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Eutrophication

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Eutrophication

From The Encyclopedia of Earth

Eutrophication is caused by the enrichment of an ecosystem with chemical nutrients, typically compounds containing nitrogen or phosphorus. Pictured is a pond in Lille (North of France). By F. Lamiot (own work) (http://creativecommons.org)

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Eutrophication is a syndrome of [../152248/index.html ecosystem]] responses to human activities that fertilize water bodies with nitrogen (N) and phosphorus (P), often leading to changes in animal and plant populations and degradation of water and habitat quality. Nitrogen and phosphorus are essential components of structural proteins, enzymes, cell membranes, nucleic acids, and molecules that capture and utilize light and chemical energy to support life. The biologically available forms of N and P are present at low concentrations in pristine lakes, rivers, estuaries, and in vast regions of the upper ocean.

Pristine aquatic ecosystems function in approximate steady state in which primary production of new plant biomass is sustained by N and P released as byproducts of microbial and animal metabolism. This balanced state is disrupted by human activities that artificially enrich water bodies with N and P, resulting in unnaturally high rates of plant production and accumulation of organic matter that can degrade water and habitat quality. These inputs may come from untreated sewage discharges, sewage treatment plants or runoff (Surface runoff) of fertilizer from farm fields or suburban lawns. In some cases the climax stage of algal blooms can release toxic chemicals such as domoic acid to the aquatic environment, creating elevated metabolic risks to a variety of fish and marine mammals.

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Algal bloom in Orielton Lagoon, Australia, 1994. (Photo by Geoff Prestedge)

Eutrophication syndromes

Eutrophication was first evident in lakes and rivers as they became choked with excessive growth of rooted plants and floating algal scums, prompting intense study in the 1960's-70's and culminating in the scientific basis for banning phosphate detergents (a major source of P, the most frequent culprit in eutrophication of lakes) and upgrading sewage treatment to reduce wastewater N and P discharges to inland waters. Symptoms of eutrophication in estuaries and other coastal marine ecosystems (where N is the most frequent contributor to eutrophication) were clearly evident by the 1980's, as human activities doubled the transport of N and tripled the transport of P from Earth's land surface to its oceans. Eutrophication has emerged as a key human stressor on the world's coastal ecosystems.

Nutrient enrichment of marine waters promotes the growth of algae, either as attached multicellular forms (e.g. sea lettuce) or as suspended microscopic phytoplankton, because algae can grow faster than larger vascular plants. Small increases in algal abundance or biomass have subtle ecological responses that can increase production in food webs sustaining fish and shellfish, even producing higher fish yields. However, over-stimulation of algal growth leads to a complex suite of interconnected biological and chemical responses that can severely degrade water quality and threaten human health and sustainability of living resources in the coastal zone.

As algal biomass builds during blooms it forms aggregates that sink and fuel bacterial growth in bottom waters and sediments. Bacterial metabolism consumes oxygen. If the rates of aeration of water by mixing are slower than bacterial metabolism, then bottom waters become hypoxic (low in oxygen) or anoxic (devoid of oxygen), creating conditions stressful or even lethal for marine invertebrates and fish. Seasonal occurrences of dead zones devoid of oxygen and animal life have expanded in the Gulf of Mexico (where the dead zone has approached the size of New Jersey), the Baltic Sea, and Sea of Marmara as a consequence of eutrophication from nutrients delivered by large rivers.

Seagrasses are important communities in undisturbed shallow coastal ecosystems, providing essential habitat for many species of marine animals. The distribution and abundance of seagrasses have greatly diminished in nutrient-enriched coastal waters, such as Chesapeake Bay and Danish estuaries, where water transparency and light availability to rooted plants have declined as result of phytoplankton growth and fouling of the grass blades by epiphytes and biofilms. These habitat changes propagate through food webs, and the abundance and species diversity of fish and shellfish decrease as seagrasses are eliminated from nutrient-enriched coastal waters.

Some phytoplankton species excrete large quantities of mucilage during blooms that is whipped into foam by wind mixing and washes ashore, making beaches undesirable for holiday visitors. Other phytoplankton species produce toxic chemicals that can impair respiratory, nervous, digestive and reproductive system function, and even cause death of fish, shellfish, seabirds, mammals, and humans. The economic impacts of harmful algal blooms can be severe as tourism is lost and shellfish harvest and fishing are closed across increasingly widespread marine regions. Marine scientists are trying to determine if and how nutrient enrichment selectively promotes the growth of harmful algal species, and if the frequency of harmful algal blooms has increased globally in response to nutrient enrichment.

Terrestrial plant succession

The progression of eutrophication events for ponds and lakes can eventually create detritus layers that produces successively shallower depths of surface waters. Eventually the water body can be reduced to a marsh or bog, whose plant community is transformed from an aquatic environment to a recognisable terrestrial ecosystem. While this system may first emerge as a Plant succession of marsh grasses and related aquatic forbs, the community may evolve to be more of a bog or fen, and finally a vernal pool or meadow. This progression can clearly spawn radical changes in the entire ecosystem, which began as an aquatic habitat, and has been transformed into a fully terrestrial community, albeit inhabited by a number of mesic plants and water oriented animals such as amphibians.

Ecological consequences

There are numerous outcomes to the ecosystems associated with eutrophication environments. Most of these are viewed as unfavorable to the biota which have historically comprised a given habitat. The general types of ecological consequences include: reduction in biodiversity, die-off of certain organisms, reduction in visibility and mobility functions due to biotic overgrowth (which effects can interfere with plant metabolism and with aquatic animal transport); reduction in dissolved oxygen and associated fitness reduction in animals dependent upon oxygen levels. In the case of utter transformation of lakes to bogs and meadows, the ecological consequences are extreme, and result in replacement of an original ecosystem with an entirely different one; such progression occurs in the natural world, although human induced additions of N and P greatly accelerate the progression as compared to a natural landscape evolution. In such accelerated circumstances, organisms may not have the time needed to migrate or adapt to the rapidly altered new environment.

Mitigation

Protection of marine waters from the harmful consequences of nutrient enrichment is a challenge to resource managers because the sources and delivery routes of N and P are diverse. Combustion of fossil fuels produces gaseous nitrogen oxides, and animal production and fertilizer use produce volatile ammonia, two sources of atmospheric N that can be carried by winds and deposited on coastal waters and lakes hundreds of kilometers from their origin. Modern high-yield agriculture, golf courses, parks and urban gardeners presently use commercial fertilizers in large quantities -- substances that became cheap to produce in the mid 20th century– the era in which N and P concentrations began to increase in surface waters carrying agricultural and urban runoff to the sea. The world's human population is growing disproportionately in the [[coastal] zone], creating an additional challenge of reducing nutrient inputs from municipal waste, septic systems, and fertilizer runoff from lawns and gardens. Projections indicate that the largest future increases in N and P delivery to the coastal ocean will occur in eastern and southern Asia where populations and economies are growing most rapidly.

The eutrophication problem illustrates how human activities on land can degrade the quality of coastal waters and habitats, with potentially large economic and ecological costs. Solutions to the coastal eutrophication problem require changes in all these activities within the watersheds and airsheds connected to coastal waters. Commitments to these solutions are now beginning– the European Union's Water Framework Directive mandates strategies to reduce N and P delivery to coastal waters, and a 2000 National Research Council report recommended a National Coastal Nutrient Management Strategy for the United States.

Proposed solutions to the eutrophication problem are multidimensional and include actions to restore wetlands and riparian buffer zones between farms and surface waters, reduce livestock densities, improve efficiencies of fertilizer applications, treat urban runoff from streets and storm drains, reduce N emissions from vehicles and power plants, and further increase the efficiency of N and P removal from municipal wastewater. As coastal fish and shellfish aquaculture expand, management considerations of this rapidly growing internal source of nutrients will be required as well.

Further Reading

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Citation

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