Herring Pond Alum Treatment Program

Project Completion Report

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Introduction

The Eastham Ponds Action Plan, submitted to the Town of Eastham Massachusetts in December, 2011, recommended an alum treatment program to help mitigate the internal (sediment) phosphorus loading in Herring Pond. This small (40 acre) pond exhibited elevated phosphorus concentrations and algal density. Residents reported declining water quality conditions. An alum treatment program for Herring Pond was ranked as the top priority recommendation of the Action Plan.

Funding for an alum treatment program of Herring Pond was approved in the Town of Eastham budget for the fiscal year beginning July, 2012. GHD and EcoLogic, in collaboration with Town officials and advisory boards, obtained the required permits and approvals for the treatment. EcoLogic collected sediment samples from Herring Pond and worked with Spectrum Analytical of Agawam MA to assay the sediments and calculate the application rate that would immobilize the pool of iron-bound phosphorus present in the pond's sediments. The Town Conservation Commission drew up an Order of Conditions to ensure that the alum treatment program would minimize the risk of harm to the environment.

GHD contracted with Aquatic Control Technology (ACT), a licensed applicator, to apply a calibrated mixture of aluminum sulfate (alum) and sodium aluminate to Herring Pond, based on the site-specific dose calculation. This contractor has successfully completed alum treatment programs across Cape Cod, including ponds in Barnstable, Harwich, Brewster and Chatham.

The alum treatment program and the associated water quality monitoring were completed over a several week period, beginning on October 24, 2012 and ending on November 13, 2012. Weather conditions and scheduling contributed to the lengthy treatment program; the chemical application itself took only three days. Water quality conditions of Herring Pond were monitored before, during, and after the alum application. The permit required four quarterly sampling events following the chemical treatment program. The final sampling event took place on April 2, 2014.

This final report summarizes the treatment program and results of the water quality monitoring.

Chronology of Treatment Program

Table 1. Details of the alum treatment program

Date	Activity Log
Wed. 10/24/12	ACT arrived on site, assembled treatment barge, calibrated spray equipment
	EcoLogic arrived on site, profiled water quality conditions at pond's deepest point
Thurs. 10/25/12	ACT treated 10 acres of the total treatment area (20 acres) with one-half the planned dose of alum. This was a modification to the original plan (calling for treating 5 acres at full dose on Day 1). ACT and EcoLogic decided to proceed with caution, due to fluctuating pH conditions in prior weeks during an major algal bloom. Decision was reviewed with Town of Eastham official (Jane Crowley, by phone). Other town officials on site during application. Nate Weeks (GHD) on site.
	EcoLogic completed water quality monitoring and visual inspections of pond conditions, before, during, and after the chemical application. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual evidence of floc outside of the treatment zone.
Fri. 10/26/12	Weather forecast threatening- Hurricane Sandy was projected to make landfall on the east coast early next week. Days 2 and 3 of chemical treatment (planned for Monday and Tuesday) called off. Barge secured.
	EcoLogic completed three rounds of visual inspection and water quality monitoring- inside and outside of the treatment area. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual indication of floc, water was very clear. Nate Weeks (GHD) on site.
Sat 10/27/12	EcoLogic completed three rounds of visual inspection and water quality monitoring- inside and outside of the treatment area. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual indication of floc, water very clear.
Sum 10/28/12	EcoLogic completed one round of visual inspection and water quality monitoring- inside and outside of the treatment area. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual evidence of floc. Conditions very windy. EcoLogic team headed off Cape in advance of the storm.
Tues 11/6/12	ACT completed treatment of 15 acres of Herring Pond- with half the planned dose (37.5 g/m^2). Now, one 5 acre section has been treated with the full dose of alum/sodium aluminate (75 g/m^2), and 15 acres have been received half of the planned dose. One more day of treatment (15 acres at half dose) is required to complete the application. Another pending storm forced delay of the final day of treatment. High winds were forecast to persist for several days.
	EcoLogic completed three rounds of visual inspection and water quality monitoring- inside and outside of the treatment area. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual indication of floc, water very clear.
Mon 11/12/12	ACT completed the alum application, dosing 15 acres of Herring Pond at a rate of 37.5 g/m^2. 20 acres received the full dose, 75 g/m^2, in a split application.
	EcoLogic completed three rounds of visual inspection and water quality monitoring- inside and outside of the treatment area. The pH and alkalinity remained stable, no evidence of stress to aquatic biota. No visual indication of floc, water very clear.
Tues 11/13/12	ACT demobilized from site, and restored the site per Order of Condition.
	EcoLogic completed post-treatment profile monitoring at the deepest location.

Water Quality Monitoring Results

Table 2. October 24, 2012: pre-treatment

Depth	pH	Water temp.	D.O	Sp. Cond.	Alkalinity	Diss. Al	Total P	SRP
	(S.U.)	(deg. C)	(mg/L)	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0	7.64	15.5	7.0	1399	26	ND	0.022	ND
2	7.61	15.5	7.0	1404	35	ND	0.019	ND
4	7.6	15.5	6.6	2410	33	ND	0.016	ND
6	7.5	15.2	6.34	1419	33	ND	0.020	ND
8	7.2	13.6	<2	30	91	ND	0.794	2.05
10	7.13	12.3	<2	24.3	140	0.017	2.28	5.88
ND= not detectable (reporting limit 0.005 mg/L)								

Table 3. November 13, 2012: post treatment

Depth	pH	Water temp.	D.O	Sp. Cond.	Alkalinity	Diss. Al	Total P	SRP
	(S.U.)	(deg. C)	(mg/L)	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0	7.57	12.6	7.50	2178	40	0.270	0.093	ND
2	7.53	13.2	7.36	1663	33	0.246	0.118	ND
4	7.6	13.5	6.79	1733	48	0.264	0.057	ND
6	7.6	13.8	6.50	1718	37	0.324	0.050	ND
8	7.6	13.8	6.50	1723	41	0.284	0.052	ND
10	7.6	13.6	6.55	1720	51	0.273	0.155	ND
ND= not detectable (reporting limit 0.005 mg/L)								

Table 4. March 11, 2013:post-treatment

Depth	pH	Water Temp.	D.O.	Sp. Cond.	Alkalinity	Dissolved Al	Total P	SRP
m	(S.U.)	(deg. C)	mg/L	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0.1	7.8	4	13.3	1305	36	0.026	0.024	ND (2)
2	7.9	4	13.2	1301	36	0.025	ND (1)	ND (2)
4	7.9	4	13.2	1294	36	0.027	ND (1)	ND (2)
6	7.9	4	13.1	1294	36	0.028	ND (1)	ND (2)
8	7.9	4	13.1	1295	37	0.030	0.035	ND (2)
ND= not detectable (1) reporting limit 0.020 mg/L (2) reporting limit 0.005 mg/L								

Table 5. May 5, 2013: post-treatment

Depth	pH	Water Temp.	D.O.	Sp. Cond.	Alkalinity	Dissolved Al	Total P	SRP
m	(S.U.)	(deg. C)	mg/L	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0.1	8.0	18.7	9.7	1946	33	ND (3)	ND (1)	ND (2)
2	8.0	18.4	9.8	1945	33	ND (3)	ND (1)	ND (2)
4	8.0	17.8	9.8	1955	33	ND (3)	0.013	ND (2)
6	8.0	14.8	9.8	2091	34	ND (3)	0.012	ND (2)
8	7.8	10.3	9.9	2078	36	ND (3)	0.015	ND (2)
8.8	7.2	9.9	4.9	2136	39	ND (3)	0.017	ND (2)
ND= not detectable (1) Reporting limit 0.010 mg/L (2) Reporting limit 0.005 mg/L (3) Reporting limit 0.05 mg/L								

Table 6. August 22, 2013: post-treatment

Depth	pH	Water Temp.	D.O.	Sp. Cond.	Alkalinity	Dissolved Al	Total P	SRP
m	(S.U.)	(deg. C)	mg/L	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0	7.3	25.7	9.7	No data	35	0.029	ND(1)	ND (2)
2	7.3	25.5	8.98		25	0.033	0.011	ND (2)
4	7.2	25.2	8.05		31	0.033	0.013	ND (2)
6	7.2	24.6	7.82		38	0.028	ND(1)	ND (2)
8	7.2	19.1	3.88		37	ND(1)	0.015	ND (2)
10	R	17.7	3.6		52	0.018	0.037	ND (2)
ND= not detectable (1) Reporting limit 0.010 mg/L (2) Reporting limit 0.005 mg/L								

Table 7. April 2, 2014: Post-treatment

Depth	pH	Water Temp.	D.O.	Sp. Cond.	Alkalinity	Dissolved Al	Total P	SRP
m	(S.U.)	(deg. C)	mg/L	(uS)	(mg/L as CaCO3)	mg/L	mg/L	mg/L
0	6.7	25.7	19.9	1,825	31.0	ND (1)	ND (1)	ND (2)
2	6.6	25.5	20.1	1,819	31.1	ND (1)	0.010	ND (2)
4	5.3	25.2	20.3	1,818	31.3	ND (1)	0.011	ND (2)
6	5.3	24.6	20.4	1,818	31.8	ND (1)	0.011	ND (2)
8	R	19.1	20.4	1,820	31.5	ND (1)	0.011	ND (2)
9.5	R	17.7	20.2	1,995	31.0	ND (1)	ND (1)	ND (2)
ND= not detectable (1) Reporting limit 0.010 mg/L (2) Reporting limit 0.015 mg/L								

pH Measurements during Alum Application

The project team monitored pH using a field instrument, and collected water samples for a field titration of total alkalinity, reported as mg/L as $CaCO_3$. This monitoring plan was in place to verify that the application of the alum and sodium aluminate mixture did not consume alkalinity and allow a rapid decline in the pond's pH. The environmental concern is that aluminum in water is amphoteric; defined as more soluble in acidic solutions and in basic solutions than in circumneutral solutions. Ionic aluminum can be harmful to aquatic life. Consequently, the project team calculated the ratio of alum and sodium aluminate to ensure that the pH would not fall below 6.5, nor rise above 8.5 during treatment. ACT and the chemical supplier completed laboratory jar testing using Herring Pond water prior to the application.

Results of frequent monitoring before, during and after the application confirmed that the pH remained in a safe range. Similarly, the alkalinity measurements were stable. The largest gradients in pH and alkalinity were related to the pond's thermal stratification. Water quality conditions at the 8 m and 10 m depth were distinctly different, as a consequence of chemical changes caused by prolonged oxygen depletion over the summer. There were no observations of pH below 6.97.

Table 8. Summary of pH monitoring during treatment

Inside Treatment Area			
Depth (m)	Max	Min	Count
0	7.8	7.24	15
2	7.7	7.32	
4	7.7	7.38	
6	7.67	7.34	
8	7.65	7.01	
10	7.6	6.97	
Outside Treatment Area			
Depth (m)	Max	Min	Count
0	7.8	7.4	14
2	7.9	7.45	
4	7.77	7.46	
6	7.73	7.42	

Reduction in Water Column Phosphorus

The decision to implement an alum treatment program for Herring Pond was made after a careful analysis of water quality conditions and the sources of phosphorus. Phosphorus is the critical nutrient affecting algal growth in the pond, and internal phosphorus loading from the pond sediments was identified as a major source.

Nitrogen and phosphorus enter the ponds primarily as dissolved nutrients where they are incorporated into biomass. Water leaves the ponds through groundwater seepage and evaporation. Particulate biomass tends to remain in the ponds, and the nutrients continue to cycle through the food web. Through this natural phenomenon, kettle ponds become more productive (eutrophic) over time.

Ponds deeper than about 5 m (16 ft.) typically exhibit some degree of thermal stratification during the summer. Bottom waters isolated from the atmosphere become depleted of oxygen as the microbial community decomposes organic material that settles to the lake bottom. As ponds become more productive, oxygen depletion is evident higher in the water column.

Herring Pond is deep enough to develop stable thermal stratification during the summer, and productive enough to exhibit seasonal anoxia. The PALS program and monitoring by the EcoLogic/GHD project team documented highly elevated phosphorus concentrations in the deeper waters. This phenomenon is a result of chemical changes at the sediment surface that occur during summer anoxia. Due to these chemical changes, phosphorus is released from sediments to the overlying waters. As waters cool in the fall, the phosphorus-rich water is mixed into the pond, setting the conditions for algal blooms the following year.

One of the parameters we tracked during the Herring Pond treatment program was the change in the mass of phosphorus in Herring Pond's water column. As explained above, the alum treatment program is designed to sequester sediment phosphorus and prevent the release of phosphorus to the water column during seasonal anoxia. To quantify this effect, we estimated the mass of phosphorus—measuring phosphorus concentration at 2 m depth intervals from the surface to the bottom, and multiplying by the proportional volume of the pond represented by each sampling depth. The results of the phosphorus mass calculations before and after the alum treatment program are summarized in Table 9.

Table 9. Reduction in mass of phosphorus in Herring Pond water

Sampling Date	Water column Phosphorus Mass (kg)	Volume-weighted Phosphorus Concentration (mg/L)	Percent reduction in pre-treatment Mass
October 2012 (*pre-treatment)*	92.13	0.104	0% (pre-treatment)
November 2013	76.02	0.086	17%
March 2013	19.96	0.022	78%
May 2013	9.98	0.011	89%
August 2013	10.29	0.012	89%
April 2014	8.89	0.010	90%

Aluminum

Herring Pond was treated with a combination of chemicals—aluminum sulfate and sodium aluminate—to ensure that the pond water would have sufficient acid neutralizing capacity (buffering capacity) to prevent the creation of aluminum ions (Al^{+3}) that are potentially harmful to aquatic life. The Order of Conditions required monitoring of the Al concentrations in the pond waters, before and after treatment. The aluminum results are reported in Tables 2 through 7.

The concentration of dissolved Al in the pond water was significantly higher immediately after the treatment was completed. The maximum concentration 324 ug/L was above the federal criterion for chronic (long-term) exposure, but below the federal criterion for acute (short-term) exposure. The toxicity criteria for Al in fresh water are cited below (EPA 1988).

> "The procedures described in the "Guidelines for Deriving Numerical Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably, when the pH is between 6.5 and 9.0, if the four-day average concentration of aluminum does not exceed 87 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 750 ug/L more than once every three years on the average."[1]

The measured Al concentrations are consistent with the field observations. The field team did not observe adverse impacts on the aquatic biota during their frequent visual assessment of Herring Pond. While chemical reactions of Al in water are not rapid compared with other compounds, water column concentrations were projected to decline over the subsequent weeks. The volume-weighted average aluminum concentration is plotted in Figure 1.

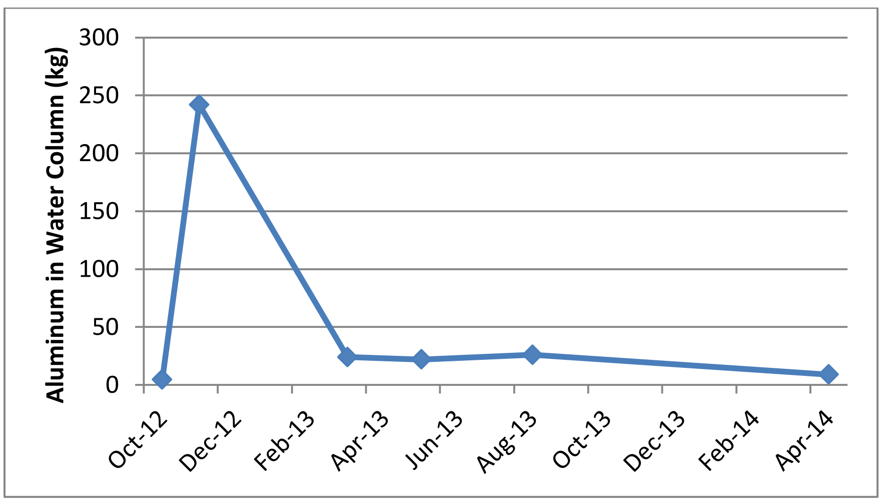

Figure 0-1. Aluminum content in Herring Pond

[1] EPA. 1988. Ambient water quality criteria for aluminum. EPA *440/5-86-008*

Groundwater quality

Among the Orders of Conditions for the alum treatment program was a requirement to measure the concentrations of aluminum and sulfate in groundwater downgradient of Herring Pond. Two residential wells were used for this testing. Results demonstrate no migration of materials from the chemical treatment program to wells (Table 10).

Table 10. Results of water quality testing of residential wells, Town of Eastham

Sample Date	Higgins Residence		DesChamps Residence	
	Dissolved Aluminum, mg/L	Sulfate, mg/L	Dissolved Aluminum, mg/L	Sulfate, mg/L
9-Oct-12	ND (1)	14	ND (1)	6.3
30-May-13	ND (2)	11	ND (2)	ND (3)
2-Apr-14	ND (1)	28	ND (1)	ND (3)
1. Not detected at reporting limit of 0.010 mg/L				
2. Not detected at reporting limit of 0.050 mg/L				
3. Not detected at reporting limit of 10 mg/L				

Water Clarity

Herring Pond is routinely monitored as part of Cape Cod's PALS (Pond and Lake Stewards) citizen monitoring program. Water clarity is measured using the Secchi disk. As shown in Figure 2, summer water clarity of Herring Pond increased dramatically following the alum treatment program of fall 2012.

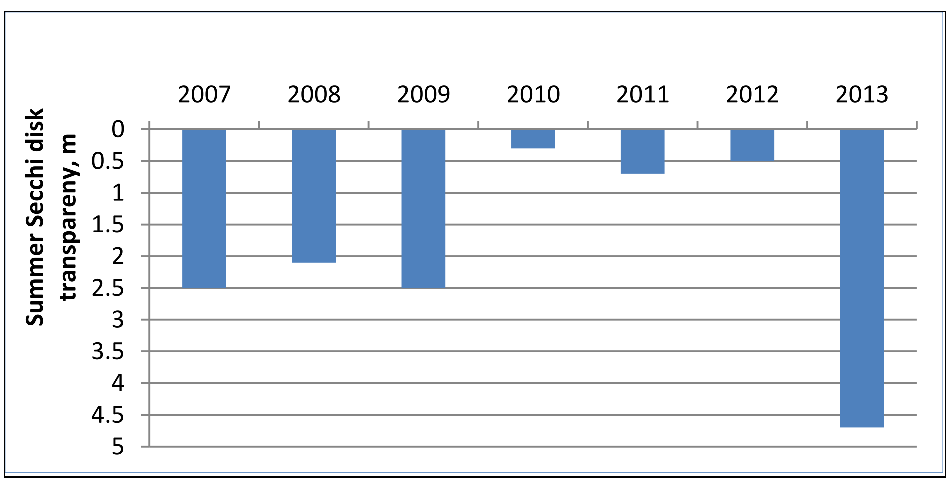

Figure 2. Summer water clarity, 2007 - 2013

Discussion

The alum treatment program was completed successfully, despite various weather-related scheduling complications. The Orders of Conditions were met. All required samples were collected and analyzed. No adverse effects on the pond biota were detected.

The effectiveness of the alum treatment program in reducing phosphorus flux from the pond sediments into the overlying waters, and stimulating algal growth, was evident in the summer of 2013. The water was much clearer and the phosphorus concentrations were low. Notably, the deep water phosphorus concentrations remained low. Eastham residents made very positive comments to Town officials.

As per the Order of Conditions issued for the alum treatment program of Herring Pond, GHD and EcoLogic have been monitoring the pond's water quality condition and are very encouraged with Herring Pond's response to the alum treatment program.