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EFFECTS OF TROUT STREAM HABITAT REHABILITATION PROJECTS ON NONGAME FISH COMMUNITIES IN FIVE SOUTHEASTERN MINNESOTA STREAMS

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Abstract:

Trout stream habitat rehabilitation projects in five streams in Winona, Olmsted, and Wabasha counties, southeastern Minnesota, were assessed for possible effects on the nongame fish community. Based on multiple-pass removal sampling in reference and rehabilitated stream sections, these rehabilitation projects had differential effects on the nongame community that appeared to be determined largely by stream gradient. In higher-gradient (>5 m/km) streams, rehabilitation project areas had nongame populations 45-58% lower then those in reference areas, but fish community diversity was higher in rehabilitated areas. In lowergradient (<5 m/km) streams, nongame populations in rehabilitated areas were 20-109% higher than those in reference areas, but fish community diversity was lower in rehabilitated areas. In higher-gradient streams, rehabilitation projects appeared to increase pool area but reduce riffle and shallow water areas, which favored trout (brown and brook) populations at the expense of the dominant nongame species such as slimy sculpin and brook stickleback. In lower-gradient streams, rehabilitation projects appeared to increase bank cover and fast-water areas, thus increasing populations of both trout and the dominant nongame species such as slimy sculpin, mottled sculpin, and white sucker.

Introduction:

Trout stream habitat rehabilitation projects have been conducted on many streams throughout the United States (Hunt 1988; Hunter 1991; White and Brynildson 1967). These projects have been designed specifically to alter stream habitat in favor of trout physiological tolerances, feeding behaviors, and reproductive capabilities (Rabeni 1990). The effects of these projects on trout populations have been widely documented (Hunt 1992, 1988, 1976, 1974; Hunter 1991). However, the effects of these projects on the nongame fish community are largely unknown. In the few instances where they have been examined, effects on the nongame fish community have been highly varied. Kwak (1993) reported that nongame fish density, biomass, and diversity were greater in rehabilitated sections of two southeastern Minnesota streams than in unrehabilitated zones. Glover and Ford (1990) reported a 6585% decrease in mountain sucker (*Catostomus platyrhynchus)* and white sucker (*Catostomus commersoni*) populations in Rapid Creek, South Dakota after completion of a rehabilitation project, but Hunt (1988) reported increased white sucker and creek chub (*Semotilus atromaculatus*) populations after a rehabilitation project was completed in Foulds Creek, Wisconsin. No other known studies have assessed, either qualitatively or quantitatively, the effects of trout habitat improvements on the nongame fish community.

Many streams in southeastern Minnesota have been degraded by various land use practices during the last century. Several of these streams have been the focus of habitat rehabilitation projects conducted by the Minnesota Department of Natural Resources and regional Trout Unlimited chapters during the past few decades. These projects have been very effective at restoring habitat for trout, but their success at restoring habitat for other, nongame species has not been evaluated. Several streams in this region also contain state-designated "Special Concern" species such as American brook lamprey *(Lampetre appendix*) and pugnose minnows (*Opsopoeodus emiliae*).

Trout rehabilitation projects have been placed in some of these streams (e.g. Beaver Creek), with no assessment of the projects' effects on these species. A better understanding of the effects that rehabilitation projects have on the nongame fish community is needed not only to protect such "Special Concern" species, but also to insure the continued survival of the entire fish community.

This study focused on assessing the effects that trout rehabilitation projects have on the nongame fish communities in five southeastern Minnesota streams. By comparing the nongame and trout populations between a trout habitat improvement zone (HIZ) and a reference zone

(RZ) in each of the streams, the effects of the habitat manipulations on both components of the fish community were determined simultaneously.

Methods:

Five streams in southeastern Minnesota, which all contained "Wisconsinstyle" rehabilitation structures (Hunt 1988), were studied during summer 1993. Information on the locality and history of each trout habitat improvement site was obtained from Minnesota Department of Natural Resources-Fisheries personnel in Lake City, MN. Structures most commonly installed at the sites included "LUNKER" structures, rip rap, bank covers, and current defectors (see Hunt 1988 for a detailed description of these structures). All of the streams studied are cold, headwater tributaries within watersheds that drain into the Mississippi River.

Within each stream, a RZ #1 was chosen in an area believed to be representative of how the HIZ appeared prior to the implementation of the rehabilitation project. Whenever it was deemed appropriate, an additional RZ #2 was sampled, located on the side (referring to upstream or downstream) opposite from the RZ # 1 site. Sites were chosen with the intent to keep pool-toriffle ratios similar between comparable HIZ and RZ sites. HIZ and RZ sites generally were sampled on the same day or successive days. No more than 10 days elapsed between sampling of HIZ #1 and RZ #1 sites within a given stream, exept Garvin Brook's which were sampled within 30 days of each other.

At each site, a representative, 50-m segment was measured, and 0.635cm-mesh blocknets were placed at upstream and downstream ends. A threepass removal procedure (Armour et al. 1983) was used to collect fish at each site. Beginning at the downstream end of each site, fish were sampled using a Smith-Root Type VII backpack electrofisher. Fish were identified, counted, examined for anomalies, and then returned to the stream alive outside of the sampling area. In a few cases, unidentified fish were preserved in 10% formalin and identified later using a taxonomic key by Eddy and Underhill (1978).

Stream and bank vegetation physiognomy was recorded at each site. Stream gradient within each study area was determined using U.S. Geological Survey 1:24,000 scale topographic maps and a map wheel. The watershed area of each stream was determined using a 1:253,440 scale topographic map and a Dietzgen Model D1806 polar planimeter.

Fish population estimates (with 95% confidence intervals) were calculated for each 50-m study reach using the procedure outlined by Armour et al. (1983). Estimates were calculated for all trout species combined and for all nongame species combined at each site. A modified t-test (Brower et al. 1990) was used to test the null hypothesis that populations in comparable HIZ and RZ sites were numerically equivalent. Simpson's and Shannon's diversity and dominance also were calculated for each site using the Aquatic Ecology Plus computer program (Eckbiad 1984). Various other metrics, such as species richness, number of individuals caught, and species capture probabilities (Armour et al. 1983), also were calculated.

Stream Characteristics:

Little Trout Creek has several stream sections containing trout rehabilitation structures that were installed in various years. The HIZ was located near the downstream end of the rehabilitation zone. HIZ structures in this area were installed between 1987 and 1989, and cover approximately 250 m of stream length. The HIZ was located in pasture land under easement by the Minnesota Department of Natural Resources, and was sparsely grazed by six cows. The RZ of Little Trout Creek was located downstream from the HIZ, in a pasture heavily grazed by approximately 30 cattle. *Rununculus sp.* was the predominant aquatic macrophyte in both the RZ and the HIZ.

Garvin Brook contained two adjacent trout improvement projects. Improvements within the stream section containing the HIZ sampling site occurred in 1984, and was maintained by a local Trout Unlimited group in 1992. All sampling sites were located on land owned by the state of Minnesota. Rip rap had been placed on the banks of the HIZ site to prevent erosion. Riparian vegetation was predominantly grasses. Two reference sites were chosen for this stream. The site designated RZ #1 was downstream from the HIZ site, and was located in an area with a grassy riparian zone. RZ #2 was upstream from the HIZ site, and was located in a forested area. The predominant aquatic macrophyte at all sites in Garvin Brook was watercress (*Nasturtium* sp.).

Big Trout Creek has undergone two habitat improvement projects, in 1986 and 1988. The HIZ site was located within the 1988 project area, which was 1005 m in length. The HIZ was in a pasture heavily grazed by 64 cattle. The banks of the stream were severely degraded by cattle activity. Two RZ sites were sampled: RZ #1 was located upstream from the HIZ site in a heavily grazed cow pasture, and RZ #2 was located downstream from the HIZ site in an area with forested riparian vegetation. RZ #1 had cutaway banks, frequently as high as 3 m. All sites lacked important beds of aquatic macrophytes.

West Indian Creek's HIZ was in a 670-m-long improvement project completed in 1987. Riparian vegetation was predominantly grass at the HIZ site, with some scattered trees. The RZ site was located upstream from the HIZ in an area with riparian vegetation which shifted from a mixed grass-forest area to a predominantly forested area along the 50-m section of the stream. Extensive beds of *Ranunculus sp.* were present in the RZ.

The Middle Branch of the Whitewater River contained a trout habitat rehabilitation zone greater than 1.5 km in length. Two habitat improvement sites and two reference sites were sampled. The site designated HIZ #1 was located near the upstream end of the 1.5 km rehabilitation project, and was downstream from Olmsted County Highway #9. The riparian zone of HIZ #1 contained grassland on one side of the stream and forest on the other. HIZ #2 was located near the downstream end of the 1.5 km rehabilitation project. The entire habitat improvement zone was located in pasture land, but the stream corridor was fenced to prevent cattle access except at designated crossings. RZ #1 was located in a heavily grazed pasture immediately upstream from Highway #9 and HIZ #1. RZ #2 was approximately 1 km upstream from RZ #1 in a heavily grazed pasture. RZ #2 was not considered directly comparable to the HIZ sites because of its headwater location, but was judged important because of its species composition (brook trout and mottled scuplin). In both reference sites, the stream banks were severely degraded due to cattle activity. All sites were subject to special "catch and release," and "barbless hooks only" fishing regulations. The Middle Branch of the Whitewater River contained extensive beds of the aquatic macrophytes *Ranunculus sp.* and *Polygonum sp.*

Results:

General results

In the five streams studied, eight of the 14 sites sampled were reference zones and six were habitat improvement zones. The stream gradients fell into two categories: higher-gradient (>5 m/km) and lower-gradient (<5 m/km; Table 1). Little Trout Creek and Garvin Brook were assigned the status of highergradient streams, whereas Big Trout Creek, West Indian Creek, and the Middle Branch of the Whitewater River were categorized as lower-gradient streams. Gradient and watershed area of the streams were not correlated (r^2 = 0.086) with one another.

During sampling, 4,664 fish were captured, representing 10 species from five families (Table 2). Of the species collected, four belonged to the family Cyprinidae. The families Salmonidae and Cottidae each were represented by two species, and the family Gasterosteidae was represented by a single species. The number of fish collected at a site ranged from 12 to 1,377 (Table 2), whereas the number of species per site ranged from two to five.

Species composition and richness

Six different taxa were observed as dominant species at individual sampling sites, with the dominant species comprising from 53% to 98% of the individuals collected at a site. The slimy sculpin was dominant at five sites (Table 2). White sucker, mottled sculpin, and brook stickleback were dominant at two sites each. Trout (either brook or brown) were the dominant species at three sites. The dominant nongame species at the three trout-dominated sites included white sucker (two sites) and mottled sculpin (one site). Species present at the fewest sites included longnose dace (three sites), blacknose dace (two sites), and central stoneroller (one site).

Brown trout were present in 13 of the 14 sites sampled (Table 2). Only five of the 14 sites sampled contained brook trout, and at three of those five sites only one individual brook trout was collected. Little Trout Creek's HIZ contained four brook trout, all within the same "LUNKER" structure. RZ #2 of the Middle Branch of the Whitewater River contained 13 brook trout but no brown trout. Only one brook trout was collected in the two HIZ sites.

In three of the five streams sampled, the species present varied between HIZ and RZ sites (Table 2). In Little Trout Creek, longnose dace were present in the RZ, but not the HIZ; furthermore, brook trout were present in the HIZ, but absent in the RZ. In Garvin Brook, brook stickleback were present only in RZ #1, and brook trout were present in all sites except RZ #1. In the Middle Branch of the Whitewater River, longnose dace were present in both HIZ sites, but absent in both RZ sites. A central stoneroller was found only in the Middle Branch of the Whitewater HIZ #2 site.

The number of species collected at each site was low, and ranged from two to five (Table 4). All streams, except the Middle Branch of the Whitewater, had numerically constant species richness between HIZ and RZ sites. Both habitat improvement sites in the Middle Branch of the Whitewater River contained two more species than either comparable RZ site.

Capture probabilities

Capture probabilities at a site were calculated -for a species only if more than 10 individuals were collected. The probability of capturing a given fish in a single pass at a site averaged 0.4499. Capture probabilities for a species at an individual site ranged from 0.002 (blacknose dace, brook stickleback; Table 3) to 0.8975 (white sucker). The two species with the greatest average capture probability (trout and white sucker) were also the species with the largest body sizes. The HIZ of Little Trout Creek was sampled on two separate occasions for trout, due to low capture probability on the first sampling occasion. However, on both occasions the number of trout collected was constant, even though the probability of capture improved during the second sampling period.

Diversity indices

In both higher-gradient streams, Simpson's and Shannon's diversity indices were numerically greater at all HIZ sites than their comparable RZ sites (Table 4). Furthermore, Shannon's diversity indices were significantly higher ($t = 13.095$, $df = 1$, $P = 0.049$) in HIZ sites than comparable RZ sites. However, Simpson's diversity indices were not significanly different ($P > 0.1$) between comparable HIZ and RZ sites. In the lower-gradient streams, Simpson's and Shannon's diversity were numerically lower in all HIZ sites than comparable RZ sites, except at the Middle Branch of the Whitewater River where HIZ #2 had greater Simpson's and Shannon's diversity than the comparable RZ #1 site (Table 4). However, Simpsons ($P > 0.1$) and Shannon's diversity ($P = 0.067$) were not significantly different between comparable HIZ and RZ sites.

Nongame fish community population estimates

All nongame fish community population estimates for higher-gradient stream HIZ sites were significantly lower than their comparable RZ sites (Figure 1; Table 5). At Little Trout Creek, 59% fewer brook sticklebacks (the dominant nongarne species) and 83% fewer creek chubs were caught in the HIZ than the RZ. At Garvin Brook, 29% and 43% fewer slimy sculpins (the dominant nongame species) were caught in the HIZ than RZ #1 and RZ #2, respectively.

All lower-gradient stream HIZ sites contained higher nongame fish community population estimates than their comparable reference zones, but only in West Indian Creek was this difference between HIZ and RZ #1 sites statistically significant (Figure 1; Table 5). The two streams where the HIZ nongame population estimates were not significantly higher had large population estimate confidence intervals (Table 5). At Big Trout Creek, 62% more white suckers were caught at the HIZ than either RZ site. At West Indian Creek, 39% more slimy sculpins (the dominant nongame species) were caught in the HIZ than the.RZ. In the Middle Branch of Whitewater, the HIZ #1 contained 88%, 97%, and 50%, more mottled sculpin than the RZ #1, RZ #2, and HIZ #2 sites, respectively. However, in this same stream 92% and 75% more white suckers were caught in the RZ #1 than in HIZ #1 and HIZ #2, respectively.,

Trout population estimates .

In four of the seven comparisons, HIZ sites had significantly higher populations of trout compared to specific RZ sites (Table 6). At West Indian Creek, the RZ contained significantly higher trout populations than the HIZ. At Big Trout Creek, the trout population was not significantly higher compared to the ungrazed RZ #2. At Garvin Brook, the HIZ had significantly lower trout populations than the RZ #1. The trout communities at the two HIZ sites of the Middle Branch of the Whitewater River were not significantly different from one another (Figure 3; Table 6).

Little Trout Creek had 400% more trout in the HIZ than the RZ. Garvin Brook had 191% more trout in the HIZ than the RZ #2, but the HIZ and RZ #1 sites were not significantly different. Big Trout Creek and the Middle Branch of the Whitewater had 165% and 2300% more trout in the HIZ than RZ #1, respectively. The HIZ of West Indian Creek had 21 % fewer trout than the RZ.

Discussion:

Gradient-dependent effects of trout stream rehabilitation

In higher-gradient streams, there was a tendency for nongame populations to decrease, and diversity indices to increase in the HIZ sites. In lower-gradient streams, there was a tendency for the nongame population to increase, and diversity to decrease in HIZ sites. The apparent gradientdependent trends of trout habitat rehabilitation projects may be attributed primarily to changes in habitat complexity of the HIZ sites. Habitat complexity has been shown to be a primary factor affecting species diversity within stream fish communities (Gorman and Karr 1978; Schlosser 1982; Angermeier and Karr 1984). Altered habitat complexity most likely caused several changes in other stream characteristics which may influence fish populations, such as temperature, maximum depth, average width, current velocity, and percent rocky substrate. Changes in habitat complexity apparently altered nongame fish community populations and diversity indices by causing changes in the abundance of the dominant nongame species.

In higher-gradient streams, trout habitat rehabilitation appeared to increase habitat complexity by increasing the number and depth of pools, and providing increased bank cover. Both Hunt (1988) and Thorn (1988) found that a primary benefit of increased pool and bank cover for trout was a reduction in winter mortality. In the present study, trout benefited from increased pool habitat and increased bank cover in higher-gradient streams, but dominant nongame species such as brook stickleback and slimy sculpin were negatively impacted. In several Wisconsin streams, Lyons et al. (1988) found brook stickleback abundance was negatively correlated to increasing pool depth. In highergradient streams, replacement of preferred shallow water areas with deeper pools apparently caused decreased brook stickleback populations. In the present study, it also was suspected that increases in trout populations may have caused declines of the dominant nongame species populations because of direct predation by trout on the smaller nongame species. Dineen (1947) found sculpins to be an important food resource for trout in three Minnesota streams. Reductions in the dominant nongame species and increases in trout populations apparently were the reasons for increased diversity in HIZ sites in higher-gradient streams.

Trout rehabilitation projects apparently increase habitat complexity in lower-gradient streams by narrowing the stream channel, thus increasing available fast-water areas as well as providing bank cover. Both trout and nongame components of the fish community responded positively to increased habitat complexity in lower-gradient streams. The increase in population estimates and decrease in diversity in lower-gradient streams were apparently a result of increased abundance of the dominant nongame species (e.g., mottled sculpin, slimy sculpin, white sucker). Diversity did not decrease in the lower-gradient Middle Branch of the Whitewater River HIZ #2 presumably because mottled sculpin populations did not increase (or dominate) as much in HIZ #2 as.in HIZ #1.

Previous studies support gradient-dependent trends

The gradient-dependent trends of habitat rehabilitation projects on the nongame fish community were supported by the findings of Hunt (1988) and Glover and Ford (1991). Hunt (1988) found increased white sucker (98%) and creek chub (31 %) populations in a rehabilitated section of Foulds Creek, Wisconsin. Foulds Creek is a lower-gradient stream (0.95 m/km), and thus follows the trend in lower-gradient streams for nongame populations to increase after habitat rehabilitation structures were installed. Glover and Ford (1991; also see Hunter 1991) found that white sucker and mountain sucker populations decreased 65-85% after a rehabilitation project was installed in Rapid Creek, South Dakota. Rapid Creek is a higher-gradient stream (9 m/km), and thus supports the trend in higher-gradient streams for decreased nongame populations after installation of trout stream rehabilitation structures. Neither Rapid Creek nor Foulds Creek were located in areas with geological characteristics similar to those in the present study, suggesting that gradientdependent effects of "Wisconsin-style" trout stream rehabilitation projects on the nongame fish community may be more than just a regional phenomenon.

Kwak (1993) studied fish populations within rehabilitation zones and reference zones in both Garvin Brook and the Middle Branch of the Whitewater River during the period between 1988 and 1990. In the Middle Branch of the Whitewater, Kwak (1993) found that nongame populations were only 3% higher in a downstream reference zone compared to a rehabilitated section. This finding of little change in the nongame population of the lower-gradient Middle Branch of the Whitewater River was consistent with the findings of the present study. However, Kwak (1993) also found that species diversity was higher in the rehabilitated section of the lower-gradient Middle Branch of the Whitewater River, which is opposite the trend of the present study. In the higher-gradient Garvin Brook, Kwak (1993) found that nongame populations were 53% higher and species diversity was lower in a rehabilitated section compared to a downstream reference reach. Both patterns are opposite those observed in the present study.

The reasons why the results of Kwak's (1993) study are in conflict with those of the present project, especially regarding Garvin Brook, are unknown. However, differences in methodology and weather conditions during the two studies may have had some impact. Even though Kwak (1993) used a multiplepass removal sampling method similar to that used in the present study, the size of the Kwak's (1993) sampling zones (34-m average) were 32% shorter than those of the present study (50-m). Shorter sampling zones may not contain all habitats representative of the stream, introducing a possible bias into the results. Kwak (1993) sampled only a single reference zone in Garvin Brook, whereas two such zones were sampled in the present study. Both of the present reference zones displayed similar patterns of population size and diversity relative to the rehabilitation zone, suggesting that the longer stream sections probably contained truly representative stream habitats and fish communities.

The-present study occurred during a record high-precipitation year, whereas Kwak (1993) apparently conducted sampling during or immediately after an extended drought (Minnesota State Climatology Office 1993, Gunard et al. 1989, 1990a, 1990b, 1991, 1992). Although no data were collected, it is likely that, during low-discharge drought periods, the unrehabilitated areas of the higher-gradient Garvin Brook became very shallow, whereas deeper water remained in the nearby rehabilitated zone. These deeper waters may have served as an attractive refugium for the dominant nongame fishes like the slimy sculpin, increasing populations but decreasing the diversity within rehabilitated areas. During high-discharge periods, like those of the present study, the unrehabilitated zones probably contained the physical habitat most attractive to sculpins. The conflicting study by Kwak (1993) thus suggests that rehabilitation project effects on the nongame fish community may be influenced by variable stream flow regimes in higher-gradient streams. Consequently, there is a need for a more comprehensive, long-term study of the effects of trout habitat improvement projects on the nongame fish community.

Effects of trout stream rehabilitation on trout populations

Trout populations were significantly higher in habitat improvement sites than in reference sites in four of seven comparisons. Hunt (1988) found that post-rehabilitation angler-hours per mile increased 72% and harvest increased 41 % in four HIZ sites after rehabilitation projects were completed in several Wisconsin streams. In the present study, it was likely that two of the three HIZ sites which did not have significant increases in trout numbers were subject to heavy fishing pressure. At both Garvin Brook and West Indian Creek HIZ sites, the paths on the streamside were heavily used, presumably by anglers. Intense cattle grazing of the HIZ streamside at Big Trout Creek maybe the reason why trout populations did not differ between the heavily grazed HIZ and the ungrazed RZ #2.

Hunt (1988) found that brook trout were usually competitively excluded when rehabilitation projects were installed in streams with sympatric populations of brook and brown trout. Thirteen brook trout were collected from the RZ #2 site of the Middle Branch of the Whitewater River; however, only one brook trout was captured in the two HIZ sites: Little Trout Creek contained sympatric populations of brook and brown trout, but the two species apparently occupied separate "LUNKER" structures within the rehabilitation zone. Garvin Brook contained one brook trout in both the HIZ and RZ #2 sites. However, approximately 1 km upstream from the RZ #2 site of Garvin Brook; in a 150-m, single pass sampling procedure, 39 brook trout and only 5 brown trout were caught (N. Mundahl, unpublished data). It is unknown if the two trout species have differential effects on the nongame communities. However, Garvin Brook, Little Trout Creek, and the Middle Branch of the Whitewater River all possibly could support brook trout in rehabilitated sites if conditions could be optimized for brook trout.

Hunt (1988) advocated continuing rehabilitation projects in streams with sympatric populations of brook and brown trout to determine under what conditions brook trout benefit more than brown trout from rehabilitation projects. To help protect brook trout within these projects, Hunt (1988) advised that special fishing regulations should be imposed to limit brook trout harvest. Hunt (1988) argued that more rehabilitation projects should be implemented to determine which structures, if any, are more beneficial to brook trout than brown trout. However, any ideology advocating further rehabilitation projects in streams with sympatric populations of brook and brown trout should be questioned, since it is known that brook trout are usually competitively excluded within HIZ sites (Hunt 1988). Structures already present should be studied to determine the circumstances in which rehabilitation projects are more advantageous to brook trout than brown trout.

Capture probabilities

The probability of catching a specific fish during a three-pass removal procedure was excellent, considering for every pass there was a 45% chance of capturing the fish. The findings of Libosvarsky (1962) that larger fish were captured more easy than small fish is consistent with white sucker and trout having the greatest average capture probabilities in this study. The low capture probabilities for brook stickleback and blacknose dace in Little Trout Creek were most likely caused by the extensive beds of *Ranunculus,* in which most of the fish were observed and captured.

Riley and Fausch (1992) reported a tendency (in over 50% of the sites they sampled) to underestimate fish population sizes when using a three-pass removal procedure. They concluded that underestimation of true population size was caused by decreasing capture probability on successive passes, which was caused by fish learning to avoid the electric current. This study focused on comparing nongame populations between sites in a stream. Since the species composition of the fish captured between sites in a stream were very similar, it is assumed that underestimation of the nongame population size was equal between sites. The assumption of equal underestimation between sites was believed valid due to the dominant nongame species being the primary factor influencing nongame populations estimates in all sites, and the dominant nongame species being constant between all sites in a stream.

Study design

This study examined the effect of trout habitat rehabilitation projects on nongame fish populations by comparing a rehabilitated section of a stream with a nearby, unaltered section of the same stream. An alternative study design would have been to monitor a single stream section's fish community before and after rehabilitation structures were installed, with subsequent analysis of any changes in fish populations. The studies by Hunt (1988) and Glover and Ford (1990) both monitored the same stream section before and after rehabilitation structures were installed. It could be argued that, since stream habitat varies widely within a stream, the design used in the present study is not as relevant as that used in studies by both Glover and Ford (1990) and Hunt (1988). However, careful effort was made in the present study to keep pool-toriffle ratios constant. In contrast, it also could by argued that, by conducting all sampling within a. few days, the design used in this study greatly reduced possible error tht could be caused by year-to-year variation in flow regimes and water quality, which could cause great fluctuation in fish population size. The study design used by both Glover and Ford (1990) and Hunt (1988) was likely more susceptible to such changes in water quality and flow regimes. Despite differences in study design, the results of the present and previous studies (Hunt 1988, Glover and Ford 1990) were remarkably similar. Apparently both study designs, if employed carefully, can be used to determine the effects of habitat manipulations on the nongame fish populations.

Effects of trout stream rehabilitation projects on water quality

In four of five HIZ sites, agricultural activities on the streamside were regulated. Boxrud and Gallagher (1992) suggested that reduced siltation may be responsible for improved patterns in invertebrate communities in the habitat improvement zone of the Middle Branch of the Whitewater River. Mundahl et al. (1992) supported the conclusion that water quality was improved in the habitat rehabilitation zone of the Middle Branch of the Whitewater River using fish community studies. Also, Kwak (1993) found that percent eroded bank was the best single predictor of trout production in southeastern Minnesota. It was probable that reduced bank erosion (or siltation) was a primary factor influencing the fish community in HIZ sites. The cause for eroded banks in many streams was agricultural activities (e.g., cattle grazing). It is probable that some of the change in fish communities in four of the HIZ sites resulted from restricting agricultural activities from the immediate streamside. It is unknown to what extent removal of cattle from the streamside would affect fish communities.

In the Middle Branch of the Whitewater River, changes or differences in species composition and population dynamics between HIZ and RZ sites suggest that the HIZ sites suffered from fewer water quality problems. Both sculpin and brook trout populations declined drastically between 1992 and 1993 in the RZ #2. In 1992, 183 sculpin and trout were captured in a 150-m single-pass procedure (N. Mundahl, unpublished data), but only 15 fish were captured with the 50-m, three-pass procedure in 1993. A reasonable explanation for the decreased fish populations in RZ #2 site between successive years was decreased water quality. The decrease in water quality was most probably caused by increased sediments washed into the stream from the record rainfall that southeastern Minnesota experienced in the spring and summer of 1993 (Minnesota State Climatology Office 1993). Longnose dace, a species intolerant of poor water quality (Ohio Environmental Protection Agency 1987), was found only in the HIZ sites. Finding longnose dace in the HIZ sites suggests that water quality was not affected in the HIZ by the spring and summer rains, but it could also only be a reflection of increased fast-water areas in the HIZ sites.

Big Trout Creek was the only HIZ site subject to heavy cattle grazing. Increased sedimentation due to cattle activity in the HIZ of Big Trout Creek could explain why trout populations were not significantly increased in the HIZ compared to the ungrazed RZ #2. However, nongame fish were significantly higher in the HIZ than the RZ #2.

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Table 1. Stream gradients and drainage areas of sites sampled in five southeastern Minnesota streams studied during summer 1993. Only the Middle Branch of the Whitewater River had differing gradients between trout habitat improvement zone (HIZ) and reference zone (RZ) sites.

Site	Gradient (m/km)	Area (km^2)
Little Trout Creek:	10.5	16.1
Garvin Brook:	7.5	36.8
Big Trout Creek:	3.9	28.8
West Indian Creek:	3.8	26.2
Middle Branch of the Whitewater River:		
HIZ #1	3.9	12.7
RZ #1	3.9	12.7
HE #2	--	14.8
RZ #2	2.2	8.0

Table 2. Numbers of American brook lamprey observed as lone individuals and group sizes of active spawners during 1995 and 1996 spawning seasons.

Stream	Number of loners	Numbers in spawning groups	Mean ± SD spawning group size
1995			
Pine Creek	6		
Badger Creek	?	?	
Pine Creek	6	3-2-5-5	3.75 ± 1.50
Rupprecht Creek	0	12-9-12-11-14-4-7	9.86 ± 3.44
S. Branch Whitewater R.	1	4-3-5-3-2	3.40 ± 1.14
N. Branch Whitewater R.	2	5-5-2	4.00 ± 1.73
M. Branch Whitewater R.	1		
Beaver Creek-Win. Co.	1		
1995 Totals	**17 (13.1%)**	**113 (86.9%)**	**5.95 ± 3.79**
1996			
Badger Creek	0	2	2.00
Beaver Creek-Hou. Co.	1		
Rupprecht Creek	4		
N. Branch Whitewater R.	5	2	2.00
Etna Creek	1		
S. Branch Root R.	1	4	4.00
North Branch Creek	4	7-4-4-4	4.75 ± 1.50
South Branch Creek	3	2-5	3.50 ± 2.12
S. Fork Zumbro R.	1		
1996 Totals	**20 (37.0%)**	**34 (63.0%)**	**3.78 ± 1.64**

Table 3. Species capture probabilities at six habitat improvement zone and eight reference zone sites in five southeastern Minnesota streams during summer 1993. The number of sites used in calculating average capture probability for a site is listed. Probability of capture was calculated for a species only if more than ten individuals were captured.

		Capture Probability	
Species	Number of sites	Average	Range
Slimy sculpin	5	0.464	0.310-0.678
Mottled sculpin	3	0.369	0.288-0.403
Brown trout	12	0.515	0.024-0.710
Creek chub	1	0.396	-
Brook stickleback	2	0.288	0.002-0.573
White sucker	3	0.522	0.262-0.898
Blacknose dace	1	0.002	-

Table 4. Diversity and species richness for six trout habitat improvement zones (HIZ) and eight reference zones (RZ) in five southeastern Minnesota streams. All sampling sites were 50 min length, and were sampled during summer 1993.

Site	Number of taxa	Simpson's diversity	Simpson's dominance	Shannon's diversity	D-max	Individuals captured
Garvin Brook:						
RZ #2	3	0.046	0.954	0.169	1.584	795
RZ # 1	3	0.127	0.873	0.396	1.584	663
HIZ	3	0.201	0.799	0.523	1.584	496
Middle Branch of the Whitewater River:						
RZ #1	3	0.558	0.442	1.207	1.584	22
RZ #2	2	0.247	0.753	0.566	1.000	15
HIZ #1	5	0.381	0.619	0.973	2.321	100
HIZ #2	5	0.627	0.373	1.656	2.321	72
Little Trout Creek:						
RZ	5	0.661	0.339	1.778	2.321	128
HIZ	5	0.679	0.321	1.926	2.321	50
Big Trout Creek:						
RZ #2	2	0.514	0.486	0.985	1.000	21
RZ #1	2	0.489	0.511	0.954	1.000	24
HIZ	2	0.427	0.573	0.871	1.000	34
West Indian Creek:						
RZ	3	0.163	0.837	0.475	1.584	866
HIZ	3	0.095	0.905	0.310	1.584	1377

Table 5. Nongame fish population estimates with 95% confidence intervals, and comparative t-test statistics for six habitat improvement zones (HIZ) and eight reference zones (RZ) in five southeastern Minnesota streams. All sites were 50 m in length, and were sampled during summer 1993.

Site	N ± 95% C. I.	t - statistic	P
Little Trout Creek:			
RZ:	172 ± 49.3		
		2.1502	< 0.025
HIZ:	71.0 ± 80.4		
Garvin Brook:			
RZ #1:	932 ± 146		
		5.772	< 0.01
HIZ:	506 ± 17.2		
		12.071	< 0.01
RZ #2:	968 ± 74.6		
Big Trout Creek:			
RZ #1:	25.1 ± 33.6		
		0.016	> 0.05
HIZ:	30.3 ± 13.2		
		3.233	< 0.01
RZ #2:	9.01 ± 0.21		
West Indian Creek:			
RZ:	1025 ± 88.5		
		9.37	< 0.01
HIZ:	1629 ± 93.5		
Middle Branch of the Whitewater River:			
RZ # 1	47.8 ± 90.1		
		1.107	> 0.05
HIZ #1	100 ± 27.6		
HIZ #2	68.4 ± 27.0		
RZ #2	3.97 ± 0.00		

Table 6. Trout population estimates with 95% confidence intervals, and comparative ttest statistics for six trout habitat improvement zones (HIZ) and eight reference zones (RZ) in five southeastern Minnesota streams. All sites were 50 m in length, and were sampled during summer 1993.

Site	N ± 95% C. I.	t - statistic	P
Little Trout Creek:			
RZ:	4.17 ± 1.19		
		2.0059	< 0.01
HIZ:	16.7 ± 4.87		
Garvin Brook:			
RZ #1:	69.9 ±68.8		
		0.3344	> 0.05
HIZ:	58.5 ± 4.59		
		1.6787	< 0.025
RZ #2:	30.7 ± 32.8		
Big Trout Creek:			
RZ # 1:	9.22 ± 0.87		
		3.4029	< 0.01
HIZ:	15.2 ± 3.49		
		0.8313	> 0.05
RZ #2:	13.1 ± 3.62		
West Indian Creek:			
RZ:	81.5 ± 16.3		
		2.0697	< 0.025
HIZ:	64.1 ± 4.05		
Middle Branch of the Whitewater River:			
RZ #1	1 (no 95% C.I.)		
		14.770	< 0.01
HIZ #1	23.0 ± 2.98		
		0.5948	> 0.05
HIZ #2	28.6 ± 18.5		
RZ #2	13.0 ± 3.11		

Figure 1. Nongame fish population estimates (with standard error bars) of 50-m sites in both six habitat improvement zones (HIZ) and eight reference zones (RZ) of five streams sampled during summer 1993. The Middle Branch of the Whitewater River is abbreviated M.B.W.W.

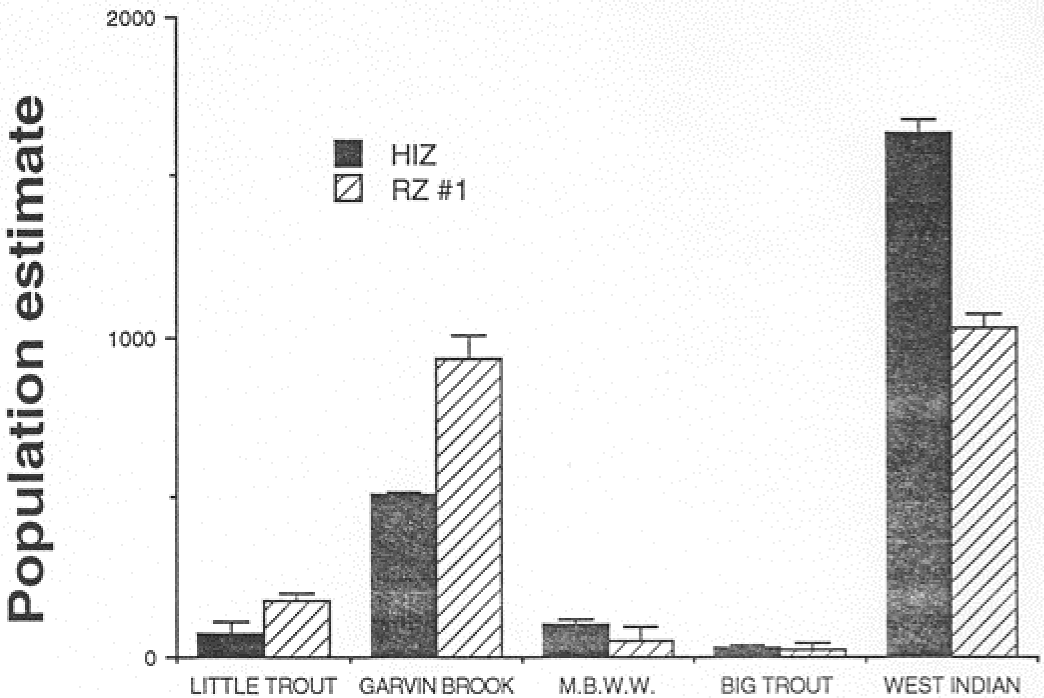
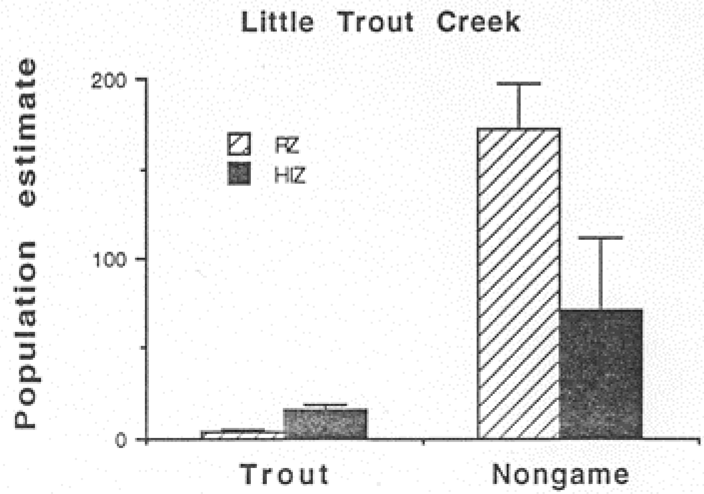


Figure 2. Population estimates (with standard error bars) of 50-m sites in both habitat improvement zones (HIZ) and reference zones (RZ) of two higher-gradient streams sampled during summer 1993.



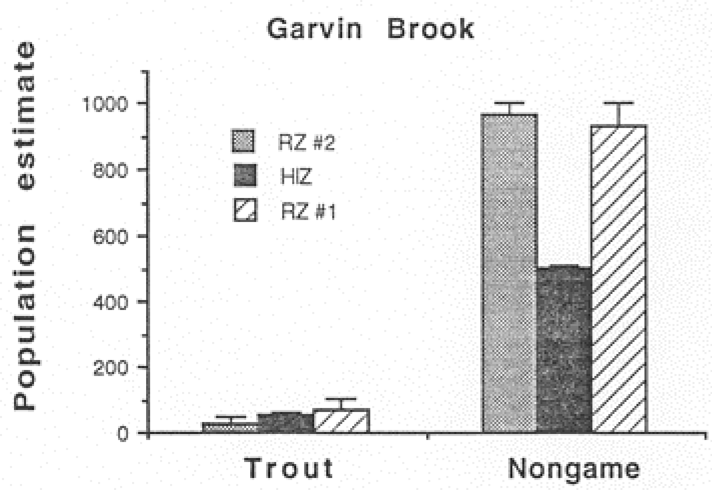
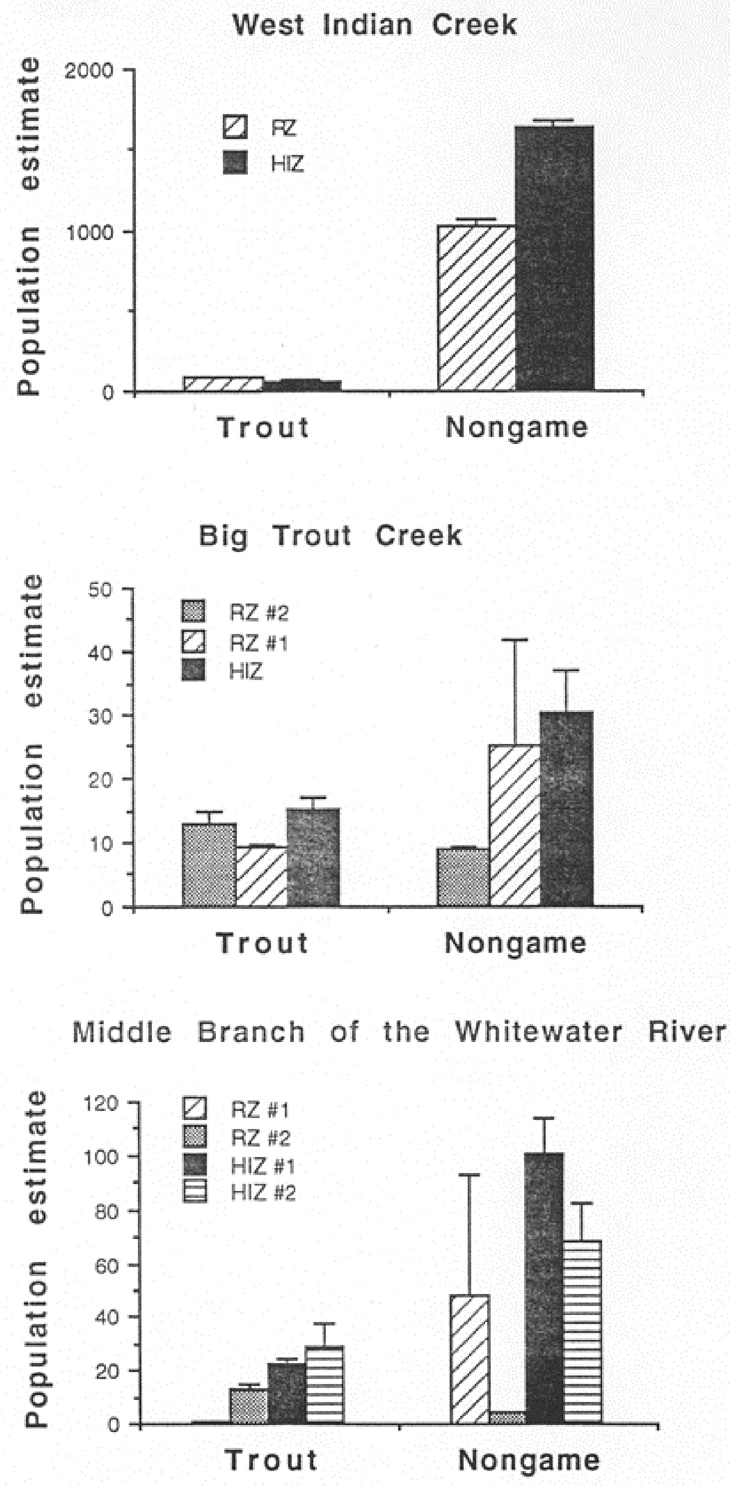


Figure 3. Population estimates (with standard error bars) of 50-m sites in both habitat improvement zones (HIZ) and reference zones (RZ) of three lower-gradient Minnesota streams sampled during summer 1993.



Appendix. Map coordinates of the sites sampled during summer 1993.

Little Trout Creek

HIZ	T106N	R5W	S19	SE 1/4
RZ	T106N	R5W	S19	SE 1/4

Garvin Brook

HIZ	T1 06N	R8W	S4	SW 1/4
RZ #1	T106N	R8W	S8	NW 1/4
RZ #2	T106N	R8W	S5	SW 1/4

Middle Branch of the Whitewater River

HIZ #1	T107N	R11 W	S35	SW 1/4
HIZ #2	T107N	R11 W	S35	NE 1/4
RZ #1	T106N	R11 W	S2	NW 1/4
RZ#2	T106N	R11W	S3	SE 1/4

Big Trout Creek

HIZ	T1 06N	R6W	S26	NE 1/4
RZ #1	T1 06N	R6W	S23	SE 1/4
RZ #2	T106N	R6W	S26	SE 1/4

West Indian Creek

HIZ	T109N	R11W	S16	SW 1/4
RZ	T1 09N	R1 1W	S21	NE 1/4