FLOW ALTERATION: DETAILED CONCEPTUAL MODEL NARRATIVE

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Water flow is an integral part of running water systems, and flow alteration can significantly affect all aspects of these ecosystems and ultimately lead to biological impairment. The flow alteration conceptual model describes the relationships among changes in water flow and aquatic communities for lotic freshwater systems (streams and rivers).

Model Format

The flow alteration 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 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

A number of common sources and human activities shown at the top of the diagram may contribute to flow alteration (i.e., the proximate stressor), broadly defined as changes in flow or discharge regime and flow-related structural habitat characteristics such as water velocity and water depth. Human activities or practices shown at the top of the diagram (agriculture, forestry, mining, etc.) may lead to:

- Point sources (including effluents), which may increase discharge;
- Changes to drainage (per stormwater and agricultural tile drainage systems), which can increase the efficiency of overland flow and decrease infiltration and groundwater recharge;
- Watershed land cover alteration, often resulting in flashier flow regimes marked by reduced infiltration (a common impact of impervious surfaces such as parking lots, rooftops, and compacted soils), reduced vegetative uptake, decreased baseflow, increased peak flow, and increased frequency of peak flows;
- Groundwater and surface water withdrawals (e.g., for irrigation), which can reduce discharge and change the surface water / groundwater interface;

- Impoundments (e.g., dams, detention basins) that might be used for hydro-electric purposes or for mitigating peak flows associated with impervious surfaces, can create still water systems upstream of the impoundment or altered flow regimes downstream; and
- Channel geomorphology and riparian vegetation alteration, which can lead to localized flow alteration; for example, structural habitat alteration such as reduced channel sinuosity and increased incision might change flow velocity and flow depth.

The above sources may result in changes in discharge patterns (watershed-scale or hydrologic flow characteristics) and changes in localized flow characteristics often associated with structural habitat changes (reach-scale or hydraulic characteristics). Additionally, changes in discharge patterns at the watershed scale may alter structural habitat and local flow patterns, thereby affecting reach-scale variables.

Both watershed- and reach-scale variables often exert a significant influence on numerous other causal agents (represented here by the rectangle in the center of the diagram, "other stressors"). For example, high discharges may decrease contaminant concentrations (e.g., for stressors such as ionic strength, metals, unspecified toxic chemicals, nutrients, and sediment) via dilution; conversely, high discharges may be associated with high contaminant concentrations, if contaminants are washed into streams with increased surface runoff. Stressors such as nutrients and sediment may in turn affect reach-scale variables, as accumulation of plants (often a function of increased nutrients) or sediment can alter local flow patterns. Discharge, as well as sources related to channel alteration, also may have a significant effect on structural habitat (e.g., channel geomorphology and riffle/pool structure), which may then influence reach-scale variables. Finally, reach-scale variables such as water depth and velocity can significantly affect water temperature and dissolved oxygen concentrations; for example, faster moving, turbulent water tends to be more aerated than slow-moving, non-turbulent water. Consult CC.7 Flow Alteration for more stressor interaction examples.

Linking Proximate Stressors to Biological Impairment

Altered flow regimes in streams and rivers can cause biological impairment through a variety of mechanisms. Frequency, magnitude, and duration of both low flows (i.e., baseflows or average flows) and high flows (i.e., peak or stormflows) may change with flow alteration. For example, low flows may decrease in magnitude or increase in duration when water is withdrawn from the channel as less water may remain in the channel and low water conditions may persist for greater lengths of time. This may lead to channel drying, resulting in increased abundance of drought-tolerant taxa, such as taxa that can fit their entire life cycles into periods between droughts. High flows often increase in magnitude and frequency when sources leading to increased surface runoff are present; increases in peak flows may result in increased scouring and displacement of biota, which may reduce epibenthic (i.e., living on benthic surfaces) taxa.

In contrast, other sources (e.g., flow-regulating impoundments may reduce magnitude or frequency of high flows, which can decrease natural scouring and displacement and increase abundance of taxa with longer life cycles that tend to compete well in more benign physical environments. Decreases in frequency, magnitude, or duration of high flows also may adversely affect floodplain-dependent taxa, if inundation of the floodplain is reduced.

Changes in discharge patterns also may take the form of altered flow variability. The diagram shows increased daily discharge variability (e.g., a dam regulating flow throughout the day to meet hydro-electric demands) and decreased seasonal discharge variability (e.g., a dam may stabilize outflow regardless of seasonal precipitation and/or snowmelt). Seasonal flow stabilization may result in increases in lentic taxa more suited to slow-moving water (e.g., macrophytes), or decreases in taxa relying on discharge-related life cycle cues (e.g., timing of seasonal flow regime shifts). In contrast, increases in daily flow variability may lead to decreases in flow refugia (i.e., slower flow areas where organisms can avoid stormflows) and subsequent scouring and displacement of organisms.

Changes in discharge pattern timing or sequencing may disrupt synchrony between discharges and organism life histories. For example, high flows may serve as a trigger for spawning or migration in certain fish species; if these high flows are prevented (e.g., through regulation), or if high flows occur earlier or later in the season, the cueing and outcome of these behaviors may be altered.

At the reach scale, changes in local flow characteristics may include changes in water depth or velocity. Decreases may contribute to biological impairment by decreasing available water column habitat or by leading to increases in lentic taxa and macrophytes. Increases in water velocity and depth may increase scouring and displacement and affect biota via changes in physical habitat, leading to increases in taxa adapted to faster moving water and deeper water column habitats.

Flow alteration, as described above, may increase non-native taxa, decrease EPT taxa, and decrease invertebrate, plant, and fish richness or diversity. Such changes are often characterized as biological impairment, and may be associated with stress from flow alteration.