Town of Plymouth
Pond & River Monitoring
Biological Monitoring Program

Data Report
September 2010
(updated July 2011)

Courtesy of Herring Ponds Watershed Association

Town of Plymouth
Department of Public Works
Environmental Management Division

Table of Contents

SECTION A

Background

The Town of Plymouth Environmental Management Division's mission is to maintain and protect the Town's natural resources. The Division, which was initiated in 2005, is active in the research and implementation of numerous projects such as stormwater remediation, water quality sampling and reporting, dam removal, wetland restoration, river restoration, land acquisition and habitat conservation. The Division also conducts biological, water quality and stream flow monitoring for major projects such as the Eel River Headwaters Restoration and Town Brook Dam Removals. A majority of these projects are funded through grants and state and federal agency cooperation.

The Environmental Management Division with cooperation of the pond Associations began the implementation of its Pond Monitoring Program in July 2008 with $14,950 in funding from the Town. 80% of this program's resources ($12,000) are devoted to biological monitoring – a variety of field measurements, collection of plankton samples and scouting the shoreline and littoral zone for aquatic vegetation with particular attention given to alien invasive plants. The remaining 20% ($2,950) are allocated to basic nutrient monitoring in select zones. In 2009 the Town of Plymouth was awarded $30,000 by the Massachusetts Environmental Trust for a 3-year Monitoring Program. A majority of the funded assists Associations in water quality sampling equipment and laboratory analysis in which the Town oversees sampling protocols and budget.

The Biological Data in Section C of this report is conducted by a Limnologist/Biologist contracted through the Town of Plymouth. Monitoring in Section E is conducted by Watershed Associations except for Town Brook, Beaver Dam Brook and Bartlett Pond which is collected by the Town's Environmental Technician. The focus of the water quality sample collection is to monitor nutrients, nitrogen & phosphorus to therefore implement solutions such as BMPs, education on fertilizer use, septic systems, etc. The laboratory conducts a full suite of analysis included in the laboratory reports, some analytes are not utilized in determining water quality of pond/river systems.

SECTION B

Bathymetric Maps

SECTION C

Biological Data

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: July 24, 2008

RE: Pond Monitoring Program: Results for July 2008

Monitoring was conducted on Little Pond, Billington Sea, Long Pond, and Little Long Pond according to the program schedule for July. On July 6th, initial efforts focused on Little Pond, but the anticipated transition to Billington Sea nearby had to be abandoned due to excessive activity by jet skis and a parking lot full to capacity. As an alternative, Long Pond was selected for monitoring that day. On July 12th, monitoring efforts were completed first on Billington Sea and then Little Long Pond.

Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter or less over the deepest portion of each pond basin, measurement of Secchi transparency, plankton sampling, and a macrophyte survey consisting of an inspection of the littoral zone and characterization of the aquatic plant community of each pond. Results of each of these monitoring tasks are given in the sections below.

Water Column Measurements (see Table 1 on page 5 and Figures 1 and 2 on page 8)

Measurement of hydrographic parameters at intervals from the surface to the bottom give a "profile" of each parameter through the water column. Little Pond and Long Pond are deep and, therefore, become thermally stratified in summer. The warm, less dense surficial layer of the water column ("epilimnion") extends to a depth of 4 and 5 meters respectively in these ponds (Figure 1). Below the epilimnion, a temperature gradient ("thermocline") exists extending to cooler, denser water with depth. Near the bottom of each pond, below the thermocline, temperatures remain very cold (about 6°C in Long Pond and 8°C in Little Pond) and comprise the bottom layer ("hypolimnion") where water densities are the greatest.

Dissolved oxygen concentrations in the epilimnia of these ponds were slightly oversaturated (Little Pond) to supersaturated (Long Pond; see Figure 2). The high dissolved oxygen concentration in Long Pond reflects intense photosynthetic activity by phytoplankton. Oxygen concentrations spike to even higher levels just below the epilimnion in Long Pond at depths of 6 to 7 meters where saturation values reach 146.5% to 153.9%. Associated with this spike in dissolved oxygen were very high pH values (8.96 to 8.99). These measurements indicate an aggregation of photosynthetically active phytoplankton in this stratum. Most likely, phytoplankton sedimenting down from the epilimnion became aggregated in this stratum due to a slowing of their sinking rate as they encountered the density gradient associated with thermal stratification. Below this stratum, dissolved oxygen concentrations gradually decreased with depth. Dissolved oxygen concentrations decline to very low levels in the hypolimnion due to decomposition of sedimenting phytoplankton; a pattern typical of many thermally stratified lakes and ponds. This is especially true of Little Pond where the bottom 3 meters of the water column had dissolved oxygen concentrations of less than 1 mg/L. The depletion of oxygen at depth indicates that Long Pond and Little Pond support significant productivity by plankton during the summer stratification period.

In contrast to the water column profiles of the deep ponds discussed above, Billington Sea and Little Long Pond are shallow and remain unstratified due to the mixing action of wind-induced turbulence at the surface. These ponds gain heat throughout the water column during summer (Figure 1). Values of other parameters are also uniform generally throughout the water column in these shallow ponds. Little Long Pond was supersaturated with dissolved oxygen from surface to bottom reflecting intense photosynthetic activity by phytoplankton in this small pond (Figure 2). However, in Billington Sea very close to the bottom (3.5 to 3.8 meters deep), measurements departed from uniformity and reflect intense decomposition occurring at or near the sediment-water interface in the form of hypoxia, lower pH, and increased conductivity.

Also noteworthy in the Billington Sea measurements, are the higher conductivity values in comparison to the other three ponds. Conductivity in Billington Sea registered 148.9 uS/cm at the surface whereas the range of surface values in the other ponds was only 70.4 to 83 uS/cm. This reflects the influence of multiple tributary discharges to Billington Sea which receives surface drainage from an extensive watershed. The other ponds are kettles lacking significant watershed inputs, having instead, hydrologic budgets that are predominately influenced by groundwater.

Measurements of Secchi transparency show that the shallow ponds support the greatest densities of phytoplankton with transparency limited to 4.5 and 5.5 feet in Little Long Pond and Billington Sea respectively. However, it is likely that some impairment of transparency in these shallow ponds is also due to sediments that become suspended from wind-induced turbulence. In the case of Billington Sea, boat and jet ski traffic also contribute to the suspension of bottom sediments. Long Pond had moderate transparency of 10 feet and Little Pond, with very good transparency of 20.5 feet, supports the lowest densities of phytoplankton among this group of ponds.

Plankton Sampling (see Table 2 on page 6)

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

The phytoplankton community of Little Pond was dominated by a desmid of the genus *Cosmarium*. Also significant in Little Pond was another desmid, *Staurastrum*, and the cyanophyte *Chroococcus*. Long Pond had the most diverse phytoplankton community with four taxa preeminent: *Gloeocystis*, *Staurastrum*, *Aphanocapsa*, and *Microcystis*. The cyanophyte *Microcystis* was also a significant component of the phytoplankton communities in Billington Sea and Little Long Pond. *Microcystis* is a common member of summer and autumn plankton communities in a variety of freshwater systems. In Billington Sea, *Microcystis* colonies formed "clumps" visible to the naked eye as small green "flecks" floating near the surface and accumulating along the leeward shore. Also significant in Billington Sea was the diatom *Melosira* and the chlorophyte *Pediastrum*. Lastly, the phytoplankton community of Little Long Pond was dominated by the chrysophyte *Dinobryon* with the dinoflagellate *Ceratium* also comprising an important part of the community along with *Microcystis*. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

Macrophyte Survey (see Table 3 on page 7 and maps sent by U.S.P.S.)

The littoral zone of Little Pond is generally fringed with emergent rushes (*Juncus*) and Pickerel-weed (*Pontederia*) with submerged vegetation mostly limited to low-growing species such as Pipewort (*Eriocaulon*), Golden-pert (*Gratiola*), and Spike-rush (*Eleocharis*) that form a "carpet" over patches of substrate. The floating pads of White Waterlily (*Nymphaea*) and Yellow Waterlily (*Nuphar*) occupy the extreme southwestern corner of the pond accompanied by emergent Water-willow (*Decodon*) along this area of shoreline. A small patch of Cattail (*Typha*) grows emergent on the western shoreline adjacent to a private dwelling having a waterfront terraced with tires. One specimen of Pondweed (*Potamogeton*) was observed in the northeastern cove of the pond. In addition to carpet-like growth of submerged vegetation, the littoral zone of Little Pond is characterized by extensive areas of sand, gravel, and cobble and deposits of leaf litter and other organic material. No alien plant species were observed.

Long Pond is similar to Little Pond (described above) in that the littoral zone is generally fringed with emergent vegetation with little submerged growth. In the case of Long Pond, this shoreline fringe generally consists of Slender-leaved Goldenrod (*Euthamia*, formerly *Solidago*), Swamp Candles (*Lysimachia*), and Blue Flag (*Iris*). An isolated patch of Narrow-leaved Cattail (*Typha angustifolia*) is growing emergent at the northern end of the pond on the shore almost directly opposite from the public boat ramp (visible from the ramp facing S.S.W.). Submerged vegetation is mostly limited to Pipewort (*Eriocaulon*), Golden-pert (*Gratiola*), and Spike-rush (*Eleocharis*) growing between embedded cobble substrates. In addition to cobble, sand and gravel compose littoral zone substrates throughout Long Pond. No alien plant species were observed.

Billington Sea supports a great diversity of aquatic plants. Unfortunately, the alien Fanwort (*Cabomba caroliniana*) was observed, apparently having been introduced since the last macrophyte survey was completed in June of 2002 (Aquatic Control Technology, Inc. letter dated January 7, 2003). Fanwort is indigenous to North America, but originally ranged west and/or south of New England so is considered alien in Massachusetts. It does proliferate to nuisance densities in many water bodies and has been documented in Plymouth as early as 2001 in the Eel River. However, in Billington Sea it currently is restricted to limited areas of the pond with native vegetation occupying most of the littoral zone.

On the day of monitoring, Fanwort was first observed as floating fragments against the north shore of the western basin (north and west of Hathaway Point; wind blowing from the south). The source of the fragments in this basin was not determined, but rooted plants were subsequently found in the tributary inlet from Briggs Reservoir along the south shore and also in the extreme southeastern corner of the pond. It remains to be seen if Fanwort expands its distribution, but the existing dense stands of native plants will function beneficially to delay and maybe restrict the spread of this invasive plant.

Native plants commonly observed in Billington Sea included Waterweed (*Elodea*), Pondweed (*Potamogeton*), Tapegrass (*Vallisneria*), and Bladderwort (*Utricularia*). Interestingly, Mint (*Mentha*) was observed growing completely submerged in the small cove indenting the north shore of the western basin. Also in the western basin, along the southwestern shore, beds of Slender Arrowhead *(Sagittaria teres*) were conspicuous with their white flowers emergent above the surface. This portion of shoreline also supported many globular, gelatinous bryozoan colonies (*Pectinatella magnifica*) growing attached to the bottom.

Lastly, monitoring of Little Long Pond was completed late in the day (after Billington Sea), so survey results for this pond must be considered preliminary and will be updated. The shoreline is almost completely fringed with emergent Water-willow (*Decodon*) and extensive areas of the littoral zone are occupied primarily by Waterweed (*Elodea*).

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN JULY 2008

Little Pond on July 6, 2008
(Secchi Transparency = 20.5 feet / 6.3 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	24.95	83.0	103.0	8.52	6.29
1	24.80	83.2	102.6	8.51	6.29
2	24.68	83.5	102.5	8.52	6.28
3	24.70	83.1	101.8	8.46	6.24
4	24.52	83.0	100.5	8.38	6.22
5	21.16	82.3	115.0	10.21	6.23
6	17.72	81.2	121.3	11.54	6.33
7	14.36	80.0	124.6	12.74	6.40
8	12.00	80.4	115.8	12.48	6.32
9	10.64	79.5	99.0	11.00	6.03
10	9.37	81.0	76.5	8.76	5.49
11	8.74	81.9	39.5	4.59	5.08
12	8.29	84.0	5.3	0.62	5.09
13	7.97	89.6	1.7	0.21	5.28
14	7.83	94.1	1.3	0.16	5.44
15	7.70	117.7	1.2	0.15	5.57

Billington Sea on July 12, 2008
(Secchi Transparency = 5.5 feet / 1.7 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	26.38	148.9	115.4	9.30	8.08
0.5	26.38	148.7	115.7	9.32	8.11
1.0	26.38	148.3	116.0	9.34	8.15
1.5	26.28	148.6	116.0	9.36	8.18
2.0	26.26	147.6	114.6	9.25	8.16
2.5	26.23	147.7	112.6	9.09	8.09
3.0	26.07	149.1	99.2	8.04	6.85
3.5	25.57	153.0	75.7	6.19	6.27
3.8	24.99	157.2	1.0	0.08	6.49

Little Long Pond on July 12, 2008
(Secchi Transparency = 4.5 feet / 1.4 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	26.92	77.8	135.9	10.85	7.83
1.0	26.91	77.7	135.7	10.83	7.84
2.0	26.76	77.8	136.6	10.93	7.87
2.4	26.30	79.9	137.5	11.10	7.68

Long Pond on July 6, 2008
(Secchi Transparency = 10 feet / 3 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	25.48	70.4	116.5	9.54	8.27
1	25.44	70.5	116.8	9.57	8.32
2	25.31	70.7	116.7	9.59	8.34
3	25.15	70.4	116.3	9.58	8.35
4	25.01	70.4	115.1	9.51	8.36
5	24.60	70.3	121.6	10.12	8.44
6	21.44	76.8	153.9	13.60	8.96
7	18.46	74.1	146.5	13.74	8.99
8	15.52	67.3	130.1	12.97	8.68
9	12.62	64.4	120.7	12.83	8.17
10	10.21	63.8	118.2	13.27	7.93
11	8.59	63.4	111.9	13.07	7.79
12	7.25	63.7	92.9	11.21	7.57
13	6.65	64.3	81.2	9.94	7.25
14	6.31	64.5	63.8	7.88	6.98
15	6.10	65.0	53.9	6.70	6.64
16	6.00	65.5	46.3	5.76	6.20
17	5.92	65.3	44.3	5.53	5.87
18	5.90	66.0	38.1	4.76	5.58
19	5.87	66.2	34.3	4.28	5.41
20	5.77	65.9	37.9	4.74	5.33
21	5.74	66.4	29.3	3.68	5.27
22	5.72	67.2	26.6	3.34	5.22
23	5.71	67.1	26.0	3.25	5.23
24	5.69	67.4	21.9	2.75	5.23
25	5.69	67.7	21.0	2.64	5.23
26	5.69	67.8	18.3	2.30	5.23
27	5.68	68.5	10.5	1.32	5.21
28	5.68	68.4	7.5	0.95	5.21
29	5.68	73.2	3.9	0.50	5.23
29.1	5.70	132.3	2.4	0.30	5.32

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN JULY 2008

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location			
	Little Pond (net to 8 m)	**Long Pond** (net to 10 m)	**Billington Sea** (net to 3 m)	**Little Long Pond** (net to 2 m)
Phytoplankton Taxa				
Bacillariophyceae (diatoms)				
Asterionella				R
Cyclotella		R		
Fragilaria		R	R	
Melosira			**V**	
Synedra		R		
Tabellaria		R		
Chlorophyta (green algae)				
Ankistrodesmus		R		
Arthrodesmus	R	R		
Closterium				R
Coelastrum		R	R	R
Cosmarium	**A**			
Crucigenia	R			
Dictyosphaerium	R	R		
Eudorina	R	R	R	R
Gloeocystis	R	**V**	R	R
Nephrocytium	R	R		
Oocystis	R			
Pandorina		R		
Pediastrum		R	**V**	R
Quadrigula	R	R	R	
Scenedesmus			R	
Sphaerocystis	R	R		R
Spirogyra		R		
Spondylosium	R	R		
Staurastrum	**C**	**V**	R	R
Xanthidium		R	R	
Chrysophyta (yellow-green algae, excluding diatoms)				
Chrysosphaerella				
Dinobryon	R			**A**
Mallomonas	R			R
Rhizochrysis	R	R		
Cyanophyta (blue-green algae)				
Anabaena	R	R	R	
Aphanocapsa		**C**		
Chroococcus	**C**	R	R	
Coelosphaerium			R	
Dactylococcopsis	R	R		
Microcystis		**V**	**V**	**C**
Oscillatoria		R		
Pyrrhophyta (dinoflagellates)				
Ceratium	R	R	O	**C**

TABLE 3 - MACROPHYTES OF PLYMOUTH PONDS OBSERVED IN JULY 2008*

SPECIES NAME	COMMON NAME	Little Pond	Billington Sea	Long Pond	Little Long
Submerged Plants					
Cabomba caroliniana	Fanwort (alien)		x		
Callitriche sp.	Water-starwort		x		
Eleocharis sp.	Spike-rush	x	x	x	
Elodea nuttallii	Waterweed		▲		▲
Eriocaulon sp.	Pipewort	x	x	x	
Gratiola aurea	Golden-pert	x	x	x	
Mentha spicata	Mint (alien)		x		
Myriophyllum humile	Water-milfoil		x		
Najas flexilis	Naiad		x		
Potamogeton natans	Pondweed		x		
Potamogeton perfoliatus	Pondweed		▲		
Potamogeton pusillus	Pondweed		x		
Potamogeton sp.	Pondweed	x			
Sagittaria teres	Arrowhead		x		
Utricularia intermedia	Bladderwort		x		
Utricularia vulgaris	Bladderwort		x		
Utricularia sp.	Bladderwort	x			
Vallisneria americana	Tapegrass		▲		
Floating-Leaved Plants					
Nuphar variegata	Yellow Waterlily	x	x		x
Nymphaea odorata	White Waterlily	x	x		
Emergent Plants					
Decodon verticillatus	Water-willow	x	x		▲
Euthamia (formerly *Solidago*) *tenuifolia*	Slender-leaved Goldenrod			▲	
Hypericum perforatum	Common St. Johnswort (alien)			x	
Iris versicolor	Blue Flag			▲	
Juncus sp.	Rush	▲	x	x	x
Lysimachia terrestris	Swamp Candles			▲	
Lythrum salicaria	Purple Loosestrife (alien)		x		
Pontederia cordata	Pickerel-weed	▲	x		
Sparganium sp.	Bur-reed		x		
Typha angustifolia	Narrow-leaved Cattail			x	
Typha latifolia	Common Cattail	x			

*** dominant species indicated with a triangle ▲**

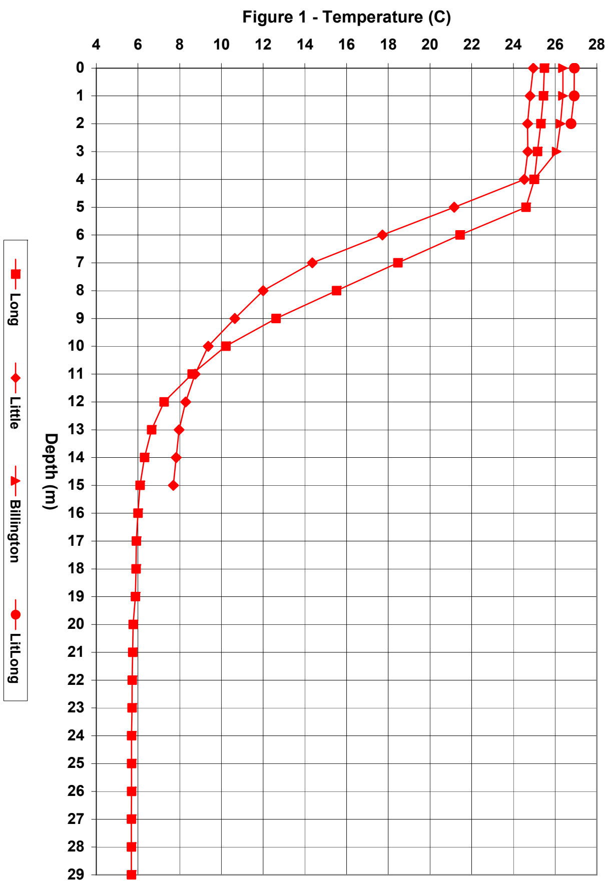


Figure 1 - Temperature (C)
4 6 8 10 12 14 16 18 20 22 24 26 28
Depth (m)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Long
Little
Billington
LitLong

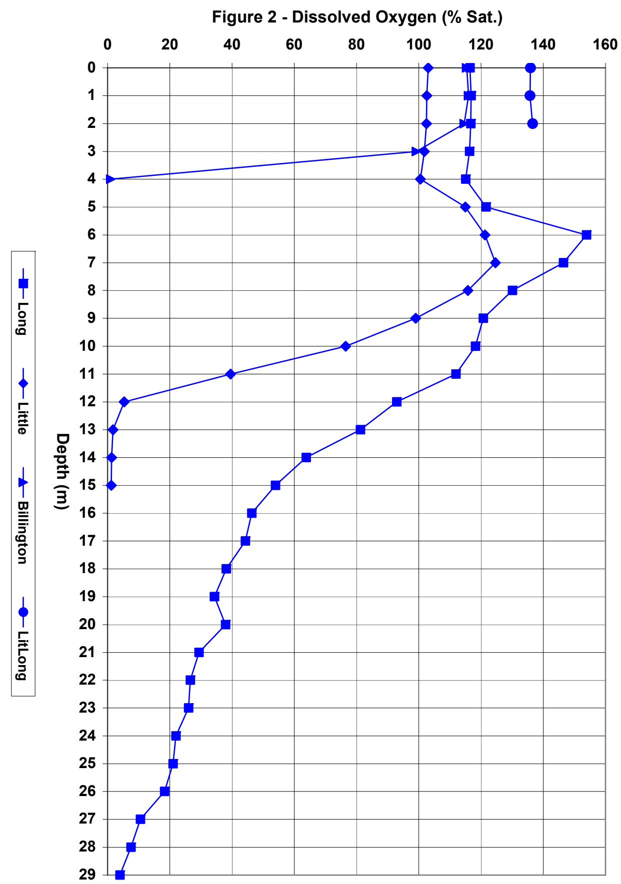


Figure 2 - Dissolved Oxygen (% Sat.)
0 20 40 60 80 100 120 140 160
Depth (m)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Long
Little
Billington
LitLong

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: August 27, 2008

RE: Pond Monitoring Program: Results for August 2008

Monitoring was conducted on Great Herring Pond (August 9th) and Great South Pond (August 23rd) according to the program schedule for August. Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter over the deepest portion of each pond basin, measurement of Secchi transparency, plankton sampling, and a macrophyte survey consisting of an inspection of the littoral zone and characterization of the aquatic plant community of each pond.

Additionally, the first task completed at Great South Pond was to record and map water depths along multiple transects across the pond in order to identify the deepest contour of the basin. This was necessary because no bathymetric map exists for this pond while maps of most other ponds are available on the MassWildlife website. Initial soundings show the center of the main basin is uniformly deep (45 feet or greater) with a maximum depth contour of 50 feet located southeast of the center of the basin. A preliminary bathymetric map based on these soundings is in preparation. Results of these monitoring tasks are given in the sections below.

<u>Water Column Measurements (see Table 1 on page 2 and Figures 1 and 2 on page 7)</u>

Measurement of hydrographic parameters at intervals from the surface to the bottom give a "profile" of each parameter through the water column. Both Great Herring Pond and Great South Pond are deep and, therefore, become thermally stratified in summer. The warm, less dense surficial layer of the water column ("epilimnion") extends to a depth of 8 meters in these ponds (Figure 1). Below the epilimnion, a temperature gradient ("thermocline") exists extending to cooler, denser water with depth. Only a small central portion of Great Herring Pond is deeper than 9 meters (30 feet) and this limited area of the basin extends just three meters more to a maximum depth of 12 meters (39 feet). For this reason, the thermocline in Great Herring Pond spans a range of only 7°C with temperature at the bottom a relatively warm 18.6°C. In contrast, much of Great South Pond is deeper than 9 meters and it has a maximum depth of 15.3 meters (50 feet), so the thermocline spans a range of 14°C with a bottom temperature of 10.4°C.

Despite its depth, stratification structure in Great South Pond consists of a thermocline extending to the bottom and lacks a clearly defined hypolimnion (a stratum having nearly uniform temperature). This is likely due to the great clarity of the water (Secchi transparency of 30 feet; discussed below) and the concomitant deep penetration of solar radiation into the water column.

Dissolved oxygen concentrations in the epilimnion of Great Herring Pond were at or near saturation to a depth of around six meters, but then were undersaturated at seven and eight meters and, in the region of the thermocline below a depth of nine meters, were extremely hypoxic. These measurements reflect intense decomposition of sedimenting plankton and indicate that Great Herring Pond supports significant productivity by plankton during the summer stratification period.

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN AUGUST 2008

Great Herring Pond on August 9, 2008
(Secchi Transparency = 10 feet / 3 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	25.44	80.0	100.9	8.27	7.34
1	25.42	80.0	101.3	8.30	7.32
2	25.33	80.1	102.2	8.39	7.18
3	25.20	80.1	97.7	8.04	7.26
4	25.14	80.0	99.2	8.18	7.26
5	25.13	80.0	96.1	7.92	7.25
6	25.13	80.0	95.7	7.89	7.38
7	24.98	80.1	76.7	6.34	7.23
8	24.59	80.7	30.9	2.57	7.25
9	23.69	84.5	1.7	0.14	7.23
10	22.08	95.8	1.4	0.12	7.03
11	19.19	118.7	1.0	0.09	6.69
12	18.57	121.3	1.0	0.09	6.76
Inlet	23.41	86.1	98.9	8.41	7.95

Great South Pond on August 23, 2008
(Secchi Transparency = 30 feet / 9.1 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	24.40	39.5	104.0	8.69	6.09
1	24.20	39.3	103.8	8.71	6.14
2	23.93	39.2	103.9	8.76	6.14
3	23.91	39.0	104.0	8.77	6.22
4	23.89	39.3	104.0	8.77	6.23
5	23.87	39.3	103.8	8.76	6.25
6	23.77	39.5	103.2	8.72	6.24
7	23.70	39.1	103.4	8.75	6.26
8	23.66	39.4	103.4	8.76	6.26
9	22.48	40.3	120.7	10.45	8.22
10	18.40	46.4	148.3	13.93	8.94
11	15.82	41.7	129.7	12.85	8.49
12	13.53	40.3	44.8	4.67	7.23
13	11.73	47.7	4.7	0.51	6.12
14	11.13	58.4	2.2	0.24	5.73
15.3	10.35	72.2	1.6	0.18	5.88

The epilimnion of Great South Pond was slightly supersaturated throughout its volume and oxygen concentrations spike to even higher levels in the upper portion of the thermocline at depths of 9 to 11 meters where saturation values reach 120.7% to 148.3%. Associated with this spike in dissolved oxygen were very high pH values (8.22 to 8.94). These measurements are analogous to those recorded in Long Pond on July 6th and indicate an aggregation of photosynthetically active phytoplankton in this stratum. Most likely, phytoplankton sedimenting down from the epilimnion became aggregated in this stratum due to a slowing of their sinking rate as they encountered the density gradient associated with thermal stratification. Below this stratum, dissolved oxygen concentrations decline rapidly with depth. The bottom two meters of the water column are hypoxic due to decomposition of sedimenting phytoplankton.

Also noteworthy in the Great South Pond measurements, are the very low conductivity values. Epilimnetic values of conductivity are about 39 uS/cm in Great South Pond; much lower than Great Herring Pond and the four ponds monitored in July. These low values attest to extremely low concentrations of dissolved ions that are characteristic of pristine kettle ponds situated in glacial deposits of stratified drift.

Measurement of Secchi transparency also demonstrates the pristine character of Great South Pond with an exceptional reading of 30 feet. Water of this clarity is characteristic of systems having very low productivity ("oligotrophic") and indicates that Great South Pond supports very low densities of phytoplankton. Great Herring Pond had moderate transparency of 10 feet.

Plankton Sampling (see Table 2 on page 5)

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

Both ponds exhibited diverse phytoplankton communities. The phytoplankton community of Great Herring Pond was dominated by the diatom *Tabellaria* with significant representation by the chlorophyte *Pandorina* and by the chrysophyte *Dinobryon*. The phytoplankton community of Great South Pond was dominated by the cyanophyte *Anabaena* and by the chlorophyte *Gloeocystis*. The ascendancy of *Anabaena* in Great South Pond likely indicates that instead of phosphorus being the nutrient limiting phytoplankton growth, which is typical of most temperate lakes and ponds, the limiting nutrient in this system is nitrogen. *Anabaena* and certain other cyanophytes are capable of utilizing atmospheric nitrogen ("nitrogen fixation") and have a competitive advantage over other organisms in a system low in nitrogen. If phytoplankton productivity is limited by a short supply of nitrogen relative to other nutrients, *Anabaena* often supplants other forms due to its ability to augment the limited supply in the water with atmospheric nitrogen. This may be only a seasonal pattern with nitrogen inputs at other times of the year causing the system to revert to limitation by phosphorus. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

Macrophyte Survey (see Table 3 on page 6)

Growth of aquatic macrophytes in the littoral zones of both ponds is generally sparse. Submerged vegetation is mostly limited to low-growing species such as Pipewort (*Eriocaulon*), Golden-pert (*Gratiola*), Waterwort (*Elatine*), and Spike-rush (*Eleocharis*) growing between embedded substrates. The littoral zones of both pond are characterized by extensive areas of sand, gravel, and cobble lacking macrophyte growth.

The inlet channel at the north end of Great Herring Pond supported the greatest density of growth observed anywhere in this system and consisted of Tapegrass (*Vallisneria*), Sparganium (Bur-reed), and Pondweed (*Potamogeton*). Localized beds of Slender Arrowhead *(Sagittaria teres*) and Naiad (*Najas*) were observed in deeper water. Patches of emergent Water-willow (*Decodon*) occur in scattered locations along the eastern shoreline and in the southwest cove. No alien plant species were observed in Great Herring Pond.

In contrast to the relatively sterile condition of most of Great South Pond discussed above, a dense community of macrophytes exists in the small cove in the extreme southwest corner of the pond. This cove contains more submerged plant biomass than the total for all other areas of the pond combined. Unfortunately, as with the case of Billington Sea, it must again be reported that the alien Fanwort (*Cabomba caroliniana*) was observed here. Other macrophyte species are present in this cove including Water-starwort (*Callitriche*), Bladderwort (*Utricularia*), Water-milfoil (*Myriophyllum*), Waterweed (*Elodea*), Naiad (*Najas*), Pondweed (*Potamogeton*), and Slender Arrowhead *(Sagittaria teres*), but Fanwort is dominant. The concentration of macrophytes in this small cove is striking and is likely due to a combination of factors including its uniformly shallow depth (8 feet or less) and its enclosed setting which has likely intensified the rate of accumulation of fine organic sediments in which these plants have taken root. It remains to be seen if Fanwort expands its distribution in Great South Pond, but the spread of this invasive plant is likely being restricted by the sterile, sandy substrates that comprise most of the littoral zone outside this cove.

Two other species are notable in the main basin of Great South Pond: Slender Arrowhead *(Sagittaria teres*) which forms extensive beds in deeper water and emergent White-bracted Boneset (*Eupatorium leucolepis*) which were conspicuously in flower along many shoreline areas.

In addition to the macrophytes observed in Great South Pond, suspended masses of green filamentous algae were frequently evident in shallow water. These subsurface “clouds” of biomass in the water column and the algae composing them are known as metaphyton. In Great South Pond, these masses were composed entirely of the green alga *Mougeotia*, a common metaphytic organism.

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN AUGUST 2008

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location	
	Great Herring Pond (net to 8 m)	**Great South Pond** (net to 10 m)
Phytoplankton Taxa		
Bacillariophyceae (diatoms)		
Asterionella		R
Attheya	R	
Cyclotella	R	R
Fragilaria		R
Melosira	O	R
Rhizosolenia		R
Synedra	R	
Tabellaria	**V**	R
Chlorophyta (green algae)		
Botryococcus	R	R
Coelastrum	R	R
Crucigenia		**C**
Gloeocystis	R	**V**
Kirchneriella		R
Mougeotia	R	
Oocystis	R	R
Pandorina	**C**	
Pediastrum	R	R
Quadrigula		R
Sorastrum	R	
Sphaerocystis		R
Staurastrum	R	R
Xanthidium	R	
Chrysophyta (yellow-green algae, excluding diatoms)		
Dinobryon	**C**	
Mallomonas	R	R
Rhizochrysis	R	
Synura	R	
Cyanophyta (blue-green algae)		
Anabaena	R	**V**
Aphanocapsa	R	
Aphanizomenon		R
Chroococcus	R	
Dactylococcopsis		**C**
Microcystis	O	R
Pyrrhophyta (dinoflagellates)		
Ceratium		R
Peridinium	R	

TABLE 3 - MACROPHYTES OF PLYMOUTH PONDS OBSERVED IN AUGUST 2008*

SPECIES NAME	COMMON NAME	Great Herring Pond	Great South Pond
Submerged Plants			
Cabomba caroliniana	Fanwort (alien)		▲
Callitriche sp.	Water-starwort		x
Elatine minima	Waterwort	x	x
Eleocharis sp.	Spike-rush	x	x
Elodea nuttallii	Waterweed		x
Eriocaulon sp.	Pipewort		▲
Gratiola aurea	Golden-pert	x	x
Myriophyllum humile	Water-milfoil		x
Najas flexilis	Naiad	x	x
Potamogeton sp.	Pondweed	x	
Sagittaria teres	Arrowhead	▲	▲
Sparganium sp.	Bur-reed	x	
Utricularia sp.	Bladderwort		x
Vallisneria americana	Tapegrass	x	
Emergent Plants			
Decodon verticillatus	Water-willow	x	
Eupatorium leucolepis	White-bracted Boneset		▲
Gratiola aurea	Golden-pert	x	x
Iris versicolor	Blue Flag		x
Lobelia dortmanna	Water Lobelia	x	

*** dominant species indicated with a triangle ▲**

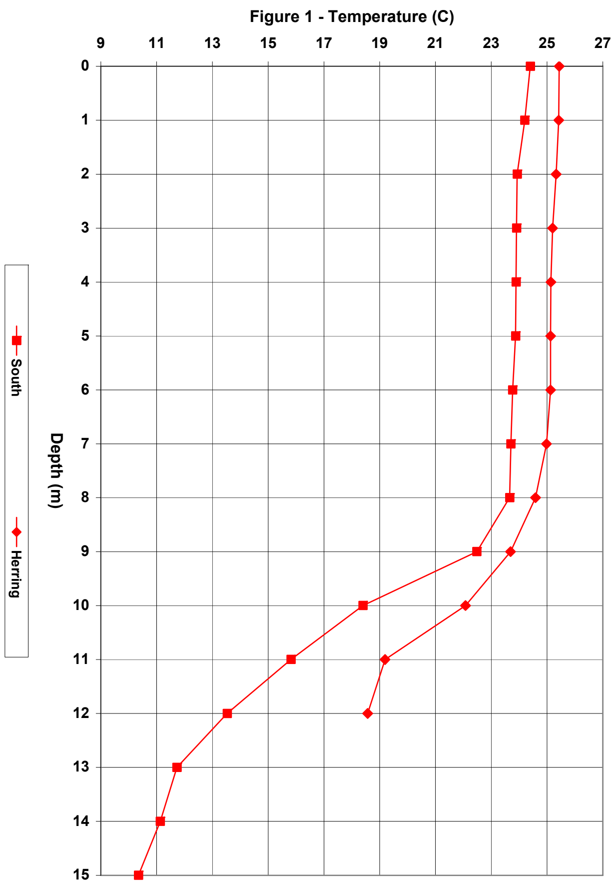


Figure 1 - Temperature (C)
9
11
13
15
17
19
21
23
25
27
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Depth (m)
South
Herring

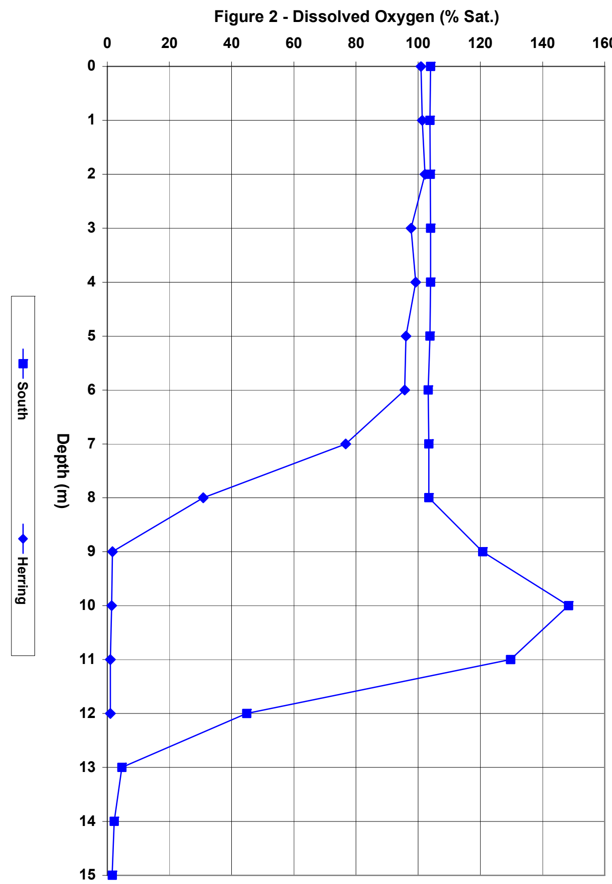


Figure 2 - Dissolved Oxygen (% Sat.)
0
20
40
60
80
100
120
140
160
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Depth (m)
South
Herring

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: November 10, 2008

RE: Pond Monitoring Program: Results for October 2008

Monitoring was conducted on Long Pond, Little Long Pond, Little Pond, and Billington Sea according to the program schedule for October. Efforts focused on Long Pond and Little Long Pond on October 11th and, on October 24th, monitoring was completed at Little Pond and Billington Sea. These ponds were the focus of monitoring efforts conducted previously in July and this report includes comparisons between both sets of data and emphasizes new observations.

Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter or less over the deepest portion of each pond basin, measurement of Secchi transparency, plankton sampling, and a macrophyte survey consisting of an inspection of the littoral zone and characterization of the aquatic plant community of each pond. Results of each of these monitoring tasks are given in the sections below.

<u>Water Column Measurements (see Table 1 on page 5 and Figures 1 and 2 on page 8)</u>

Measurement of hydrographic parameters at intervals from the surface to the bottom gives a "profile" of each parameter through the water column. Little Pond and Long Pond are deep and, therefore, become thermally stratified in summer. The profiles recorded in October show that the epilimnia of each pond had lost heat and their thermoclines had been eroded downward by wind-induced turbulence in comparison to the profiles recorded in July. This weakening of stratification structure is a seasonal process and leads eventually to fall "turnover" when the entire water column is mixed by wind energy and becomes homogeneous.

In the case of Little Pond, the water column was mixed to a depth of 11 meters with the bottom four meters comprising a residual hypolimnion exhibiting hypoxia (Figure 1). Long Pond was mixed to a depth of 10 meters, but this mixed stratum retained more heat (and a higher temperature) than the much smaller Little Pond (Figure 2). Among monitored ponds, Long Pond is exceptional for its great depth, so gains and loses heat relatively slowly due to its large volume. Intense activity by phytoplankton in Long Pond (noted in July) has supplied a constant "rain" of organic matter into the hypolimnion where October measurements show hypoxic conditions extending throughout the bottom 13 meters of the water column due to decomposition processes. Fall turnover will alleviate the hypoxic conditions in both Little and Long Ponds.

Little Long Pond and Billington Sea are shallow and remain unstratified due to the mixing action of wind-induced turbulence at the surface (noted in July). These ponds also lost heat in comparison to the profiles recorded in July (Table 1).

Conductivity decreased slightly in all four ponds monitored in October which likely reflects a widespread, seasonal decline in the loading rate of dissolved ions. Billington Sea remained the pond with the highest conductivity water due to the influence of surface drainage from an extensive watershed (noted in July; see Table 1). The other ponds are kettles lacking significant watershed inputs, having instead, hydrologic budgets that are predominately influenced by groundwater.

Since July, measurements of Secchi transparency increased in Little Long Pond from 4.5 to 7.3 feet and in Long Pond from 10 to 16.5 feet (Table 1). This reflects reduced densities of phytoplankton. In contrast, transparency in Billington Sea remained the same as in July (5.5 feet) and decreased slightly in Little Pond from 20.5 feet to 19 feet.

Plankton Sampling (see Table 2 on page 6)

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

Little Pond was unique among the monitored ponds in that none of the organisms important in the July phytoplankton community were noteworthy in October. Instead, the community was dominated exclusively by the cyanophyte *Microcystis* which was not detected in July. *Microcystis* is a common member of summer and autumn plankton communities in a variety of freshwater systems.

Phytoplankton communities of the other ponds exhibited some consistency in composition between July and October. Specifically, Little Long Pond was again dominated by the chrysophyte *Dinobryon* with significant representation by the diatom *Rhizosolenia* and also by *Microcystis*. Among the phytoplankton of Long Pond, *Staurastrum* and *Aphanocapsa* were again significant with the addition of *Synedra* and *Tabellaria* as important members in October. However, *Microcystis* was reduced from very common in July to rare in October. Lastly, Billington Sea had the most diverse phytoplankton community with five taxa preeminent: *Pediastrum*, *Melosira*, and *Microcystis* as in July, with the addition of *Fragilaria* and *Coelosphaerium* as important members in October. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

Macrophyte Survey (see Table 3 on page 7)

The littoral zone of Little Pond is generally fringed with emergent Rushes (*Juncus*) and Pickerel-weed (*Pontederia*) with submerged vegetation mostly limited to low-growing species such as Pipewort (*Eriocaulon*), Golden-pert (*Gratiola*), and Spike-rush (*Eleocharis*) that form a "carpet" over patches of substrate. In deeper water, Terete Arrowhead (*Sagittaria teres*) forms dense, localized beds. The floating pads of White Waterlily (*Nymphaea*) and Yellow Waterlily (*Nuphar*) occupy the extreme southwestern corner of the pond accompanied by emergent Water-willow (*Decodon*) along this area of shoreline. A small patch of Cattail (*Typha*) grows emergent on the western shoreline adjacent to a private dwelling having a waterfront terraced with tires. One specimen of Pondweed (*Potamogeton*) was observed in the northeastern cove of the pond. In addition to carpet-like growth of submerged vegetation, the littoral zone of Little Pond is characterized by extensive areas of sand, gravel, and cobble and deposits of leaf litter and other organic material. No alien plant species were observed.

Long Pond is similar to Little Pond (described above) in that the littoral zone is generally fringed with emergent vegetation with little submerged growth. In the case of Long Pond, this shoreline fringe generally consists of Slender-leaved Goldenrod (*Euthamia*, formerly *Solidago*), Swamp Candles (*Lysimachia*), and Blue Flag (*Iris*). An isolated patch of Narrow-leaved Cattail (*Typha angustifolia*) is growing emergent at the northern end of the pond on the shore almost directly opposite from the public boat ramp (visible from the ramp facing S.S.W.). Additionally, an isolated patch of emergent Bulrush (*Scirpus*) is located on the shore of the promontory that forms the northern margin of the western cove. Submerged vegetation is mostly limited to Pipewort (*Eriocaulon*), Golden-pert (*Gratiola*), and Spike-rush (*Eleocharis*) growing between embedded cobble substrates. In addition to cobble, sand and gravel compose littoral zone substrates throughout Long Pond. No alien plant species were observed.

The pond map generated by MassWildlife states that outflow from Long Pond is via groundwater and "reportedly a pipe into Halfway Pond" (MassWildlife Map of Long Pond, Updated: March 7, 2007 S.T.H.). Careful inspection of the shoreline within the western cove of Long Pond closest to Halfway Pond confirmed the existence and function of this connection. The "pipe" is actually an antiquated wooden structure entrenched on the bottom in shallow water. It consists of vertical planks forming walls about 1.5 feet apart that extend out from the bank about 20 feet into the cove forming an open trough, but the bottom is filled with sand, so is not visible. At the point where this structure enters the bank a plank covers the trough forming a roof. Flow out of Long Pond was verified by agitating submerged fine sand and organic debris near the entrance of this structure and observing the movement of particles consequently suspended. The suspended particles were rapidly entrained in a current and drawn into the structure's mouth. The precise location and condition of the downstream end of this structure, in Halfway Pond, will be determined in June 2009 according to the monitoring program schedule.

Billington Sea supports a great diversity of aquatic plants. Unfortunately, the alien Fanwort (*Cabomba caroliniana*) was observed, apparently having been introduced since the last macrophyte survey was completed in June of 2002 (Aquatic Control Technology, Inc. letter dated January 7, 2003). Fanwort is indigenous to North America, but originally ranged west and/or south of New England so is considered alien in Massachusetts. It does proliferate to nuisance densities in many water bodies and has been documented in Plymouth as early as 2001 in the Eel River.

Fanwort appears to occupy most of the deeper, central portion of the western basin. This was determined by using a throw rake at various locations because water opacity prevented plants and the bottom from being visible from the surface. Fanwort is also present in the tributary inlet from Briggs Reservoir along the south shore and in the extreme southeastern corner of the pond. Deep substrates in the main (eastern) basin of Billington Sea appear to be occupied mainly by native Waterweed (*Elodea*). Other native plants dominate in shallow littoral zone areas (see below). It remains to be seen if Fanwort expands its distribution, but the existing dense stands of native plants will function beneficially to delay and maybe restrict the spread of this invasive plant.

Native plants commonly observed in Billington Sea included Waterweed (*Elodea*), Pondweed (*Potamogeton*), Tapegrass (*Vallisneria*), and Bladderwort (*Utricularia*). Interestingly, Mint (*Mentha*) was observed growing completely submerged in the small cove indenting the north shore of the western basin. Also in the western basin, along the southwestern shore, beds of Terete Arrowhead *(Sagittaria teres*) were conspicuous in July with their white flowers emergent above the surface. This portion of shoreline also supported many globular, gelatinous bryozoan colonies (*Pectinatella magnifica*) growing attached to the bottom.

Although much smaller than Billington Sea, Little Long Pond is similar in being shallow and in having water of limited transparency due to high densities of phytoplankton. Throw rake sampling in deeper portions of Little Long Pond show that another similarity to Billington Sea is extensive coverage by Waterweed (*Elodea*). This plant appears to dominate on substrates beyond the limit of visibility in central portions of Little Long Pond. The other important macrophyte in Little Long Pond is Water-willow (*Decodon*) which forms a nearly continuous fringe of emergent growth along much of the shoreline. A variety of other emergent plants are prominent in the small southeastern bay adjacent to the outflow channel from Little Long to Long Pond including Throughwort (*Eupatorium*), Rush (*Juncus*), Bulrush (*Scirpus*), and Common Cattail (*Typha latifolia*). Also in this small bay, Yellow Waterlily (*Nuphar*) grows in patches a short distance out from the public landing. No alien plant species were observed.

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN OCTOBER 2008

Little Pond on October 24, 2008 (Secchi Transparency = 19 feet / 5.8 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	13.44	78.8	88.3	9.21	6.44
1	13.44	78.8	87.1	9.09	6.43
2	13.43	78.9	86.9	9.06	6.43
3	13.43	78.9	87.3	9.11	6.42
4	13.43	78.9	87.2	9.10	6.40
5	13.43	78.9	87.3	9.11	6.40
6	13.39	78.9	87.1	9.09	6.38
7	13.40	78.9	86.9	9.08	6.37
8	13.34	79.1	85.2	8.91	6.35
9	13.35	78.8	84.5	8.83	6.33
10	13.22	79.1	80.5	8.44	6.30
11	12.50	79.1	56.0	5.96	6.16
12	9.29	98.4	2.6	0.30	5.81
13	8.65	105.5	2.1	0.24	5.62
14	8.50	108.1	1.8	0.21	5.48
15	8.47	110.2	1.7	0.20	5.45

Billington Sea on October 24, 2008 (Secchi Transparency = 5.5 feet / 1.7 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	10.99	123.3	105.3	11.61	7.70
1	10.81	123.1	104.5	11.57	7.80
2	10.27	121.5	103.1	11.56	7.84
3	10.26	122.5	99.7	11.18	7.85
4	10.27	123.0	95.7	10.72	7.87

Little Long Pond on October 11, 2008 (Secchi Transparency = 7.3 feet / 2.2 meters; on bottom)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	15.84	70.0	112.4	11.13	8.20
1.0	15.39	70.3	112.8	11.27	8.29
2.0	15.01	71.3	115.3	11.63	8.26
2.2	14.97	71.3	116.0	11.71	8.23

Long Pond on October 11, 2008 (Secchi Transparency = 16.5 feet / 5 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	17.97	66.0	109.3	10.35	8.78
1	17.90	65.3	106.1	10.07	8.93
2	17.75	65.3	106.2	10.10	8.96
3	17.72	65.3	105.8	10.07	8.96
4	17.67	65.2	105.8	10.08	8.97
5	17.61	65.2	105.4	10.06	8.98
6	17.58	65.3	105.7	10.09	8.98
7	17.56	65.3	105.2	10.05	8.99
8	17.55	65.3	104.2	9.95	8.98
9	17.51	65.2	104.3	9.97	8.98
10	17.12	65.3	103.6	9.99	8.99
11	15.04	64.7	114.1	11.49	9.00
12	10.49	63.8	109.6	12.23	9.05
13	8.40	62.9	89.1	10.45	9.03
14	7.48	62.9	47.7	5.72	8.86
15	6.88	63.1	19.8	2.41	8.73
16	6.63	63.8	3.1	0.38	8.57
17	6.43	64.4	2.3	0.28	8.46
18	6.20	64.1	1.8	0.22	8.35
19	6.15	63.9	1.6	0.20	8.31
20	6.02	63.9	1.5	0.19	8.25
21	5.97	64.5	1.5	0.19	8.19
22	5.92	65.1	1.5	0.19	8.12
23	5.91	65.5	1.5	0.18	8.03
24	5.89	65.9	1.4	0.17	7.94
25	5.89	66.2	1.4	0.17	7.86
26	5.89	66.4	1.4	0.17	7.77
27	5.88	66.9	1.4	0.17	7.69
28	5.87	67.3	1.3	0.16	7.61
29	5.87	69.6	1.3	0.16	7.44

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN OCTOBER 2008

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location			
	Long Pond (net to 10 m)	**Little Long Pond** (net to 2 m)	**Billington Sea** (net to 3 m)	**Little Pond** (net to 8 m)
Phytoplankton Taxa				
Bacillariophyceae (diatoms)				
Asterionella			R	
Cyclotella	R			
Fragilaria	R	R	**V**	R
Melosira		R	**V**	R
Navicula		R		
Nitzschia	R			
Rhizosolenia		**C**	R	
Synedra	**C**			
Tabellaria	**C**	R	R	R
Chlorophyta (green algae)				
Ankistrodesmus		R		
Arthrodesmus	R	R	R	R
Botryococcus	R		R	R
Coelastrum	R	R		
Cosmarium	R			R
Crucigenia				R
Dictyosphaerium				R
Eudorina	R			R
Kirchneriella		R		
Mougeotia				R
Nephrocytium				R
Pandorina	R			
Pediastrum	R	R	**C**	R
Quadrigula				R
Scenedesmus			R	R
Sphaerocystis	R			R
Staurastrum	**C**			R
Volvox		R		
Xanthidium	R			
Chrysophyta (yellow-green algae, excluding diatoms)				
Dinobryon	R	**V**	R	R
Mallomonas	R	O	R	R
Rhizochrysis	R		R	R
Cyanophyta (blue-green algae)				
Anabaena			R	R
Aphanizomenon	R			
Aphanocapsa	**V**			R
Coelosphaerium			**C**	R
Dactylococcopsis	R			R
Gloeotrichia	R			
Gomphosphaeria				R
Microcystis	R	**V**	**C**	**A**
Oscillatoria			R	R

TABLE 3 - MACROPHYTES OF PLYMOUTH PONDS OBSERVED IN 2008*

SPECIES NAME	COMMON NAME	Little Pond	Billington Sea	Long Pond	Little Long
Submerged Plants					
Cabomba caroliniana	Fanwort (alien)		▲		
Callitriche sp.	Water-starwort		x		
Elatine minima	Waterwort	x	x	x	x
Eleocharis sp.	Spike-rush	x	x	x	x
Elodea nuttallii	Waterweed		▲		▲
Eriocaulon sp.	Pipewort	x	x	x	
Gratiola aurea	Golden-pert	x	x	x	
Lobelia dortmanna	Water Lobelia				x
Mentha sp.	Mint		x		
Myriophyllum humile	Water-milfoil		x		
Najas flexilis	Naiad		x		
Potamogeton natans	Pondweed		x		
Potamogeton perfoliatus	Pondweed		▲		
Potamogeton pusillus	Pondweed		x		
Potamogeton sp.	Pondweed	x			
Sagittaria teres	Arrowhead	x	x		
Utricularia intermedia	Bladderwort		x		
Utricularia radiata	Bladderwort				x
Utricularia vulgaris	Bladderwort		x		
Utricularia sp.	Bladderwort	x			
Vallisneria americana	Tapegrass		▲		
Floating-Leaved Plants					
Nuphar variegata	Yellow Waterlily	x	x		x
Nymphaea odorata	White Waterlily	x	x		
Emergent Plants					
Decodon verticillatus	Water-willow	x	x		▲
Eupatorium perfoliatum	Throughwort				x
Euthamia (formerly *Solidago*) *tenuifolia*	Slender-leaved Goldenrod			▲	
Hypericum perforatum	Common St. Johnswort (alien)			x	
Iris versicolor	Blue Flag			▲	
Juncus sp.	Rush	▲	x	x	x
Lysimachia terrestris	Swamp Candles			▲	
Lythrum salicaria	Purple Loosestrife (alien)		x		
Pontederia cordata	Pickerel-weed	▲	x		
Scirpus sp.	Bulrush			x	x
Sparganium sp.	Bur-reed		x		
Typha angustifolia	Narrow-leaved Cattail			x	
Typha latifolia	Common Cattail	x			x

*** dominant species indicated with a triangle ▲**

Figure 1 – LITTLE POND

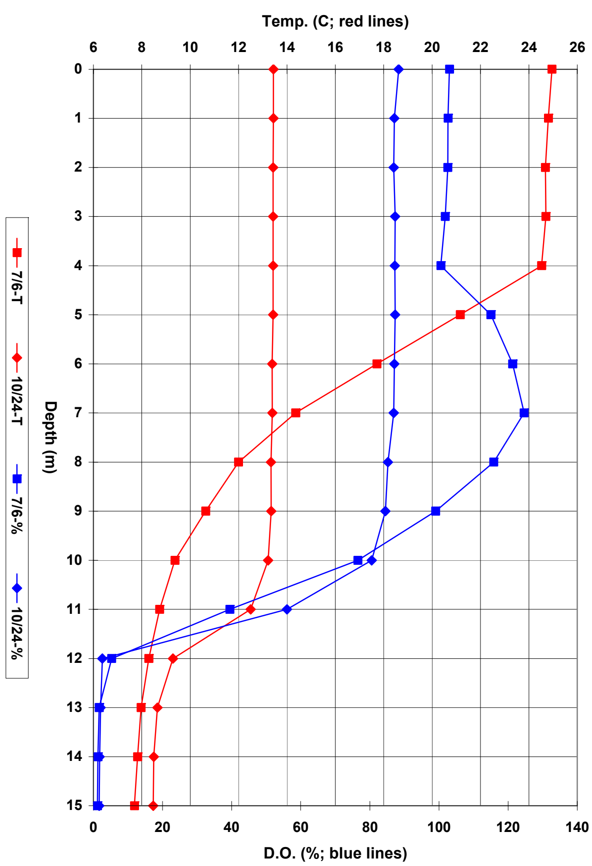
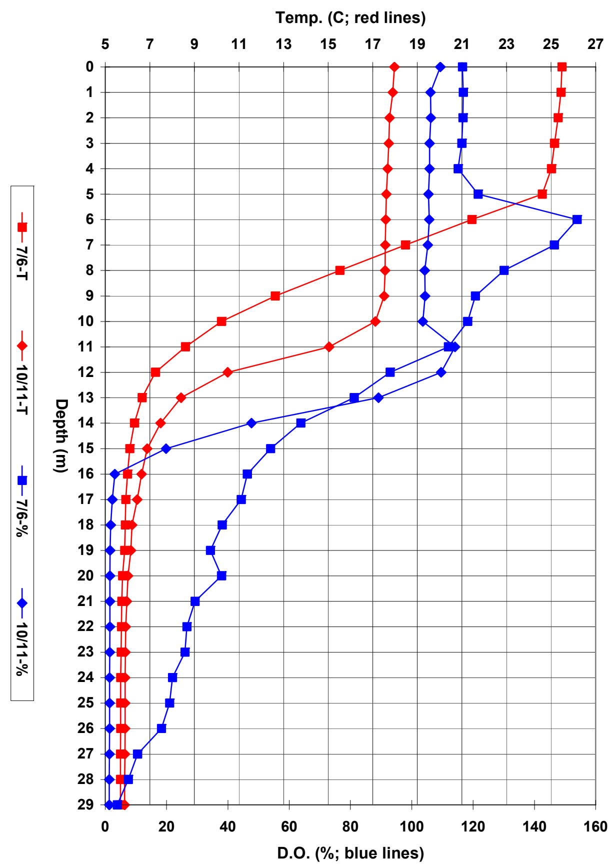


Figure 2 – LONG POND



MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: May 5, 2009

RE: Pond Monitoring Program: Results for April 2009

Monitoring was conducted on Great Herring Pond (April 18th) and Great South Pond (April 25th) according to the program schedule for April. Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter over the deepest portion of each pond basin, measurement of Secchi transparency, and plankton sampling. An inspection of the littoral zone of each pond was also conducted, but growth by rooted aquatic plants is only getting started this early in spring, so the most notable observations were of amphibian egg masses and a higher water elevation (see below). The aquatic plant community of each pond was characterized during the prior monitoring effort last August. Results of April monitoring tasks are given in the sections below.

<u>Water Column Measurements (see Table 1 on page 2)</u>

Measurement of hydrographic parameters at intervals from the surface to the bottom gives a "profile" of each parameter through the water column. At this early season of the year, the development of thermal stratification is just beginning, so both ponds had water columns that were nearly uniform from top to bottom. As the days get longer and warmer, a thermocline will develop in each pond and eventually each will exhibit thermal structure and water column characteristics similar to those documented last August.

Values of specific conductivity in each pond were similar to those recorded last August. As noted at that time, the very low values recorded in Great South Pond are characteristic of pristine kettle ponds situated in glacial deposits of stratified drift. The contrast in pH values between the two ponds is also similar to last August with Great South Pond having consistently lower values.

Measurements of Secchi transparency showed the greatest change in Great South Pond with transparency reduced to 21 feet compared to an exceptional reading of 30 feet last August. This is a typical pattern for an "oligotrophic" system such as Great South Pond because these systems generally support a brief spurt of growth by diatoms each spring, which consumes most of the scant supply of nutrients, followed by a summer period of minimal phytoplankton productivity.

Consequently, the lower transparency measurement this April likely coincided with peak densities of diatoms (prominent in the plankton sample, see below) whereas this summer, when densities of phytoplankton are likely very low due to scarce nutrients, water clarity will be restored to around 30 feet like last August.

Great Herring Pond, a much more productive system, showed a slight increase in transparency from 10 feet last August to 11.5 feet this April, but this fluctuation is minor compared to those that might be observed with more frequent measurement. A baseline survey of Great Herring Pond conducted by DWPC/DEQE (now DEP) on July 21, 1981 documented a Secchi transparency measurement of 7.9 feet (2.4 m).

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN APRIL 2009

Great Herring Pond on April 18, 2009 (Secchi Transparency = 11.5 feet / 3.5 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	10.13	76.5	108.5	12.21	6.16
1	10.09	76.7	108.5	12.22	6.13
2	9.84	76.5	108.2	12.26	6.12
3	9.70	76.7	107.6	12.23	6.09
4	9.62	76.3	107.1	12.21	6.07
5	9.46	76.3	106.4	12.16	6.02
6	9.43	76.3	105.9	12.11	6.03
7	9.39	76.3	105.9	12.12	6.02
8	9.39	76.3	105.8	12.12	6.01
9	9.38	76.4	105.7	12.11	5.99
10	9.37	76.4	105.6	12.10	5.97
11	9.36	76.4	103.8	11.90	5.87
12	9.31	76.4	102.0	11.70	5.83
12.5	9.33	76.6	102.5	11.75	5.78

Great South Pond on April 25, 2009 (Secchi Transparency = 21 feet / 6.4 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	10.82	40.2	105.9	11.73	5.73
1	10.80	40.2	105.8	11.72	5.70
2	10.70	40.3	106.0	11.77	5.73
3	10.64	40.3	105.7	11.76	5.72
4	10.61	40.2	105.6	11.75	5.71
5	10.58	40.2	105.5	11.75	5.70
6	10.57	40.4	105.2	11.71	5.66
7	10.42	40.2	105.0	11.73	5.65
8	10.06	40.2	104.2	11.75	5.65
9	9.92	40.2	104.0	11.76	5.59
10	9.69	40.1	102.9	11.70	5.55
11	9.48	40.3	102.3	11.68	5.53
12	9.29	40.3	100.5	11.54	5.48
13	9.27	40.3	99.5	11.42	5.43
14	8.95	40.6	96.1	11.13	5.38
15	8.82	40.3	93.3	10.83	5.37

<u>Plankton Sampling (see Table 2 on page 4)</u>

Plankton in each pond was sampled using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

Both ponds exhibited diverse phytoplankton communities. The phytoplankton community of Great Herring Pond was dominated by the diatom *Asterionella* and the chrysophyte *Uroglenopsis* with significant representation by the diatom *Tabellaria* and the chrysophyte *Dinobryon*. These latter two taxa were also important in the phytoplankton community of Great Herring Pond last August.

Similar to Great Herring Pond, the phytoplankton community of Great South Pond was dominated by the diatom *Asterionella* and the chrysophyte *Uroglenopsis*. Two other diatoms contributed significantly to the community of Great South Pond: *Fragilaria* and *Tabellaria*. None of the taxa of importance last August were significant this April. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

Littoral Zone Inspection

In Great Herring Pond, egg masses of the Spring Peeper (*Pseudacris crucifer*) were observed as ropey, whitish, jelly-like deposits resting on the bottom in water a few inches deep along undeveloped portions of the western shoreline. These covered extensive areas of substrate and must have been laid only a short time earlier because they had not been colonized by periphyton. Green tufts of macroscopic algae were also evident growing on the bottom in shallow water and microscopic analysis showed these to be the chlorophytes *Draparnaldia* and *Chaetophora*.

The water level in Great South Pond was 2 to 3 feet higher than observed last August. The pipe and dug channel between adjacent Boot Pond and Great South Pond was “high and dry” last August, but this connection was functioning in April with water flowing out of Boot Pond and discharging into Great South Pond. Clumps of pussy willow (*Salix discolor*) grow emergent in shallow water along many areas of shoreline in Great South Pond, some forming shrubby “islands” in the high water, and these were conspicuously in blossom. Lastly, in the small cove in the extreme southwest corner of the pond where the alien Fanwort (*Cabomba caroliniana*) was observed last August, only Water-starwort (*Callitriche*) was evident as bright green, new growth.

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN APRIL 2009

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location	
	Great Herring Pond (net to 8 m)	**Great South Pond** (net to 10 m)
Phytoplankton Taxa		
Bacillariophyceae (diatoms)		
Asterionella	**V**	**V**
Cyclotella	R	R
Fragilaria		**C**
Melosira	R	R
Rhizosolenia	R	R
Synedra	R	R
Tabellaria	**C**	**C**
Chlorophyta (green algae)		
Arthrodesmus	R	R
Botryococcus		R
Closterium		R
Gloeocystis	R	
Kirchneriella	R	
Micractinium	R	
Mougeotia		R
Sphaerocystis		R
Staurastrum	R	
Xanthidium		
Chrysophyta (yellow-green algae, excluding diatoms)		
Dinobryon	**C**	R
Mallomonas		
Rhizochrysis	R	
Synura		
Uroglenopsis	**V**	**V**
Cyanophyta (blue-green algae)		
Anabaena	R	R
Dactylococcopsis		R
Lyngbya	R	
Microcystis	R	
Pyrrhophyta (dinoflagellates)		
Ceratium		
Peridinium	R	

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: October 26, 2009

RE: Pond Monitoring Program: Results for June and July 2009

Monitoring was conducted on Gallows Pond and Halfway Pond on June 13th according to the program schedule for June. However, monitoring of Round Pond and Bloody Pond was delayed until July 12th due to inclement weather that persisted for much of the season. Access to these last named ponds was kindly provided by Ms. Judy Savage and Mr. Ethan Warren respectively. Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter over the deepest portion of each pond basin, measurement of Secchi transparency, plankton sampling, and a macrophyte survey consisting of an inspection of the littoral zone and characterization of the aquatic plant community of each pond.

Additionally, the first task completed at Gallows Pond and Round Pond was to record and map water depths along multiple transects across the ponds in order to identify the deepest contour of each basin. This was necessary because no bathymetric map exists for these ponds while maps of most other ponds are available on the MassWildlife website. Soundings show Gallows Pond to reach a maximum depth of about 31 feet with the deepest area located mostly to the northeast of the center of the basin. Soundings show Round Pond to reach a maximum depth of about 24 feet with the deepest area located slightly south of the center of the basin. Bathymetric maps of each pond have been sent in a separate communication. Preliminary monitoring data were generated on Gallows Pond and Halfway Pond in 2007 and these data are included in this report for comparison to the 2009 results given in the sections below.

<u>Water Column Measurements (see Table 1 on page 3)</u>

Measurement of hydrographic parameters at intervals from the surface to the bottom give a "profile" of each parameter through the water column. Gallows Pond is deep and, therefore, become thermally stratified in summer. The warm, less dense surficial layer of the water column ("epilimnion") extends to a depth of 6 meters in this ponds (Figure 1). Below the epilimnion, a temperature gradient ("thermocline") exists extending to cooler, denser water with depth. Stratification structure in Gallows Pond consists of a thermocline extending to the bottom and lacks a clearly defined hypolimnion (a bottom stratum having nearly uniform temperature). This is due to the great clarity of the water (Secchi transparency of 28 feet; discussed below) and the attendant deep penetration of solar radiation into the water column.

The epilimnion of Gallows Pond was slightly supersaturated throughout its volume and oxygen concentration spiked to even higher levels in the upper portion of the thermocline at a depth of 7 meters where saturation values reach 111%. This spike in dissolved oxygen concentration at depth was also observed in 2007 and indicates an aggregation of photosynthetically active phytoplankton. Net sampling in both 2009 and 2007 showed the population of a single organism to be the cause (see below). Below this stratum, dissolved oxygen concentrations decline with depth due to decomposition of sedimenting phytoplankton.

Also noteworthy in the Gallows Pond measurements are the very low conductivity values. Conductivity values of about 32 uS/cm in Gallows Pond are the lowest recorded in any pond yet monitored with the only comparable value being 39 uS/cm observed in Great South Pond. These low values attest to extremely low concentrations of dissolved ions that are characteristic of pristine kettle ponds situated in glacial deposits of stratified drift.

Measurement of Secchi transparency also demonstrates the pristine character of Gallows Pond with an exceptional reading of 28 feet (Secchi transparency in Great South Pond last August was 30 feet). Water of this clarity is characteristic of systems having very low productivity (“oligotrophic”) and indicates that Gallows Pond supports very low densities of phytoplankton. However, phytoplankton communities are dynamic and the Secchi transparency of 24 feet recorded in July of 2007 indicate greater densities of phytoplankton present in Gallows Pond at that time.

Bloody Pond consists of two basins tenuously connected by a narrow strait. These basins are very different from each other in terms of morphometry, water quality, and biology and essentially function as two separate ponds. The north basin has slightly higher conductivity values indicating higher concentrations of dissolved ions and, likely, nutrients. The north basin has lower water clarity, as measured with the Secchi disk (11.5 feet compared to 17 feet in the south basin), indicating greater densities of phytoplankton. A contrast was also evident in the composition of the phytoplankton communities in each basin (see below).

The north basin exhibits a more pronounced thermal stratification structure in contrast to the south basin. This is due to the absorption of radiant energy by relatively high densities of phytoplankton (and reduced water transparency) in the upper portion of the water column. A steep thermocline occurred in the north basin between depths of four and five meters and dissolved oxygen concentration diminished rapidly below this gradient due to microbial decomposition of sedimenting phytoplankton.

In contrast, the greater water clarity of the south basin enabled deeper penetration of light, deeper absorption of energy, and formation of a more gradual thermocline extending to a deeper depth. The thermocline of the south basin extended between three and nine meters deep and a slight spike in dissolved oxygen concentration was present at a depth of eight meters. Similar to Gallows Pond, this spike in dissolved oxygen was the result of photosynthetic activity by an aggregation of photosynthetically active phytoplankton.

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN JUNE AND JULY, 2009
(also including Gallows Pond profile recorded in 2007)

Gallows Pond on June 13, 2009
(Secchi Transparency = 28 feet / 8.5 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	19.50	31.7	103.5	9.50	5.40
1	19.22	31.6	102.0	9.42	5.41
2	19.17	31.2	101.8	9.41	5.42
3	19.12	31.5	102.3	9.46	5.42
4	19.05	31.5	101.9	9.44	5.42
5	18.97	31.7	100.9	9.36	5.38
6	18.50	31.5	100.1	9.38	5.34
7	16.07	31.4	111.0	10.94	5.22
8	14.24	31.2	99.8	10.23	5.06
9	13.04	32.2	62.1	6.54	4.70

Gallows Pond on July 22, 2007
(Secchi Transparency = 24 feet / 7.3 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	25.50	35.7	100.5	8.23	6.55
1	25.48	35.8	100.4	8.22	6.46
2	25.45	35.7	100.2	8.21	6.44
3	25.39	35.9	100.1	8.21	6.41
4	25.35	35.8	99.8	8.19	6.43
5	25.27	35.8	98.9	8.13	6.41
6	18.83	34.5	117.6	10.94	6.35
7	15.25	34.3	104.0	10.43	6.12
8	13.84	34.4	92.3	9.55	5.91
9	13.26	34.7	64.5	6.76	5.65

Halfway Pond on June 13, 2009
(Secchi Transparency = 6.5 feet / 2 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	19.78	48.5	107.3	9.80	5.84
1	19.13	48.1	107.5	9.94	5.88
2	18.91	48.6	104.9	9.74	5.90
3	18.83	49.1	103.3	9.61	5.91
3.5	18.49	49.5	85.8	8.04	5.69

Bloody Pond/North Basin on July 12, 2009
(Secchi Transparency = 11.5 feet / 3.5 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	22.37	98.0	107.2	9.31	5.52
1	22.06	98.1	107.5	9.39	5.57
2	21.99	98.1	107.7	9.42	5.67
3	21.94	97.8	107.7	9.42	5.71
4	21.65	98.2	106.4	9.36	5.74
5	18.51	100.2	78.8	7.38	5.39
6	17.69	100.3	24.1	2.30	5.01
7	17.05	100.9	2.6	0.25	5.02

Bloody Pond/South Basin on July 12, 2009
(Secchi Transparency = 17 feet / 5.2 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.3	23.13	92.0	105.8	9.05	5.55
1	23.10	91.7	105.7	9.05	5.64
2	22.91	91.7	105.8	9.09	5.70
3	22.76	92.0	105.5	9.09	5.78
4	21.71	91.5	104.2	9.15	5.79
5	20.72	91.2	103.9	9.31	5.79
6	19.31	90.3	92.7	8.54	5.72
7	17.85	90.3	72.4	6.88	5.38
8	14.96	87.5	81.3	8.20	5.25
9	12.50	88.1	58.5	6.23	5.00
10	11.71	87.6	28.7	3.11	4.85
11	11.09	95.3	3.0	0.33	4.94

Round Pond on July 12, 2009
(Secchi Transparency = 18 feet / 5.5 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	22.59	47.1	104.1	9.00	5.24
1	22.58	47.1	104.1	9.00	5.25
2	22.56	47.1	103.7	8.97	5.28
3	22.52	46.8	102.5	8.87	5.27
4	22.46	47.1	102.9	8.92	5.25
5	22.35	47.3	102.1	8.87	5.21
6	22.26	47.4	102.3	8.90	5.24
7	21.56	48.9	87.8	7.74	5.16

Round Pond is shallow and transparent enough to gain heat uniformly throughout its water column and not undergo thermal stratification. Supersaturated values of dissolved oxygen indicate penetration of enough light to sustain photosynthesis nearly throughout the water column.

In contrast to the water column profiles of the deep ponds discussed above, Halfway Pond is shallow and remains unstratified due to the mixing action of wind-induced turbulence at the surface. Similar to other shallow ponds being monitored such as Billington Sea and Little Long Pond, Halfway Pond gains heat throughout the water column during summer (Table 1). Values of other parameters are also uniform generally throughout the water column. Halfway Pond was supersaturated with dissolved oxygen from the surface almost to the bottom reflecting intense photosynthetic activity by phytoplankton. Halfway Pond had a low Secchi transparency of 6.5 feet due to high densities of phytoplankton.

Plankton Sampling

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

The sample from Gallows Pond was remarkable in being dominated by the ciliate protozoan *Climacostomum* (Table 2 on page 5). This ciliate was tentatively, but incorrectly identified as *Tintinnopsis* in 2007 based on inspection of a preserved sample. However, the recent sample was split so that one portion retained live organisms (was not preserved with Lugol's Solution) and observations of living specimens enabled positive identification. In particular, this ciliate possesses numerous small green algae living symbiotically within its cell body (endosymbiotic algae; also know as zoochlorellae). A dense aggregation of *Climacostomum* at a depth of 7 meters likely is the cause of the spike in dissolved oxygen to supersaturated concentrations due to photosynthetic activity by the algal endosymbiotes. As a ciliate, this organism is able to adjust its vertical position in the water column and apparently migrated to the depth where the combination of temperature, light intensity, nutrients, and quiescent conditions below the thermocline were optimum for growth. This organism and the associated dissolved oxygen spike at depth have been observed consistently in the years 2007 and 2009.

Halfway Pond was dominated by the diatoms *Asterionella* and *Melosira*, but the cyanophyte *Anabaena* was also a significant component of the community (Table 3 on page 6). In August of 2007, *Anabaena* was ascendant over all other organisms in the community and this may be a pattern that recurs every summer in Halfway Pond.

Round Pond was dominated by the common dinoflagellate *Peridinium* (Table 4 on page 7). Members of this group are known to ingest bacteria, but are also photosynthetic as shown by the supersaturation values of dissolved oxygen discussed above. Interestingly, *Peridinium* was also a significant component of the community of the north basin of Bloody Pond, but this community was dominated by the diatoms *Asterionella* and *Tabellaria* (Table 4). The south basin of Bloody Pond contrasted sharply with the north basin with *Tabellaria* being the only significant member of the plankton common to both basins. The south basin exhibited an aggregation of *Climacostomum* at a depth of 8 meters similar to Gallows Pond (discussed above) as well as significant representation by the chrysophyte *Dinobryon*. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

TABLE 2 - RESULTS OF GALLOWS POND PHYTOPLANKTON SAMPLING CONDUCTED IN 2007 AND 2009
(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

Phytoplankton Taxa	**July 22, 2007**	**June 13, 2009**
Bacillariophyceae (diatoms)		
Asterionella	R	
Attheya	R	
Navicula	R	
Nitzschia	R	
Rhizosolenia	R	
Tabellaria	R	R
Chlorophyta (green algae, excluding desmids)		
Ankistrodesmus	R	
Coelastrum	R	
Crucigenia		R
Mougeotia	R	
Gloeocystis		R
Pediastrum	R	
Radiofilium	R	
Chrysophyta (yellow-green algae, excluding diatoms)		
Dinobryon	R	R
Mallomonas	R	R
Cyanophyta (blue-green algae)		
Anabaena	R	**C**
Aphanocapsa	R	R
Dactylococcopsis		R
Oscillatoria	R	
Rhabdoderma	R	
Desmidiaceae (desmids)		
Arthrodesmus		R
Bambusina	R	
Gonatozygon	R	
Staurastrum	R	
Pleuroteanium		R
Triploceras	R	
Xanthidium	R	R
Pyrrhophyta (dinoflagellates)		
Peridinium	R	R
Protozoa		
Climacostomum *	**A**	**A**
Phacus	R	

* This ciliate was tentatively, but incorrectly identified as *Tintinnopsis* in 2007. Additional observations in 2009 confirm the identity given above.

TABLE 3 - RESULTS OF HALFWAY POND PHYTOPLANKTON SAMPLING CONDUCTED IN 2007 AND 2009

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

Phytoplankton Taxa	**August 26, 2007**	**June 13, 2009**
Bacillariophyceae (diatoms)		
Asterionella		**V**
Cyclotella		R
Melosira		**V**
Nitzschia		R
Rhizosolenia		R
Synedra		R
Tabellaria		R
Chlorophyta (green algae, excluding desmids)		
Coelastrum	R	
Pediastrum	R	R
Scenedesmus	R	
Chrysophyta (yellow-green algae, excluding diatoms)		
Dinobryon		R
Mallomonas	R	R
Cyanophyta (blue-green algae)		
Anabaena	**A**	**C**
Aphanocapsa		R
Microcystis	R	
Desmidiaceae (desmids)		
Arthrodesmus	R	
Spondylosium		R
Staurastrum	R	R
Pyrrhophyta (dinoflagellates)		
Ceratium		R

Macrophyte Surveys (see Table 5 on page 8)

Growth of aquatic macrophytes in Gallows Pond is extremely sparse. Submerged vegetation is limited to low-growing Waterwort (*Elatine*) and Spike-rush (*Eleocharis*). Bloody Pond also supports little submerged vegetation, but emergent plants including Slender-leaved Goldenrod (*Euthamia*) and Blue Flag (*Iris*) form a fringe of growth along the southeastern shoreline. A small indentation near the tip of the westward-extending peninsula that divides the north and south basins of Bloody Pond supports lush emergent growth of Leatherleaf (*Chamaedaphne*) and Water-willow (*Decodon*).

TABLE 4 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS ON JULY 12, 2009

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

Phytoplankton Taxa	Round Pond	Bloody Pond North Basin	Bloody Pond South Basin
Bacillariophyceae (diatoms)			
Asterionella		**V**	R
Cyclotella		R	R
Rhizosolenia	R	R	
Synedra	R	R	R
Tabellaria	R	**V**	**V**
Chlorophyta (green algae)			
Arthrodesmus		R	R
Dictyosphaerium	R		
Nephrocytium		R	R
Quadrigula		R	
Spondylosium	R		R
Xanthidium			R
Chrysophyta (yellow-green algae, excluding diatoms)			
Dinobryon		R	**C**
Mallomonas	R	R	
Rhizochrysis		R	R
Synura	R		
Cyanophyta (blue-green algae)			
Anabaena	R		R
Aphanocapsa		R	R
Dactylococcopsis			R
Microcystis		R	R
Oscillatoria	R		
Pyrrhophyta (dinoflagellates)			
Peridinium	**A**	**C**	R
Protozoa			
Climacostomum			**V**

In contrast to the relatively sterile condition of Gallows and Bloody Ponds and their lack of floating-leaved vegetation, both Halfway and Round Ponds support extensive beds of this growth form. Halfway Pond supports four species of floating-leaved plants with Yellow Waterlily (*Nuphar*) and White Waterlily (*Nymphaea*) being the most abundant. Additionally, localized beds of Slender Arrowhead *(Sagittaria teres*) were observed in deeper water. In Round Pond, White Waterlily (*Nymphaea*) and Floating-heart (*Nymphoides*) were the dominant plants, usually occurring together. Scattered patches of Pondweed (*Potamogeton*) and Bladderwort (*Utricularia*) were also observed in Round Pond. No alien plant species were observed in any of these four Ponds.

TABLE 5 - MACROPHYTES OF PLYMOUTH PONDS OBSERVED IN JUNE AND JULY OF 2009*

SPECIES NAME	COMMON NAME	Gallows Pond	Halfway Pond	Round Pond	Bloody Pond
Submerged Plants					
Elatine minima	Waterwort	x			
Eleocharis sp.	Spike-rush	▲	x	x	x
Eriocaulon sp.	Pipewort			x	x
Potamogeton sp.	Pondweed			x	
Sagittaria teres	Arrowhead		x		
Utricularia sp.	Bladderwort			x	
Floating-Leaved Plants					
Hydrocotyle umbellata	Water Pennywort		x		
Nuphar variegata	Yellow Waterlily		▲		
Nymphaea odorata	White Waterlily		▲	▲	
Nymphoides cordata	Floating-heart		x	▲	
Emergent Plants					
Chamaedaphne calyculata	Leatherleaf			x	x
Decodon verticillatus	Water-willow				x
Euthamia (formerly *Solidago*) *tenuifolia*	Slender-leaved Goldenrod				▲
Iris versicolor	Blue Flag				▲
Lysimachia terrestris	Swamp Candles				x
Sisyrinchium angustifolium	Blue-eyed Grass				x

*** dominant species indicated with a triangle ▲**

In addition to the macrophytes observed in Round Pond, suspended masses of green filamentous algae were frequently evident in shallow water. These subsurface "clouds" of biomass in the water column and the algae composing them are known as metaphyton (observed previously in Great South Pond). In Round Pond, these masses were composed entirely of the green alga *Zygnema*, a common metaphytic organism.

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: April 28, 2010

RE: Pond Monitoring Program: Results for April 2010

Initial monitoring efforts were conducted on four ponds in April as follows: Clear Pond on the 18th, Boot Pond on the 19th, and Bartlett and Fresh Ponds on the 23rd. Access to the first three ponds listed was kindly provided by Ms. Diane Brennan, Mr. Bill Parker, and Ms. Christine Bostek respectively. Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) measured with a multiprobe at intervals of one meter over the deepest portion of each pond basin, measurement of Secchi transparency, and plankton sampling. Characterization of the aquatic plant community of each pond will be conducted on a subsequent visit later in the season when plant growth is more prominent.

Additionally, the first task completed at Boot Pond was to record and map water depths along multiple transects across the pond in order to identify the deepest contour of the basin. This was necessary because no bathymetric map exists for this pond. Soundings show Boot Pond to reach a maximum depth of about 36 feet with the deepest area located in the southern portion of the main basin, just north of the narrow "ankle" area. The smaller southern basin composing the "foot" has a maximum depth of about 16 feet. However, water elevation on the day these soundings were recorded appeared approximately 2 to 3 feet higher than normal (the channel connecting Boot Pond to Great South Pond across May Hill Road was "bank-full"), so depths will be correspondingly reduced when the water subsides to its normal elevation. A bathymetric map of Boot Pond will be sent in a separate communication following another visit to the pond. Monitoring results for April 2010 are presented in the sections below.

Water Column Measurements (see Table 1 on page 2)

Measurements of hydrographic parameters at intervals from the surface to the bottom give a "profile" of each parameter through the water column. Clear, Boot, and Fresh Ponds are deep enough to become thermally stratified in summer. The preliminary development of a stratification pattern is evident in these ponds which will become pronounced as summer approaches. Surface waters will continue to gain heat and form a layer of warm, less dense water known as the "epilimnion." Below the epilimnion, a temperature gradient ("thermocline") will extend to cooler, denser water with depth. Bottom waters will remain relatively cold and often become hypoxic due to microbial demand for oxygen as is evident early in these ponds.

In contrast to the water column profiles of the relatively deep ponds discussed above, Bartlett Pond is shallow and will remain unstratified due to the mixing action of wind-induced turbulence at the surface. Similar to other shallow ponds being monitored such as Billington Sea and Halfway Pond, the water column of Bartlett Pond will gain heat uniformly during summer.

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN APRIL 2010

Clear Pond on April 18, 2010
(Secchi Transparency = 17 feet / 5.2 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	12.07	182.3	94.5	10.35	5.36
1	11.95	182.6	94.2	10.35	5.33
2	11.88	182.2	93.8	10.32	5.38
3	11.76	182.8	93.3	10.30	5.40
4	10.32	186.1	93.9	10.71	5.34
5	9.18	184.4	78.5	9.20	5.39
6	8.78	197.4	46.6	5.51	5.23
6.4	8.60	203.1	14.0	1.67	5.13

Fresh Pond on April 23, 2010
(Secchi Transparency = 14.5 feet / 4.4 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	14.70	266.9	101.2	10.45	5.89
1	14.64	266.6	101.0	10.45	5.92
2	14.62	267.0	101.2	10.48	5.99
3	14.52	266.9	101.0	10.47	6.04
4	13.17	266.7	100.5	10.74	6.09
5	11.41	266.6	97.2	10.81	6.10
6	10.16	266.7	94.6	10.83	6.04
7	9.19	267.9	88.1	10.31	5.93
8	8.68	269.1	76.4	9.06	5.84
9	8.40	275.9	44.8	5.34	5.55
9.7	8.31	279.9	31.4	3.75	5.41

Boot Pond on April 19, 2010
(Secchi Transparency = 22 feet / 6.7 meters)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	12.21	32.2	97.5	10.65	5.01
1	12.20	32.2	97.4	10.64	5.08
2	12.17	32.0	97.4	10.66	5.12
3	12.14	32.0	97.0	10.62	5.15
4	12.10	32.0	96.9	10.62	5.16
5	12.04	32.2	96.8	10.61	5.16
6	9.74	31.4	98.7	11.41	5.17
7	9.26	31.6	95.6	11.19	5.12
8	9.05	31.5	89.6	10.54	5.05
9	8.85	31.8	82.8	9.78	4.94
10	8.76	32.0	71.6	8.48	4.81
10.2	8.72	32.0	65.6	7.78	4.77

Bartlett Pond on April 23, 2010
(Secchi Transparency = 4 feet / 1.2 meters; on bottom)

Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	14.33	166.4	106.4	11.09	5.90
0.6	14.30	166.8	106.3	11.09	5.94
1.0	13.36	152.4	91.2	9.71	5.80
1.25	12.92	212.3	2.5	0.27	6.33
1.32	13.18	1409.0	2.0	0.21	6.39

Despite its shallow depth, Bartlett Pond did exhibit gradients in dissolved oxygen and conductivity with depth. Bartlett Pond was supersaturated with dissolved oxygen at the surface, reflecting intense photosynthetic activity by phytoplankton, but was nearly anoxic close to the bottom. This indicates high demand for oxygen near the sediment-water interface. Also notable at this interface is the increase to very high conductivity values. It is likely that these reflect the influence of ocean storms that periodically force seawater and sediment up the outlet channel (approximately 300 meters in length) and into the pond. The high conductivity values demonstrate that deposits of storm-driven ocean sediments in Bartlett Pond contain residual salt. Moderately elevated conductivity values in Fresh Pond also reflect its close proximity to the ocean, but salt deposition in this pond is exclusively by wind-blown ocean spray.

In contrast to the high conductivity values discussed above, conductivity values in Boot Pond are very low. Conductivity values of 32 uS/cm in Boot Pond match Gallows Pond as the lowest among all ponds yet monitored. These low values attest to extremely low concentrations of dissolved ions that are characteristic of pristine kettle ponds situated in glacial deposits of stratified drift.

Measurement of Secchi transparency also demonstrates the pristine character of Boot Pond with 22 feet recorded under suboptimal conditions (strong wind). Water of this clarity is characteristic of systems having very low productivity ("oligotrophic") and indicates that Boot Pond supports very low densities of phytoplankton similar to Gallows Pond and Great South Pond. Clear Pond and Fresh Pond had moderate water clarity with Secchi transparency values of 17 and 14.5 feet respectively.

Plankton Sampling (see Table 2 on page 4)

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column except in Bartlett Pond where the net was towed horizontally due to the shallow depth of this basin. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

Clear Pond was dominated by the chrysophytes ("golden-brown algae") *Synura* and *Mallomonas* and the diatom *Asterionella*. *Mallomonas* was also significantly represented in Boot Pond, but the community was dominated by the cyanophytes ("blue-green algae") *Coelosphaerium* and filaments of *Oscillatoria*. Fresh Pond was dominated by the diatom *Asterionella* and by filaments of the chlorophyte *Spirogyra*.

Bartlett Pond was dominated by the chrysophytes *Dinobryon* and *Synura*. Additionally, this pond supports profuse growth of benthic algae (algae growing attached to the bottom). Analysis of benthic algae samples showed them to be composed mostly of the filamentous diatom *Melosira*, but also with representation by *Oscillatoria* and *Spirogyra*. All of the organisms observed in these ponds are common and typical of freshwater plankton and benthic algal communities.

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN APRIL 2010

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location			
	Clear Pond (net to 5 m)	**Boot Pond** (net to 8 m)	**Bartlett Pond** (net to 1 m)	**Fresh Pond** (net to 8 m)
Phytoplankton Taxa				
Bacillariophyceae (diatoms)				
Asterionella	**C**	R		**V**
Cyclotella	R			
Eunotia	R			
Fragilaria			R	
Melosira			R	
Navicula			R	
Nitzschia			R	
Tabellaria	R	R	R	R
Chlorophyta (green algae)				
Arthrodesmus				R
Desmidium	R			
Elakatothrix		R		
Eudorina		R	R	R
Gloeocystis				R
Mougeotia		R	R	R
Pandorina			R	
Pediastrum				O
Quadrigula	R			
Sphaerocystis		R		
Spirogyra			R	**V**
Staurastrum	R			
Zygnema	R			
Chrysophyta (yellow-green algae, excluding diatoms)				
Dinobryon	O		**A**	
Mallomonas	**C**	**C**	R	R
Synura	**A**	R	**V**	
Uroglenopsis		R	R	
Cyanophyta (blue-green algae)				
Anabaena				R
Coelosphaerium		**V**	R	
Dactylococcopsis		R		
Oscillatoria		**V**		
Phormidium				R
Pyrrhophyta (dinoflagellates)				
Ceratium	R	R		
Peridinium	R	R	R	R

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: June 5, 2010

RE: Pond Monitoring Program: Results for May 2010

Monitoring efforts were conducted on three ponds in May as follows: Big Sandy Pond and Lout Pond on the 16th and Little South Pond on the 21st. Monitoring efforts consisted of the following: water column measurements of hydrographic parameters (temperature, specific conductance, pH, and dissolved oxygen) recorded with a multiprobe at intervals of one meter over the deepest portion of each pond basin, measurement of Secchi transparency, plankton sampling, and a macrophyte survey consisting of an inspection of the littoral zone and characterization of the aquatic plant community of each pond.

Water elevations in all three ponds appeared higher than normal, especially in Big Sandy Pond where yards and beaches were flooded, water was up against building foundations (some were sandbagged), and shoreline erosion was evident including slumped banks.

An additional first task completed at Little South Pond was to record and map water depths along multiple transects across the pond in order to identify the deepest contour of the basin. This was necessary because no bathymetric map exists for this pond. Soundings show Little South Pond to reach a maximum depth of about 23 feet with the deepest area located in the eastern portion of the basin. However, water elevation on the day these soundings were recorded appeared approximately 2 to 3 feet higher than normal (water extended out beyond the gate at the access and was a few inches deep in portions of the parking area), so depths will be correspondingly reduced when the water subsides to its normal elevation. A bathymetric map of Little South Pond will be sent in a separate communication. Monitoring results for May 2010 are presented in the sections below.

<u>Water Column Measurements (see Table 1 on page 2)</u>

Measurements of hydrographic parameters at intervals from the surface to the bottom give a "profile" of each parameter through the water column. Big Sandy Pond and Lout Pond are deep enough to become thermally stratified in summer. Big Sandy Pond had an epilimnion (a surface layer of warm, less dense water) that extended to a depth of 7 meters. Between 7 and 8 meters the temperature deceased sharply from 14.5°C to 12.5°C and below this a temperature gradient ("thermocline") extended to cooler, denser water with depth. Wind-induced turbulence at the surface of these ponds causes their epilimnia to gain heat uniformly and to remain oxygenated due to constant mixing and exposure to the atmosphere. In contrast, bottom waters will remain relatively cold and often become hypoxic due to microbial demand for oxygen as is evident in these ponds.

TABLE 1 - WATER COLUMN PROFILES OF PLYMOUTH PONDS RECORDED IN MAY 2010

Big Sandy Pond on May 16, 2010 (Secchi Transparency = 19 feet / 5.8 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	16.08	82.2	102.8	10.18	5.37
1	16.04	82.4	102.8	10.19	5.44
2	15.89	82.3	102.4	10.18	5.48
3	15.81	82.3	102.2	10.18	5.52
4	15.70	82.1	101.7	10.15	5.53
5	15.21	82.1	99.4	10.03	5.55
6	14.94	82.2	97.9	9.93	5.55
7	14.55	82.4	95.1	9.73	5.52
8	12.51	81.4	70.7	7.57	5.22
9	11.12	81.3	54.8	6.06	5.04
10	10.60	81.9	45.9	5.13	4.96
11	10.11	81.9	35.8	4.05	4.91
12	9.90	82.4	28.1	3.19	4.88

Lout Pond on May 16, 2010 (Secchi Transparency = 12.5 feet / 3.8 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	19.66	37.3	105.6	9.72	4.80
1	17.95	37.0	102.3	9.74	4.87
2	15.47	36.5	99.2	9.96	4.93
3	12.43	35.6	89.6	9.61	4.74
4	8.80	36.2	74.9	8.74	4.47
5	7.53	35.7	74.5	8.98	4.45
6	6.22	36.5	68.0	8.46	4.31
7	5.65	36.6	67.8	8.56	4.31
8	5.44	36.6	62.2	7.90	4.27
9	5.24	36.9	52.8	6.73	4.22
10	5.15	37.2	37.4	4.79	4.22
10.8	5.21	45.6	2.1	0.27	4.87

Little Sandy Pond on May 21, 2010 (Secchi Transparency = 19 feet / 5.8 meters)					
Depth meters	Temp degC	SpCond uS/cm	DO %Sat	DO mg/l	pH units
0.2	18.54	41	105.8	9.96	5.22
1	18.49	41.2	105.7	9.96	5.28
2	17.71	40.9	104.6	10.02	5.32
3	17.39	40.8	104.2	10.04	5.35
4	16.78	40.5	103.2	10.08	5.36
5	16.6	40.9	101.3	9.92	5.36
6	16.42	40.9	95.1	9.35	5.27
6.9	16.32	40.9	88.1	8.68	5.17

Lout Pond is notable for the lack of a discrete and homogeneous epilimnion having instead a very steep thermocline extending from the surface down to a depth of 6 meters. This is due to the highly stained, tea-colored water that is conspicuous in this pond. The brown staining indicates high concentrations of humic substances which are dissolved organic compounds derived from the decomposition of plant material. These organic compounds readily absorb solar radiation and cause surface water to gain heat while rapidly attenuating light penetration with depth (Secchi transparency was only 12.5 feet; see below). Bottom water of Lout Pond remained very cold compared to the other ponds due to limited penetration of radiant energy. Leaf fall from the forest surrounding this small pond is the main source of plant material that decomposes and forms humic substances in the water. Another characteristic of high humic compound content is low pH (range in Lout Pond is 4.2 to 4.9) because these compounds are acidic.

In contrast to the ponds discussed above, Little South Pond is shallow and transparent enough to gain heat almost uniformly throughout its water column and not undergo thermal stratification. Supersaturated values of dissolved oxygen indicate penetration of enough light to sustain photosynthesis nearly throughout the water column.

Conductivity values in Big Sandy Pond are moderately elevated likely due to the influence of very dense shoreline development. Conductivity values in Lout Pond and Little South Pond are very low. These low values attest to extremely low concentrations of dissolved ions that are characteristic of pristine kettle ponds situated in glacial deposits of stratified drift.

Big Sandy Pond and Little South Pond had good water clarity each having a Secchi transparency value of 19 feet. The reading in Little South Pond was made difficult by strong winds and likely would have been somewhat greater under optimal viewing conditions. Water clarity in Lout Pond was limited to 12.5 feet due to staining by humic substances as discussed above. This finding appears to contradict DFW records which state "water color is clear and transparency is excellent at 19 feet" (DFW Pond Map text updated: March 9, 2007). It may be that the disparity is attributable to different seasons when the measurements were recorded, an exceptional leaf fall that temporarily increased the concentration of humic compounds, or, more likely, represents a long-term shift in water quality since the original DFW observations.

Plankton Sampling (see Table 2 on page 4)

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column. Samples were preserved in the field using Lugol's Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance.

Big Sandy Pond was dominated by the chlorophyte ("green algae") *Chlorella* which accumulated as a bright green surface scum along portions of the windward shoreline. Another chlorophyte important in Big Sandy Pond was *Elakatothrix*. Both the foregoing taxa were also important in Little South Pond along with the chrysophyte ("golden-brown algae") *Mallomonas*. Lastly, Lout Pond was dominated by the chlorophyte *Dictyosphaerium* and, secondarily, by *Mallomonas*. All of the organisms observed in these ponds are common and typical of freshwater plankton communities.

Macrophyte Surveys

Growth of aquatic macrophytes in Big Sandy Pond and Little South Pond is extremely sparse. Submerged vegetation is limited to low-growing Waterwort (*Elatine*) and Spike-rush (*Eleocharis*). Lout Pond also supports little submerged vegetation, but scattered specimens of Water-purslane (*Ludwigia palustris*) and Pondweed (*Potamogeton*) were observed in shallow water. Also in Lout Pond, small patches of Yellow Waterlily (*Nuphar*) and tangled masses of Bladderwort (*Utricularia*) were evident along the western shoreline. No alien plant species were observed in any of these three ponds.

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN MAY 2010
(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location		
	Big Sandy Pond (net to 10 m)	**Lout Pond** (net to 8 m)	**Little South Pond** (net to 5 m)
Phytoplankton Taxa			
Bacillariophyceae (diatoms)			
Asterionella	R	O	R
Cyclotella	R		**C**
Fragilaria			R
Synedra	R		
Tabellaria	R	R	R
Chlorophyta (green algae)			
Arthrodesmus	R	O	
Botryococcus	R	R	R
Chlorella	**A**		**V**
Closterium		R	
Cosmarium	R		
Crucigenia	O	R	O
Desmidium			R
Dictyosphaerium	O	**A**	
Elakatothrix	**C**		**V**
Gloeocystis	O	R	
Kirchneriella			R
Mougeotia		R	
Nephrocytium	R		
Oocystis	R		
Pediastrum	R		R
Quadrigula	R		
Scenedesmus	R		
Sphaerocystis	R	R	R
Spondylosium	R		
Staurastrum	R		R
Zygnema			R
Chrysophyta (yellow-green algae, excluding diatoms)			
Chrysosphaerella			R
Dinobryon	**C**	R	R
Mallomonas	O	**C**	**V**
Uroglenopsis	R		
Cyanophyta (blue-green algae)			
Anabaena	R	R	R
Coelosphaerium	R		
Oscillatoria	R		
Pyrrhophyta (dinoflagellates)			
Ceratium		O	
Peridinium	R	R	R
Protozoa			
Difflugia	R		

MEMO

To: David Gould and Kim Michaelis
DPW Environmental Management
11 Lincoln Street
Plymouth, MA 02360

Date: June 30, 2010

RE: Pond Monitoring Program: Results for June 2010

Concluding monitoring efforts were conducted on the four ponds initially investigated in April. These ponds and the dates of June monitoring are as follows: Clear Pond and Boot Pond on the 20th, Fresh Pond on the 26th, and Bartlett Pond on the 27th. Monitoring efforts focused on aquatic vegetation (macrophyte) surveys because, during the April monitoring effort, plant growth was only in the early stages of development. Macrophyte surveys consisted of an inspection of the littoral zone and characterization of the aquatic plant community of each pond. Additionally, plankton samples were collected in each pond to supplement those collected in April. Monitoring results for June 2010 are presented in the sections below.

<u>Macrophyte Surveys (see Table 1 on page 2)</u>

Clear Pond supports a diverse macrophyte flora with submerged growth dominated by low-growing Pipewort (*Eriocaulon*), Spike-rush (*Eleocharis*), Waterwort (*Elatine minima*), and Golden-pert (*Gratiola aurea*). Terete Arrowhead (*Sagittaria teres*) and Bladderwort (*Utricularia*) dominate in deeper portions of the littoral zone. Patches of emergent growth consisting mostly of Rush (*Juncus*) and Bur-reed (*Sparganium*) are common. A small stand of Common Reed (*Phragmites australis*) is established at the northern end of the pond adjacent to the inlet channel. Common Reed is considered an invasive species, although its status as an alien or nonindigenous species is in question. Also, a small stand of the alien species Narrowleaf Cattail (*Typha angustifolia*) is located on the northeastern shoreline. This native of Eurasia is potentially invasive and is known to hybridize with the native Common Cattail (*Typha latifolia*). The macrophyte community of Clear Pond is not very different from that documented in the historical survey report (undated) by Lyons Skwares Associates of Westwood, Massachusetts.

Growth of aquatic macrophytes in Boot Pond is sparse compared to the other three ponds. Submerged growth consists mainly of low-growing Pipewort and Spike-rush in most areas with Terete Arrowhead common in deeper water. However, dense beds of Water-starwort (*Callitriche*), Water-milfoil (*Myriophyllum humile*), and Bladderwort exist in the "toe" portion of the pond. Floating pads of Yellow Waterlily (*Nuphar variegata*) form small patches in the "toe" and eastern "ankle" area of the pond. A small stand of Common Reed is established at the extreme northeastern corner of Boot Pond adjacent to May Hill Road.

TABLE 1 - MACROPHYTES OF PLYMOUTH PONDS OBSERVED IN JUNE 2010*

SPECIES NAME	COMMON NAME	Clear Pond	Boot Pond	Fresh Pond	Bartlett Pond
Submerged Plants					
Callitriche sp.	Water-starwort	x	x		x
Ceratophyllum demersum	Coontail				x
Elatine minima	Waterwort	x		x	
Eleocharis sp.	Spike-rush	x	x	x	x
Elodea nuttallii	Waterweed	x			
Eriocaulon sp.	Pipewort	x	▲	x	x
Gratiola aurea	Golden-pert	x		x	
Lobelia dortmanna	Water Lobelia			x	
Ludwigia palustris	Water-purslane	x			
Myriophyllum humile	Water-milfoil	x	x		x
Myriophyllum tenellum	Water-milfoil				x
Potamogeton perfoliatus	Clasping-leaved Pondweed				x
Potamogeton sp.	Pondweed	x			x
Sagittaria graminea	Arrowhead			x	
Sagittaria teres	Terete Arrowhead	▲	▲		
Utricularia sp.	Bladderwort	▲	x		
Vallisneria americana	Tapegrass	x			
Floating-Leaved Plants					
Nuphar variegata	Yellow Waterlily		x	x	x
Nymphaea odorata	White Waterlily			x	x
Emergent Plants					
Decodon verticillatus	Water-willow			▲	▲
Iris versicolor	Blue Flag	x			
Juncus sp.	Rush	x	x	x	x
Lysimachia terrestris	Swamp Candles			x	
Lythrum salicaria	Purple Loosestrife (alien)				x
Myrica gale	Sweet Gale				x
Peltandra virginica	Arrow-arum				x
Phragmites australis	Common Reed (invasive)	x	x		x
Pontederia cordata	Pickerel-weed			x	x
Sambucus canadensis	Elderberry				x
Solanum dulcamara	Bittersweet Nightshade (alien)				x
Sparganium sp.	Bur-reed	x	x	x	x
Typha angustifolia	Narrowleaf Cattail (alien)	x			
Typha latifolia	Common Cattail	x		x	▲

*** dominant species indicated with a triangle ▲**

Most of the macrophyte growth in Fresh Pond is located along the northern and eastern shorelines where a discontinuous fringe comprised mostly of emergent Water-willow (*Decodon verticillatus*) is a dominant feature of the littoral zone. This plant also forms an extensive meadow of emergent growth contiguous with the northeastern portion of the pond, just southwest of the end of Delancy Drive. Rush, Bur-reed, and Pickerel-weed (*Pontederia cordata*) also occur in this fringe with floating pads of White Waterlily (*Nymphaea odorata*) and Yellow Waterlily forming patches in deeper water. Along the southeastern shoreline the fringe of Water-willow is interrupted by areas cleared for docks or beaches. Three drainpipes, apparently for stormwater conveyance, were observed along the southern shoreline of Fresh Pond. No invasive or alien plant species were observed in this pond.

Water-willow is also the dominant plant in Bartlett Pond where it forms a dense fringe of growth around most of the periphery of the pond. This plant also forms extensive emergent meadows in each of the three arms of the pond that radiate eastward from the location of the outlet. Also contributing to the shoreline fringe and emergent meadows are Common Cattail, Sweet Gale (*Myrica gale*), Purple Loosestrife (*Lythrum salicaria*), and Bittersweet Nightshade (*Solanum dulcamara*). The latter two plants are alien species introduced from Eurasia and are invasive. In the emergent meadow that borders the inlet channel in the southernmost arm of the pond Elderberry (*Sambucus canadensis*) is also a component of the flora. Submerged growth is sparse in central, open water areas of the basin, but the inlet channel supports a diverse flora (Table 1). Common Reed is a component of the shoreline fringe in the area adjacent to the outlet.

The description of the macrophyte community of Bartlett Pond given above represents a profound change from the community that existed in this pond according to the historical survey report (undated) by Lyons Skwares Associates of Westwood, Massachusetts. That survey recorded a variety of floating-leaved and emergent plants growing around the periphery of the pond that have been completely replaced by the dense emergent fringe of Water-willow. Water-willow was not recorded in the historical survey, so apparently arrived after that time and then proceeded to spread throughout the littoral zone at the expense of other plants. Water-willow also appears to be encroaching on open water in the pond through its habit of arching stems out into the water and then growing roots at the extended tips.

The diversity of submerged vegetation in central areas of the basin is also greatly reduced from that reported in the historical survey with only the inlet channel retaining a diverse community. Waterweed (*Elodea*), identified as the “primary species” in the historical report, was not observed in the recent survey. These changes are probably linked to one or more episodes of wide-ranging disturbance such as extended drawdown of water elevation in the pond resulting from manipulation of upstream cranberry bogs or, more likely, inundation by seawater during violent coastal storms.

<u>Plankton Sampling (see Table 2 on page 4)</u>

Plankton in each pond were sampling using a net with 35 micron mesh openings manipulated vertically through the water column except in Bartlett Pond where the net was towed horizontally due to the shallow depth of this basin. Samples were preserved in the field using Lugol’s Solution and analyzed using a compound microscope to identify phytoplankton taxa and determine their relative abundance. The phytoplankton communities of all four ponds had changed radically since the previous sampling effort in April. Pond phytoplankton communities are dynamic and seasonal shifts in community composition and the relative abundance of phytoplankton taxa are typical.

TABLE 2 - RESULTS OF PHYTOPLANKTON SAMPLING OF PLYMOUTH PONDS IN JUNE 2010

(Estimates of percent composition indicated as follows: **A**bundant = 60-100%, **V**ery Common = 30-60%, **C**ommon = 5-30%, **O**ccasional = 1-5%, **R**are < 1%)

	Sampling Location			
	Clear Pond (net to 5 m)	**Boot Pond** (net to 8 m)	**Fresh Pond** (net to 8 m)	**Bartlett Pond** (net to 1 m)
Phytoplankton Taxa				
Bacillariophyceae (diatoms)				
Asterionella		**V**		
Cyclotella		R		
Eunotia	R			R
Fragilaria				R
Melosira	R			**V**
Navicula				R
Tabellaria	R	**V**		
Chlorophyta (green algae)				
Closterium				R
Coelastrum	R			
Dictyosphaerium		R		
Eudorina				**C**
Gloeocystis	R	R	R	
Mougeotia	R		R	
Pediastrum			R	R
Quadrigula		R		
Sorastrum			R	
Sphaerocystis	R		R	
Staurastrum	R		R	
Volvox				R
Chrysophyta (yellow-green algae, excluding diatoms)				
Chrysosphaerella				R
Dinobryon	**A**	R		R
Mallomonas			R	R
Rhizochrysis				R
Cyanophyta (blue-green algae)				
Anabaena		R	R	
Chroococcus			R	
Coelosphaerium	R		R	
Merismopedia			R	
Microcystis		R	**A**	
Oscillatoria			R	R
Pyrrhophyta (dinoflagellates)				
Ceratium	R	R		R
Peridinium	R			
Protozoa				
unidentified ciliates				**C**

Clear Pond was dominated by the chrysophyte ("golden-brown algae") *Dinobryon* in contrast to April when the chrysophytes *Synura* and *Mallomonas* and the diatom *Asterionella* prevailed. Accumulations of filamentous algae were occasionally observed along the eastern shoreline and there were composed mainly of the diatom *Eunotia* with minor representation by the diatom *Tabellaria* and the chlorophytes ("green alga") *Desmidium*, *Mougeotia*, and *Oedogonium*.

Boot Pond was dominated by the diatoms *Asterionella* and *Tabellaria* as opposed to April when the community was dominated by the cyanophytes ("blue-green algae") *Coelosphaerium* and filaments of *Oscillatoria*. Colonies of the cyanophyte *Microcystis* dominated in Fresh Pond in the June whereas previously, in April, the community was dominated by the diatom *Asterionella* and by filaments of the chlorophyte *Spirogyra*.

Bartlett Pond was dominated by the diatom *Melosira*, the chlorophyte *Eudorina*, and by unidentified ciliates (Protozoa). In April, the chrysophytes *Dinobryon* and *Synura* had dominated the community. *Melosira* composed most of the benthic algae observed on the bottom of this pond in April, so it is likely that the benthic population contributed in some manner to those observed recently in the phytoplankton. Ropey masses of filamentous algae were entangled in the emergent fringe of Water-willow (see above) in many places and these were found to be composed entirely of the chlorophyte *Rhizoclonium*. Lastly, mats of filamentous algae observed in the inlet channel to Bartlett Pond were composed of the chlorophyte *Vaucheria*. All of the organisms observed in these ponds are common and typical of freshwater plankton and benthic algal communities.