AMMONIA: Narrative for detailed conceptual diagram

High concentrations of ammonia in aquatic systems can have lethal and sub-lethal effects on aquatic organisms, potentially changing community structure and ecosystem function. This conceptual diagram illustrates linkages between ammonia-related stressors (middle of diagram), the human activities and sources that can increase those stressors (top of diagram), and the biological responses that can result (bottom of diagram). In some cases, additional steps leading from sources to stressors, modes of action leading from stressors to responses, and other modifying factors also are shown.

This narrative generally follows the diagram top to bottom, left to right. For more information on interpreting CADDIS conceptual diagrams, see the Conceptual Model page in the Causal Database section of CADDIS.

Linking Sources to Stressors

Channel alteration can increase ammonia concentrations in several ways. Alterations that reduce channel complexity (e.g., piping or channelizing streams) can result in decreased nitrogen uptake. Impoundment of stream channels can result in decreased ammonia volatilization upstream of impoundments, due to decreased water velocities (and increased water depths); reduced water flows downstream of impoundments (or in streams affected by water withdrawals) can limit habitat availability, crowding biota and concentrating ammonia-rich waste products. Many human activities and land uses also decrease riparian and watershed vegetation, which may decrease the amount of nitrogen taken up by terrestrial plants, and further reduce channel complexity due to reduced woody debris inputs.

Certain human activities and land uses can directly introduce ammonia into aquatic systems. Sources associated with agriculture include animal wastes from contained animal feeding operations (CAFOs), other livestock operations, and aquaculture facilities, as well as fertilizers applied to cropfields. Sources associated with urban and suburban development include fertilizers applied to golf courses and lawns; human wastes from sewer and septic systems and wastewater treatment plants; landfill wastes; and nitrogenous vehicle emissions. Industries (e.g., coal-fired power plants and other industrial facilities) also may release ammonia to the environment. Ammonia from these sources can be introduced into aquatic systems via four main transport pathways (or transport-defined sources): stormwater runoff, leakage or leachate into groundwater sources, atmospheric emissions and deposition, or direct effluent discharges. Each of these transport-defined sources can lead to increased ammonia inputs into surface waters.

In streams, ammonia may be dissolved in the water column or associated with sediments. At non-toxic concentrations, ammonia acts as a nutrient and can stimulate microbial and plant production (see the nutrient module for more information on these pathways). Ammonia concentrations also will depend upon the nitrogen cycle, or the transformation of nitrogen among different oxidation states. This cycle is dependent on microbial activity and dissolved oxygen levels, so these factors play an important role in determining ammonia concentrations.

At high enough concentrations, ammonia can be toxic to aquatic organisms. In general, unionized ammonia (NH_3) is the form most toxic to aquatic biota. The relative contribution of unionized versus ionized forms to total ammonia concentrations depends on certain water quality criteria, most notably pH: as pH increases, so does the proportion of ammonia in its unionized form. Stressors such as ionic strength and temperature also may influence ammonia toxicity, through their effects on ammonia tolerance and toxicity.

Linking Stressors to Biological Responses

When ammonia concentrations or fluctuations increase within streams, ammonia concentrations within aquatic organisms may rise due to reduced nitrogen excretion and increased diffusion of ammonia across gill membranes. Increases in internal ammonia concentrations can have several detrimental effects, including reduced immune, osmoregulatory, nervous system, and respiratory function. For example, Na^+ efflux rates are elevated in the presence of ammonia, and fish must increase Na^+ influx to remain in Na^+ balance.

These different modes of action all may contribute to decreased condition, decreased growth, altered behavior, and increased susceptibility to other stressors in affected biota. For example, increased ammonia concentrations may result in increased gill and organ damage, increased fin erosion, or increased mucous secretion in fish; possible changes in behavior include hyperexcitability, hyperventilation, and convulsions. Ultimately, these effects may result in changes in population and community structure and ecosystem function. For example, taxa particularly sensitive to unionized ammonia, such as unionid mussels and fish, may decrease, while more tolerant organisms become more dominant.