Background on Water Quality Parameters Shown in the Graphs:
Coastal Pond Water Quality- A Brief Primer

The term "eutrophication" carries a wide range of meaning. It is generally associated with an increase in productivity (the cycling of carbon into living matter) and high concentrations of nutrients (Wetzel, 1983). The term was devised to indicate the extreme end of a range of conditions in lakes from clear and unproductive to excessively productive on the eutrophic end. Eutrophication in marine waters is characterized by a number of conditions that are undesirable from the human use perspective. These include excess microscopic phytoplankton, sometimes abundant larger aquatic plants (wrack algae), low oxygen levels in the water sometimes to the point of causing a die off of animals, a reduction in the number of species living in the system with a shift from filter feeders (scallops and clams) to detritus feeders like snails and, under extreme conditions, burrowing worms. The eutrophic state can develop under natural conditions where nutrients released from the surrounding uplands enter the pond in quantities that are not flushed out quickly enough and stimulate excessive productivity. The process is hastened by man made nutrients that are released in concentrations far in excess of the natural processes. These nutrients are released from development in the watershed by runoff of stormwater, erosion of soil from farmland, disposal of sewage by septic systems or by treatment facilities and by fertilizers applied to farmland and landscaping. The nutrients are also added from outside the watershed by acid rain that is contaminated through the stack emissions of power plants, manufacturing processes and auto exhaust.

One nutrient that all of these activities release and which is required for plant growth is nitrogen. The other major nutrients required for growth of phytoplankton and algae include phosphorus, carbon, hydrogen and oxygen. Generally, the last three are sufficiently available in coastal waters so that they do not hinder growth of these aquatic plants. In phytoplankton, nitrogen and phosphorus are required in the approximate ratio of 16 to 1 (Redfield, 1963). While other less important nutrients may also affect growth rates, these two are of primary importance and, by their availability alone, usually determine the amount of growth of biomass in the system. In ocean waters, it is generally found that nitrogen is the deficient nutrient and phosphorus is usually present in sufficient quantities for growth of phytoplankton (Valiela, 1995). For this reason, marine waters are often described as being nitrogen limited. This means, if nitrogen is added to the water, phytoplankton can reproduce to take advantage of the supply and the amount of organisms in the water column can increase until once again limited by availability of nitrogen or another necessary nutrient.

While some increase in the phytoplankton population is not necessarily a problem, with enough nutrients, the population can explode. High populations of phytoplankton (often called an algae bloom) cloud the water reducing light transmission. In large numbers, overnight oxygen uptake by these living organisms or the die off and decay of phytoplankton can reduce oxygen levels to the point where other organisms are stressed or killed. This may have occurred in Edgartown Great Pond in 1993, when the oyster population died out following a late summer algae bloom and in James Pond in 2003 when a 5 acre raft of windblown algae accumulated in the northeast corner of the system generating strong odors and low dissolved oxygen saturation.

Reduced light penetration limits the vigor of eelgrass that requires sunlight, as does any green plant. Eelgrass is an important component of the ecosystem providing cover for bait fish, scallops, tautog, blue crabs and eels as well as food and a substrate for the growth of a myriad of aquatic plants and animals. It also acts as a sediment stabilizer through its dense root system.

While the available light level limits the potential success of eelgrass, both phytoplankton and large macro-algae (wrack algae) are typically limited by the availability of nutrients rather than light (Valiela, 1995). In coastal salt ponds, common wrack algae include *Ulva*, *Enteromorpha* and *Cladophora*. The differing growth limitations set up a situation where, as nutrients are added to the system, phytoplankton and wrack algae increase, reduce the light penetrating to the bottom and cause a decline of eelgrass which may eventually be replaced entirely by macro-algae. The wrack algae however do not fill the role that eelgrass plays as a key component of the shallow, marine habitats. The macro-algae also tend to break loose late in the season or after a storm and gather into large mats which may smother desirable, filter feeding shellfish such as clams, scallops and oysters, encourage detritus (debris) feeders such as snails and, when severe, anoxia (lack of oxygen), aquatic animal die off and odors.

Nutrient stimulation of phytoplankton blooms also reduces available light to the eelgrass beds at the bottom particularly where the water depth is 2 or more meters. Nutrients also increase the growth of single cell and chain algae (e. g. diatoms) that grow on the surface of the eelgrass blades further blocking the sun light. Reduced light may stress the eelgrass making it more susceptible to wasting disease or may just reduce its vigor and lead to thinning of the eelgrass and eventual loss of entire beds over time.

Numerous studies of coastal ponds by researchers have concluded that nitrogen loading from shoreline development may have adverse impacts on these waters. Waquoit Bay, Cape Cod, has been thoroughly studied over 30 years (Valiela et al 1990). It is a coastal pond with a fixed inlet through a barrier beach. As residential land use increased in the recharge area, the pond has steadily lost formerly extensive eelgrass beds. The loss was attributed primarily to nutrient loading from septic systems in the watershed (Kennish, 1996).

It seems clear that addition of nitrogen to our coastal ponds will lead to undesirable consequences if it exceeds a threshold known as the loading limit. Interim loading limits have been determined by the MV Commission but establishing final limits is the goal of the Massachusetts Estuaries Project. We should be very concerned at what the future nitrogen loading of the recharge area may do to our ponds. Once the recharge area is built out, it will take 20 years or more for the system to reach equilibrium and for the full effect of the nitrogen loading to appear in the pond to which the recharge area contributes groundwater. If the "effect" on the pond is undesirable, changes made to reduce nitrogen loading further back in the recharge area will take another 20 years or more to reach the pond and reverse the negative impacts. For this reason, we need to make every effort to anticipate possible impacts with a conservative limit on nitrogen loading within the watershed recharge area.

<u>Water Column Parameters:</u>

There are key chemical and physical measures that are indicators of the condition of a water body under study. When collected over time, these measures can identify the trophic state of the system. The trophic state of a coastal pond is a descriptive term that indicates the amount of biomass production in the system. The most familiar trophic state is the eutrophic condition that indicates excessive biomass production.

The measures discussed here include **chlorophyll pigment(s)** that are an indicator of the microscopic algae population in the water column. The depth at which the Secchi disk can no longer be seen is the **extinction depth** and indicates the amount of light penetration through the water column. The amount of **dissolved oxygen** is a fundamental necessity for the animals living in a pond. It is affected by the algae population but also by the amount of organic matter that is decaying in the pond. The amount of **nitrogen** in the water column indicates whether a system is over- productive and if the nitrogen input from the watershed is excessive.

Although there are many other approaches to characterizing the condition of a pond including population studies of the benthic organisms, distribution and amount of aquatic plants and fish population, these parameters have not yet been evaluated. In examining the data presented for each pond, the rating system devised by the Buzzard's Bay Program (Costa et al, 1996) is helpful. The ratings are summarized in Table 1. The lab analyses data is included in spreadsheet form in Appendix 1.

Table 1: Buzzard's Bay Eutrophication Index (Costa et al, 1996)

Parameter	Zero Score	Perfect Score
Oxygen Saturation (lowest 1/3 observed)	40% saturation or less	90% saturation or more
Transparency (Secchi disk)	0.6 meters or less	3 meters or more
Phytoplankton **pigments**	10 parts per billion or more	3 ppb or less
Dissolved inorganic nitrogen (DIN)	10 micromolar (0.14 ppm) or more	1 micromolar or less
Total organic nitrogen (TON)	0.6 ppm or more	0.28 ppm or less

In reviewing the charts, we suggest that you use these ***desirable*** goals for water quality:

- Maintain ratings that are over 60% of the perfect score value for Dissolved Oxygen saturation (i.e. over 54%) and Secchi depth (over 1.8 meters) and
- Less than 60% of the zero score value for pigments, DIN (less than 6 micromoles/liter) and TON (0.38 parts per million) for the growing season.

<u>NOTE ON NITROGEN INDICATORS</u>: ***In the recently released Massachusetts Estuaries Project Edgartown Great Pond, Total Nitrogen (TN) is used as an indicator of system quality rather than Total Organic Nitrogen (TON). The recommended target Total Nitrogen concentration to maintain eelgrass in***

Edgartown Great Pond is at or below 0.5 milligrams per liter. In this report we continue to use TON as the standard not only for consistency with previous reports but also because TON comprises well over 90% of TN. The addition of dissolved inorganic nitrogen makes little difference to the rating system at sample stations where the salinity is over 10 parts per thousand.

CAVEAT: The application of any rating system to such a diverse group of ponds is prone to misinterpretation. The caveat to the text that follows is that these ratings will change as the amount of specific information we have increases. The ratings may also change from year to year depending on weather, the temperature of the offshore water and other factors not known at this time. The rating system will be refined specifically for each pond during the Massachusetts Estuaries Project study of these systems.

Ponds Involved in the 604(b) Grant During 2006

Oyster Pond:

Oyster Pond is a 200-acre south shore pond, separated by a barrier beach from the Atlantic Ocean. It is only tidal for relatively short periods of time following a man-made cut through the barrier beach. The cut is made to maintain salinity in the brackish range suitable for oyster growth as well as to release a large store of nutrients that accumulate in the pond in exchange for "cleaner" Atlantic Ocean water. During the drain down period the pond drops 4 feet or more before becoming tidal for a period ranging from less than one week up to a month. When it drains down, the water near the north end of the system becomes very fresh from groundwater discharge that is focused at the head of the pond. This can set up a strong horizontal salinity gradient and, under the right wind conditions, vertical stratification can become well established, particularly in the southern half of the Pond. Vertical stratification can set the stage for a loss of oxygen in the deep water which is isolated from the air leading to water quality problems throughout the pond and eliminating animals from the deeper water areas.

During 2005, the total organic nitrogen concentration averaged between 0.42 and 0.46 parts per million, above the desired target for eelgrass health of 0.38 ppm but within recently suggested limits of 0.5 ppm for Edgartown Great Pond (Massachusetts Estuaries Project, 2007). Chlorophyll pigments were also elevated above the desired goal, varying from 7.2 to 7.5 parts per billion (ppb) in the southern half of the system and up to 16.2 ppb at the northernmost station. Dissolved inorganic nitrogen showed a similar pattern, ranging from 0.6 to 1.3 micromoles per liter at the south end up to 3.2 at the northern station. The ratio of inorganic nitrogen to phosphorus shows a nitrogen limitation in the southern half of the system at all times, whether open to the ocean or not. The stations at the northern half of the system are variable, being phosphorus limited when that end of the pond is fresh and nitrogen limited when it is more saline as indicated by the ratio of the inorganic nitrogen to orthophosphate. Water quality during 2005 was near the undesirable rating depending on station location and timing relative to the inlet to the ocean closing.

The 2006 Total Organic Nitrogen averaged 0.49 milligrams per liter (ppm) across all sampling stations over the course of the sampling period. This exceeds the target goal of around 0.4 ppm for eelgrass, meets the 0.5 ppm guidance for Edgartown Great Pond (MEP Draft 2007) and is below the zero score value of 0.6 ppm as in the Buzzard's Bay water quality rating system. During the same time period, the average value for total pigments (chlorophyll plus phaeo-pigments) was 7.99 micrograms per liter (ppb). The pigment concentration was lowest at the sample station furthest south and highest to the north. The concentrations exceeded the target of 6 ppb at all stations on all dates except for August 1. During the sampling period, water quality fell into the Marginal category.

In the Charts for Oyster Pond, note the following:

- The Total Organic Nitrogen content is above the desired level over the course of the sampling period.
- Dissolved inorganic nitrogen is very low throughout the sampling period as it is quickly utilized by phytoplankton and other growing plants and turned into biomass.
- The concentration of pigments in the water column exceeds the target of 6 parts per billion over most of the sampling period.
- The Pond was open to the ocean for the mid-July sampling but was then closed for the remainder of the sampling period.
- The salinity data show that the pond was stratified in July as indicated by the shallow salinity levels (labeled S) being significantly lower than the deeper salinity (labeled D). This isolates the saltier, heavier water from the air that is the source of oxygen.
- Dissolved oxygen saturation declines over the sampling period to somewhat below desirable levels but not as low as some years because the stratified condition didn't last too long.
- Secchi extinction depths are less than the goal because of all the phytoplankton in the water column that intercept the light.

James Pond:

James Pond is a 41-acre north shore pond separated from Vineyard Sound by a barrier beach that is breached to the Sound periodically during the year. Typically the Pond is breached in late winter or early spring and again during early summer if it has closed. In some years, the system will remain tidal with very low flow for months adequate to maintain salinity. When it is open to the Sound, flow from the system is sufficiently sluggish and the pond level remains high enough above the Sound that the tides in the system are diurnal. The system is shoaled by an extensive flood tidal delta and overwash deposits at the north end. The channel has been redirected by sand overwash so that it follows a long route and discharges into the pond across the tidal flat in a diffuse manner. James Pond receives small freshwater discharges from two streams and from the groundwater.

During 2005, total organic nitrogen concentration averaged between 0.7 and 1.0 parts per million, well above all thresholds for eelgrass health. Chlorophyll pigments varied between 14.0 and 32.5 parts per billion. At the stations nearest the inlet, productivity was nitrogen limited over the course of the sampling period. Those stations further south varied from being nitrogen limited to being phosphorus limited. Water quality throughout the system rated an undesirable rating during 2005.

In 2006, Total Organic Nitrogen exceeded 0.6 ppm (the zero score value) at nearly all stations throughout the sampling period. The average TON concentration at all sampling stations over the course of the sampling period was 1.20 ppm, twice the Buzzard's Bay rating system zero score. Total pigment concentrations averaged 68.8 ppb throughout the Pond over the course of the study but dropped dramatically to values near the target score value of 6.0 ppb in September. Generally, water quality falls in the Undesirable category during the sampling period.

In the charts for James Pond, note that:

- Total organic nitrogen is very high throughout the sampling period.
- Chlorophyll concentrations are excessive indicating tremendous growth of microscopic phytoplankton.
- Dissolved inorganic nitrogen levels are very low as it is quickly tied up in biomass.
- The dissolved oxygen saturation (the amount of oxygen in the water compared to what the water could hold at that temperature) is quite high. This often results from excessive amounts of algae and rooted underwater plants. The high concentration during the day often crashes overnight and causes oxygen stress in bottom dwelling organisms.
- The light penetration as indicated by the Secchi disk much lower than the goal.

Katama Bay:
Katama Bay is a 1700-acre tidal system that includes Edgartown Harbor, two large mooring fields, a number of oyster aquaculture operations and receives drainage from Caleb's Pond, a 39-acre tidal pond. The system is separated from the Atlantic Ocean to the south by a barrier beach that has periodically breached in the past creating times when the system has very strong tides. This barrier has remained mostly intact in recent years. Along the north side of the barrier beach, significant flood tidal deltas from past breaches have created an extensive system of tidal flats and channels that create a complex, variable-depth habitat that has been a rich source of soft-shelled clams and quahogs. The system has had eelgrass in the past, but it is believed that there is none today (Charles Costello, personal communication, personal knowledge).

During 2005, total organic nitrogen concentration averaged between 0.27 to 0.36 parts per million, meeting the goal for eelgrass health. The concentration increases into Mattakeset Bay that receives fresh drainage from Herring Creek. Lower values were found in the Harbor near Chappaquiddick Point and just outside of the system where tidal exchange is most vigorous. Similarly, the chlorophyll pigments were at acceptable levels in the system and even lower just outside the system. The inorganic nitrogen to phosphorus ratio indicates that the system is strongly limited by the availability of nitrogen with the exception of the station in Mattakeset Bay where phosphorus was limiting at times. The sample station near the Herring Creek discharge indicates that most of the time, that portion of the Bay was limited by the availability of phosphorus. Water quality in the system varied from good to approaching undesirable depending on distance from the tidal outlet.

In 2006, excluding station KAT1 located outside the system and KAT8, the drainage from Herring Creek, TON averaged 0.37 ppm meeting the target for eelgrass health. Total pigment values at the same stations averaged 5.2 ppb also meet the water quality goal. Katama Bay water quality was Acceptable to Good over the course of the summer sampling. Poorer water quality on August 15 lowers the overall rating.

In the charts for Katama Bay, note that:

- Total organic nitrogen content is near the target concentration for most of the sampling period.
- Pigment concentration exceeds the goal of 6 parts per billion in mid-August but is near that goal for the remainder of the summer.
- Dissolved inorganic nitrogen is very low in the Bay but Herring Creek carries a higher concentration from the groundwater that feeds it.
- Dissolved oxygen saturation levels are good during the sampling.
- Secchi disk extinction depths are good indicating good light levels in most of the Bay.

Ponds not included in the 604b grant program include Farm Pond, Sengekontacket, Tisbury Great, Cape Poge, Tashmoo, Lagoon and Oak Bluffs Harbor.

Farm Pond:

Farm Pond is a small coastal system that receives restricted tidal flow from Nantucket Sound through a culvert under Beach Road. Despite the limited tidal flow, the Pond has had a substantial eelgrass population. On the Farm Pond charts, please note:

- Total organic nitrogen exceeds the desired concentration for much of the sampling period.
- The concentration of pigments, in particular chlorophyll, is higher than desirable and increases to unacceptable levels late in August.
- Dissolved inorganic nitrogen levels spike up on August 2 but generally are very low. The spike occurred during a dry period and is not rain related.
- Dissolved oxygen levels are acceptable.
- The Secchi disk depths cannot be accurately determined because the Pond is so shallow. The depths shown are the depth to the bottom.

Sengekontacket:

Sengekontacket is a large well circulated tidal pond. The eelgrass beds in the system were lost in the late 1980's and very early 1990's. The Sengekontacket charts show:

- Total organic nitrogen averages around 0.4 ppm that is close to the goal for eelgrass health. Trapp's Pond has somewhat higher concentrations particularly in the mid-September sample.
- The pigment concentrations are generally low except for Trapp's Pond at the end of the sampling period. Over the years, it appears that Sengekontacket produces more large algae with its nutrient load rather than excess phytoplankton.
- Dissolved inorganic nitrogen levels are very low.

- Dissolved oxygen saturation values are above the minimum acceptable value throughout the sampling period.
- The Secchi extinction depths are minimum depths as the water is too shallow to get a reading. They indicate that the water column is quite clear.

Tisbury Great Pond:
Tisbury Great Pond is a large south shore coastal pond that is tidal only for a portion of the year. The Pond has no eelgrass beds. The water quality charts for this pond show:

- Total organic nitrogen levels are somewhat high but within the average summertime goal for water quality.
- Pigment concentrations generally exceed the desired level.
- Dissolved inorganic nitrogen levels are low except for the late August sample when the Pond was open to the ocean and the water column had become stratified with the fresher water at the top and the salty water at the bottom. The fresh water is the prime source of nitrogen and this results in the higher concentration at station 4.
- The dissolved oxygen saturation level dips below the minimum acceptable level at station 4 in late August. This results from the stratification that developed at this station after the pond was opened. Fortunately the condition did not persist and saturation levels rebounded.
- Secchi disk extinction depths are lower in August as the phytoplankton levels increase and particularly at station 4 further up in the Pond compared to stations further down toward the south end.

Cape Poge Pond:
Cape Poge is a large tidal pond that, during good years, is the top producer of bay scallops in the State. The Pond has substantial eelgrass beds. All three water column parameters are in the desirable range during the sampling season. Both the dissolved oxygen saturation levels and the Secchi extinction depths are indicative of good water quality during the sampling period.

Tashmoo:
Tashmoo Pond was sampled by UMASS Dartmouth personnel. The Pond is a moderate sized tidal pond that has some eelgrass but has lost beds at the south end of the system. The water quality charts show:

- Total organic nitrogen is higher at the south end of the Pond (station 3) further away from the inlet. Other than that station, the other stations had acceptable levels of TON.
- Pigment concentrations follow a similar pattern but are well above the goal at both stations 2S and station 3.
- Dissolved inorganic nitrogen levels are very low as this nutrient is quickly turned into phytoplankton leading to the high pigment levels.

Lagoon Pond:
Lagoon Pond is a large tidal pond that has lost significant eelgrass in the last 10 years but still has some coverage in the West Arm and near the inlet. The water quality charts show:

- Station 2 is a little more than half way to the south end of the Pond where the water quality impacts from nitrogen are clearer. Total organic nitrogen here is higher than the goal in the middle and deep part of the water column.
- The pigment concentration follows a similar pattern being too high in the lower water column and better but still over the goal near the surface.

Oak Bluffs Harbor:

The Harbor is a small, heavily used port that is surrounded by high density development that was only recently sewered to remove the substantial source of nitrogen in the wastewater. The charts indicate:

- Total organic nitrogen is substantially higher in the Harbor than it is outside in the Sound. It averages right around the desired goal for bringing eelgrass back but that may not be possible with the large mooring field in the system.
- Total pigment concentrations are higher than desirable, peaking in July.
- The dissolved inorganic nitrogen coming from Sunset Lake is much higher than desirable but the Harbor levels are significantly lower as this nutrient is turned into biomass.

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