Section 9 - Nutrient Dynamics Summary

As noted in Section 5.15, during most of the winter and spring in Martins Pond, the N:P ratios were all well over 30:1 (in some cases an order of magnitude higher) indicating the potential for P limitation. However, during the summer and early fall sampling dates (June through September 2005), with the exception of 8 August, the N:P ratios were less than 16:1, indicating the potential for N limitation. Thus, based on the N:P ratios observed in the current study, it appears that Martins Pond may be shifting from P limiting conditions to N limiting conditions over the course of the year.

To examine potential seasonal correlations between N and P loadings, the percent difference between N and P fluxes exiting Martins Pond versus entering the pond were plotted and summarized in Figure 38. The Figure shows that during the course of the 2005-06 study, both N and P exhibited patterns where there was either more N or P exiting the pond than entering (positive values) or there was more N or P entering the pond than exiting (negative values). There appears to be no positive or negative correlation between P and N availability, defined in these terms. Bars dropping below zero in Figure 38 reflect some sort of assimilation or utilization of that nutrient and might be considered 'sink' conditions. Overall, the relationship between N and P is complex and dynamic and ascertaining when nutrient limitations occur and what nutrient is limiting is problematic. While the bioassays conducted indicated potential N limitation, they also clearly indicated light limitation and the two are difficult to tease apart.

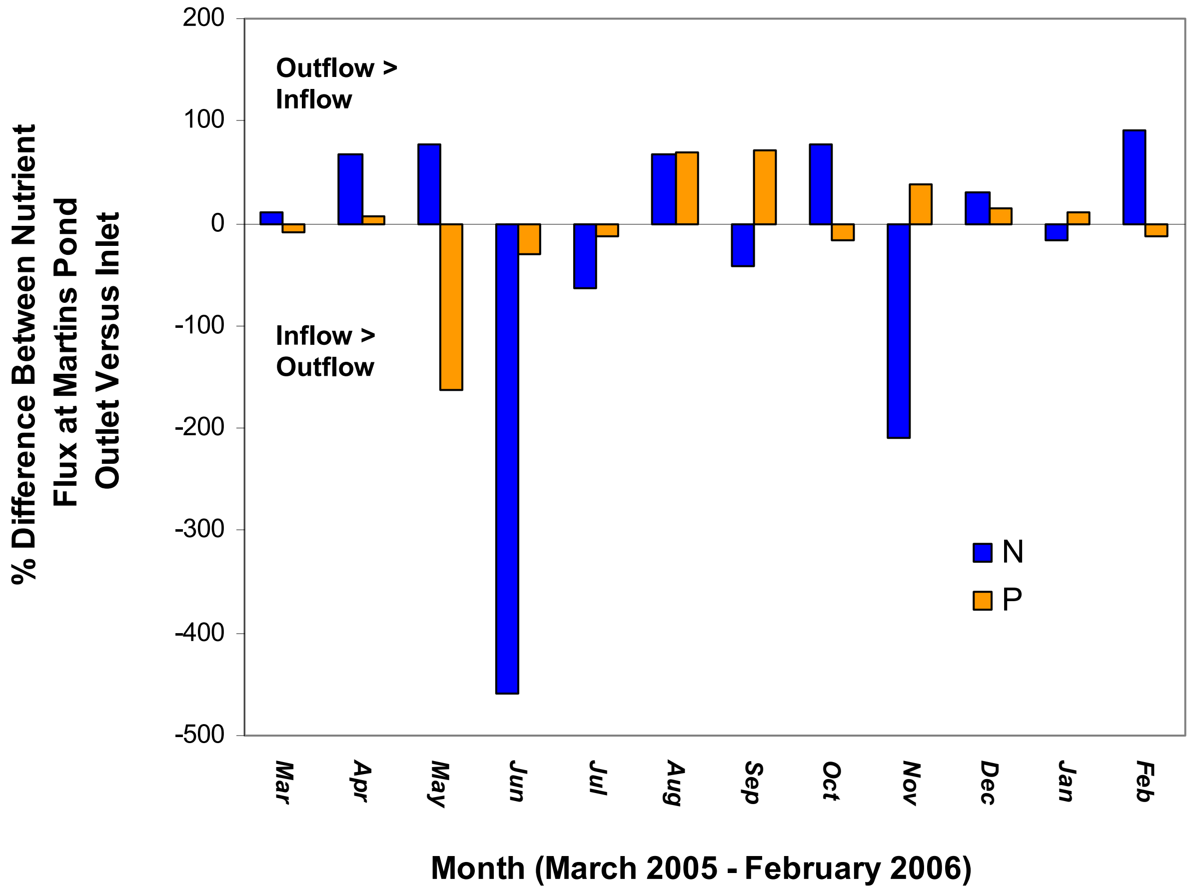

Figure 38. A comparison of the monthly difference in nutrient flux at the Martins Pond outlet versus the inlet. Positive values represent percent N and/or P outflows > inflows. Negative values represent percent N and/or P inflows > outflows for each month. When comparing yearly flux, there was a 41.7% increase in N and a 3.7% increase in P leaving Martins Pond versus entering over the study period.

It is difficult to conclude that it would be practical and/or desirable to adequately control P levels in surface waters, sediments and hydric soils in the Martins Pond watershed. The watershed currently has inherently high levels of P and these levels appear considerably higher than 20 years previous (Table 31). Whether or not current P levels are the result of land use changes, non-point sources or released from hydric soils and sediments in this watershed does not change the current situation, although it does point to the need for watershed management to control N and P inputs. Thus it may be more valuable to consider management of N:P ratios in the watershed and in Martins Pond rather than absolute concentrations of either. The wide range of N:P ratios observed across sample sites and sample dates (Table 25), point to complex processes regulating N and P dynamics in each subwatershed (see Barica 1990). N:P ratios change dramatically as one moves downstream along the Skug and there is great variability among tributaries draining into the Skug River. These spatial and temporal patterns point to a unique trophic environment where the importance of both absolute levels of N and P as well as the N:P ratio must be considered in any proposed manipulation of water quality in the watershed (Rast and Holland 1988).

The regulation of biogeochemical cycles by microbial populations is important in the cycling of N, S, P and C. Much of the watershed pool of these elements resides as organic forms in forest floor, mineral soil and hydric soil compartments. These organic complexes are subjected to microbial transformations which regulate N, S and P dynamics and availability which, in turn, indirectly influence the movement of other solutes in solutions and ultimately influence the concentrations of these ions in surface waters. One of the most important relationships emerging from these interconnected biogeochemical cycles is the relationship between nitrogen and phosphorus. Despite the complexity of the water quality results from the 2005-06 study of the Martins Pond watershed, there are predictable changes that can be explained as a function of the redox environment in Martins Pond and alluvial sediments, as well as in riparian and wetland soils. As each of these environments become progressively reduced, there is a loss of oxygen and aerobic respiration, loss of nitrate through denitrification, changes in iron through iron reduction, and loss of sulfate through reduction (Carlyle and Hill 2001). In addition, reductions in the concentration of oxygen and changes in redox potential of sediments can result in the mobility and consequent availability of phosphorus into the overlying water column (Broch 1993). The extent of the P release will be influenced by soil-water redox potential, sediment type, water depth, temperature and turbulence (Sallade and Sims 1997). The 2005-06 results for the Martins Pond watershed indicate seasonal total P increases (Figure 29) were inversely related to sulfate levels (Figure 26).

Furthermore, in those riparian and wetland soils and pond sediments that become saturated with P, it may take several years for noticeable depletion, thus these substrates could provide P to surface waters for extended periods (Young and Ross 2001). The very high total P levels observed in Martins Pond and the lower Skug River in 2002 (Figure 31) may have been due to several factors, including evapoconcentration, a watershed source and/or a benthic P influx during low oxygen conditions at the water-sediment interface. In addition, the settling of dead algae and macrophytes could have served as an energy source for microorganisms that, in turn, enhanced microbial activity in sediments during that summer and early fall.

In calm summer and early fall periods in Martins Pond a temporary thermocline can develop and this was observed periodically in 2002 during the summer and early fall. Stratification can prevent the efficient mixing of surface and deeper water layers, resulting in a prolonged residence time of the near-bottom water. This prolonged residence time in combination with the high sediment O_2 consumption (related to the high sediment organic matter content noted in Martins Pond) can lead to dramatic decreases in the near-bottom O_2 concentration during certain periods. Although the O_2 may not be completely depleted from the near-bottom water, the lowered O_2 concentration may cause anoxia at the sediment-water interface, thus triggering the release of P. When conditions become anaerobic, the hydrolysis of ferric and aluminum phosphates can release the bound phosphorus. This can occur in ponds, alluvial sediments and wetlands, all of which are in relative abundance in the Martins Pond watershed.

Overall, the Martins Pond watershed is a complex system with several subwatersheds with unique land covers and with different soil, topography, land use and stormwater management infrastructure. It is difficult to point to a single factor that explains the loadings of N and P, the observed seasonal shifts in N:P ratios in Martins Pond and the great variability in N:P ratios across the subwatersheds analyzed in this study. However, both wetland and sediment biogeochemistry in the watershed clearly have the potential to influence N and P concentrations in surface waters. Hydric soils comprise some 21% of the watershed (Table 8) and the importance of these soils as an interface between surface and shallow groundwater is likely very important. Given the inherently high total P levels in the watershed, as observed in winter and spring, and given that there are seasonal peaks of P in summer and fall (Figure 29), P may not be the major limiting nutrient in Martins Pond, at least in the summer.