EcoLogic Memorandum

TO: Frank Samson and Nate Weeks
FROM: Mark Arrigo and Liz Moran
RE: Harwich Ponds
DATE: June 30, 2008

The purpose of this memorandum is to provide data summaries and interpretation of water quality conditions in the ponds of Harwich MA. At the request of the Task Force, we address four topics.

1. Update Great Sand Lakes data evaluation to include results from 2007

2. Summarize recent data from other ponds in Harwich

3. Offer an opinion on the Walkers bloom and Eurasian Watermilfoil presence (per email January 2008)

4. Offer an opinion on the Skinnequit sediment data (per email January 2008)

2007 Data Evaluation

Great Sand Lakes: Bucks and John Joseph Ponds

Phosphorus

Phosphorus is the limiting nutrient for all of the ponds in the Town of Harwich. Elevated concentrations of phosphorus result in increased algal growth. Average total phosphorus concentrations in upper and lower waters of Bucks and John Joseph Ponds were compared between the time period 2001-2006 and 2007. The comparison showed that the 2007 data were generally consistent with historic data (Figure 1). The slight differences observed are attributable to typical annual variations and do not indicate significant changes in water quality.

Both Bucks Pond and John Joseph Ponds continue to show evidence of elevated phosphorus concentrations in the deep waters (hypolimnion) by late summer. This is a result of chemical changes at the sediment surface when the deep waters become anoxic (devoid of oxygen). Mineral complexes binding phosphorus are reduced and soluble phosphorus is released to the overlying water. Because Bucks Ponds is weakly stratified, periods of anoxia and sediment phosphorus release are interspersed with periods of complete mixing. Oxygen present in the upper waters is mixed throughout the water column; soluble phosphorus in the lower waters is mixed as well. Consequently, phosphorus concentrations in Bucks Pond tend to be higher than John Josephs. John Josephs is deep enough so that winds are not able to break down thermal stratification. In this pond, phosphorus released from sediments does not affect the upper waters until the water column cools and mixes in the fall.

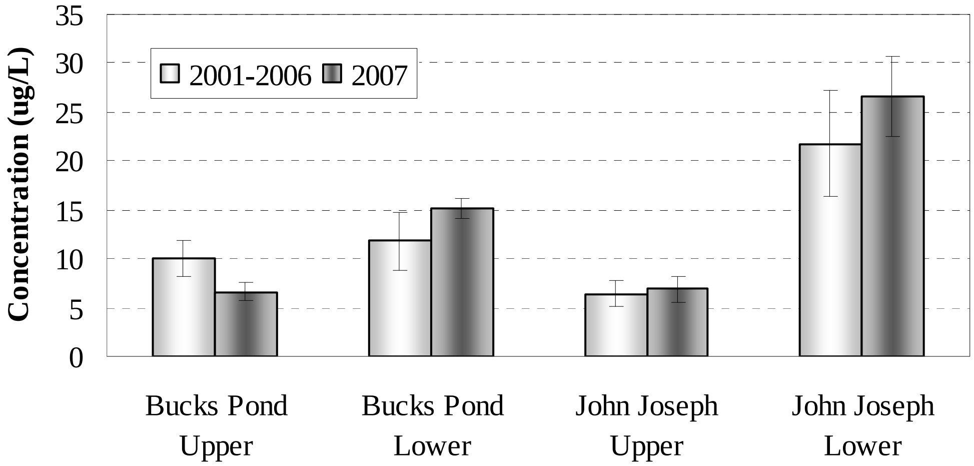

Figure 1. Comparison of average total phosphorus concentration in upper and lower waters for the periods 2001-2006 and 2007.
Note: Average shown with standard error.

Harwich Ponds

Phosphorus

The average total phosphorus concentrations measured in 2007 for the Harwich ponds are displayed in Figure 2. Concentrations vary from a low of 5.5 ug/l in Andrews Pond to a high of 62 ug/l in Grass Pond. These concentrations indicate that the ponds in Harwich range from unproductive (oligotrophic) to highly productive (eutrophic). Based on these concentrations Skinequit, Robbins, Cornelius, Hinckley's and Grass Ponds would all be expected to have at least somewhat elevated levels of algal growth.

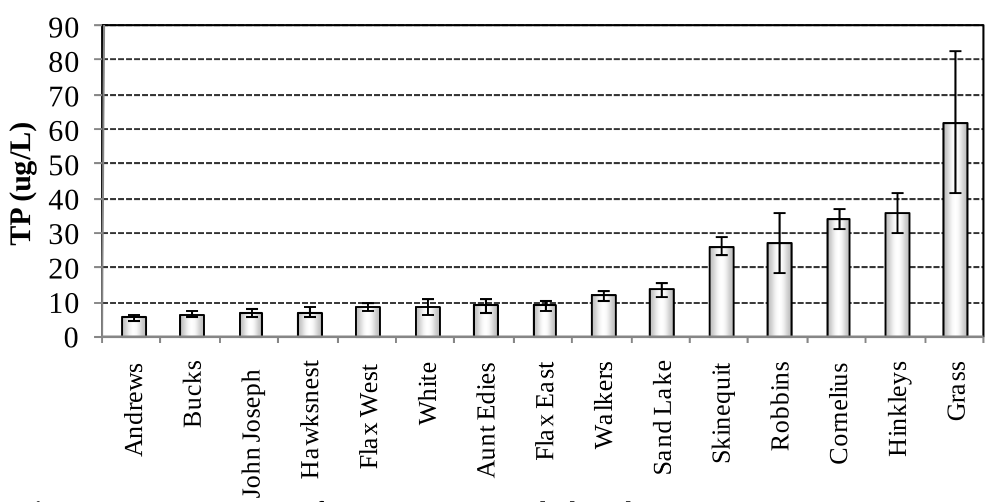

Figure 2. Comparison of 2007 average total phosphorus concentration in upper waters for fifteen ponds in Harwich.
Note: Average shown with standard error.

Internal Recycling of Phosphorus

As described above, internal recycling of phosphorus can occur when phosphorus held in the sediments is released. This typically occurs in productive lakes. The ratio of phosphorus in deep water compared to shallow water for eleven ponds is displayed in Figure 3, using 2007 data. Higher values correspond to elevated concentrations in the deeper waters. Only Robbins Pond had phosphorus concentrations in deeper waters less than surface waters. Walkers, Hawksnest, White and Walkers ponds had concentration of phosphorus in the lower waters that were only slightly higher than the upper waters (less than 1.5 times higher). Andrews, Hinkleys, and Sand Pond had elevated concentrations in the deeper waters that were on the order of 1.5 to 1.9 times the concentration in the upper waters. The concentration of phosphorus in the deeper waters of Bucks Pond was 2.3 times greater than the surface waters and in John Josephs it was 3.9 times higher. The concentration of phosphorus in the lower water of Skinequit is quite elevated. There is an obvious build up of phosphorus in the lower water through the summer; the earliest 2007 sample from deep water on June 21 was 370 ug/L, the latest on September 18 was 939 ug/L.

In general, ponds the size of those in Harwich that are deeper than about 35 feet will be resistant to mixing because of the relatively deep water compared to their surface areas. This means that it is unlikely that significant quantities of phosphorus will be mobilized from lower water to the surface waters during the period of strong stratification (summer). However, phosphorus released from the deep waters will still eventually become available for algal growth in the kettle ponds, given the relatively long residence time and the lack of surface outlets. As discussed earlier, in deeper ponds phosphorus released is less likely to be available for algal production that growing season. In shallower lakes with more transient stratification, this phosphorus can mix into the upper, sunlit waters and be available for algal growth.

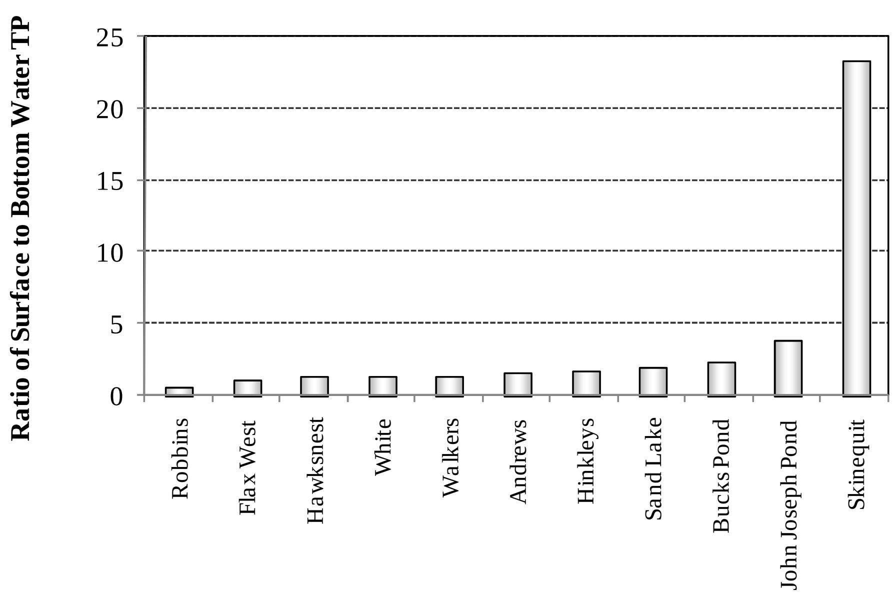

Figure 3. Ratio of deep water phosphorus to surface water phosphorus in eleven ponds in Harwich. Higher numbers indicate increased P release from sediments.

Chlorophyll-a

Chlorophyll-a concentration is an indicator of algal abundance. The amount of algae production in a waterbody is largely a function of the concentration of the limiting nutrient (usually phosphorus), light, and water temperature.

The concentration of chlorophyll-a in the Harwich Ponds is generally related to the amount of phosphorous in the water (Figure 4). The Ponds with the lowest concentrations of phosphorus tend to have the lowest chlorophyll-a concentrations and vice-versa. There are some outliers however. Skinequit Pond has much higher concentrations of chlorophyll-a than might be expected from the observed phosphorus concentrations and Grass Pond has lower levels than might be expected. Algal blooms, and therefore the associated chlorophyll-a levels, are highly variable throughout summer. For example, there were five samples collected in Skinequit Pond in 2007, four had concentrations less than or equal to 16 ug/l, and one result collected during an intense algal bloom measured at 126 ug/l.

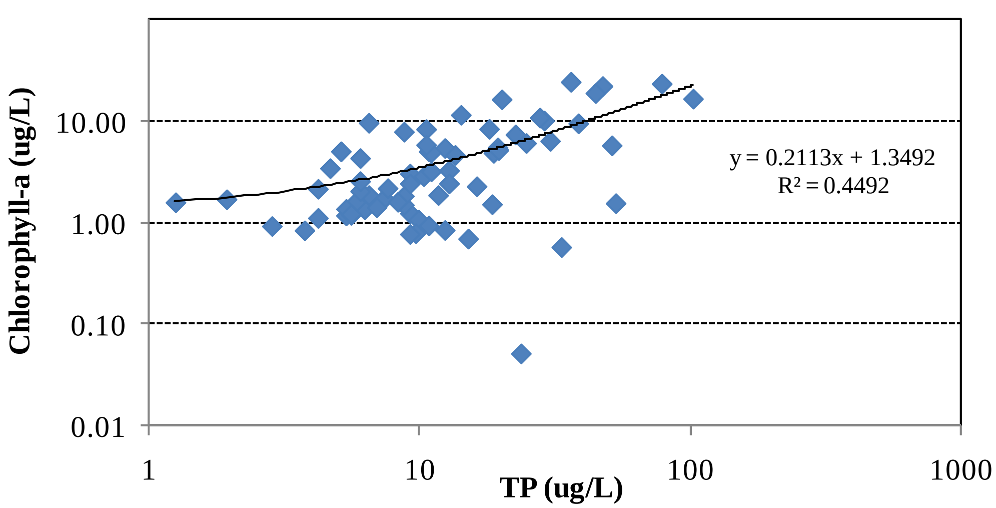

Figure 4. Correlation of paired chlorophyll-a and total phosphorus samples in fifteen Harwich ponds, 2007. Note: axis on Log scale.

Average chlorophyll-a concentrations are generally low in most ponds (Figure 5). Only three ponds, Cornelius, Hinkleys, and Skinequit have levels that would likely be perceived problematic by lake users. The concentrations documented in Skinequit are very high and likely affect recreational use.

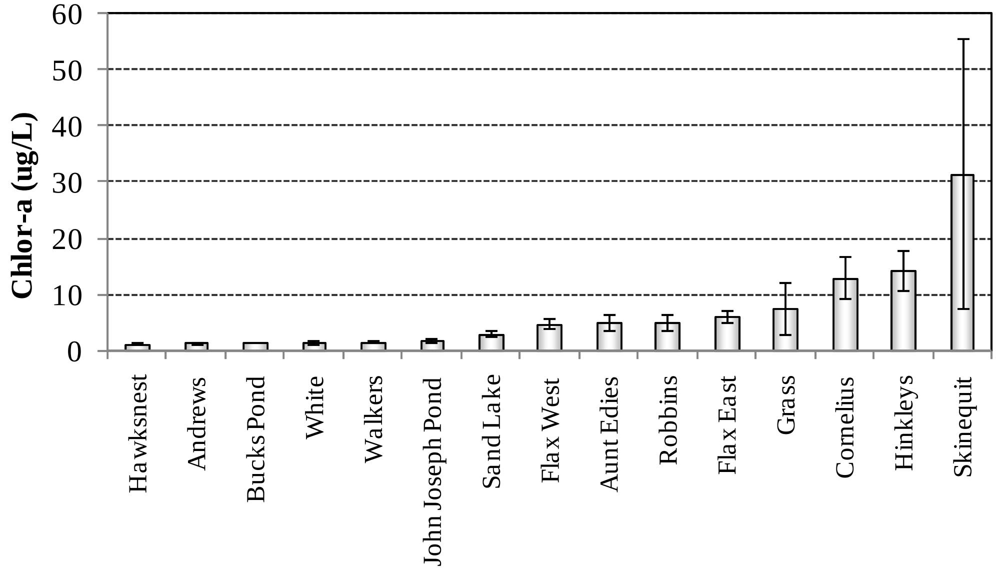

Figure 5. Comparison of 2007 average chlorophyll-a concentration in upper waters for fifteen ponds in Harwich.
Note: Average shown with standard error.

Water Clarity

Water clarity, as measured by Secchi disk in summer (June-September), is generally inversely related to the concentration of chlorophyll-a in the Harwich Ponds, which in turn is correlated with lake phosphorus concentrations. This is expected as the higher the levels of algae in the water the decrease light penetration. The water clarity in Cornelius and Hinkleys is poor, and in 2007 was at or below the State Health Department Swimming Standard of 1.75m for beaches (Figure 6). Water clarity in Skinequit was also poor and only slightly better than health department standards.

The ponds with the lowest phosphorus and chlorophyll-a concentrations have the best water clarity. Secchi disk measurements in Bucks, White, John Josephs, Andrews and Hawksnest are greater than 4m, which is exceptional.

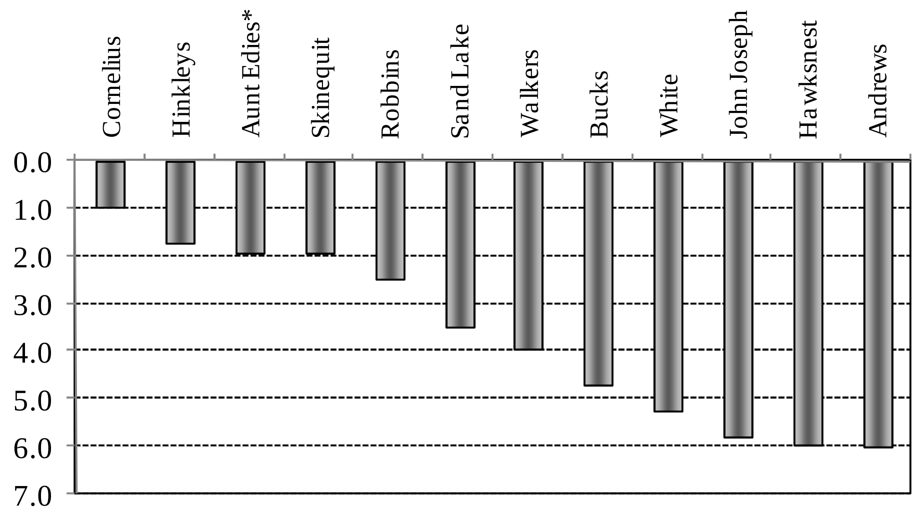

Figure 6. Comparison of 2007 Secchi disk measurements for eleven ponds in Harwich. * Note: Secchi disk measurment for Aunt Edies is equal to the depth of the pond.

Trophic State Indicators

EcoRegional Criteria

The Cape Cod Ecoregional Criteria are based on water quality conditions measured by the Cape Cod Commission and EPA in Cape Cod ponds. EPA criteria are based on the lowest 25^{th} percentile of the 92 ponds sampled. The Cape Cod Commissions criteria are based on two sets of data. The more stringent (CC-Least) is based on the eight most pristine ponds in their survey and represents a best case scenario. The other Cape Cod criteria (CC-All) was based on current impact of all ponds sampled and best represents Cape Cod reference conditions.

Table 1 shows the results of 2007 measurements in each of the ponds in Harwich compared with the EPA and Cape Cod Commissions Ecoregional Criteria. Measurements that exceed the Cape Cod reference condition (CC-All) are highlighted. This comparison shows which ponds are most impacted and also indicates where data gaps exist.

Table 1. 2007 Harwich Ponds data compared with Cape Cod Ecoregional Criteria. Shaded cells exceed Cape Cod reference condition (CC-All).

Pond	Impacted Criteria			
	Chlorophyll-a (µg/L)	**Total Nitrogen (mg/L)**	**Total Phosphorus (µg/L)**	**Secchi Disk (m)**
EPA Ecoregion14	6	0.41	9	<2
CC-Least	1	0.16	7.5	--
CC-All	1.7	0.31	10	--
Andrews	1.3	1.10	5.5	6.0
Aunt Edies	NA	0.40	9.0	1.9
Bucks Pond	1.4	0.36	6.6	4.7
Cornelius	NA	0.70	34.5	1.0
Flax East	NA	0.61	9.1	1.3
Flax West	4.8	0.58	8.7	2.8
Grass	NA	1.20	62.4	NA
Hawksnest	1.2	0.21	7.0	6.0
Hinkleys	14.3	0.54	36.1	1.7
John Joseph	1.7	0.37	6.9	5.8
Robbins	NA	0.41	27.3	2.5
Sand Lake	3.0	0.33	13.8	3.5
Skinequit	31.5	0.55	26.2	1.9
Walkers	1.6	0.30	12.0	3.9
White	1.5	0.27	8.7	5.3

Shaded cells indicate where pond data exceed the ecoregional criteria.

NA = indicates no data available.

Carlson Trophic State Index

The Carlson trophic state index uses the chlorophyll-a, total phosphorus, and Secchi disk readings to designate the trophic classification of a lake. It is useful for comparing lakes within a region and for assessing changes in trophic status over time. Oligotrophic lakes are low in productivity and generally have clear well oxygenated water. Many of these lakes are suitable for coldwater fish species like trout, but often do not have a highly productive fish community. Eutrophic lakes are very productive and have high standing crops of algae that decrease water clarity. Eutrophic lakes may also have extensive vegetation beds. These lakes often have high standing crops of warmwater fish such as bass. Mesotrophic lakes are in an intermediate trophic stage.

Of the fifteen Harwich Ponds sampled in 2007, 40% are considered oligotrophic, 33% mesotrophic and 27% eutrophic.

Table 2. 2007 Results of Carlson Trophic State Index Calculations

Pond	Chlorophyll-a TSI	Total Phopshorus TSI	Secchi Disk TSI	Mean TSI	Designated Trophic State
Hawksnest	32	32	31	32	Oligotrophic
Andrews	33	28	34	32	Oligotrophic
Bucks	34	31	37	34	Oligotrophic
John Joseph	37	32	37	35	Oligotrophic
White	35	35	No data	35	Oligotrophic
Walkers	35	39	41	38	Oligotrophic
Flax West	46	35	No data	40	Mesotrophic
Sand Lake	41	41	42	41	Mesotrophic
Flax East	48	36	No data	42	Mesotrophic
Aunt Edies	46	35	51	44	Mesotrophic
Robbins	46	51	47	48	Mesotrophic
Skinequit	64	51	52	56	Eutrophic
Cornelius	56	54	60	57	Eutrophic
Hinkleys	57	55	60	57	Eutrophic
Grass	50	63	No data	57	Eutrophic

Water Quality Conclusions

In general, the water quality of the ponds in Harwich is very good. Most ponds are classified as either oligotrophic or mesotrophic. A minority of ponds have elevated levels of productivity that is causing occasional nuisance blooms of algae. The ponds with higher water quality need to be protected from additional sources of phosphorus to slow the process of eutrophication. The more productive ponds should be considered for restoration activities. The impact that onsite wastewater systems have on the ponds' water quality should be evaluated in the ponds for which this analysis has not been completed.

Opinion on the Walkers bloom and Eurasian Watermilfoil Abundance

In 2007 Walkers Pond experienced nuisance blooms of algae. A water sample was collected and the single most prevalent taxa in the sample identified, although there were likely numerous other species present. The primary alga present was a chlorophyte (green algae) identified as belonging to the genus *Mougeotia*. Species level identification could not be determined. *Mougeotia* is a relatively common green alga. Unlike some cyanobacteria (blue-green algae) there is no danger of toxins being released from this type of algae when it decomposes. Blooms such as this can be caused by several factors. Nutrient concentrations must be high enough to support the algal biomass, and grazing pressure from zooplankton must be low. The exact cause of the nuisance bloom in 2007 is not clear as samples from the routine monitoring program indicates phosphorus and chlorophyll-a concentrations were relatively low (mean: 12 and 1.6 ug/L respectively). If a similar bloom occurs in 2008 we recommend collecting additional chlorophyll-a and total phosphorus samples while the bloom is evident.

Walkers Pond contains areas of Eurasian watermilfoil, an invasive aquatic plant. Growth appears to be most prevalent in north and south ends of the pond. Options for controlling the milfoil growth are limited because Eurasian watermilfoil is difficult if not impossible to eradicate once it is established. In smaller waterbodies, there has been limited success in controlling milfoil by using an aquatic herbicide called Sonar® (fluridone). Other control methods sometime used are: installation of benthic barriers, harvesting, rotovation (underwater rototilling), dredging, the use of triploid (sterile) grass carp, and biocontrol using herbivorous beetle larvae. Benthic barriers are potentially useful in isolated areas such as around boat docks, but not feasible for a whole lake application. Because milfoil can grow from fragments, harvesting, rotovation, and dredging may result in significant short term reductions, but the fragments that are produced from these methods result in rapid re-colonization and expansion. Triploid grass carp are voracious herbivores that prefer native species over milfoil. The result of stocking grass carp is usually a near elimination of desirable native species with some reduction in milfoil. The damage caused by the elimination of native species generally outweighs the benefits of milfoil reduction. The milfoil weevil is a small, herbivorous aquatic beetle native to New York. It feeds and develops only on milfoil (prior to the invasion of Eurasian milfoil the weevil likely fed upon the native northern milfoil). The weevil will not eradicate milfoil but can slow its spread, and reduce the standing crop and thus has shown the most promise as a potential biocontrol method.

Opinion on the Sediment Data

Sediment samples were collected from two locations each on Skinequit and John Josephs Ponds in 2007 to help understand the potential for phosphorus release from the sediments.

The sediment sample collected from John Josephs North end appears to have been composed primarily of solids, which are not expected to contain high levels of phosphorus. It is not known if this sample is representative of predominant sediment type in that pond.

Both ponds have high levels of phosphorus in their softer sediments. However, Skinequit has a much higher iron-bound phosphorus, the type that would most easily be released during anoxic conditions. This is likely the reason why phosphorus release from the sediments appears significantly higher in Skinequit.

Table 3. Results of sediment analysis for phosphorus in Skinequit and John Joseph ponds in 2007.

Pond	**Total Phosphorus** (mg/kg dry)	**Iron bound P** (mg/kg dry)	**Loosely-sorbed P** (mg/kg dry)	**% Solids**
Skinequit North	1350	308	BRL	18.8
Skinequit South	1080	109	BRL	18.4
John Joseph North	140	1.7	BRL	95.6
John Joseph South	1670	BRL	BRL	19.3

Note; BRL below reporting levels