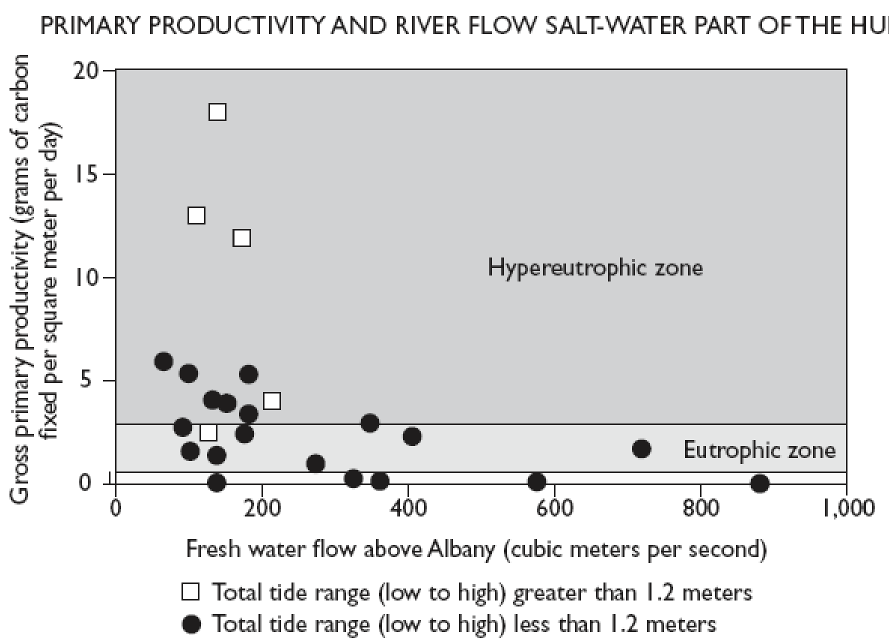
Eutrophication and the Saltwater Hudson River

Part 1: Primary Production and Eutrophication in the Hudson

Since the Industrial Revolution, the Hudson River has had problems with pollution, yet the challenges and focus regarding pollution management has changed and evolved. In the last twenty years interest went from reducing toxic substances, such as PCBs and DDT, to controlling nutrient pollution and consequent eutrophication. More than sixty percent of coastal waters in the U.S. are moderately to severely degraded by nutrient pollution, most of which originates in the interior of the U.S.

Eutrophication from excess nutrients (primarily nitrates and phosphates) leads to algal blooms, which leads to a degradation of water quality due to reduced dissolved oxygen levels and a subsequent decrease in biodiversity. In the Hudson River, primary productivity (a measurement of the amount of photosynthesis by organisms like plants and algae) has increased dramatically since the 1970s. Estuaries are classified as eutrophic when annual production ranges between 200 and 500 g C m^{-2} y^{-1}, and as very eutrophic (sometimes called hypereutrophic) when annual production exceeds 500 g C m^{-2} y^{-1}. If you break this down to a daily rate, the Hudson would be considered very eutrophic anytime daily production goes above 2 to 3 g C m^{-2} d^{-1}. *(Note: when you see a negative exponent after a measurement value, it represents 'per'. That is, 500 g C m^{-2} y^{-1} is the same as 500 grams of carbon per square meter per year.)*

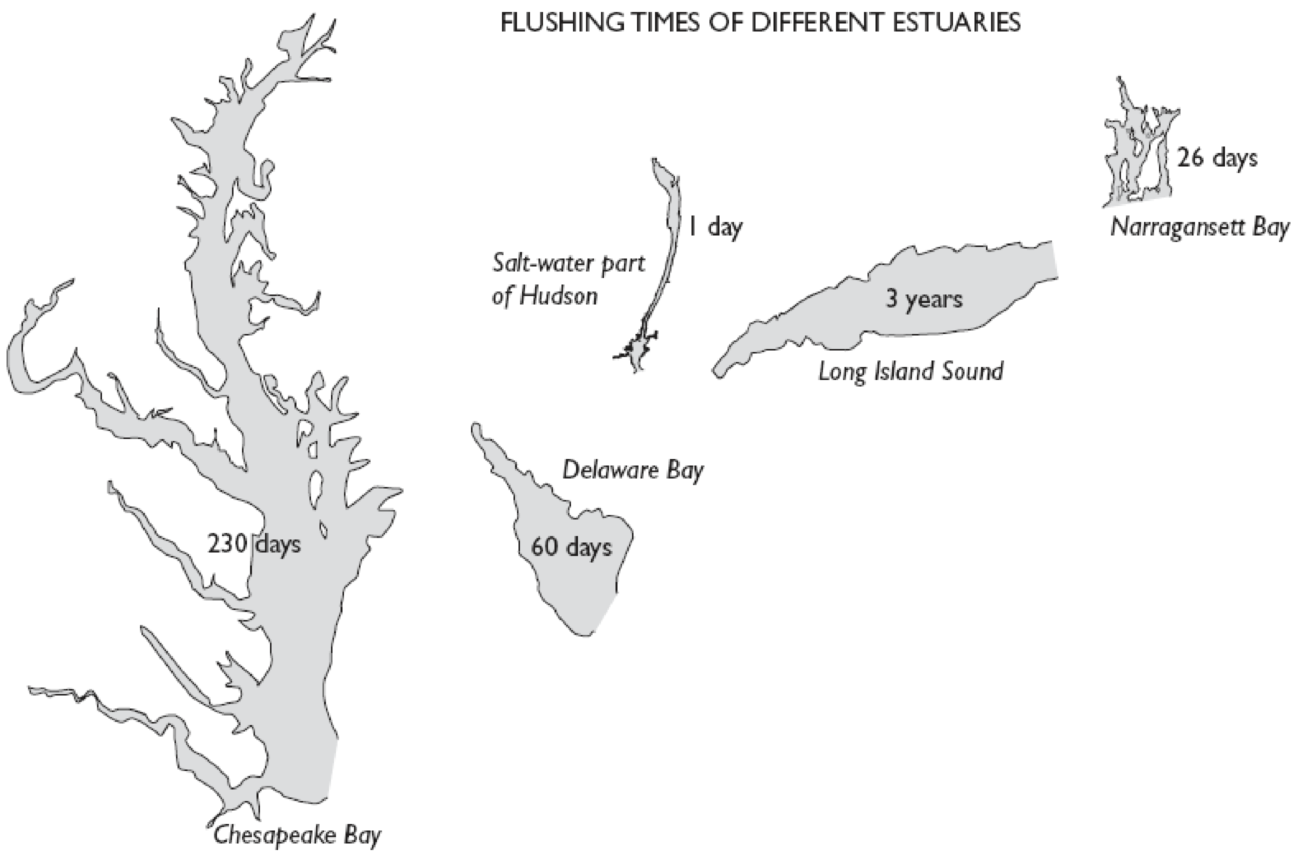
Gross primary productivity, or GPP, is the amount of energy, expressed in carbon, which has been captured or produced by plants through photosynthesis. It is a way for scientists to understand how productive, or how much biomass (and therefore energy) is consumed by plants in an ecosystem.



This graph shows the relationship between freshwater flow and GPP in the Hudson River. Data was collected in the spring, summer, and fall of 1994, 1995, and 1997 in the lower Hudson River estuary (where the river is salty). The dotted line represents the approximate value for GPP above which an estuary is considered to be very eutrophic. The open squares represent low tide range (less than 1.15 m), while the dark triangles represent high flow range (greater than 1.15m). Howarth et al, 2000.

1. How often did the lower, saltwater portion of the Hudson River go above the ‘very eutrophic’ line?
2. Was the lower Hudson more likely to be very eutrophic during low tide ranges or during high tide ranges?
3. What does this tell you about the relationship between the tides and GPP? Do you think this would be the same for other parts of the Hudson? Why or why not?

The lower parts of the Hudson River estuary flush frequently, since there is a lot of freshwater coming down the river from the watershed. The mean residence time is the average amount of time a particular atom stays the system. Use this table to compare residence times of different estuaries. The saline portion of the Hudson refers to the area of the estuary that has some saltwater, generally from around Peekskill south to the tip of Manhattan.



Data from Howarth, et.al. 2006.

4. How often is the lower, saline Hudson River “flushed”?
5. Why do you think the Hudson River is less sensitive to nutrient pollution than other estuaries with longer residence times?
6. What do you think would happen if we created a large dam at the mouth of the Hudson River?
7. Based on the data you’ve seen so far, what two things affect the amount of phytoplankton production in the Hudson River?

Step 2: Wastewater Treatment

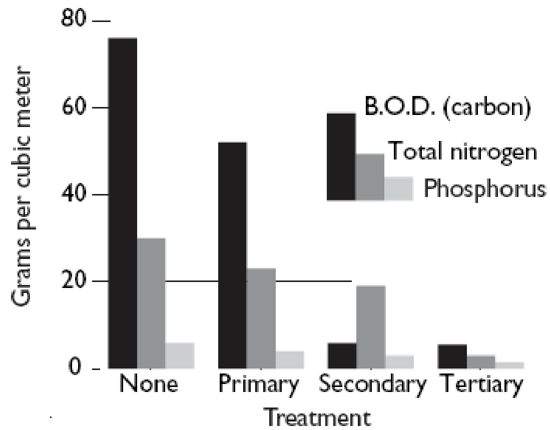
Finally, take a look at some information about current treatment and possible treatments that would remove different quantities of nitrogen and phosphorus, as well as improve biological oxygen demand. The first primary treatment plants in the New York City metropolitan area were built in the 1930s, and secondary treatment plants were not built until after the Clean Water Act required facilities to reduce their Biological Oxygen Demand (a measure of the organic material in the water) levels in 1972. As of the early 1970s, close to 40% of the wastewater discharged into the Hudson River estuary was raw sewage, 15% received primary treatment, and 47% received secondary treatment. There is, however, an additional way to remove nutrients from wastewater, which involves upgrading existing plants or building new treatment plants that include 'nutrient removal' processes.

Primary treatment removes materials that can be easily collected from the raw wastewater and disposed of including large particles (rock, sand, gravel), human waste and floating materials. This step is done entirely with machinery, and is often referred to as mechanical treatment. Secondary treatment is designed to substantially reduce the biological content of the sewage using aerobic biological processes. This is done by allowing bacteria, fungi, and protists to decompose the organic materials, and during this process oxygen is added to allow the microbes to breathe and grow. During this process microbes actually eat and digest potentially harmful waste. The bacteria and solid waste eventually accumulate and settle out in suspension, at which point they are removed from the water, dried, and become nutrient loaded 'sludge'. This sludge is sometimes sent to a landfill or incinerator, or sometimes it is processed to become fertilizer.

In the 'nutrient removal' process, additional nitrogen and phosphorus are removed by the treatment plant. The removal of nitrogen is accomplished by changing the ammonia to nitrate through the process of nitrification, followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas, which is non-reactive and not a pollutant, is released to the atmosphere and thus removed from the water. Phosphorus can be removed biologically in a process called enhanced biological phosphorus removal. In this process, specific bacteria, called polyphosphate accumulating organisms, are selectively enriched and accumulate large quantities of phosphorus within their cells (up to 20% of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids have a high fertilizer value.

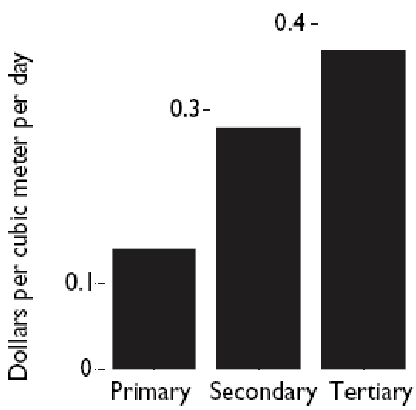
This chart shows the average effluent concentrations and costs for sewage treatment systems in the U.S. Although the costs may not seem high, keep in mind that a sewage treatment plant might take in anywhere between 600 m^3 and 3000 cubic meters (or more!) of sewage per day. That would equal $168 a day or $61,320 a year for the smaller system, or $840 a day or $306,600 a day for a larger system. That's a lot of money for a village, town, or even city to spend on wastewater treatment.

CHEMISTRY OF SEWAGE TREATMENT PLANT EFFLUENT



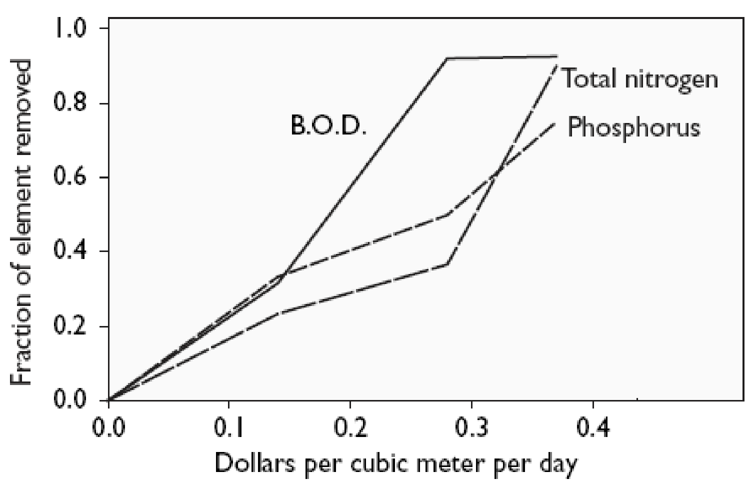
Treatment System	BOD (g C m^{-3})	TN (g N m^{-3})	TP (g P m^{-3})
No treatment	76	30	6
Primary	52	23	4
Secondary	6	19	3
Nutrient Removal	5.6	3	1.5

COSTS OF SEWAGE TREATMENT



Treatment System	Total Costs ($ per cubic meter per day)
No treatment	0
Primary	0.14
Secondary	0.28
Nutrient Removal	0.37

COST-EFFECTIVENESS OF DIFFERENT SEWAGE TREATMENTS

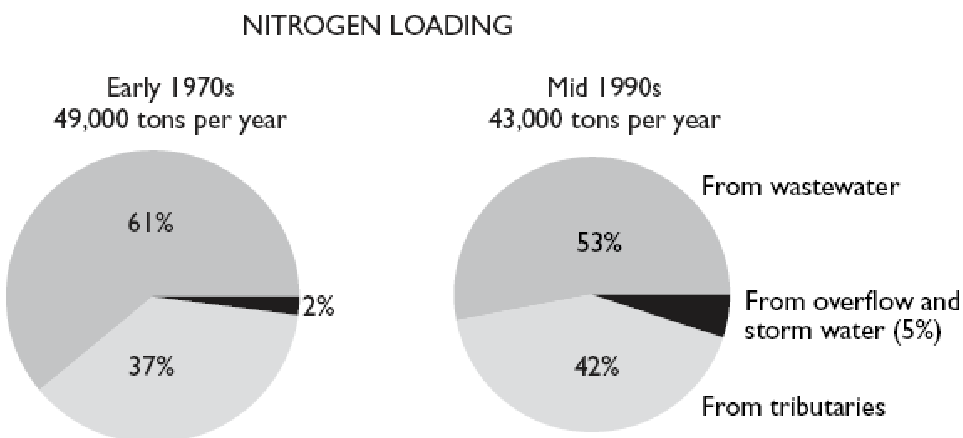


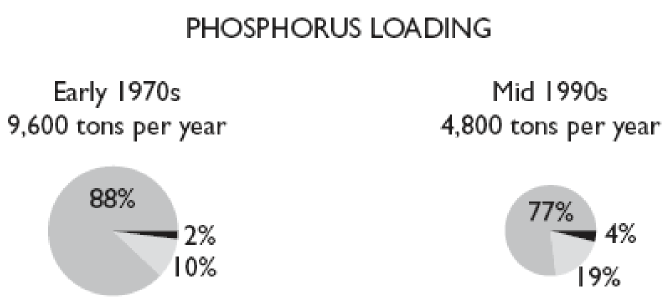
1. What percent of BOD is removed by primary treatment? Secondary? And with nutrient removal?
2. What percent of nitrogen is removed by primary treatment? Secondary? And with nutrient removal?

3. What percent of phosphorus is removed by primary treatment? Secondary? And with nutrient removal?
4. Compare the costs between removing nutrients at the secondary and ‘nutrient removal’ levels. If you are the manager of a sewage treatment plant that treats 1,500 m^3 of sewage per day, what is the difference in the amount you would spend per day with the two different types of treatment plants? What would be the difference per year? Do you think these costs are justified?
5. For which nutrients does the ‘nutrient removal’ process remove the largest amount? Do you think this justifies the additional costs? Why or why not?

Part 3: Nutrient Loading over Time

Since we are concerned about the health of the coast where the Hudson River enters the Atlantic Ocean, it is important to understand how things have changed over time, and what needs to be done in the future. In the early 1970s, several things occurred that affected water quality. First, the Clean Water Act was signed in 1972, and a ban on phosphates in laundry detergents was initiated in 1973. Use the graph and table to answer the questions below.





	Early 1970s	Mid 1990s
Total nitrogen (10^3 tons/y)	**49**	**43**
Contribution from wastewater plants effluent	61%	53%
Contribution from upriver tributaries	37%	42%
Contribution from sewer overflow and storm water	2%	5%
Phosphorus (10^3 tons/y)	**9.6**	**4.8**
Contribution from wastewater plants effluent	88%	77%
Contribution from upriver tributaries	10%	19%
Contribution from sewer overflow and storm water	2%	4%

1. How did the total nitrogen and phosphorus amounts change between the 1970s and the 1990s? Why do you think this occurred?
2. Where does the majority of the nutrient input come from?
3. Where would the nutrients that are labeled "upriver tributaries" originate?
4. What could be done to reduce upriver tributary nutrient loading?

References:

Howarth, R.W., Swaney, D., Butler, T.J., and Marino, R. 2000. Climatic control on eutrophication of the Hudson River estuary. *Ecosystems*. 3:210-215.

Howarth, R., Anderson, D., Cloern, J., Elfring, C., Hopkinson, C., Lapointe, B., Malone, T., Marcus, N., McGlathery, K., Sharpley, A., and D. Walker. 2000. Nutrient Pollution of Coastal Rivers, Bays, and Seas. *Issues in Ecology*. No. 7.

Howarth, R.W., Marino R., Swaney D., and E. W. Boyer. 2006. Wastewater and Watershed Influences on Primary Productivity and Oxygen Dynamics in the Lower Hudson River Estuary, in *The Hudson River Estuary*, Levinton & Waldman, editors. Cambridge Press.