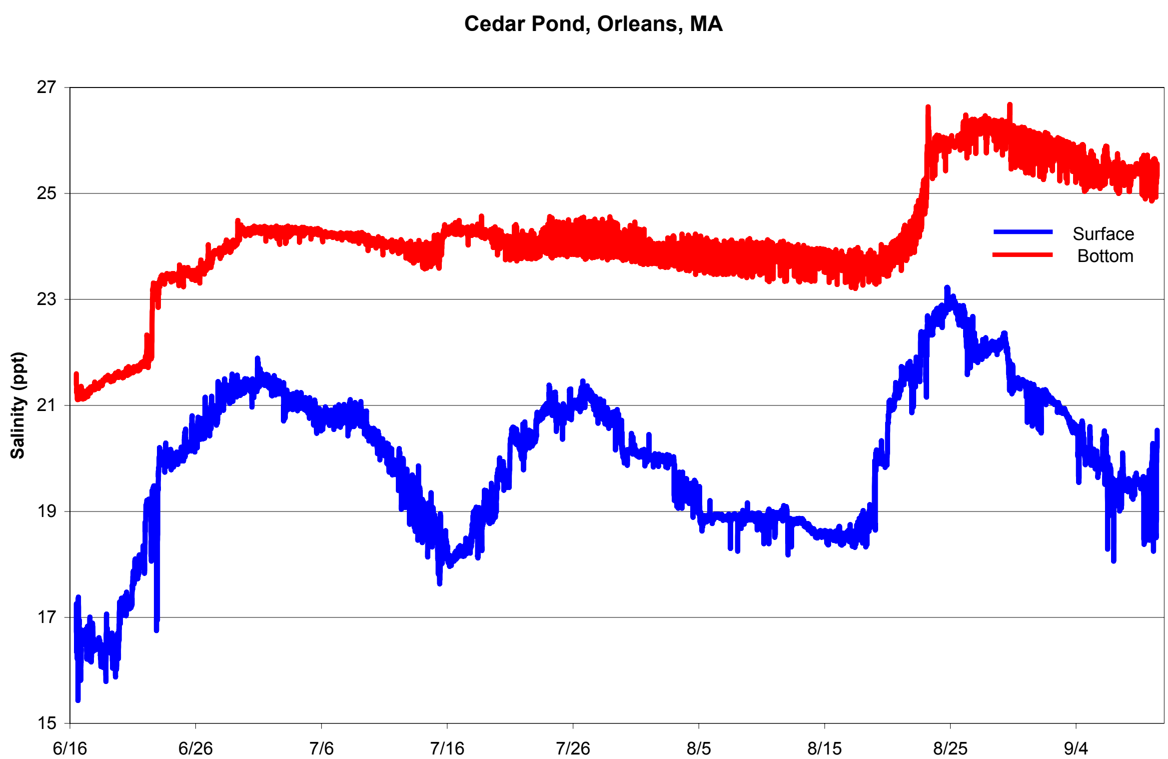

Figure 4. Surface versus bottom water salinity in Cedar Pond during summer 2009, showing water column stratification (SMAST mooring). Note the periodic large inflows of salt water.

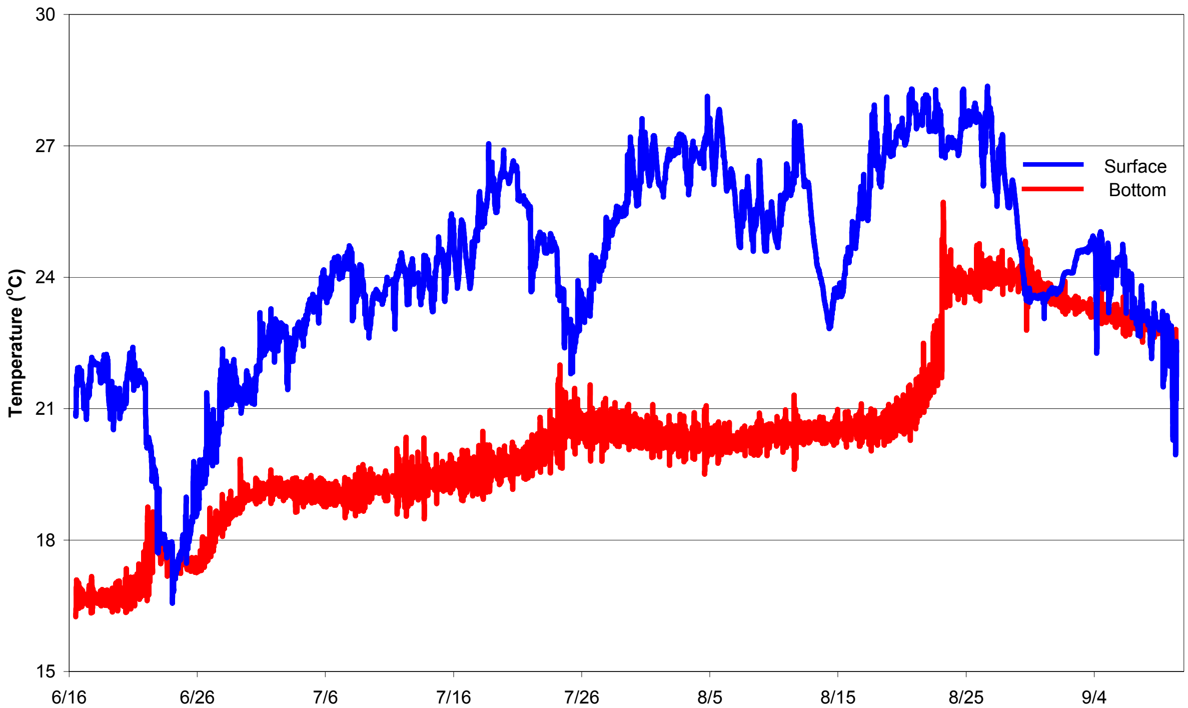

Figure 5. Surface versus bottom water temperature in Cedar Pond during summer 2009 (SMAST mooring). Note the colder bottom waters resulting from the Pond's stratification.