"Impacts of Management Intensive Grazing on Southeastern Minnesota Streams"

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Introduction and Objectives

Farmers are developing and implementing sustainable farming practices in response to environmental and economic problems associated with conventional agriculture in the United States. Sustainable farming offers long-term benefits to the ecosystem and the farming family's quality of life, while allowing a comparable profit to conventional approaches due to reduced inputs and a diversity of production (Robinson 1990). The impacts on water quality of a potentially environmentally sound, profitable farming system known as Management Intensive Grazing (MIG) are being studied as part of a larger, comprehensive evaluation of the biological, financial, and social aspects of adopting sustainable farming practices. Although the overall project is broad in scope and addresses biological, economic, and social issues, this project focuses on aquatic processes in relation to MIG.

Many farmers want to improve the ecosystem and sustainability of their farms but lack the necessary information and tools to evaluate the effectiveness of management changes they institute. The ecological benefits of specific grazing practices in relation to watershed management have been extensively studied on rangelands in the western United States and arid regions throughout the world (e.g., Blackburn 1983, Bohn and Buckhouse 1986, Graul 1980, Kauffman and Krueger 19984, Kondolf 1993, Medina and Martin 1988, Platts and Nelson 1985, Quinn et al. 1992, Rinne and Medina 1988, Van Haveren and Jackson 1986, Wagstaff 1986, Williamson et al. 1992), but have received attention only recently in the midwest primarily because MIG is relatively new. The concepts developed in the arid west for rangeland management also apply broadly to the midwest. For instance, practices such as removing cattle from streams, protecting riparian zones, and increasing vegetative cover and diversity apply to midwestern streams in general, but specific results are not readily transferable due to differences in management objectives, geomorphology, climate, etc.

To achieve sustainability, and to a lesser extent for production purposes, Anderson (1993) advocates that land should be managed primarily as watersheds. Watershed management emphasizes the role of the entire landscape in capturing, storing, and safely releasing water throughout the system. MIG is a rotational grazing scheme that meets many criteria specified by Anderson (1993) in watershed management. To implement MIG farmers partition a given pasture into small areas (2-3 acres) termed “paddocks”. Cattle or dairy cows are allowed to graze on a paddock for 2-3 days, then are rotated to another paddock. The original paddock is not grazed again for 30 days or longer. MIG provides substantial and continuous vegetative cover that typically includes several grass species and legumes. Increased vegetative cover reduces erosion, potentially improves soil quality, depends on manure as fertilizer, and eliminates pesticide use. Sedimentation and chemical runoff from soil erosion are some of the main threats to aquatic systems (Robinson 1990), thus MIG should be a boon to water quality and aquatic organisms.

The aquatic project reported on here is part of a larger monitoring team, which combines the expertise and participation of farmers, researchers, public agency staff, non-profit staff and consultants to develop monitoring approaches that will help farmers measure ecological, financial and social impacts of changes in their farming systems. Due to the diversity of backgrounds of our team members we can pursue a holistic approach to evaluate the effectiveness of MIG as an ecologically sustainable farming practice.

The monitoring team has developed the following set of project objectives for both the short-term (two to three years) and the longer-term (four to eight years):

1. Document ecological changes associated with MIG and develop and test indicators related to ecosystem health and sustainability that can be used by farmers for monitoring ecosystem health in several specific areas, including aquatic fauna and both instream and riparian habitat quality.

2. Implement a new model for designing agricultural research that:
   a) Is participatory and farmer-driven.
   b) Uses a whole-systems approach that depends on dialogue among all team members.
   c) Fosters changes in research approaches by all project team members and their institutions.

3. Engage farmers, researchers, public agency officials and others in feedback and application of farmer-friendly monitoring and whole systems participatory research.

The aquatic study focuses on ecological information and monitoring tools to evaluate MIG as a sustainable farming system in relation to streams. The stream system is proposed as one of many ecological indicators of overall farm and watershed condition. Development of ecological information and monitoring tools may help reverse the increasing emphasis on solving agriculture's environmental problems through regulations, which may preempt locally developed management solutions well suited to individual farms. For the aquatic portion of the overall study, cattle grazing impacts to streams are being compared by monitoring water chemistry, physical habitat, and biotic communities along stream reaches where conventional grazing and MIG are practiced.

Site Description

Farms located on five streams in southeastern Minnesota were initially identified in 1994 as study sites based on farmer involvement with the monitoring team. Study sites include farms practicing both continuous grazing and MIG so that comparisions may be drawn between stream reaches influenced by different management practices. A sixth stream was added in 1995 to expand the data set so that a larger number of comparisons could be made between grazing practices, thus providing additional information on the influence of land use practices on streams. A longitudinal (upstream/downstream) study design was established on four streams and a paired watershed design was developed on the other two streams. This report focuses on the paired watershed and one of the longitudinal sites. The number and pairing of stations at these sites provide an ample amount of data to begin comparing areas under MIG and continuous grazing.

The paired watershed study compares two first order streams in the Whitewater River watershed (Figure 1). Land use is agricultural, consisting of corn and soybean production and cattle grazing. MIG is practiced along one stream and continuous grazing occurs along the paired stream.

The longitudinal site is located on a third and fourth order warmwater stream tributary to the Zumbro River (Figure 1). Land use in the watershed is agricultural, with corn and soybean production predominant in the headwater region and increasing amounts of cattle grazing in its lower reaches. Seven stations were established along the 8 kilometer longitudinal study reach. The two upstream stations are undergoing a transition from continuous grazing to MIG. Data from the first two stations provide information on the influence of upstream land use practices on the stream. The third station is located at the upstream end of a continuous grazing operation, and the fourth station is at the downstream end of the same operation. Any change in stream measures from station three to station four should reflect influences of land use practices at the continuously grazed farm. MIG has been practiced at stations five and six for the past seven years, and the farm at station seven is undergoing a transition from continuous grazing practices to MIG.

Data Collection

Data collection was completed at all sampling stations during 1995. Parameters measured include water chemistry variables, physical habitat measurements, and benthic macroinvertebrate and fish sampling.

Water chemistry sampling was designed to characterize the streams and provides background information on the overall influence of chemical characteristics on stream dynamics. Sampling was conducted monthly from May through September 1995. Variables measured include dissolved oxygen, pH, conductivity, temperature, chloride, nitrate-nitrogen, ammonia-nitrogen, ortho-phosphorous, sulfate, total organic carbon (TOC), turbidity, and fecal coliform.

Physical habitat measurements were taken along ten to thirteen transects at each sampling station during July. Station length was approximately 35 times the average width of the stream and transects were 2 mean stream widths apart (Simonson et al., 1994). Measurements taken at each transect included depth, velocity, width, substrate composition, substrate embeddedness, streambank angle, and the percentage of bare soil on the streambank (Platts, et al. 1983; Simonson et al. 1994). The sampling protocol defines embeddedness as the amount of fine material surrounding course material in the substrate. Streambank angle is the angle from the water surface to the slope of the adjacent bank.

Benthic macroinvertebrate samples (three replicates) were taken in May and September 1995 from a riffle habitat at each sampling station. Samples were sorted and identified in the lab to the family level. Hilsenhoff's Family Biotic Index and Rapid Bioassessment Protocol (RBP) indices are being used to characterize the water quality of the sites using macroinvertebrate samples (Hilsenhoff, 1977, 1982; EPA, 1989). RBP metrics being used include the number of insect taxa (families); the number of families from the orders Ephemeroptera, Plecoptera, and Trichoptera or the "EPT index"; the percentage of individuals in a sample that are from the dominant family found in the sample or the "Percent Dominance"; and the ratio of individuals from the EPT orders to chironomidae or "EPT:Chironomidae".

Fish were sampled at each of the paired stations and at five of the seven longitudinal stations by electrofishing a segment approximately 35 times the average width of the stream at each station (Lyons et al, 1992). Fish numbers and species were recorded and densities ($\#/m^2$) were calculated.

Mean pair comparisons by site were made for the physical habitat and insect metric values using the Tukey-Kramer HSD (honestly significant difference) test. In addition, linear regressions were performed on the insect metric values at the longitudinal site.

Preliminary results

Data analysis is in progress; however, sufficient analysis is complete to discuss preliminary results from the paired watersheds and the longitudinal site described above.

Water Chemistry

Of the twelve water chemistry variables measured, two were consistently different between continuously grazed and MIG stations at both the longitudinal and the paired watershed sites. Turbidity and fecal coliform levels were higher at continuously grazed stations than at rotationally grazed stations (Figures 2 and 3). Values for the remaining ten variables were not significantly different between grazing practices.

Physical Habitat

Values for four of the seven physical habitat variables measured differed between grazing practices at the longitudinal site. Average width of the stream and bank angle were higher at the downstream continuously grazed station than at the MIG stations (Figures 4). The percentage of fine materials comprising the substrate was also greater at the lower end of the continuously grazed stream reach, and significantly higher at the downstream conventional station than at all other stations. Embeddedness was highest at station 1. Levels of embeddedness at stations 1, 2, 4, and 5 were significantly greater than levels at stations 3, 6, and 7 (Figure 5).

Physical habitat measures were not significantly different between the continuously grazed and MIG stations in the paired watersheds.

Macroinvertebrates

Data from the macroinvertebrate samples taken in May 1995 indicate that two of the five macroinvertebrate indices suggest there is a greater level of disturbance and organic pollution at the downstream end of the continuously grazed section than at the MIG sections along the longitudinal study reach. A higher Hilsenhoff FBI value indicates a greater level of organic pollution at a site (Hilsenshoff, 1977). Overall, FBI values decreased from upstream to downstream with the highest FBI values found at the continuously grazed stations along the longitudinal reach (Figure 6). The Percent Dominance metric suggests that disturbed areas tend to have insect communities dominated by one family. Percent dominance values peaked at the lower continuously grazed station, and decreased at downstream MIG stations (Figure 7). The FBI and Percent Dominant values were significantly higher at the downstream conventional station than at two of the three downstream MIG stations. The number of taxa, EPT, and EPT:Chironomidae indices did not significantly differ between continuously grazed and MIG stations along the longitudinal study reach.

The macroinvertebrate index values were not significantly different between the paired watershed sites.

Fish

Fish species richness was similar at all stations along the longitudinal study site; however, fish density increased from upstream to downstream (Figure 8).

Species richness and fish densities were both greater at the continuously grazed station in the paired watershed study. Only one fish was found at the MIG paired station.

Discussion

Although all parameters measured are not significantly different between continuous grazing and MIG stations, values for a number of parameters are significantly different. For instance, significant differences exist for the FBI and Percent Dominance metrics at the longitudinal site, but other insect metrics do not significantly differ. However, the overall trend is that most measures at continuously grazed stations indicate a greater level of disturbance. A number of smaller differences in individual measures may combine to provide lines of evidence that there are measurable differences in stream communities and water quality related to grazing practices.

Water chemistry values obtained were typical for the streams being studied, and reflect their agricultural and geological nature. Specifically, higher fecal coliform and turbidity levels along continuously grazed stations at both the longitudinal and paired sites suggest that more fecal waste and sediments are entering streams along continuously grazed reaches.

Continuously grazed streams in the western U.S. are characterized by a greater channel width and bank angle as the cattle trample and grade down the banks (Duff, 1979; Marcuson, 1977; Platts, 1979). Fine materials (silt, sand, and clay) have been shown to comprise a larger part of the substrate and surround larger substrate materials (gravel, cobble, and boulders) along continuous grazing operations as a result of increased erosion and fine sediments entering the channel (Winegar, 1977). Width, bank angle, fine material, and embeddedness values peaked at the lower end of the continuously grazed site along the longitudinal study reach, while values decreased at the lower stations where MIG is employed. These data suggest that stream physical habitat may degrade along the continuously grazed portion of the stream, but exhibits recovery as it flows through areas under MIG.

The higher FBI and Percent Dominance values at the conventionally grazed segment of the longitudinal site suggest greater disturbance levels along this section . However, the lack of a difference in index values at the paired watershed sites suggest there is no difference in macroinvertebrate community composition related to upland grazing practices in these watersheds.

Although fish diversity was similar along the longitudinal reach, fish density increased downstream. The increase in fish density may be related to MIG, but other factors make interpretation difficult. One possible explanation for the increase in fish density in a downstream direction at the longitudinal site is that the stream changes from a third to a fourth order stream at the lower stations, increasing the discharge. The lower two stations are also approxmiately 6.4 - 8 kilometers from the point where the stream enters the Zumbro river, which may act as a source of fish immigration to these stations. The upper two stations are approximately twice as far from the Zumbro River (16 kilometers) and may not be influenced by upstream movement of fish from the river. At the paired stations, interpretation is also confounded by other factors. Discharge of the stream in the continuously grazed watershed is approximately twice that of the stream where MIG is practiced. The higher discharge at the continosly grazed stream may explain the difference in fish species and numbers between sites. The paired continuously grazed stream is also perennially connected to the Whitewater River, whereas the paired MIG stream very rarely flows into the Whitewater and has not been connected for at least the last two years. Fish may therefore move up into the continuously grazed stream more readily than into the MIG stream.

A complete analysis of the watersheds under study must take spatial and temporal relationships into account. Upstream influences on study sites must be considered to fully understand the dynamics of the systems. The length of time for changes in physical habitat to occur as a result of a change in grazing practices must also be considered. Similarly, it is not known how much time is needed for a given stream system to reach dynamic equilibrium as a result of management changes and climatological variability. Changes in fish communities will likely not be discernible until at least two generations have experienced the management changes that have taken place.

It will be important to continue monitoring the streams involved in this study to detect potential changes over time and to further analyze the data already collected within the spatial context of each watershed being monitored. The suite of chemical, physical, and biological parameters will be monitored through the summer of 1996. Additional watershed level studies are necessary to provide further insight into the influence of cattle grazing practices on aquatic systems in the Midwestern U.S.

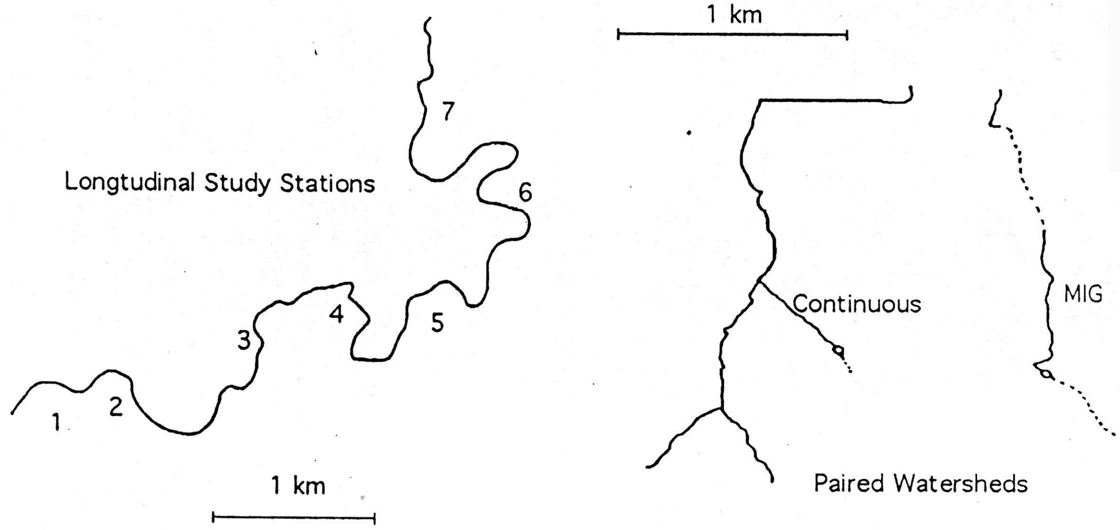

Figure 1. Longitudinal and Paired Watershed Sites

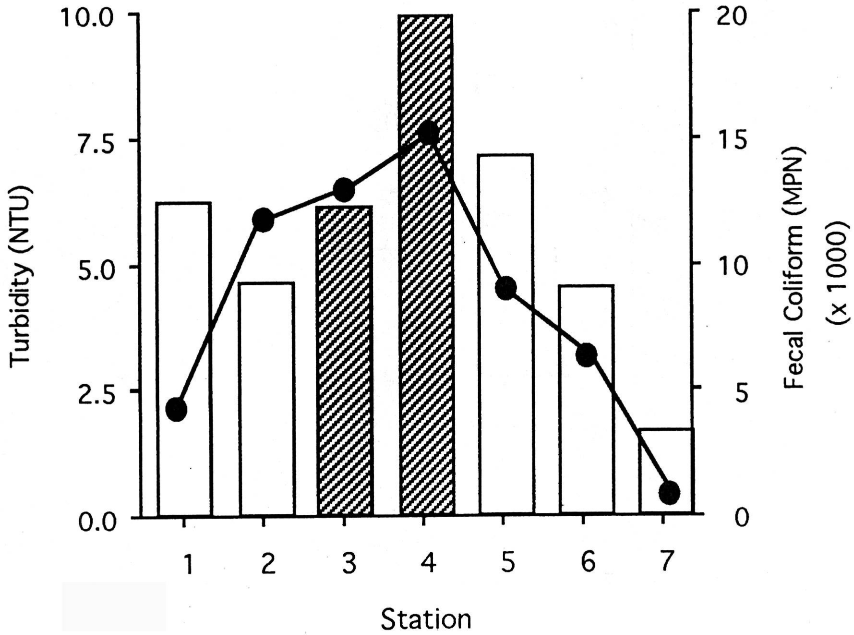

Figure 2. Turbidity (bars) and fecal coliform levels (line) at stations along the longitudinal study reach. Continuously grazed stations are crosshatched. Station 1 is at the upstream end of the site and station 7 is at the downstream end.

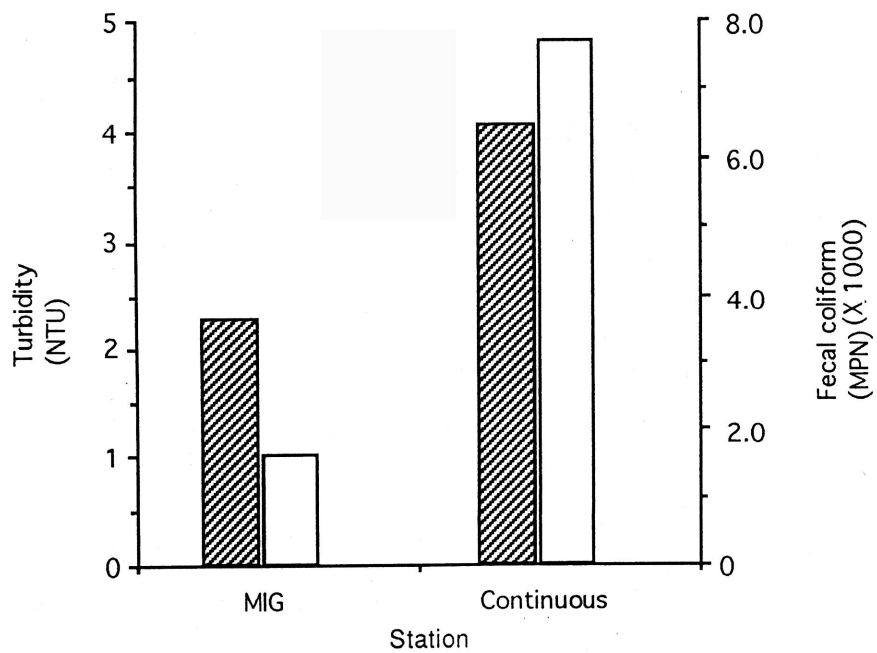

Figure 3. Turbidity (crosshatched) and fecal coliform levels (open) at paired watershed sites.

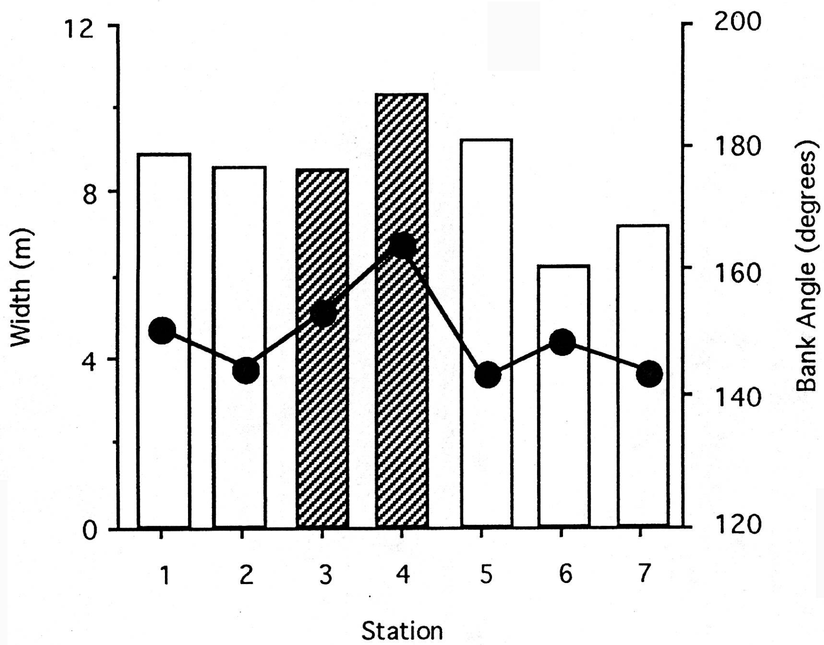

Figure 4. Stream width (bars) and Bank angle (line) at stations along the longitudinal study reach. Continuously grazed stations are crosshatched.

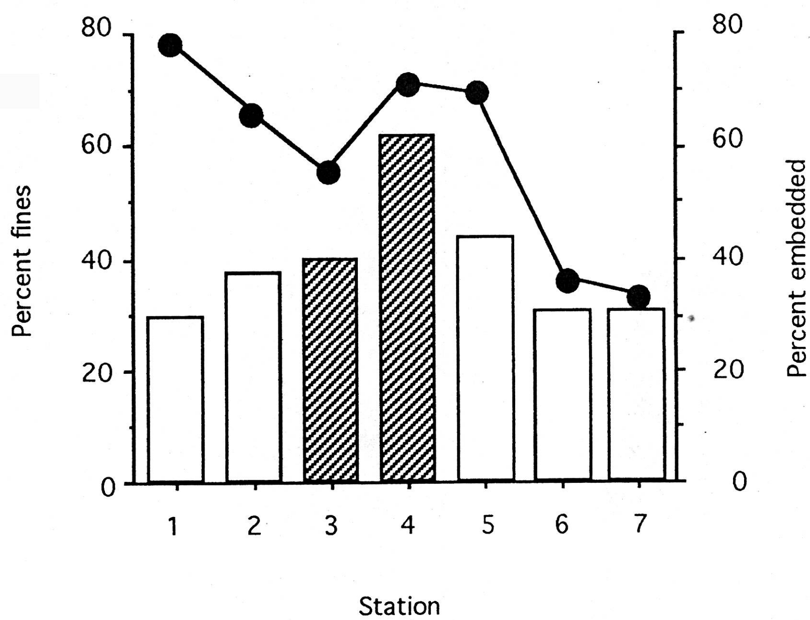

Figure 5. Percentage of fine materials (clay, silt, and sand): bars and embeddedness (line). Continuously grazed stations are crosshatched.

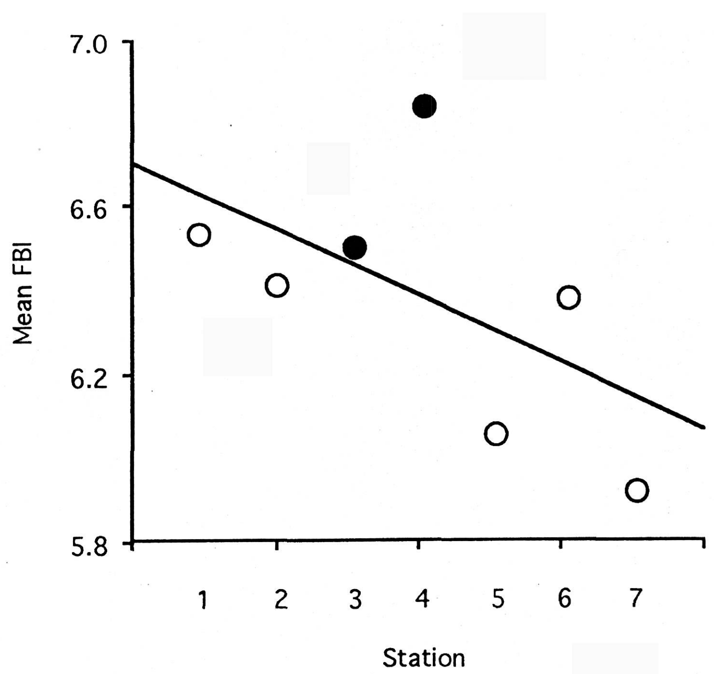

Figure 6. Family Biotic Index (FBI) values for insect communities at the longitudinal study stations (r^2=0.74). FBI=$\Sigma n_i T_i / N$; A higher FBI value indicates a greater level of organic pollution and disturbance at a station. Continuously grazed stations are solid.

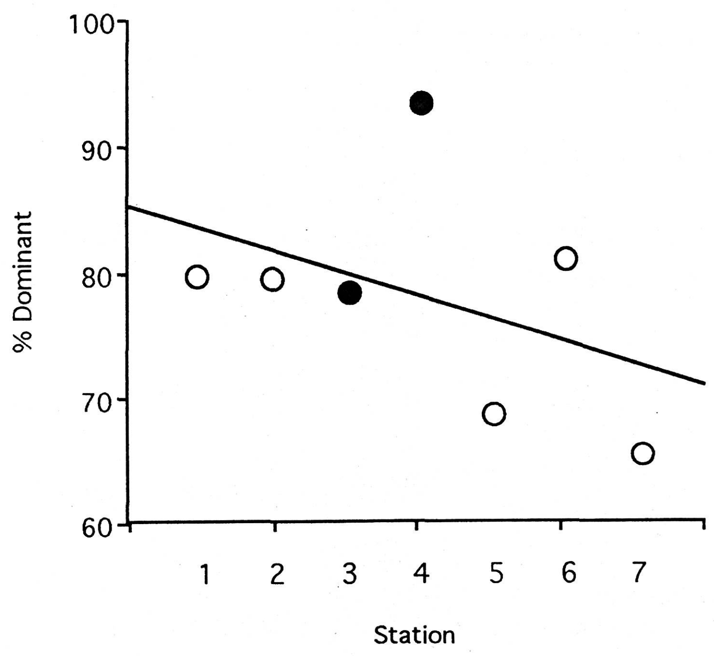

Figure 7. Percent Dominance of the most abundant family at the longitudinal study stations (r^2=0.65). Dominance is thought to increase at disturbed stations. Continuously grazed stations are solid.

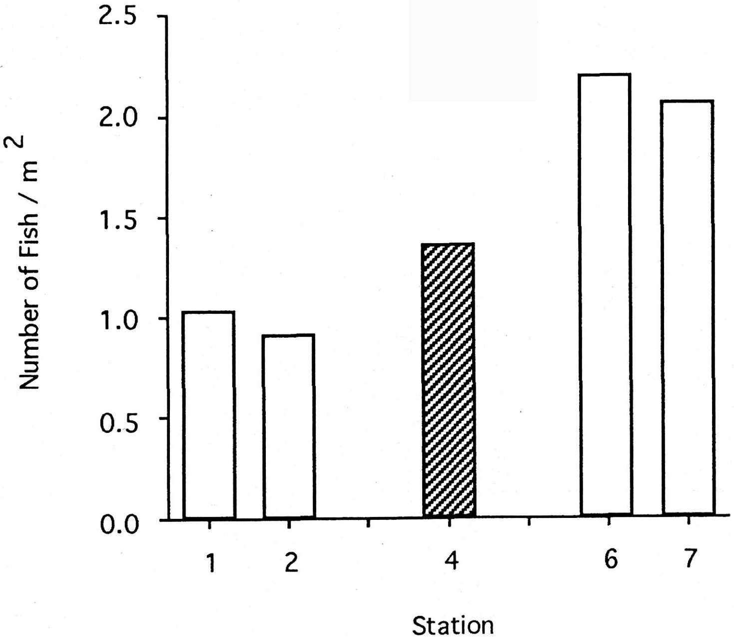

Figure 8. Fish density (#/m^2) at five of the seven longitudinal study stations. Continuously grazed station is crosshatched.

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