MANAGEMENT OF NITROGEN DEPOSITION IN COASTAL BAYS AND ESTUARIES

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Stating the obvious!

- Nitrogen in the Earth's atmosphere – 78%
- Nitrogen in the Earth's crust – 20 ppm
- Nitrogen in the human body – 4th most abundant element
- Nitrogen is essential to life: *it is needed for construction of life's basic building blocks, i.e., DNA and RNA molecules, and is also required to make proteins and enzymes that are crucial to the functioning of our bodies*

There is no substitute for nitrogen intake!

Our medical doctor friends tell us:

Nitrogen deficiency can result in growth retardation in children; wasting of muscles, changes in skin pigmentation, reduced mental capacity, fatigue, and susceptibility to infections.

“Protein Paranoia”

- The US recommended daily allowance is less than one-half of a quarter pounder each day (or roughly 50 lb per year)
- Americans consume the most: roughly 275 lb per person each year
- Western European, Brazil, Argentina, New Zealand: 150-200 lb/year

Other countries

- China – meat consumption is on a rampant increase having steadily gone up:
  - 20 lb/year in the 1970s
  - 120 lb/year in recent years
- Pakistan – 27 lb/year
- India – 12 lb/year
- These figures do not include seafood consumption, which in the US is about 16 lb/year

Meat Production

- Because of this voracious (and increasing) appetite for meat:
- We are sharing the Earth's natural resources with more than a billion cows, about a billion pigs, nearly 2 billion sheep and goats, and 14 billion chickens
- Yearly meat production amounts to more than 200 million tons:
  - China -- 60 million
  - US – 37 million
  - Brazil – 13 million
  - France – 6 million

As it turns out, the amount of naturally-occurring, biologically useful nitrogen on the Earth is quite limited and cannot support such production of meat and all the grains and vegetation that are required as nourishment for the cows, pigs, and chickens.

It has been estimated – and not without controversy and contradictions – that the natural sources of nitrogen would support only 4 billion people on the Earth.

Coping with nitrogen deficiency

- Crop rotation (wheat, barley, clover and turnips)
- Improved watering of crops and agriculture (pump operated irrigation)
- Fast growing vegetables and grains
- “Resting of the soil”
- Importing crops to replenish nitrogen (e.g., sorghum from Africa, citrus from China, and spices and sugarcane from India) in the “Fertile Crescent,” which once was the most productive patch of land in the world (8th to 13th centuries)

Haber-Bosch Process – Nitrogen fixation

- Fritz Haber -- professor of physical chemistry and electrochemistry –demonstrated (1909) a process of converting atmospheric nitrogen to liquid ammonia
- Carl Bosch – a pioneer in high-pressure physics and manufacturing – agreed to investigate large scale production

Haber-Bosch Process

- Within years (1913), commercial production of ammonia was feasible, and Germany was producing 60,000 tons of ammonia – making it self-sufficient in the production nitrogen compounds (for example ammonium nitrate) for use in making bombs and explosives during World War I.
- The process is now producing nearly 100 million tons of nitrogen fertilizers each year (ammonium sulfate, ammonium phosphate, ammonium nitrate, and urea)
  - 27 million tons used in China
  - 11 million tons used in US
  - 11 million tons used in India

There is no imminent shortage of nitrogen-based fertilizers

The Haber-Bosch Process has been termed the “Detonator of the Human Population Explosion” implying that the current human population and its lifestyles could not have been supported by the naturally occurring nitrogen cycle.

So, what's the big problem?

- Only about 14 percent of nitrogen used as fertilizers results in crops and even lesser amount in human food. The remaining amount is lost:
  - during food production, including transportation and application of fertilizers, spoilage and waste
  - seepage to groundwater and surface water streams
  - as crop residue, animal waste
  - via escape of gaseous chemicals to the atmosphere.
- Nitrate in particular does not bind well with soil; it can be readily transported over long distances, typically ending up in large waterbodies

A Global Environmental Issue– subject of conferences, research initiatives and declarations

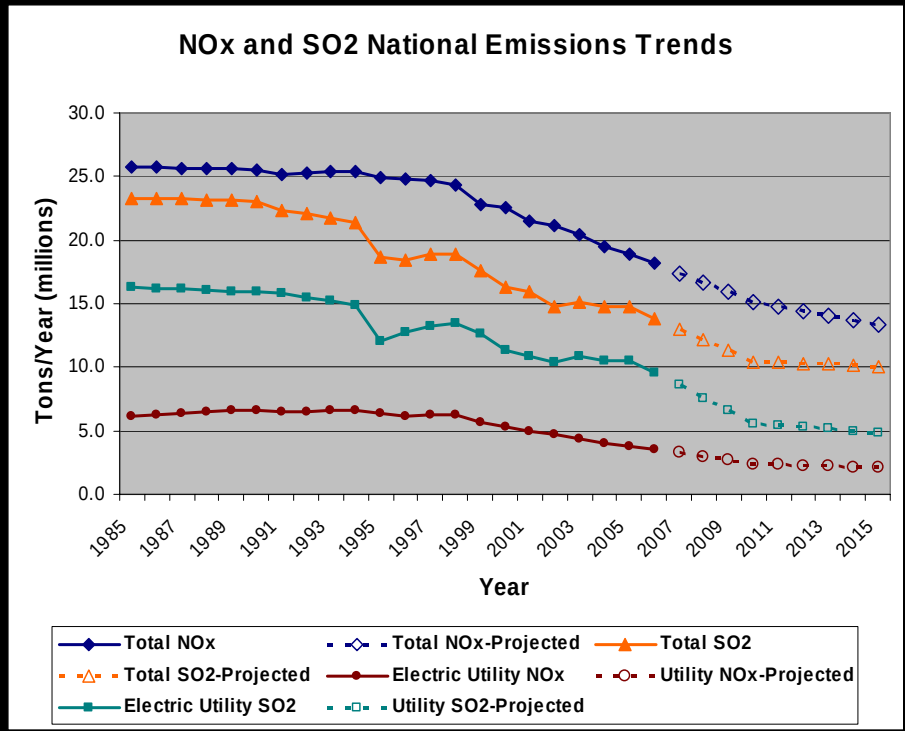
The direct and indirect delivery of fertilizers (reactive nitrogen) into coastal bays and estuaries has increased tremendously in recent years, and there are indications that the problem will worsen globally

In nearly all parts of the world, the effects of excessive nutrient enrichment in coastal waters are obvious:

- *Unwanted and excessive algal growth that cannot be utilized by animals*
- *Accumulation of large amounts of dead and decaying plant matter, and that sucks up dissolved oxygen in the water*
- *"Dead zones" have now been documented all over the world*
- *Coral reefs are surrounded by murky green, not azure blue, waters, with 40% of the world's reefs in jeopardy of being lost.*

Trends in national and utility-only NO_X and SO2 emissions from 1985 to 2006 and projected to 2015

- Burning of fuel at high temperature (automobiles, power plants, electric utilities, other industries)
- Escape from fertilized fields



CAFOs –animal meat producing factories

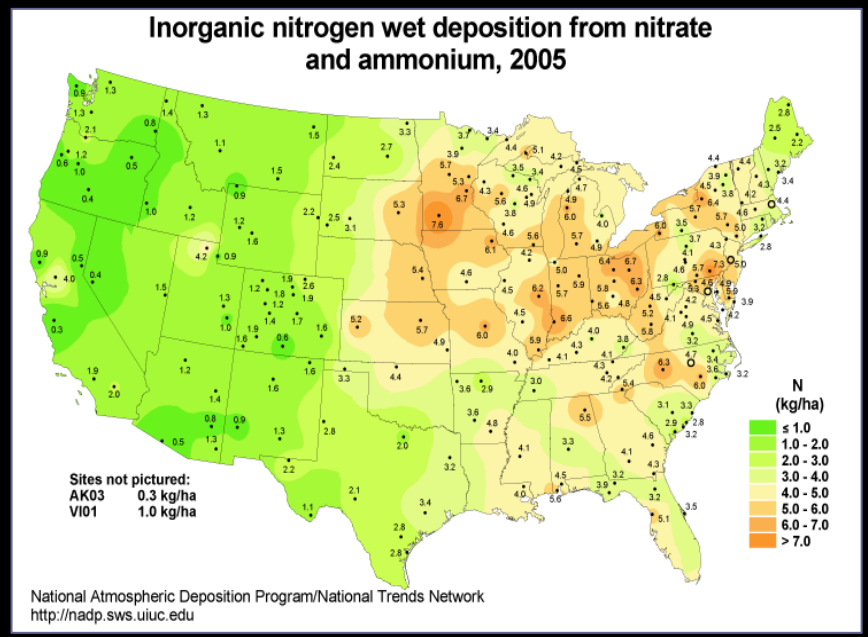
- In a book entitled “This Steer’s Life,” (Michael Pollan, NY Times: March 31, 2002), it was noted that “we have … transformed what was once a solar-powered ruminant into the very last thing we need: another fossil fuel machine.”
- It has been estimated that annual production of cows in the US requires 158 million barrels of crude oil equivalents – or more energy per cow than I use as gasoline each year!
- There is a general lack of management of manure from these operations; the argument is that you will not be allowed to put untreated human waste from a town of 120,000 people on a farmland but you can do that if you had a CAFO farm with 4,000 cows.

Effects of nitrogen overload

- Nitrogen saturation of watersheds, i.e., more nitrogen is deposited than plants can use or bacteria can transform – causing excessive algal growth even in the most remote alpine lakes
- Lakes, streams and soils are becoming acidic, resulting in fundamental changes in ecosystems
- Nitrogen in groundwater contaminates drinking water; in some areas much above the criterion (400 vs. 10 mg NO_3-N/L
- Nitrogen oxides promote formation of fine particulate matter in the air (respiratory problems)
- Nitrous oxide is an important greenhouse gas [it has a global warming potential 329 times greater than that of carbon dioxide]

Journey and fate of atmospheric nitrogen deposition

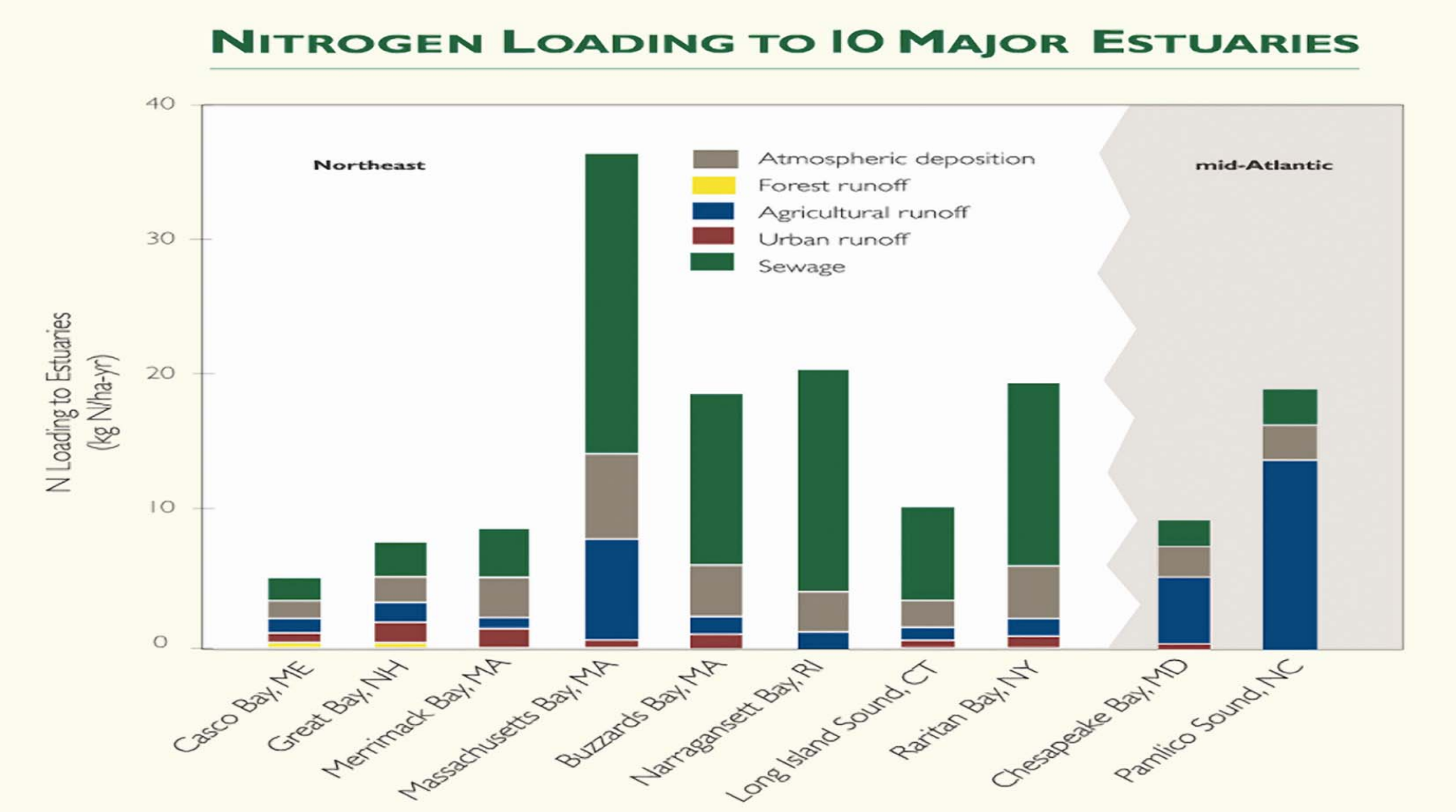
Would the transport of nitrogen from the watershed to rivers and streams be minimal if atmospheric deposition were less than 8 kg/ha/year (as was shown in a northeast forest)?



Nitrogen and HABs

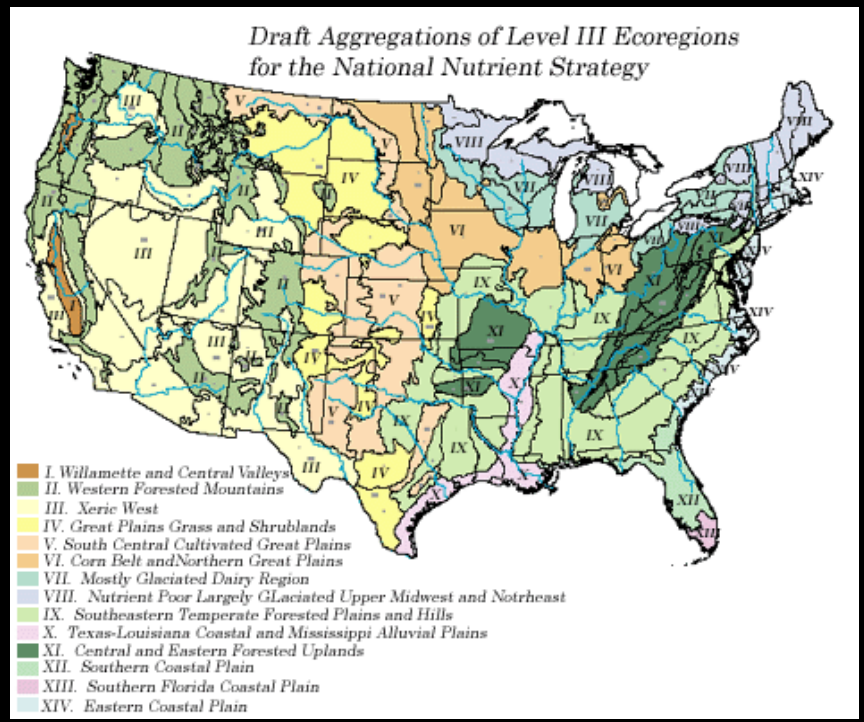
- Largely due to greatly increased inputs of reactive nitrogen to coastal bays and increased number of harmful algal bloom observations in recent years, nitrogen-related issues in coastal waters are stated or implied to include HABs.
- A direct relation between nitrogen over-enrichment, nearly always reported as concentration of dissolved inorganic nitrogen (DIN), and the onset and magnitude of HABs has remained difficult to quantify.

Relative contribution of nitrogen sources to different estuaries on the US East Coast



No numerical criteria for nitrogen control

- None for coastal bays and estuaries
- Just a handful of states have “approved” ones for entire classes of rivers and streams
- No toxicological benchmarks for protection of coastal and estuarine organisms; in Canada, an interim guideline exists (but not from impacts of eutrophication): 18 mg NO_3/L



What's limiting?

- Is nitrogen the limiting nutrient?
- Reviews of nitrogen-to-phosphorus ratios in marine and freshwater environments (e.g., Guildford and Hecky, 2000) suggest:
  - Nitrogen limitation -- when the N:P ratio is less than 20
  - Phosphorus limitation– when the ratio is more than 50 (i.e., little to do whether the system is marine or freshwater)
- Are effective phosphorus controls upstream exacerbating nitrogen effects downstream and in estuaries?

Thank You

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