IONIC STRENGTH: DETAILED CONCEPTUAL MODEL NARRATIVE

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Changes in ionic strength and composition may benefit some aquatic organisms while harming others, ultimately changing organism community composition. The ionic strength conceptual model describes such relationships for lotic freshwater systems (streams and rivers).

Model Format

The ionic strength conceptual model diagram depicts sources near the top of the figure, leading down the diagram to steps in the causal pathway, proximate stressors, modes of action, and eventually biological responses at the bottom. This narrative generally follows the diagram from left to right, top to bottom. For more information on interpreting CADDIS conceptual model diagrams, see the Conceptual Model Library homepage.

Linking Sources to Proximate Stressors

A number of common sources and human activities may contribute to ionic strength as a proximate stressor, broadly defined as increased total ionic strength or altered ionic composition. Contributing landscape changes (e.g., channel alteration and water withdrawal), natural geologic characteristics, and human activities generally work in combination to effect changes in ionic strength and composition of surface waters.

Most sources are associated with release of wastes from agricultural, resource exploration and extraction, residential, commercial, industrial, and recreational practices. Sources that may have elevated ion content or potentially toxic ionic components include animal wastes, fertilizers, combustion by-products (e.g., cooling water), landfill and septic leachates, road salts and deicing agents, industrial and waste water treatment plant effluents, and mining wastes (e.g., tailings and co-produced water from oil drilling and coal bed methane mining processes). These waste products may increase ions in subsurface waters, ions adsorbed to particles, and ions in watershed runoff, all of which may ultimately reach surface waters; they also may be discharged directly to streams and rivers. For example, winter safety activities may involve salting paved surfaces and then plowing ion-rich snow into riparian areas, where it melts and carries ions to surface waters.

Human activities may be associated with releases of ion-rich wastes, as described above, or land cover alterations that indirectly alter ionic strength and composition. For example, changes in vegetation or increases in impervious surfaces can increase delivery of ions to streams, via increased deposition and surface runoff. Decreased watershed vegetation may lead to increased soil and bank erosion and decreased nutrient uptake. These impacts may result in increased ion delivery to surface waters via runoff, sediment particles, or subsurface flows. In addition, mining and other land clearing activities may expose geologic substrates, providing another terrestrial source of ions for surface waters. Groundwater withdrawal in coastal regions may increase the ion content of subsurface water due to saltwater intrusion. Agricultural practices such as planting shallow-rooted vegetation and irrigating crops may raise groundwater table elevations, thereby mobilizing ions which may reach surface waters; this process is sometimes referred to as “dryland salinity”.

Ion content of streams and rivers is related to several other potential stressors, including temperature, sediment, pH, metals, other toxic chemicals, and flow alteration. For example, salt solubility increases as temperature increases; salts can alter soil structure and potentially increase soil erosion (sediment); pH and the bioavailability of toxic substances may vary with ionic strength. Potential interactions among stressors should be considered when ionic strength is a possible cause of impairment. Consult CC.6 Ionic Strength for more information on stressor interactions.

Linking Proximate Stressors to Biological Impairment

The diagram shows human activities and sources ultimately contributing to two proximate stressors: increases in total ionic strength and changes in ionic composition. Although ionic strength may decrease due to human influences in certain cases (e.g., downstream of dilute industrial discharges), ionic strength most often tends to increase with human activity. Even though organisms may be capable of handling gradual increases in ionic strength, rapid fluctuations may be harmful and are considered an additional proximate stressor under increased ionic strength.

There is debate among scientists as to the exact mechanisms responsible for toxicity associated with ionic strength, but evidence appears to indicate that elevated ionic strength, or large fluctuations in ionic strength over relatively short time periods, may affect freshwater biota via several modes of action including osmotic stress, increased competition for gill binding sites, and increased ion exchange.

Documented biological responses to ionic strength-related proximate stressors include increased abundance of certain brackish, saltwater, or ion-tolerant taxa (including amphipods, decapods, and isopods) and decreased abundance of certain ion-sensitive taxa such as mayflies and soft-bodied organisms. However, biological responses frequently are site- and species-specific and do not apply to all situations.

Common mechanisms by which changes in ionic composition may adversely impact biota include increased concentration of toxic ions or changes in the toxicity of specific ions. These compositional changes have been associated with decreased bioavailability of essential elements (e.g., magnesium) and with changes in biotic assemblages.