Final Report Summary

Our data indicate that the eutrophication of LIS started around 1800 AD, as indicated by increased burial rates of Corganic, BSi, sewage indicators (C. perfringens) and benthic foram abundances. Data from Dr. M.Altabet on the same cores show that the nitrogen concentrations and nitrogen isotope signatures changed at the same time (ongoing studies), indicating that the nutrient sources displayed a dramatic change during this period. The salinity and water temperature have oscillated over time within a narrow range, but showed more extreme events over the last 200 years. The low salinity peaks in the 20th century suggest that wet periods now translate more directly into, low salinity events of several years, possibly with related water stratification and hypoxia events. The low salinity events of the early 1900's and 1950's and 1970's correlate well with the regional precipitation records (Figure 18). Climatic trends are conform northern hemispheric temperature patterns, with good evidence for modern global warming which may have enhanced water stratification over the last 50 years. The oxygen demand record shows a strong increase from 1800 on, and correlates reasonably well with the paleo temperature record. The strong hypoxia-anoxia of the last decades may be the result of the combined effects of high bottom water temperature (high rates of Corganic mineralisation and enhanced water column stratification) as well as high organic productivity (availability of labile organic carbon). Most parameters in the modern Sound show decreasing water quality to the west.

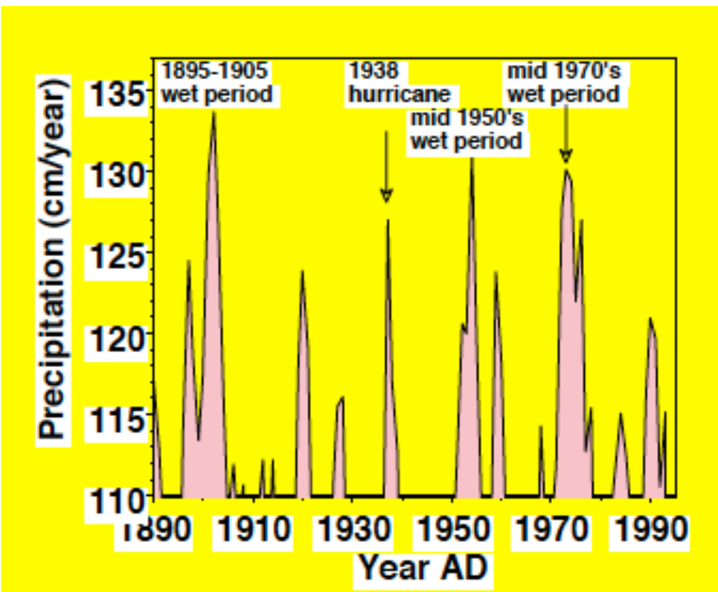

Figure 18. Precipitation record for southern New England.

The changes in benthic foraminiferal faunas can be separated into two separate events:
I. overall foraminifera abundance increased since about 1800, which was coupled with an increase in relative abundance of E. excavatum at all water depths. The increase in abundance of this diatom-consuming species E. excavatum at depths below the photic zone suggests that the higher productivity of pelagic diatoms since 1800 could now be delivered to the sea floor in greater numbers. The decrease in relative abundance of E. advena in the deeper water cores is likely coupled to this increase of E. excavatum abundance.
II. The second major event was heralded with the increase in relative abundance of A. beccarii, which started in the early 1970s in western LIS. This appearance of A. beccarii rapidly spread to the east, starting at the mouths of the main rivers. This increase in A. beccarii abundance was accompanied by a decrease in E. excavatum abundance, suggesting a major shift in the food chain or environmental parameters at this time.

Similar increases in relative abundance of Ammonia species relative to Elphidium species have been observed in the Gulf of Mexico and in Chesapeake Bay, and were explained as a result of hypoxia. Laboratory studies of both Ammonia and Elphidium species indicate that they are highly resistant to hypoxia and even anoxia, and show no difference in susceptibility. Another possible cause of the increasing relative abundance of A. beccarii might be the increase in LIS water temperatures with modern global warming. Laboratory and field studies indicate that Ammonia species need temperatures in excess of 20 oC for about 30 days to reproduce successfully and prolifically. It is only during the last few decades that LIS bottom waters were that warm for that long.

The high nitrogen influx of the last few decades (as indicated by the C. perfringes records in cores) may have played a major role as well. The biogenic silica data indicate that recently diatom productivity may have decreased. Such a change in primary producers away from diatoms has been observed in modern phytoplankton studies in LIS as well as in other eutrophied waters (e.g., Gulf of Mexico). The newly emerging species are dinoflagellates and cyanobacteria, which may be better adapted to use the high nutrient influxes. At high nutrients levels, diatoms become Si-limited and can no longer sustain blooms because they become Si-limited. A decrease in availability of diatoms would explain why the diatom-consuming species E. excavatum could no longer compete successfully with the more omnivorous A. beccarii.

If high N/Si ratios have indeed led to a decreasing availability of diatoms in LIS, the consequences for the overall ecosystem may be severe. Diatoms as primary producers form one of the basic elements of the LIS food chain, and are the preferred food of many organisms at higher levels (e.g., copepods). Dinoflagellates and cyanobacteria are much less used as a food source, and such a change in the base of the food chain may have led to changes in the overall ecosystem, including the documented higher abundance of jellyfish and lowered abundances of fish and shell fish.

In conclusion, the eutrophication has been an ongoing process for close to two hundred years, possibly with the associated low oxygen conditions of the LIS bottom waters. With the eutrophication came the associated changes in benthic ecosystem, with higher productivity and enhanced levels of diatom consuming foraminifera. The occurrence of hypoxia may have been exacerbated by higher temperatures and increased water stratification. A second major ecosystem shift occurred over the last 30-40 years, possibly a result of the change in population dynamics of diatoms which became silica-limited and the take over of dinoflagellates as primary producers and A. beccarii species as benthic foraminifera. Again, a combined effect of eutrophication and increased water temperatures may have played a role.