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Abstract
Nonpoint source pollution has been increasingly recognized as a major cause of reduction in water quality. Nationally, agricultural runoff accounts for approximately 46% of sediment, 47% of total phosphorus, and 52% of total nitrogen discharged into waterways; in Iowa, these percentages are much higher. Sediment is the greatest overall polluter nationwide, affecting nearly all components of aquatic ecosystems.

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Prediction and field validation of sediment impacts on riffle insect communities

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$18,419 for one year

Background

Nonpoint source pollution has been increasingly recognized as a major cause of reduction in water quality. Nationally, agricultural runoff accounts for approximately 46% of sediment, 47% of total phosphorus, and 52% of total nitrogen discharged into waterways; in Iowa, these percentages are much higher. Sediment is the greatest overall polluter nationwide, affecting nearly all components of aquatic ecosystems.

Riffle habitats having a coarse substrate of cobbles and pebbles provide many microhabitats. Typically, such riffles have the greatest density and species richness of aquatic insects; however, these are the stream habitats most sensitive to sedimentation. Sediments may either be deposited or transported in a given riffle; saltating and suspended sediments increase macroinvertebrate drift (insects carried by the current from an area), resulting in decreased insect densities and reduced species richness. Sediments also fill in the spaces within riffles (called interstitial spaces); this changes their shape, reduces velocity of the current, reduces the dissolved oxygen, makes refuge from predatory fish more scarce, and reduces availability of macroinvertebrate food sources such as leaf litter and periphyton (protozoa, bacteria, fungi, etc.). Although periphyton and fish are also affected by sedimentation, the goal of this project was to determine the level of sedimentation that causes significant changes in riffle insect community structure.

Studies to date have not related the degree of sedimentation in terms of these interstitial changes to changes in riffle insect community structure, especially in terms of investigating the *long-term response* of intact riffle communities subjected to various sedimentation levels. This project was able to address this long-term response using facilities designed to maintain laboratory "microcosms" of riffle insect communities. The Ecosystem Simulation Laboratory at the University of Northern Iowa, where this project was conducted in part, is one of the few laboratories currently using newly developed methodologies to conduct ecological and toxicological research with stream microcosms containing riffle insect communities.

The project objectives included employing techniques to directly or indirectly measure the impact of five sediment levels on the survival, drift, emergence, behavior, growth, reproduction, and interactions of insects indigenous to many Iowa streams.

Approach and methods

The laboratory study employed 15 oval, artificial streambeds constructed of molded fiberglass. A standpipe in each stream maintained depth and volume; current was provided by electrically powered paddle wheels (see photo). Daylight-equivalent light was provided with a photoperiod that corresponded with sunrise and sunset on day 15 of the 30-day test. Containers placed in each stream microcosm prevented loss of substrate; each was filled with a combination of coarse sand and cobbles to reflect desired levels of sediment impact (cobbles 0,25,50,75, and 100% embedded in sand). Each treatment was replicated three times.

Test organisms were colonized in a natural riffle of the Volga River in northeast Iowa. The riffle is sediment-free in the top 6 cm (2.4 inches). The substrate is dominated by cobbles (6-13 cm) resting on pebbles (1-2 cm). The organisms were colonized for 21 days in rock-filled plastic containers having six holes in each side. The containers were attached to wooden planks previously embedded and secured in the stream bottom. (This approach increased the likelihood that the macroinvertebrate colonizers would be more representative of the natural community.)

After 21 days, the artificial substrates were removed from the stream with nets to prevent loss of organisms and transported to the laboratory, where organisms were placed in the 15 stream microcosms. An hour later, drift samples were taken from each microcosm to quantify mortalities caused by transport. Investigators monitored water chemistry parameters weekly. Communities of bacteria, protozoa, and attached diatoms that serve as food for the riffle insects had been colonized earlier in the same riffle; these were placed in the mesocosms two weeks before the macroinvertebrates were introduced.

During the 30-day test, insect drift was quantified every seven days. At the end of the 30 days, remaining insects were removed from the microcosms, identified to the lowest taxonomic unit possible, and enumerated.

This project also consisted of a field study of riffles in the Volga River. Five sites with levels of sediment reflecting those of the stream microcosms were identified. Samples taken from each site were preserved for identification and enumeration; physical and chemical attributes of the stream were recorded at each site. Because the sites were within five kilometers (3.1 miles) of each other, the effects of regional influences on faunal diversity and stream physical/chemical parameters were minimized. Investigators collected six substrate samples at each site and froze them until they could be analyzed. They analyzed the percent of organic content and determined weight and volume of various particle size classes at each site.

To determine the species abundances per microcosm, investigators combined adults and immatures. Taxa that averaged at least four individuals in one or more treatments/sites were included in the statistical analyses. Changes in macroinvertebrate densities among the treatments/sites were used to determine sedimentation effects in both field and laboratory sites. Species abundances were not directly compared to those from the artificial streams because it is impossible to define a suitable correction factor for the differences in surface area and volume of substrate sampled.

Findings

Laboratory study: Except for hardness, which was artificially lowered in the stream microcosms to reduce limestone buildup, physical and chemical characteristics of the microcosms reflected those in the natural stream at the colonization riffle. Drift samples taken one hour after macroinvertebrates were introduced indicated no significant mortality due to transport. Although their numbers were low, mayflies exhibited a significant post-sunset drift response during week one of the test in the 25% and 100% embedded treatments. No significant drift response occurred at any treatment level during the following three weeks.

At the end of the 30-day test, neither species richness nor total number of insects at any treatment level was significantly reduced. Moreover, no significant differences were found in the functional group composition of macroinvertebrates among any treatments; of the 18 species present in numbers sufficient for statistical analysis, only one mayfly *(Caenis tardata)* was significantly reduced in the 50% and 100% embedded treatments relative to the unembedded treatment.

The low drift response, combined with a lack of significant mortality for most species, suggests that, although some taxa may attempt to emigrate via drift from riffles that are 25% or more embedded in sand, most aquatic insects can survive in riffle areas heavily impacted by coarse sand.

Field study: The five riffle sites were similar in most physical and chemical characteristics. The particle size of material in the unembedded riffle, however, was much larger than in the 100% embedded site. Between these extremes, particle size at the other sites was more heterogeneous. The percentage of organic matter present was significantly higher at the unembedded site, but differences were not significant among the 25% to 100% embedded sites.

As in the laboratory study, the total number of insects among different levels of embeddedness present in the natural riffles was not significantly different. Although overall species richness was similar among the sites, the *mean* number of species in the 100% embedded riffle was six fewer than in the unembedded riffle, primarily because of the absence or near absence of several mayfly and stonefly species.

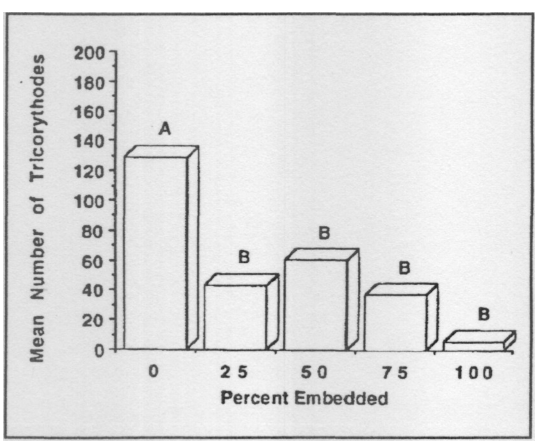
Of the 31 species present at the field sites in numbers sufficient for individual statistical analyses, eight taxa in four orders were significantly affected by increasing levels of sediment. One mayfly species, *Tricorythodes* spp. (Tricorythidae) was significantly reduced in all embedded sites relative to the unembedded site (see Fig. 1). Three other mayfly taxa were significantly reduced at all sites exhibiting 50% or more substrate embeddedness.

Caenis tardata and *Tricorythodes* spp. are sprawlers, which enables them to thrive on fine sediments. Thus it was somewhat surprising that their densities were significantly reduced by moderate sedimentation levels. *Stenonema* spp. and *Isonychia bicolor* are clingers that live in the higher currents found in stream riffles. *Stenonema* spp. are found under loose cobbles; /. *bicolor* is usually found clinging to submerged rocks and feeding on very fine particles that it filters from the water. Because sediment interferes with both species' ability to cling and thus feed, the significant decrease in these mayfly densities at the sediment-impacted field sites is not surprising (although both species were also found in low numbers in all artificial stream treatments).

Three mayfly taxa were present only at sites moderately impacted by sediments; a fourth was found in relatively high but variable densities at all sites. One Lepidoptera (a butterfly-type insect), *Petrophila* sp. (Pyralidae), a clinger and a scraper, was significantly reduced, compared with the unembedded site, at all sites having any substrate embeddedness (see Fig. 2).

Densities of one riffle beetle (Coleoptera: Elmidae), *Stenelmis* sp., were significantly reduced beginning at the 75% embedded level. This species, which clings to substrates in stream riffles, apparently avoids habitats heavily impacted by sediments. Another riffle beetle, *Optioservus*, sp., was found in low numbers at all field sites, but it appears to prefer sites not impacted by sediments.

Of the eight dipteran (two-winged insect) taxa analyzed, two subfamilies of Chironomidae (Chironominae and Tanypodinae) exhibited significant density *increases* at sediment-impacted sites. Chironominae are burrowers adapted for survival in both depositional and



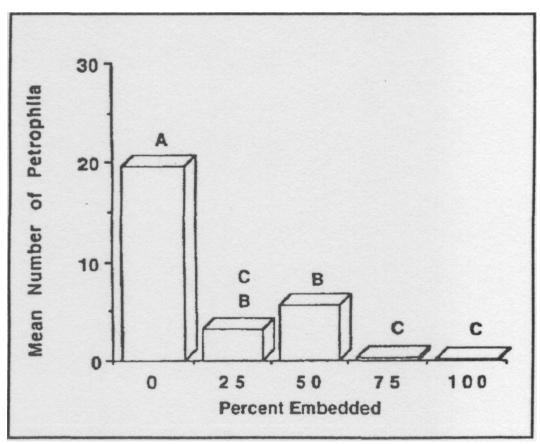


Fig. 1. (left) Mean number of Tricorythidae (a mayfly) in five Volga River riffles exhibiting various levels of substrate embeddedness. Percent embedded indicates embeddedness level of predominant material in the surrounding substrate. Treatments with the same letter are not significantly different.

Fig. 2. (right) Mean number of Petrophila sp. (Lepidoptera: Pyralidae), a butterfly-like insect, in five Volga River riffles exhibiting various levels of substrate embeddedness. Percent embedded indicates embeddedness level of predominant material in the surrounding substrate. Treatments having the same letter are not significantly different.

erosional areas; they were found in relatively high numbers at all sites, but their densities increased significantly at the 100% embedded site. Tanypodinae are active predators; their densities increased significantly in the 75 and 100% embedded sites. An increase in prey (Chironominae) may have resulted in the observed increase in Tanypodinae densities. Another subfamily of Chironomidae was present at all sites but in significantly reduced densities—relative to the unembedded site—at the 50,75, and 100% embedded sites. There were no significant differences in these dipterans among the artificial stream treatments.

The investigators categorized macroinvertebrates into functional feeding groups: collector-filterers, collector-gatherers, scrapers, predators, piercers, and shredders. Collector-filterers generally prefer larger cobbles and boulders; in this study their densities were significantly higher—unexpectedly so—at the 75% embedded site relative to the unembedded site, probably because large cobbles were present at all sites except the 100% embedded and because downstream reaches of streams and rivers generally contain more filterable organic material.

The increased amount of interstitial spaces at the 0% embedded site contained more settled organic matter, creating a large food source for most collector-gatherer macroinvertebrates. However, there was a significant increase in collector-gatherer densities at the 100% embedded site, which was due to large numbers of Chironominae, a burrower, at that site. Scrapers feed on communities of diatoms, bacteria, and protozoa on cobble and boulder surfaces; lower numbers of scrapers at sediment-impacted sites reflected the detrimental effects of sedimentation on these food source communities. Predator densities among the five sites did not differ significantly, although there was a shift in the kinds of predators present at the unimpacted versus the impacted sites. At the 0% and 25% embedded sites, predators such as stoneflies and dragonflies were present along with some of the dipteran predators. Predators at the 75 and 100% embedded sites consisted primarily of Tanypodinae and a few other dipterans. Piercers and shredders were found in low variable numbers; they did not appear to be affected by sedimentation.

Overall, the laboratory results suggest that most riffle insects can survive on sediment impacted substrates, but some mayflies will migrate from such areas. The field results validate the laboratory predictions in that (1) there were no significant differences in total numbers among the natural riffle sites; and (2) although mean species richness was slightly lower at the most heavily sedimented site, most species were present at all sites; and (3) there were significant decreases in densities of some mayflies beginning at the 25% embedded level. Results suggest that changes in riffle insect community structure will begin to occur when cobbles become 25% embedded in sand; these changes will be more apparent at the 50 and 100% embedded levels.

Implications

Sedimentation of surface water habitats caused by row-cropping or cattle grazing adjacent to riparian areas is a major concern in Iowa. Although sustainable agriculture practices such as buffer/filter strips are being used increasingly to reduce both sediment and chemical runoff into surface water, research on these management strategies has generally not considered the key ecological roles that insects play in these stream ecosystems. As a result, little information is available on the effect of various sedimentation levels on stream insect communities. Without such information, it has been difficult to determine the amount of sediment reduction necessary to enhance aquatic ecosystem structure and function.

While some changes caused by sedimentation may not be as detrimental as researchers had previously thought, the findings generated by this project will allow those who investigate the effectiveness of various filter/buffer strips to set sediment reduction goals that are economically realistic yet effective in preserving stream ecosystem structure and function.

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