HERBICIDES: Narrative for detailed conceptual diagram

High concentrations of herbicides and their metabolites in streams can have lethal and sub-lethal effects on aquatic biota, potentially changing community structure and ecosystem function. This conceptual diagram illustrates linkages between human activities and sources (top of diagram), herbicide-related stressors (middle 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 are shown.

This narrative generally follows the diagram top to bottom, left to right. For more information in interpreting CADDIS conceptual diagrams, see the About Conceptual Diagrams page.

Linking Sources to Stressors

Anthropogenic activities and land uses, such as industry, urban development, forestry, and agriculture can contribute herbicides to streams. Herbicide manufacturers, industrial facilities, and wastewater treatment plants may discharge effluents containing herbicides; accidental or unpermitted discharges also may occur. In some cases, herbicides are applied directly to surface water for aquatic weed control (e.g., for water-based recreation). Herbicides may be applied to golf courses, lawns and other managed landscapes, forests, crop fields, and orchards to control a variety of unwanted vegetation. In some cases, herbicides may be transported atmospherically in spray drift. These applied herbicides may enter streams via stormwater runoff, groundwater discharges, or direct atmospheric deposition. Stored herbicides, both at sites where they are used and at sites where they are manufactured, also may be transported to streams via runoff or groundwater transport. The extent to which these transport pathways occur depends upon several factors, including land cover, precipitation patterns, timing and rates of application, and environmental persistence of the herbicides.

Linking Stressors to Biological Responses

In streams, herbicides can be dissolved in the water column or bound to sediments, and the effects they have will depend upon the medium in which they occur. Exposures may be episodic (e.g., pulsed deliveries of insecticides with stormwater runoff) or continuous (e.g., long-term exposure to herbicide-contaminated sediments). The bioavailability, uptake, and toxicity of herbicides and their metabolites during these exposures will depend upon factors such as temperature, pH, and dissolved oxygen concentrations.

The most direct effects of herbicide pollution are decreased condition, growth, and reproduction, and increased mortality, of plants (i.e., macrophytes, periphyton, and phytoplankton). For example, exposure to herbicides may lead to elevated internal herbicide concentrations and decreased photosynthesis, cell division, and amino acid production in plants. Effects on aquatic plants can indirectly affect fish and invertebrates by modifying habitat and food availability. Exposure to herbicides also can directly increase mortality and change the behavior and reproduction of fish and invertebrates. Possible changes in behavior include increased invertebrate drift and increased avoidance by fish. Ultimately, these effects may result in changes in community structure (e.g., decreased richness and

diversity, changes in functional feeding groups) and ecosystem function. For example, aquatic vegetation is especially susceptible to herbicides, so it may decrease in abundance and richness; as a result, the relative abundances of invertebrate feeding groups may shift.