LOW pH: Narrative for detailed conceptual diagram

pH is a measure of hydrogen ion concentration in an aqueous solution: pH decreases as hydrogen ion concentration increases, and these acidic conditions can adversely affect aquatic biota. This conceptual diagram illustrates linkages between low pH and associated pH fluctuations (middle of diagram), the human activities and sources that can contribute to low pH (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

Certain human activities and land uses can result in increased input of hydrogen ions into aquatic systems. Land drainage can reduce soil saturation and lead to sulfur oxidation and the release of sulfuric acid. Other sources of hydrogen ions include acid mine drainage and other mining wastes from active and historical mines; natural, acid-generating geologies and lithologies subjected to weathering; natural organic acids (e.g., humic acids); animal wastes from CAFOs, dairies, and aquaculture facilities; coal piles and landfills associated with residential, municipal, commercial, and industrial facilities; and emissions and effluents from coal-fired power plants, metal plating plants, and other industrial facilities. Hydrogen ions 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 and subsequent transport, atmospheric emissions and deposition, or direct effluent discharges. Each of these transport-defined sources can contribute to increased hydrogen ion inputs into surface waters. When atmospheric deposition of hydrogen ions occurs in the form of snowfall, snowmelt can result in pulsed delivery of hydrogen ions to surface waters.

Whether inputs of hydrogen ions to aquatic systems lead to decreases in pH depends upon buffering capacity, or the ability of the system to neutralize those inputs. Streams with high bicarbonate concentrations are highly buffered, and may not become acidic even with significant hydrogen ion inputs; once buffering capacity is exceeded, however, pH will decrease. Instream oxidation-reduction processes also may influence pH. For example, nitrification and respiration both produce hydrogen ions, so nutrient (especially nitrogen) concentrations may play a significant role in pH dynamics. Decreases in pH also can affect other stressors, such as by increasing free metal ions, increasing the bioavailability and toxicity of toxic substances, and increasing ionic strength (see the metals, ionic strength, and toxic substances modules for more information on these pathways).

Linking Stressors to Biological Responses

Decreases in pH and associated increases in pH fluctuation can adversely affect aquatic organisms via many potential modes of action. Low pH can lead to dissolution of calcium carbonate shells, ultimately leading to decreases in taxa with calcium carbonate shells (e.g., mussels and snails). When low pH solutions (e.g., acid mine drainage) are neutralized upon entering higher pH streams, metals in those solutions can precipitate and smother or armor stream bottoms. Low pH also can compromise ionoregulatory and osmoregulatory function, or lead to changes in food availability.

These different modes of action all may contribute to decreased condition, decreased growth, altered behavior, and increased susceptibility to other stressors in affected biota. Possible decreases in condition include gill hyperplasia, gill and fin erosion, lesions and skin damage (increasing susceptibility to fungal infections), and increased mucous secretion; possible changes in behavior include hyperexcitability. Ultimately, these effects may result in increased mortality and decreased reproductive success, particularly in terms of impaired egg fertilization and development. This can lead to changes in population and community structure and ecosystem function. Taxa sensitive to low pH (e.g., certain mayfly and stonefly taxa) may decrease, while more tolerant taxa (e.g., tipulids, megalopterans, spike rushes) may increase; sensitive life stages (e.g., eggs in fish) also may decline. These changes in community structure may in turn affect ecosystem functions such as leaf decomposition.