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Nitrate in Coastal Waters

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Much of the nitrogen that gets into streams and rivers ends up in the sea, where it remains a potent source of controversy, particularly in the estuaries and bays in which rivers meet the ocean. Chapter 1 detailed the enormous increase in the use of nitrogen fertilizer since 1900. This has been accompanied by large increases in the deposition of nitrogen oxides generated by traffic and industry and, as a result of this human activity, the quantity of nitrogen circulating in the global nitrogen cycle has doubled since pre-industrial times. Rivers now contribute twice as much nitrogen to marine waters as they did 100 years ago (Vitousek *et al.*, 1997). Eutrophication is therefore a problem in marine as well as in fresh waters. It has caused startling changes in the growth of aquatic plants and algae in coastal waters (Nixon, 1995). The excessive algal growth in particular has destroyed critical aquatic habitats and lowered the concentration of dissolved oxygen, thereby killing fish and shifting the balance between marine organisms (Howarth *et al.*, 2000). This eutrophication threatens the long-term sustainability of fisheries and the use of coastal waters for recreation.

This chapter introduces the environmental consequences of the enrichment of marine waters by plant nutrients, particularly nitrogen (Table 8.1), together with the principal concepts needed to understand it and the methods used to study it. It reviews the evidence implicating nitrogen in the fouling of marine waters and presents several case studies of large marine ecosystems. These studies, of the Baltic Sea, the Gulf of Mexico and the open waters of the Pacific, provide a warning against assuming that any single factor can explain all the complexities and intricacies of marine waters.

Table 8.1. Responses of aquatic ecosystems to eutrophication.

Increased biomass of phytoplankton and suspended and attached algae.
Decreased transparency of water column.
Shift in phytoplankton composition to bloom-forming species, some of which may be toxic.
Accumulation of carbon within the system.
Changes in vascular plant production and species composition.
Decrease in living aquatic habitats, including seagrasses and coral reefs.
Depletion in deep-water oxygen concentration, resulting in hypoxia.
Changes in species and production of fish.
Decline in aesthetic values.

Consequences of Eutrophication of Coastal Waters

Stratification and oxygen depletion

Two levels of oxygen depletion are defined for marine studies. Either can arise from enrichment of coastal waters with plant nutrients:

- Hypoxia, defined as when the supply of oxygen is low.
- Anoxia, which implies there is no oxygen supply at all.

Hypoxia resulting from eutrophication has caused widespread damage to fisheries ranging from Chesapeake Bay and the Gulf of Mexico in North America to the Baltic and Black Seas in Europe (Howarth *et al.*, 2000). Oxygen depletion occurs, as it does in fresh water, as an after-effect of the stimulation of algal growth by a supply of nutrients in the water. Large algal blooms fix carbon dioxide from the atmosphere and increase the organic biomass in the water. (Biomass is simply the mass of living material.) These algae increase the oxygen concentration in the water while they are photosynthesizing during active growth, but the microorganisms that decompose them when they die consume oxygen. The resulting oxygen demand can be a problem for the whole ecosystem.

This is a particular problem in stratified aquatic systems that are isolated from the oxygen in the atmosphere. Summer stratification occurs in freshwater lakes deeper than 3–5 m when the upper water layers absorb heat from the sun and become warmer and therefore less dense than the water at the bottom of the lake. When this stratification occurs, a layer with a steep temperature gradient known as the *thermocline* effectively isolates the water at the bottom and prevents oxygen from diffusing from the atmosphere to the water beneath the thermocline (Wetzel, 2001). Estuarine systems have a related problem. When fresh water from the river meets salt water coming in from the ocean, a layer of low-salinity water floats above a layer of denser saline water. This, combined with the temperature gradient, gives rise to a steep density gradient known as the *pycnocline*, which also prevents oxygen from diffusing from the atmosphere to the water at the bottom. The combination of the pycnocline and decomposing algal biomass settling to the bottom can cause severe oxygen depletion in the water at the bottom.

Changes in species composition

Enrichment with plant nutrients may favour the metabolic processes of one set of organisms at the expense of another, allowing the favoured organisms to grow more rapidly and dominate the ecosystem. It can therefore alter the species composition and the biodiversity, ultimately affecting the structure and food web of the whole ecosystem. In estuaries and bays, eutrophication has been linked to harmful algal blooms described as 'red tides' that can kill many fish and other marine organisms (Vitousek *et al.*, 1997; Howarth *et al.*, 2000).

Seagrass destruction

Patches of seagrass form important spawning and nursery habitats for fish and other marine organisms in shallow estuaries. The rates of seagrass destruction rival those of tropical forests and its loss causes serious problems in the Baltic Sea, the Gulf of Mexico and in estuaries along the east coast of the USA. The survival and growth of seagrass depend on the amount of light that can penetrate through to it (Howarth *et al.*, 2000). Increasing the supply of nitrogen in the water decreases the penetration of light to the surface of the seagrass leaf by stimulating the growth of two undesirable types of species: phytoplankton (floating algae) in the water above the seagrass and epiphytes (attached algae) growing directly on seagrass leaves (Fig. 8.1).

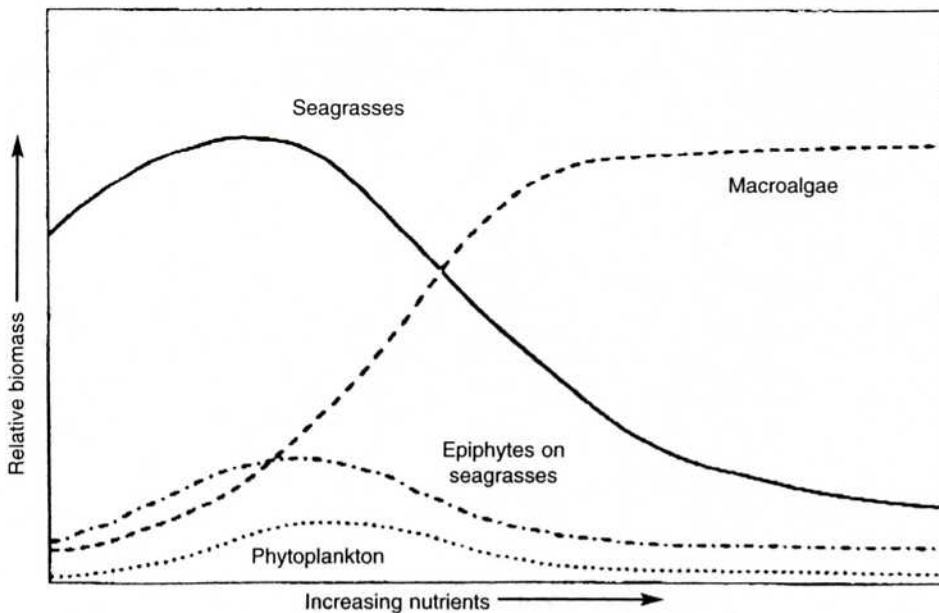


Fig. 8.1. Effect of nitrate with other nutrients in shallow marine systems. Decline in seagrass beds with increase in other species. (Redrawn from Harlin, 1995.)

