

As mentioned above, the tidal connection of Cedar Pond to Rock Harbor sustains a salinity concentration in the pond. Limited salinity measurements within the pond range between 8 and 16 parts per thousand (ppt). Salinity measurements by Massachusetts Estuaries Project Technical Team members at the head of the Rock Harbor marsh generally are 7 ppt, while TP concentrations range between 172 and 195 ppb (Brian Howes, UMASS-D/MEP, personal communication). Using a range of 7 to 16 ppt and TP range from Dr. Howes, the estimated mass of phosphorus in Cedar Pond from tidal inputs ranges between 4.3 and 11.1 kg.

By combining the watershed and tidal phosphorus loading estimates and subtracting the total from the average mass of phosphorus in the pond, an estimate of the sediment phosphorus load can be developed. Using all the ranges, the estimated range for sediment regeneration is 4.2 to 11.5 kg per residence time. Based on this range, sediment regeneration is estimated to account for 21 to 58% of the total mass of phosphorus measured in the pond.

Although further data collection could be used to refine the analysis of existing conditions, consideration of Secchi measurements and the phosphorus loading analysis suggests that the system is close to steady state. If the maximum estimate of reasonable phosphorus loads is used, the annual watershed load will increase by only 11% or only 1% of the overall average phosphorus mass. It is also worth noting again that nitrogen, not phosphorus, is the key nutrient for controlling ecological conditions in Cedar Pond.

The overall assessment of Cedar Pond shows a highly impaired ecosystem with anoxic conditions, internal regenerated phosphorus, and extremely high phosphorus concentrations. Regenerated phosphorus from pond sediments accounts for 21 to 58% of the phosphorus in the pond. Cedar Pond is also not a freshwater pond and, as such, the above information should be evaluated within the context of nitrogen loads and a better understanding of the pond's ecological connections to the Rock Harbor estuary system. It is recommended that this analysis be part of the planned Massachusetts Estuaries Project technical review that is planned for Rock Harbor.

Long term monitoring of Cedar Pond should continue, but at a reduced rate until management strategies are implemented. Monitoring recommendations are discussed greater detail in a subsequent section.

VII. Recommendations

VII.1. Monitoring Recommendations

Project staff prepared an April 6, 2007 memo providing monitoring recommendations to the town for summer 2007. The memo is included in Appendix B. These recommendations are reinforced and expanded on in the following discussion.

Orleans volunteers under the guidance of the Marine and Fresh Water Quality Task Force (WQTF) have regularly collected data from 20 ponds. The majority of laboratory water quality datasets for most ponds generally consist of monthly to biweekly water quality samples collected during two summers (June-October 2002 and 2003). This data is supplemented with additional once-a-year PALS snapshot data from 2001-2006. Secchi transparency readings have generally been collected in the field on a monthly to biweekly basis between May and November from

2002 through 2006. Dissolved oxygen and temperature profiles throughout the water column have also generally been collected in the field on a monthly to biweekly basis between May and November for 2002 and 2006 with additional measurements for Crystal, Bakers, and Pilgrim during 2000.

In general, most of the ponds have between 15-20 total phosphorus (TP) readings and more dissolved oxygen and Secchi readings. Since Secchi and DO readings can be collected in the field and do not require laboratory analysis costs, their collection is relatively less expensive and generally depends on the access to field equipment and volunteer time. Since the upper portions of the water columns in most of the ponds are well mixed by normal Cape Cod winds, the upper DO readings tend to be stable. Deeper in these ponds, closer to the sediments where DO can be impacted by excessive oxygen consumption in the sediments, readings are consistently unstable. Total phosphorus, total nitrogen and chlorophyll all follow a similar pattern. The review of the data and the detailed analysis of selected ponds indicate that this variability is due to the impairment and lack of stability in these ecosystems. This finding also suggests that sufficient monitoring data has generally been gathered for the current list of parameters in order to begin development and evaluation of remedial and protection strategies for the following ponds: Bakers, Boland, Crystal, Deep, Gould, Icehouse, Kettle, Meadow Bog, Pilgrim, Reubens, Sarahs, Shoal, Twinings, Uncle Harvey's, Uncle Israel, Uncle Seth, and Wash. Cedar is not included in this list because it presents a number of additional issues since it is slightly salty and part of the Rock Harbor estuary system.

This conclusion then leads to the question of whether additional monitoring will be beneficial or useful. Additional monitoring would be useful if the monitoring program is refocused into a tiered effort to address additional data needs for ponds in the Town. It is suggested that this effort focus on 1) sampling and assessment of ponds that have not been monitored, 2), collection of targeted data from the well-monitored ponds that will help to better define remedial and protection strategies, 3) long-term monitoring and review to assess whether negative water quality trends are impacting these ponds, and 4) provisions to monitor and review the benefits of any remedial or protection strategies that are implemented. Each of these recommendations is briefly discussed below.

Even though the current dataset is sufficient to begin to define remedial and protection strategies for the approximately 18 ponds that have been the primary focus of volunteer monitoring efforts, these systems should continue to be regularly monitored, but with reduced frequency, in order to assess whether the systems are changing significantly. It is recommended that the town consider changing the monitoring program for these ponds to a twice-annual sampling strategy. Water samples and field readings would be collected in April and August/September using the PALS sampling protocols and parameters. The August/September sampling for long-term trend analysis could continue to be funded through the PALS Snapshot as long as it continues to be supported by UMASS Dartmouth, School of Marine Science and Technology and the Cape Cod Commission. A brief review at the end of each sampling season should be conducted to identify training needs for the next season and identify any other potential concerns. Every five years, gathered data should be reviewed for trend analysis and long term monitoring concerns. In addition, at the time any remedial activities are initiated either in a watershed or within a pond, it is recommended that monitoring frequency would then

be increased to at least once a month between April and November for at least one year or longer depending on projected groundwater flow times and/or pond residence times to assess whether projected benefits are realized. Details regarding the parameters to be measured could be worked out at the time the increased frequency and remedial activities are planned.

The reduced frequency of sampling recommended for the other ponds that have been monitored would allow volunteers to focus efforts on the approximately 40 other ponds in Orleans that have not been monitored. It is recommended that the WQTF consider adding additional ponds to the sampling program. The Commission's Cape Cod Pond and Lake Atlas lists Orleans as having 63 ponds, while approximately 20 are currently sampled. It would be useful to determine what is known about the ponds that are not sampled and assess whether monitoring and/or physical characterization (*e.g.*, bathymetry) is desired. It is recommended that the WQTF initiate a process to evaluate the interest and desirability of sampling or other information gathering for the ponds that have not been monitored.

Targeted additional data from the ponds that have been monitored will be necessary prior to the final development of remedial or protective strategies, but it is likely that this monitoring should be completed during the review of these strategies. Additional data to be collected would be evaluation of sediment nutrient (and potentially metals) concentrations, measurement of stormwater nutrient loads, and better measurement of stream inputs and outputs from selected ponds. Lake management consultants developing management strategies traditionally conduct these types of activities, but with proper training and guidance, volunteers could collect the samples to reduce costs to obtain this information. Further discussion of this issue should be addressed on a pond-by-pond basis and is discussed below for the ponds that were selected for detailed review.

The above recommendations are dependent on adequate funding. Volunteers provide savings for labor costs and the town has made investments in equipment costs, but implementation of the above refocusing will require additional funding for laboratory analysis and, potentially, equipment costs. Commission staff are available to help the town evaluate potential costs for monitoring options.

In summary, data for the regular monitoring parameters is sufficient to begin the development of remedial/protective strategies for the following ponds: Bakers, Boland, Crystal, Deep, Gould, Icehouse, Kettle, Meadow Bog, Pilgrim, Reubens, Sarahs, Shoal, Twinings, Uncle Harvey's, Uncle Israel, Uncle Seth, and Wash. Cedar will require additional consideration because of its salinity. Plans should be considered to develop strategies for the other 13 ponds that have not been reviewed in detail. It is further recommended that existing volunteer monitoring be refocused into a reduced frequency, longer-term schedule for the 17 ponds listed until management activities are implemented and consideration be given to extending monitoring to other ponds in Orleans that have not been monitored.

VII.2. Recommendations for Next Steps for Bakers, Crystal, Pilgrim, Cedar, and Boland
The review of data contained in this report indicates that sufficient basic data has been gathered from Bakers, Crystal, Pilgrim, Cedar, and Boland ponds in order to proceed toward the development of remedial/management activities to address their impairments and/or preserve

their water quality. Each of these ponds has unique characteristics that suggest that the next steps will require pond-specific tailoring of these activities.

VII.2.1. Bakers Pond Recommendations

Bakers Pond is relatively healthy and only one of Orleans' monitored ponds that is solidly oligotrophic, approximating a classic Cape Cod kettle pond. Bakers has adequate deep dissolved oxygen to support a cold-water fishery and meets state DO standards for most of its volume.

There are signs for concern, however, that warrant long-term monitoring: deep anoxia has risen higher in the water column over the past 60 years and phosphorus loading analysis suggests that the potential load reaching the pond will triple before reaching steady state. It is recommended that long term monitoring use the existing data as a baseline and develop management strategies based on whether results worsen significantly beyond current results.

It is recommended above that Bakers Pond monitoring be transitioned to a schedule of early spring and late summer. This monitoring would then be compared to pertinent available data. For example, total phosphorus concentrations in the upper 9 m of Bakers Pond between June and September average 4.8 ppb (n=52) after correcting for outliers. Dissolved oxygen concentrations at a depth of 9 m have never dropped below 6 ppm, while one DO reading at 10 m and 14 (of 46 readings) at 11 m have been less than 6 ppm. Anoxic concentrations (<1 ppm) have never been recorded at 11 m depth and have been recorded 7 (of 46 readings) at 12 m. It is recommended that these results be used to develop a series of thresholds that, if exceeded, lead to development of management strategies. It is further recommended that the Town of Orleans work through the development of these thresholds and management activities that are triggered by their exceedance through a consensus building process perhaps facilitated through the WQTF. Commission staff are available to assist in this process.

VII.2.2. Crystal Lake, Pilgrim Lake, and Boland Pond Recommendations

Recommendations for Crystal Lake, Pilgrim Lake, and Boland Pond are grouped together because all of these systems are clearly ecologically impaired and fail to meet state surface water standards for dissolved oxygen. Within each pond, the sediment oxygen demand is causing low dissolved oxygen concentrations and these concentrations are, in turn, causing the release of phosphorus from the sediments that is prompting algal growth and reducing Secchi transparency. Remedial solutions for these ponds will have to be individually tailored, but the potential solutions will come from the same list of options.

Sediment oxygen demand in freshwater ponds is traditionally addressed by either aeration, alum treatment or dredging of the sediments. Within each of these categories are a variety of approaches and technologies. Recent efforts on the Cape to evaluate potential options have included the Management Plan for Long Pond in Brewster and Harwich (ENSR, 2001). In addition, the state has recently released a General Environmental Impact Report that reviews the use of lake management and remedial approaches in Massachusetts (Mattson, *et al.*, 2004). It is recommended that the Town of Orleans use these reports as a starting point for a process to review potential options and costs for implementing a strategy to address the sediments within each of these ponds. Commission staff are available to assist in this process.

As the town moves through this process, it should also be kept in mind that the ultimate source of the sediments that are causing the impairments in these ponds is the phosphorus reaching ponds from their watersheds. Whatever options are considered should also include options to address phosphorus loads coming from the watersheds. Commission staff are also available to assist in this process.

VII.2.3. Cedar Pond Recommendations

Cedar Pond is also an impaired system, but unlike Crystal Lake, Pilgrim Lake and Boland Pond, it is not a freshwater pond. It is part of the estuary system that interacts with Rock Harbor. Data presented above shows that nitrogen is likely its controlling nutrient, not phosphorus. However, it is clear that sediment oxygen demand is creating the impairments in the pond and remedial solutions will have to address these sediments. Developing strategies to address the impairments in Cedar Pond will have to account for these nutrient differences and the impact of tidal flows, but the list of potential management options for the sediments will likely be similar to those for the impaired freshwater ponds.

The Rock Harbor estuary system is currently under review by the Massachusetts Estuaries Project. MEP results will review the nitrogen loads coming from the Harbor watershed, how tides move in and out of the system, and an overall assessment of the ecological health of the system. Once the MEP analysis of Rock Harbor is available, it is recommended that the Town of Orleans combine the information available in this report with the MEP results and begin a process to review potential options and costs for implementing a strategy to address the ecosystem impairments in Cedar Pond. As with the freshwater ponds, these strategies will have to address both in-lake conditions and watershed nutrient loads. Commission staff are available to assist in this process.

VII.3. Recommendations for Town-wide Management Activities

All five of the ponds reviewed in detail have water quality concerns related to the land uses within their watershed. Four of the five have impaired water quality that impacts the ecosystem of these ponds to varying degrees, some in highly significant ways. It is clear from the town-wide overview of the ponds that every pond reviewed has excessive nutrients and average dissolved oxygen conditions in almost all fail to meet state surface water standards. What is not clear is how significant these impairments are in the other ponds.

In order to systematically address these findings, it is recommended that the Town of Orleans consider development of a pond remediation program to individually address the existing impairments and develop ways to ensure the long-term health of these ecosystems. This program would begin by completing watershed loading, water and nutrient budget development and water quality review for the 13 ponds with adequate data that were not selected for detailed review. This program would also incorporate the development and review of remedial and management options discussed above for the five ponds that have detailed review in this report. This program would also likely require funding for remedial in-lake activities such as alum treatments and aeration, as well as implementation of best management practices, such as removing or minimizing stormwater discharge into the ponds. As part of this program, the town could also consider review of existing town regulations (*i.e.*, subdivision rules, conservation commission regulations, board of health regulations) as part of the watershed management

activities to better protect pond water quality when land is developed and when existing properties are sold. The town may also want to consider combining all of these activities with monitoring programs, so all pond-related activities are coordinated and mutually supportive. Commission staff are available to assist the town in discussion of these types of activities.

VIII. Conclusions

As part of Barnstable County's Growth Management Initiative and the Pond and Lake Stewardship (PALS) program, the Cape Cod Commission has completed an initial review of pond monitoring data collected by Town of Orleans monitoring volunteers from 18 ponds between 2000 and 2005. Results from an initial review of the data were presented before the Orleans Marine and Fresh Water Quality Task Force (WQTF) in May 2006 and the town was asked to select five ponds for more detailed evaluation. Through the WQTF, the town selected Bakers, Boland, Cedar, Crystal, and Pilgrim for detailed review.

The initial review found that 16 of the 18 ponds in Orleans has average dissolved oxygen concentrations during June through September that are worse than the state surface water standards. Review of phosphorus data show that every pond has average concentrations that exceed the "healthy" pond threshold developed by the Cape Cod Commission (Eichner, *et al.*, 2003).

The detailed review completed for the five selected ponds more thoroughly defined and quantified the extent of the impairments found in the initial review. Detailed review included delineation of watersheds and review of phosphorus loading, as well as more refined reviews of dissolved oxygen and temperature profiles, Secchi transparency readings, and phosphorus concentrations. Development of the watersheds allowed Commission staff to review current and future sources of phosphorus loads. Because phosphorus becomes bound to sand as it travels through the aquifer, phosphorus does not reach a pond until all binding sites are between its source and the pond are used. Therefore, it can take decades for loads from a nearby septic system, for example, to reach a pond shoreline.

The detailed review of the five individual ponds shows that these ponds span a continuum of ecological conditions. Bakers Pond is relatively pristine, although it has some deep-water conditions that warrant additional monitoring. Crystal Lake is relatively impaired, but most of the impairment is deeper in the pond and only occasionally are the impairments seen at the surface. Pilgrim Lake and Boland Pond are impaired with regular mixing of internal sediment-regenerated phosphorus prompting algal growth and near eutrophic conditions. Cedar Pond is significantly impaired, but it has ecological conditions more typical of an estuary and should be considered once the Massachusetts Estuaries Project review of Rock Harbor is completed. All ponds, except Bakers, have dissolved oxygen concentrations that are worse than state surface water minimums. In addition, existing conditions in the four freshwater ponds represent only a fraction of the nutrient loads coming from watershed development; water quality will worsen in time as systems move closer to steady state.

Since the results from the detailed and town-wide data reviews consistently show impairments in almost all of Orleans' ponds, it is recommended that the Town of Orleans consider development of an integrated pond remediation and monitoring program. This program

would be tasked with addressing the existing impairments and prevent future impairments of each pond, develop ways to ensure the long term health of these ecosystems, and integrate ongoing monitoring to assess long term water quality trends and efficacy of remedial projects. The suggested details of such a program are described in a series of recommendations. Cape Cod Commission staff are available to assist the town in discussion of these types of activities, the pond analysis results, and recommendations contained in this report.

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