# DISSOLVED OXYGEN: DETAILED CONCEPTUAL MODEL NARRATIVE

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Aerobic aquatic life requires oxygen for survival, and most are dependent upon oxygen dissolved in the water column. Dissolved oxygen (DO) concentrations are normally sufficient to maintain healthy biotic assemblages in unpolluted, free-flowing streams, but low or extremely high DO levels can impair aquatic communities. The following conceptual model diagram depicts relationships among sources and human activities, processes increasing or decreasing dissolved oxygen in surface waters, and effects on aquatic biota.

## Model Format

The DO conceptual model diagram depicts sources and contributing landscape changes 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 top to bottom, left to right. For more information on interpreting CADDIS conceptual model diagrams, see the Conceptual Model Library homepage.

## Linking Sources to Proximate Stressors

Certain human activities, such as agricultural, residential, and industrial practices, can contribute to DO depletion (or, less frequently, DO supersaturation), and subsequent biological impairment. These practices may directly introduce chemical contaminants, organic loading, and nutrients to streams, via point and non-point sources such as wastewater treatment plant effluents, fertilizers, animal wastes, landfills, and septic systems. Increases in these substances can increase chemical and biochemical oxygen demand, most notably due to increased respiration of plants and especially microbes.

Physical alteration of the stream channel, through impoundments or channel alterations, can contribute to low dissolved oxygen concentrations in several ways. For example, an impoundment downstream of a location will slow water velocities and increase water depths, which will tend to reduce turbulence and lower incorporation of oxygen into the water column via aeration, as well as reduce diffusion of oxygen from the atmosphere. Channel incision also reduces oxygen diffusion due to decreases in surface-to-volume ratio with increasing stream depth. An impoundment upstream of a location (upper far right of diagram) may reduce DO levels if downstream water releases come from deeper, oxygen-depleted waters of the reservoir (i.e., if they are hypolimnetic), but may increase DO levels if discharges are highly turbulent;

whether DO levels increase or decrease will depend on impoundment size and type of release. Land cover alterations also may reduce stream DO levels by altering in-stream physical characteristics. For example, decreases in riparian vegetation often associated with these activities can reduce large woody debris inputs to the channel, reducing turbulence and aeration; homogenization of stream substrates can have similar effects. In addition these alterations may increase delivery of chemical contaminants, organic material, and nutrients to streams with surface runoff.

In addition to these processes discussed above, DO concentrations are closely linked to several other stressors. Interactions between nutrient concentrations and DO were mentioned earlier – basically, nutrient enrichment stimulates oxygen-generating (photosynthesis) and oxygen-depleting (respiration) processes. DO levels also are affected by water temperature, ionic strength, and dissolved solids: oxygen solubility decreases as these parameters increase, reducing the amount of available DO in the water. Increased bedded sediment can decrease interstitial flow, reducing oxygen availability for sediment-dwelling organisms, and decreases in water velocity can lower oxygen delivery rates.

**Linking Proximate Stressors to Biological Impairment**

DO concentrations directly impact abiotic and biotic stream environments. Low DO (blue rectangle, center) affects the oxidation and reduction (redox) reactions which determine the bioavailability of many inorganic compounds, as well as biologically important materials such as nitrogen and sulfur. For example, lower redox potential (↓ Eh) may decrease the release of precipitated metals, which actually may benefit organisms by reducing bioavailability); however, it also may increase the release of precipitated phosphates, encouraging the proliferation of nitrogen-fixing cyanobacteria and potentially altering food resources for fish and invertebrate assemblages.

The most direct effect of low DO is respiratory distress in biota, which may be exacerbated by relatively rapid fluctuations in available DO. During periods of low DO, some species may increase movement to enhance ventilation across gill structures, attempt to gulp air from the surface, or gather around photosynthesizing plants. Respiratory stress can cause low DO-sensitive taxa [e.g., EPT taxa, or Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), and salmonid fishes] to decrease; often these taxa are considered indicators of good water quality. Decreases in low DO-sensitive life stages also are potential indicators. Conversely, more tolerant organisms (e.g., cyprinids, amphipods, and chironomids with hemoglobin) and life stages may increase. Increased populations of plant-breathers (e.g., insects that can obtain air from plants, such as certain beetle larvae) and air-breathers (e.g., insects that can carry air bubbles with them underwater) also may be observed. If DO depletion is significant enough, widespread fish kills may occur.

Although biological impairments related to dissolved oxygen usually result from insufficient DO levels, too much DO, or supersaturation, also may pose a problem in certain situations. This supersaturation may result from extremely high levels of oxygen-generating photosynthesis, or from extremely high turbulence and aeration downstream of impoundments. Ultimately, these rapid or large increases in DO may affect organisms by contributing to stressful fluctuations in DO levels, altering redox potentials and bioavailability of potentially toxic substances (e.g., metals), or leading to gas bubble disease (a condition indicated by gas bubbles forming under skin and around eyes).