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Review

Clear as mud: A meta-analysis on the effects of sedimentation on freshwater fish and the effectiveness of sediment-control measures

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ABSTRACT

Increase in fine sediments in freshwater resulting from anthropogenic development is a potential stressor for fish and thus may cause population declines. Though a large body of literature exists on the topic, there have been few attempts to synthesize this information in a quantitative manner. Through meta-analysis we investigated the effects of sediment in lotic environments on resident ichthyofauna using ecologically-relevant endpoints for tolerant (e.g., northern pike *Esox lucius*) and intolerant (e.g., brook trout *Salvelinus fontinalis*) species. Further, the efficiency of sediment-control devices was explored to inform mitigation measures. An increase in suspended and deposited sediments was demonstrated to have a negative effect on all parameters and tolerances tested (feeding behavior [feeding rate, reaction distance to food item]; spawning success [survival of fry to eyed stage, fry emergence]; species richness; $P < 0.001$) except fish abundance ($P = 0.058$). Heterogeneity between studies was a factor in all analyses. Although there were insufficient studies to conduct meta-analysis on sediment-control devices, weighted percent efficiency estimates revealed that properly installed sediment-control fences tended to have a higher percent efficiency (73–80%) than sediment traps and basins (40–52%). These results highlight the negative impact that increases in suspended and deposited sediments can have on resident fishes from the individual to the population, and the need for more transparent and thorough statistical reporting. The analysis also identifies a clear need for rigorous experimental studies contrasting different sediment-control devices and strategies given that little such work has been published. That alone is remarkable given that

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sediment-control devices are often a requirement of regulators for riparian development activities, yet the evidence to support the effectiveness of the primary mitigative strategies is weak.

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1. Introduction

Freshwater ecosystems are among the most threatened environments in the world (Richter et al., 1997; Malmqvist and Rundle, 2002). Though all freshwaters are facing a barrage of threats, fluvial systems are particularly vulnerable (reviewed in Dudgeon et al., 2006) in part due to increased erosion in the form of sedimentation,[1] a process that is recognized as a primary form of aquatic habitat degradation and anticipated to increase alongside increased precipitation resultant from global climate change (Easterling et al., 2000). In general, many human land-use activities contribute to sedimentation by altering natural rates of sediment flux and organic matter inputs to freshwater systems (Waters, 1995). Anthropogenic disturbances such as agriculture, logging, mining, and urbanization, can negatively affect rivers and streams, in part by increasing sedimentation and ultimately altering biodiversity and ecological processes (Hornung and Reynolds, 1995). Human development and other activities tend to promote high rates of soil erosion as riparian vegetation is removed and bank soil is exposed (Patten et al., 2001). As surface water moves from catchments to watercourses, it transports eroded materials into waterways, where they become either suspended or deposited sediment (Hornung and Reynolds, 1995). Water with increased suspended sediments and altered substrates may be suitable for only a limited aquatic fauna (Swanson et al., 1988). As healthy freshwater ecosystems are responsible for many ecosystem services including water purification, decomposition, and nutrient cycling (Holmlund and Hammer, 1999), research on sediment effects and control measures is important to inform management objectives focused on maintaining overall freshwater ecosystem health.

[1] For consistency, sedimentation in this article includes increases in suspended sediment, siltation and turbidity.