GRAND VALLEY STATE UNIVERSITY
FACULTY RESEARCH AND DEVELOPMENT CENTER

Research Grant-in-Aid Final Report

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Title of Proposal: Survival of stocked brown trout (*Salmo trutta*) in the Pigeon River, Ottawa County, Michigan.

Dates of Project: May 1, 2006 through August 31, 2006

Amount of Grant: $2,724

Were you able to accomplish what you proposed with the funding granted?

We accomplished all major activities in the proposal with the funding granted. After surveying four stream sections as originally proposed, we discovered relatively low trout populations in the stream. To provide for a more extensive survey of the stream, we included a total of nine 1000-foot stream stretches in the study, and completed a more detailed survey of the entire fish population assemblage as a result.

To what extent was the project outlined in the grant application successfully completed?

All major objectives of the proposed project were successfully achieved. We now have a greatly improved understanding of the current fish population in the Pigeon River, the relative abundance of trout, the habitat conditions in the stream, and an updated record of summer water quality conditions. We also were able to document apparent differences in success of the different strains of brown trout stocked between 2003 and 2006. The results of this study provide information needed to guide future efforts to protect and manage this and similar small coldwater streams in urbanizing areas of southern Michigan.

Did this project result in a performance, exhibition, or publication? If so, please provide details and, if possible, provide copies of publications.

This study is part of Daniel Mays' Biology MS Project, which will continue into the fall. As a result, we will not present the results to the public until Dan's MS Project is near completion. This preliminary report will be provided to cooperating agencies (Michigan Department of Natural Resources, Ottawa County Parks and Recreation Department, Ottawa Conservation District) and other interested parties. Daniel Mays also will be preparing presentations for the 2007 Student Scholarship Day and the 2007 meetings of the Michigan Academy of Science, Arts, and Letters. Upon completion of the project, we anticipate publishing the results in the Michigan Academician or other suitable outlet.

NARRATIVE REPORT OF THE ACTIVITIES OR RESEARCH FUNDED BY THIS GRANT

Introduction

The Pigeon River drains a 41,500-acre watershed in Ottawa County, Michigan, and discharges into Lake Michigan at Port Sheldon. Presettlement vegetation in this watershed was mostly hardwood forests in the uplands, with large areas of wetlands in low-lying areas (Comer et al., 1995). Following land clearing for agriculture, the extensive wetlands were drained during the early 1920s. Currently, approximately 49% of the watershed is agricultural, largely at the headwaters and in the central portion of the watershed. Another 36% of the watershed is forested, primarily in the western third of the watershed, and less than 1% of the watershed is now occupied by wetlands (MacDonald et al., 2001). The lower mainstream of the Pigeon River is designated as a coldwater fishery, but degraded water quality in the 1980s resulted in the loss of its trout population and cessation of active fishery management (Pigeon River Watershed Advisory Committee, 1997; Creal and Wuycheck, 1998). In the mid-1990s, regulatory actions by state agencies and cooperative efforts to reduce non-point source pollution instituted through the Pigeon River Watershed Project (e.g., Wiley and Seelbach, 1998) produced measurable improvements in water quality. As a result, the Michigan Department of Natural Resources (MDNR) reinstituted trout stocking in the Pigeon River in 2003 to provide a recreational fishery (Harrington, 2005). For this project, in cooperation with the MDNR, we conducted fish, habitat, and water quality surveys to evaluate the reestablishment of the trout population as part of continuing efforts to improve the river's biotic community.

Methods

Study Sites: We established nine 1000-ft sampling stations (Table 1) in the designated coldwater fishery stretch of the Pigeon River in Olive and Port Sheldon Townships of Ottawa County, Michigan. Three stations were surveyed between 120th and 128th Avenues, three stations were surveyed between 128th and 136th Avenues, and three stations were surveyed below 136th Avenue. All sampling stations had intact streamside forests and included runs or pools with varying amounts of large woody debris for habitat.

Fish Community Assessment: All fish survey data were collected following standard procedures from the MDNR Manual of Fisheries Survey Methods (Wills et al., 2005). Fish population surveys were performed at each station in mid-June and again in mid-August, 2006. Fish sampling was performed with a pulsed-DC backpack electroshocker and two netters. During both sampling periods, we used one-pass electrofishing to characterize the composition of the fish population. We measured and counted all brown trout, other game fishes, and all non-game fishes to obtain length-frequency data and a measure of relative abundance. To determine the age class distribution of brown trout, scale samples were taken from each brown trout collected during the August sampling period. We did not perform a mark/recapture study of the trout population as originally proposed because the relatively few trout found in the stream would not provide a statistically valid sample to estimate the total trout population.

In-Stream Habitat Conditions: In mid-July, we systematically sampled at 75-ft intervals (Wills et al., 2005) throughout each 1000-ft station to characterize stream physical characteristics. At each sample point, we measured width and depths, rated bank stability, characterized riparian vegetation, determined bottom substrate, and classified the specific habitat type (pool, riffle, or run). We also measured the basal area of the surrounding forest at each point with a 10-factor basal area prism and estimated the canopy density of streamside vegetation using a spherical densiometer. We quantified large woody debris (>6" diameter) for entire 1000-foot stretches. Qualitative and quantitative measurements of the relative proportions of substrate, woody debris, and habitat types were recorded as detailed in Wills et al. (2005).

Physical and Chemical Water Quality Measurements: Once each month from May through August, we recorded water temperatures, determined dissolved oxygen levels, and collected samples for chemical analyses at four representative 1000-ft stations as originally proposed. We measured water temperature and dissolved oxygen levels in the field using a YSI Model 55 dissolved oxygen meter (YSI, Inc., Yellow Springs, OH), and confirmed dissolved oxygen levels in the laboratory using the Winkler titration method on one 300-mL sample per station. We measured stream flow (ft^3/sec) on each date using a Teledyne Gurley Model 625 Pygmy water current meter (Teledyne Gurley, Troy, NY). Data collected was entered in the field on an electronic data recorder (JS 600 Fieldbook, Juniper Systems, Logan UT). We also placed continuous water temperature recorders at four stations to record stream temperatures at one-hour intervals throughout the study period.

Chemical analyses conducted at GVSU included conductivity, pH, and dissolved oxygen titrations. We measured conductivity with a YSI Model 35 conductance meter (YSI, Inc., Yellow Springs, OH), determined pH with a Cole-Parmer Series 5986 pH meter (Cole-Parmer Instrument Co., Vernon Hills, IL), and completed dissolved oxygen titrations with a Hach digital titrator (Hach Co., Loveland CO). On each sampling date we also collected a one-liter water sample at each station for analysis in the Annis Water Resources Institute (AWRI) laboratory (chloride, sulfate, ammonium N, nitrate N, soluble reactive P, total P, and total suspended solids). Analytical methods followed the standard, quality-assured protocols developed for use in the AWRI analytical laboratory (APHA, 1992).

Statistical Analyses: Among-station analyses of variance for water quality variables were conducted with sampling stations considered a fixed effect and by treating sampling dates as a block effect (MacDonald et al., 2001). We used one-way analyses of variance to compare in-stream habitat characteristics among stations by treating 75-ft sampling intervals as within-station replicates. We used Tukey's multiple comparison test to judge significant differences among sample means (Steel and Torrie, 1980). Habitat data also were analyzed using principal components analysis. Data were manipulated using EXCEL, RBASE, and SYSTAT.

Results and Discussion

Water Quality and Hydrology: Water quality in the Pigeon River during the Summer of 2006 was similar to that documented in the late 1990s by MacDonald et al. (2001). As observed previously, dissolved oxygen, pH, and conductivity decreased following large rains (5/16/2006 and 7/12/2006), while oxygen deficits increased (Table 2). Mean dissolved oxygen concentrations increased and oxygen deficits decreased from Station 3 to Station 9 as water quality improved downstream, also similar to trends previously observed by MacDonald et al. (2001) in this system. Degraded water from Sawyer Creek, which enters the Pigeon River just below 120th Avenue, is the primary cause of the lower dissolved oxygen concentrations observed above 128th Avenue (MacDonald et al., 2001). Higher dissolved oxygen levels are associated with improved conditions for brown trout (Eklov et al., 1998), suggesting that stations in the lower Pigeon River should be most suitable for trout. Elevated conductivity at upstream stations, most noticeable during low flows in August (Table 2), is related to discharge of high-conductivity effluent from a point source above 104th Avenue (MacDonald et al., 2001). Average daily stream temperatures remained below 20 °C for most of the summer, with the exception of short periods in late July and early August (Figure 1). Late spring flows were dominated by water from the upper watershed, and stream temperatures tended to be similar throughout the system until mid-June. In contrast, mid-summer flows were strongly influenced by groundwater influx from the lower watershed, and stream temperatures were lower at downstream stations until the end of August (Figure 1). Stream discharge during the Summer of 2006 varied with rainfall, increasing during May and July rains, and dropping in August after a period of lower rainfall and high evapotranspiration (Table 2). Average summer flows in 2006 were similar to the average summer baseflow of 15.7 ft^3/sec determined for Station 9 between 1997 and 2000 (MacDonald et al., 2001). Reductions in flow between Stations 5 and 8 (Table 2) in part represent the effects of irrigation withdrawals below Station 6. The impacts of irrigation withdrawals on discharge in the Pigeon River become more pronounced as stream flow begins to drop in late summer (e.g., August, 2006). Because of low summer baseflows in this system, large irrigation withdrawals during periods of low rainfall can greatly diminish stream flows in the Pigeon River and have the potential to adversely affect the biota of the stream. This suggests that to reduce the adverse impacts of low streamflows, irrigation withdrawals in the Pigeon River watershed should be carefully controlled when streamflow drops below the summer average baseflow of 16 ft^3/sec at West Olive Road. During low streamflows, using alternate sources of water for irrigation (wells, storage tanks, etc.) may be needed to help maintain instream flows.

Inorganic ion and nutrient concentrations measured in the Summer of 2006 (Table 3) were similar to those observed previously in this stream (MacDonald et al., 2001). Total phosphorus and sulfate concentrations decreased from Station 3 to Station 9 (Table 3), related to dilution by groundwater in the lower Pigeon River (MacDonald et al., 2001). Chloride and soluble reactive P concentrations also tended to decrease downstream, but not significantly so (Table 3). While both N and P concentrations remained in the range typical of many agricultural watersheds (Omernik, 1976; 1977), soluble reactive P and nitrate concentrations measured in the summer of 2006 tended to be less than those measured during the late 1990s (MacDonald et al., 2001). While water quality has not noticeably improved since the late 1990s, it also has not deteriorated, and stream temperatures (< 20 °C) and dissolved oxygen concentrations (> 6 mg/L) normally remain in a range suitable for brown trout (Everhart et al., 1975). Storm flows episodically degrade water quality, however, and low stream flows resulting from drought combined with irrigation withdrawals increase environmental stress in this small stream later in the summer. Additional efforts to improve water quality and reduce hydrologic fluctuations in this system are needed to further increase its suitability to sustain a desirable fish population.

Stream and Habitat Characteristics: Stream widths and depths tended to be fairly similar at all nine stations measured in this study (Table 4). Average widths were greatest at Stations 1 and 6, while average depths were greatest at Stations 4 and 9 (Table 4). In general, habitat values and brown trout growth are better in areas of stream segments with deeper water (Greenberg and Dahl, 1998; Lamouroux and Capra, 2002), suggesting that Stations 2, 4, 5, 6, and 9 might provide more optimal habitat. Stations 7 and 8 had the smallest channel dimensions because they were both side channels in the river where it splits into multiple channels downstream of 136th Avenue. All stations were well-shaded by riparian vegetation, and did not differ significantly in canopy cover (Table 4). Most stations had riparian forest basal areas in excess of 80 ft^2/ac, typical of fully-stocked forests, with the exception of Station 9 (Table 4). All nine stream stretches were dominated by fairly shallow runs (Figure 2), although some stretches contained deep pools. Most stations had some riffle areas, characterized by shallow, turbulent flows over sandy substrate. The dominant bottom substrate throughout the Pigeon River was sand (Figure 3), with only small amounts of material coarser than pea gravel found in any stretch. In some stretches, small areas of the underlying clayey till were exposed where overlying sand had been scoured away during high flows. Stations immediately upstream of road bridges (Stations 3 and 6, Figure 3) were characterized by very sandy bottoms resulting from impoundment of floodwater and deposition of sediments. The absence of naturally occurring coarse substrates is a habitat limitation in this system (Huusko and Yrjana, 1997; Maki-Petays et al., 1997; Harwood et al., 2002; Lamouroux and Capra, 2002), as there are very limited gravel deposits, and most of these are the result of human additions of gravel or cobbles (e.g., below 96th Avenue, at 120th Avenue, above 136th Avenue, and above West Olive Road).

Most stretches contained substantial quantities of large woody debris (Figure 4), providing a major habitat element in this sandy system. Throughout the stream, large logs that were associated with deeper pools and runs provided cover for all of the large brown trout that we found in this stream. Most stretches also contained substantial areas of log jams and brush deposits (Figure 5), which provided cover for most of the smaller trout that we found in the stream. Preserving all types of woody debris intact in this stream is critical for providing suitable habitat for trout and other fish species since it is one of the only permanent structural elements in this sand-based system. These types of shelter can be especially important for winter survival, especially since brown trout will compete for available cover (Harwood et al., 2002). A few stations (1, 6, 9) had localized areas of rubble, cobble, or gravel riprap added for erosion control that also provided fish habitat, but these areas were restricted in size and location (Figure 5). Because of the dominance of sand substrate in this system, the few gravel deposits suitable for spawning are heavily used by trout and salmon (e.g., above West Olive Road, N.W. MacDonald, personal observations). Unfortunately, these areas are typically at road crossings where spawning fish are easily observed and often removed rapidly by poachers. Planned addition of suitable coarse substrates to more protected areas of the stream might facilitate successful spawning of either resident trout or migratory trout and salmon.

Riparian vegetation classes varied systematically from upstream to downstream in the study area (Figure 6), with the upper stations (1-5) predominantly bordered by closed-canopy deciduous forests. Below Station 5, grasses, forbs, and brushy shrubs like tag alder became increasingly common until they were the dominant riparian vegetation at Station 9. Most of the stream is well-shaded, with even Station 9 having canopy coverage of over 70% (Table 4). Bank stability classes also varied systematically from upstream stations to downstream stations (Figure 7), with the poorest stability ratings observed at Station 1 (120th Avenue). The upstream stations are most directly impacted by high storm flows, with downstream stations experiencing successively less concentrated flows since floodwaters are retained and slowed in the surrounding intact riparian floodplain between 120th Avenue and US 31. Bank stability also appears to improve as riparian vegetation becomes more heavily dominated by grasses, forbs, and shrubs at the downstream stations (Figure 6). At Station 9 (Hemlock Crossing Park), bank stability ratings again decline, most likely as a result of the concentrated storm flows experienced below West Olive Road. The trends in bank stability ratings are symptomatic of the negative effects that high storm flows have in this system, including increased erosion and sedimentation, episodically degraded water quality, and elevated environmental stress on the fish population (MacDonald et al., 2001). Regaining hydrologic control of this and similar small stream systems is needed if we are to successfully manage them for desirable fish species such as brown trout.

Principal components analysis, combining all of the measured habitat variables, elucidates which stations are most similar across the whole suite of habitat conditions. Major axes shown in Figure 8 separate the stations based on trends in riparian vegetation and stream bottom substrate (Factor 1) and on channel size variables (Factor 2). Stations with fairly shallow depths, narrow widths, and few pools fall on the lower half of the figure, while stations with larger channels and deep pools fall on the upper half of the figure. Similarly, stations surrounded by dense forest with predominantly sandy substrate occur on the left half of the figure, while stations with more open riparian vegetation and less sandy substrate occur on the right half of the figure. For example, Stations 7 (136th downstream) and 8 (142nd upstream) are smaller side channels of the stream, and occur near the bottom of Figure 8. Station 9 (Hemlock Crossing Park) differs most from the other stations because of its less densely forested riparian zone and greater occurrence of clayey substrate, and falls to the far right of Figure 8. In general, the stations in the upper left hand corner of Figure 8 had habitat conditions suitable for larger brown trout, while the stations in the lower left hand corner of Figure 8 had habitat conditions more typically occupied by smaller brown trout (Heggenes et al., 1999).

Fish Population Composition: We sampled a total of 535 fish in June and 639 fish in August (Table 5), although average catch per unit effort did not differ by month (35 fish per hour in June, 42 fish per hour in August, P=0.08). The fish population composition of the Pigeon River was fairly similar among stations and between sampling dates (Table 5). Common species included blackside darters, central mudminnows, Johnny darters, largemouth bass, sunfish, and white suckers. Smaller numbers of grass pickerel, logperch, pirate perch, and rock bass also were found at several stations. This species assemblage is very similar to that found in a previous survey at Station 9 in July, 2000 (N.W. MacDonald, unpublished data). We found round gobies at most stations in 2006, but they were most prevalent at Station 9 at the lower end of the stream. In contrast, we found no round gobies at Station 9 in 2000. We found brown trout at 7 of 9 stations during the June and August surveys. Smaller trout (6 to 8 inch groups) were found above or below stocking locations at 120th Avenue, 136th Avenue, and West Olive Road (Table 5; Stations 1, 6, 7, and 9), consistent with reports that hatchery fish tend to remain near their site of stocking (Jonsson et al., 1999; Sundstrom et al., 2004). We found larger brown trout (15 to 17 inch groups) at Stations 2, 4, and 5 (Table 5) where there were deep pools with large woody debris and slower-moving water, typical of habitat preferences for larger brown trout (Maki-Petays et al., 1997; Naslund et al., 1998). We found no trout in either June or August at Station 3 (upstream of 128th Avenue) or at Station 8 (upstream of 142nd Avenue). Station 3 tends to be shallow and lacks deep pools (Figure 2), while Station 8 is a side channel and experiences low flows late in the summer (1.05 ft^3/sec in August, 2006). The relatively low numbers of brown trout found in the Pigeon River is consistent with the abundance of brown trout being negatively associated with the number of coexisting fish species (Naslund et al., 1998).

Length-frequency data for the Pigeon River show that most of its fish are less than 6 inches long (Table 6). Abundant darters, mudminnows, gobies, and small sunfish less than 3 inches long provide potential forage for larger game fish, and growth of brown trout has been shown to be positively related to the number of coexisting fish species (Naslund et al., 1998). Largemouth bass are fairly abundant at most of the stations we sampled, but only a few were longer than 6 inches, and none were greater than 8 inches long. The relative abundance of largemouth bass in the 3 to 6-inch length class, however, suggests that they may compete with newly stocked brown trout for food and cover. The only species with lengths consistently greater than 6 inches included white suckers, carp, northern pike, and brown trout. We collected and measured both carp and pike in June, and although we saw them in the stream at other times, we did not capture either species during our August survey. Northern pike are effective predators of small stocked brown trout (Hyvarinen and Vehanen, 2004), and predation by pike in the Pigeon River may be one source of mortality of stocked trout. We also observed both mink and great blue herons along the Pigeon River, and these species may add to predation mortality of stocked trout (Aarestrup et al., 2005). Stocked brown trout also are susceptible to angling removals (Mezzera and Largiader, 2001), but the amount of fishing pressure on the Pigeon River is not known.

We found brown trout in two distinct size classes in both June and August, between 6 and 9 inches in length, or between 15 and 18 inches in length (Table 6). We found no brown trout with lengths between 9 and 15 inches, suggesting that one or more year classes of stocked trout are no longer present in the Pigeon River. Brown trout are typically stocked in the Pigeon River in late March to mid-April, with approximately equal numbers released at 120th Avenue, 136th Avenue, and West Olive Road. Stocking records (MDNR, 2006) indicate that a total of 2200 Gilchrist Creek-strain brown trout were stocked in 2003, with another 1500 Gilchrist Creek-strain brown trout being stocked in 2004. In 2005, 2200 Seeforellen-strain brown trout were stocked in the Pigeon River, followed by 2360 Seeforellen-strain brown trout in 2006. The 6 to 9-inch fish that we found in the stream in 2006 appear to be from the most recent planting of Seeforellen-strain trout. The relatively low numbers of recently stocked fish captured is similar to reports by Aarestrup et al. (2005) of 74% of stocked brown trout either dying or emigrating within 5 weeks of introduction in a Danish stream. In contrast, the 15 to 18-inch trout that we found in the stream are most likely survivors from the 2003 and 2004 plants of Gilchrist Creek-strain fish. The missing year class (between 9 and 15 inches) appears to be the 2005 planting of Seeforellen-strain trout. Gilchrist Creek-strain brown trout were originally derived from a wild brown trout population in northern Michigan. Gilchrist Creek-strain trout have been shown to survive and grow in the Rogue River, a marginal trout stream in Kent County, Michigan (Wills, 2005), and appear to have done so in the Pigeon River as well. The Seeforellen strain, in contrast, tends to migrate downstream to reservoirs, lakes, or the sea, and may be less likely to remain as a resident stream fish (M. Luttenton, personal communication; Humphreys et al., 2005). We received reports of fair numbers of small brown trout (around 6 inches long) being collected during impingement studies at the Consumers Energy Campbell Plant on Pigeon Lake in early May (A. Parker, personal communication), suggesting that many of the Seeforellen-strain trout planted in mid-April in the Pigeon River may have moved downstream soon after stocking. High stream flows following heavy rain in mid-May (Table 2) may have accentuated the migration of recently-planted trout, as downstream movement of young migratory brown trout is correlated with increased stream discharge and water temperature (Hembre et al., 2001; Aarestrup et al., 2002). Downstream movement of recently stocked trout in the Pigeon River may not be a direct result of flooding, however, as Weiss and Kummer (1999) observed that flooding had no significant effects on movement or survival of stocked brown trout. Instead, they concluded that strain-specific behaviors governed post-stocking movements more than subsequent flooding. If this is true in the Pigeon River, many of the Seeforellen-strain trout stocked in 2005 also may have migrated downstream. If the Seeforellen-strain trout actively migrate to Lake Michigan, they may return to the Pigeon River as adults to spawn, and augment the stream fishery at that time as observed in several Connecticut streams (Humphreys et al., 2005).

The apparent absence of any trout stocked in 2005 also may be related to extremely low flows in the Pigeon River resulting from an extended drought during the Summer of 2005. Rainfall recorded at the Muskegon National Weather Service Station between April and August, 2005 totaled 197.1 mm compared to the normal of 369.0 mm. Discharge at Station 9 was only 3.5 ft^3/sec on 9/14/2005, one of the lowest mid-September discharges in 10 years of record for the Pigeon River (N.W. MacDonald, unpublished data). The extremely low flows experienced in the summer of 2005 may be implicated in the relatively low numbers of trout found in the Pigeon River in 2006, as periods of low flow are associated with both physiological stress and constraints on habitat (Heggenes et al., 1999). The only trout that appeared to have survived this extreme event were the Gilchrist Creek-strain trout that may be better acclimated to the environmental conditions in the Pigeon River. It is notable that we found large trout only above 136th Avenue, in stretches of the stream that tend to have lower dissolved oxygen levels (Table 2) but are not affected by the irrigation withdrawals below 136th Avenue. Further improvements in water quality in the upper Pigeon River, especially reductions in biochemical oxygen demand introduced from Sawyer Creek, would improve its suitability for trout (Eklov et al., 1998). Because growth and survival of stocked brown trout are density dependent (Bohlin et al., 2002; Sundstrom et al., 2004; Brannas et al., 2004), concentrating stocking at three locations may contribute to high mortality of trout in the Pigeon River. For example, we found no small trout in stations above or below 128th Avenue, even though suitable unoccupied riffle/run habitat was relatively abundant. Adding an additional stocking location at 128th Avenue would spread out the stocked trout over the available habitat more effectively. Such a stocking strategy, while requiring private landowner cooperation, might result in improved initial dispersal and subsequent increased survival of stocked brown trout in this stream system. Periods of acclimatization in in-stream enclosures prior to release have been shown to increase survival and growth of stocked brown trout (Jonsson, 1999), and this might be an option to experimentally pursue in the Pigeon River.

Summary and Management Implications

Water quality, habitat, and the forage base of small fish appear to be generally suitable to sustain a stocked brown trout population in the Pigeon River. Brown trout were present in the majority of stream stretches surveyed, but not at high levels of abundance, suggesting low survival, high emigration, or a combination of both. Gilchrist Creek-strain trout surviving from stockings in 2003 and 2004 had grown well, attaining lengths of between 15 and 17.5 inches. There was no evidence of the Seeforellen-strain trout stocked in 2005, however, as no trout between 9 to 15 inches were collected during the survey. Small numbers of Seeforellen-strain trout stocked in 2006 (6 to 8 inches) were present in the stream during both June and August surveys, but many of these small fish may have moved downstream into Pigeon Lake in May, shortly after stocking. Relatively low total numbers of trout found in the Pigeon River in 2006 also may reflect poor survival as a result of the extremely low stream flows experienced during the summer drought in 2005. Predation by large pike, mink, and great blue herons also may be a factor in the apparent low survival of newly stocked trout. Survival and growth of Gilchrist Creek-strain trout suggest that the specific strain of trout employed may be important to the success of future stocking activities in the Pigeon River. Seeforellen-strain trout either have not survived well in the Pigeon River, or have moved downstream toward Lake Michigan shortly after stocking. As a result, continued stocking with Seeforellen-strain trout to provide a resident trout fishery may not be successful in the Pigeon River. Gilchrist Creek-strain trout surviving from the 2003 and 2004 stocking were some of the largest game fish present in the Pigeon River, suggesting that continued stocking with Gilchrist Creek-strain brown trout may be warranted and would provide opportunities for anglers to fish for large brown trout in this small stream. Adding another stocking site at 128th Avenue, and fine-tuning the number of trout stocked to the available habitat may further increase survival of stocked brown trout. Continued efforts to improve water quality, reduce high storm flows, and maintain adequate summer baseflows also are needed to improve conditions for trout survival in the Pigeon River.

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Table 1. Locations of 1000-foot stream stretches surveyed on the Pigeon River, Ottawa County, Michigan in the Summer of 2006.

Station	Location Description	End	UTM Coordinates┼
1	120th Avenue, Sections 3&4, T6N R15W	1	574,763 m E, 4,753,514 m N
		2	575,034 m E, 4,753,641 m N
2	Pigeon Creek Park, Section 4, T6N R15W	1	574,177 m E, 4,753,169 m N
		2	574,453 m E, 4,753,295 m N
3	128th Avenue, upstream, Section 9, T6N R15W	1	573,345 m E, 4,752,691 m N
		2	573,561 m E, 4,752,828 m N
4	128th Avenue, downstream, Section 8, T6N R15W	1	573,097 m E, 4,752,597 m N
		2	573,240 m E, 4,752,709 m N
5	DeWitt Property, Section 8, T6N R15W	1	572,287 m E, 4,752,361 m N
		2	572,537 m E, 4,752,367 m N
6	136th Avenue, upstream, Section 8, T6N R15W	1	571,729 m E, 4,752,118 m N
		2	571,995 m E, 4,752,134 m N
7	136th Avenue, downstream, Section 7, T6N R15W	1	571,366 m E, 4,752,093 m N
		2	571,610 m E, 4,752,248 m N
8	142nd Avenue, upstream, Section 7, T6N R15W	1	570,531 m E, 4,751,825 m N
		2	570,787 m E, 4,751,857 m N
9	Hemlock Crossing Park, Section 12, T6N R16W	1	569,398 m E, 4,751,735 m N
		2	569,647 m E, 4,751,638 m N

┼ Universal Transverse Mercator eastings and northings in meters for (1) downstream and (2) upstream ends of survey stretches. All positions are in UTM zone 16 north.

Table 2. Water quality and discharge measurements at four stations on the Pigeon River, Ottawa County, Michigan during the Summer of 2006.

Variable	Date	Station 3	Station 5	Station 8†	Station 9	
Temperature, °C	5/16/2006	12.3	12.5	12.5	12.6	
	6/12/2006	14.4	13.7	13.3	12.4	
	7/12/2006	19.2	19.0	19.1	19.0	
	8/16/2006	14.1	14.0	14.0	14.1	
	Station Means	**15.0**	**14.8**	**14.7**	**14.5**	**P=0.518‡**
Dissolved Oxygen (titration), mg/L	5/16/2006	6.49	6.98	7.09	7.35	
	6/12/2006	7.51	7.96	8.31	8.36	
	7/12/2006	5.81	5.90	6.39	6.57	
	8/16/2006	7.32	7.65	7.84	8.36	
	Station Means**	**6.78d**	**7.12c**	**7.40b**	**7.66a**	**P<0.001**
Dissolved Oxygen @ Saturation§, mg/L	5/16/2006	10.73	10.67	10.67	10.65	
	6/12/2006	10.21	10.38	10.50	10.70	
	7/12/2006	9.19	9.23	9.21	9.23	
	8/16/2006	10.28	10.31	10.32	10.28	
	Station Means	**10.10**	**10.15**	**10.17**	**10.22**	**P=0.541**
Oxygen Deficit¶, mg/L	5/16/2006	-4.24	-3.69	-3.58	-3.30	
	6/12/2006	-2.70	-2.42	-2.19	-2.34	
	7/12/2006	-3.38	-3.33	-2.82	-2.66	
	8/16/2006	-2.96	-2.66	-2.48	-1.92	
	Station Means**	**-3.32a**	**-3.03ab**	**-2.77bc**	**-2.56c**	**P=0.001**
Conductivity, µmhos/cm	5/16/2006	455	446	433	442	
	6/12/2006	935	869	754	743	
	7/12/2006	608	566	532	530	
	8/16/2006	1247	1059	771	748	
	Station Means	**811**	**735**	**622**	**615**	**P=0.071**
pH	5/16/2006	7.44	7.49	7.52	7.53	
	6/12/2006	7.80	7.85	7.83	7.82	
	7/12/2006	7.51	7.52	7.52	7.56	
	8/16/2006	7.81	7.85	7.75	7.85	
	Station Means	**7.64**	**7.68**	**7.66**	**7.69**	**P=0.156**
Discharge, ft^3/sec	5/16/2006	ND#	ND	ND	156.8	
	6/12/2006	12.6	15.2	11.2	18.3	
	7/12/2006	16.9	23.0	22.5	30.1	
	8/16/2006	5.9	5.9	3.6	6.1	
	Station Means	**11.8**	**14.7**	**12.5**	**18.1**	**P=0.109**

† Values for Station 8 represent weighted means or sums (discharge) of the two main channels at this location.
‡ P values for Station effect from analyses of variance.
§ Dissolved oxygen at saturation predicted from measured stream temperature.
¶ Oxygen deficit calculated as concentration at saturation – concentration determined by titration.
# ND, not determined; discharge could not be measured at Stations 3, 5, and 8 on 5/16/2006 because of flooding at these locations. Means and P values for discharge do not include data from 5/16/2006.
** Stations means followed by different letters differ significantly at P<0.01.

Table 3. Water chemistry measurements at four stations on the Pigeon River, Ottawa County, Michigan during the Summer of 2006.

Variable	Date	Station 3	Station 5	Station 8┼	Station 9	
Chloride mg/L	5/16/2006	46	46	45	45	
	6/12/2006	207	192	146	155	
	7/12/2006	124	114	106	97	
	8/16/2006	360	276	175	165	
	Station Means	**184**	**157**	**118**	**116**	**P=0.120╪**
Sulfate mg/L	5/16/2006	50	49	47	45	
	6/12/2006	48	46	41	40	
	7/12/2006	56	55	52	45	
	8/16/2006	51	40	37	37	
	Station Means**	**51a**	**48ab**	**44b**	**42b**	**P=0.004**
Ammonium N mg/L	5/16/2006	0.20	0.20	0.14	0.12	
	6/12/2006	0.08	0.09	0.09	0.09	
	7/12/2006	0.17	0.20	0.19	0.16	
	8/16/2006	0.08	0.12	0.09	0.07	
	Station Means	**0.13**	**0.15**	**0.13**	**0.11**	**P=0.091**
Nitrate N mg/L	5/16/2006	3.26	3.14	3.13	3.03	
	6/12/2006	1.64	1.53	2.23	2.11	
	7/12/2006	1.27	1.15	1.49	1.28	
	8/16/2006	2.32	1.78	2.90	2.85	
	Station Means	**2.12**	**1.90**	**2.44**	**2.32**	**P=0.072**
Soluble Reactive P mg/L	5/16/2006	0.046	0.062	0.043	0.069	
	6/12/2006	0.033	0.047	0.033	0.034	
	7/12/2006	0.068	0.048	0.032	0.017	
	8/16/2006	0.047	0.035	0.028	0.027	
	Station Means	**0.049**	**0.048**	**0.034**	**0.037**	**P=0.346**
Total P mg/L	5/16/2006	0.15	0.15	0.14	0.13	
	6/12/2006	0.12	0.11	0.10	0.11	
	7/12/2006	0.17	0.17	0.13	0.14	
	8/16/2006	0.08	0.08	0.05	0.05	
	Station Means**	**0.13a**	**0.13a**	**0.11b**	**0.11b**	**P=0.006**
Suspended Solids mg/L	5/16/2006	5	6	5	5	
	6/12/2006	10	10	13	16	
	7/12/2006	16	19	13	21	
	8/16/2006	3	4	2	4	
	Station Means	**8.5**	**9.8**	**8.4**	**11.5**	**P=0.176**

┼ Values for Station 8 represent means of samples from the two main channels at this location.
╪ P values for Station effect from analyses of variance.
** Station means followed by different letters differ significantly at $P<0.01$.

Table 4. Average stream channel and riparian vegetation characteristics in nine 1000-foot stretches of the Pigeon River, Ottawa County, Michigan in July, 2006.

Station	Width (feet)	Depth† (feet)	Thalweg‡ (feet)	Canopy§ (%)	Basal Area¶ (ft^2/ac)
1	26.2 a	0.93 bcd	1.49 abc	84.9	86.2 abc
2	20.8 ab	1.15 abc	1.83 ab	82.9	101.5 ab
3	22.6 ab	0.77 bcd	1.17 bc	89.3	130.0 a
4	22.5 ab	1.51 a	2.20 a	83.5	97.7 abc
5	22.5 ab	1.09 abcd	1.67 abc	87.4	86.9 abc
6	23.7 a	1.26 ab	1.92 ab	76.0	80.8 bc
7	14.8 c	0.59 cd	0.92 c	84.1	91.5 abc
8	17.1 bc	0.56 d	0.86 c	80.1	96.2 abc
9	22.2 ab	1.55 a	2.16 a	71.8	51.5 c
P#	<0.001	<0.001	<0.001	0.113	<0.001

† Average stream depth based on systematic measurements at 0.2, 0.4, 0.6, and 0.8 times stream width at each transect.
‡ Average of the greatest stream depth found at each transect, typically where the greatest flow of water occurs.
§ Average amount of overhead vegetative canopy cover along the stream stretch, measured from the center of the stream at each transect.
¶ Average basal area of surrounding forest as measured from the center of the stream at each transect.
# Probability values from one-way analysis of variance comparing station effects. Means within a column followed by different letters differ significantly at $P<0.05$.

Table 5. Fish population composition at nine stations on the Pigeon River, Ottawa County, Michigan.

Common Name	Station 1	2	3	4	5	6	7	8	9	Species Total
				June, 2006 number of fish per survey stretch						
Blackside darter	0	3	4	1	4	6	6	4	7	35
Brown trout	**1**	**3**	**0**	**1**	**1**	**3**	**4**	**0**	**1**	**14**
Carp	9	0	0	0	0	0	0	0	0	9
Central mudminnow	13	7	9	6	7	10	9	1	0	62
Grass pickerel	1	3	1	0	0	0	2	0	1	8
Johnny darter	19	9	15	12	2	4	6	4	7	78
Largemouth bass	4	1	0	3	9	3	7	13	3	43
Logperch	0	0	0	0	0	1	0	0	1	2
Northern pike	2	0	0	0	1	0	1	0	0	4
Pirate perch	0	0	3	0	0	3	0	1	0	7
Rock bass	0	0	1	0	0	2	0	0	1	4
Round goby	0	3	4	4	6	7	0	2	26	52
Spottail shiner	0	1	0	0	0	0	0	0	0	1
Sunfish spp.†	23	20	16	15	18	17	28	23	18	178
White sucker	2	3	4	12	7	3	2	1	3	37
Yellow perch	0	0	1	0	0	0	0	0	0	1
June Station Totals	74	53	58	54	55	59	65	49	68	535‡
				August, 2006 number of fish per survey stretch						
Banded killifish	0	0	0	0	0	0	0	1	0	1
Blackside darter	0	0	4	4	6	7	0	8	25	54
Brown trout	**1**	**1**	**0**	**0**	**2**	**0**	**2**	**0**	**1**	**7**
Central mudminnow	23	19	28	8	17	14	23	15	3	150
Grass pickerel	6	5	2	1	3	1	7	4	0	29
Johnny darter	8	6	24	5	2	9	16	16	27	113
Largemouth bass	5	2	4	4	5	5	0	11	2	38
Smallmouth bass	0	0	2	0	0	0	0	0	0	2
Logperch	0	0	0	0	2	0	0	0	4	6
Pirate perch	0	2	0	2	1	3	0	0	0	8
Rock bass	0	0	0	0	1	0	0	0	1	2
Round goby	0	0	3	2	7	5	0	4	16	37
Shiner spp.§	0	0	1	0	0	0	0	0	1	2
Sunfish spp.†	31	18	23	21	40	14	6	11	5	169
White sucker	2	3	1	1	7	4	0	0	3	21
August Station Totals	76	56	92	48	93	62	54	70	88	639‡

† Sunfish species include green, bluegill, and pumpkinseed sunfish and their hybrids.
‡ Total fish captured during each survey period.
§ Shiner species include spotfin and spottail shiners.

Table 6. Length-frequency relationships for fish species sampled in the Pigeon River, Ottawa County, Michigan during the Summer of 2006.

Common Name	Length Class (inches) <3	3-6	6-9	9-12	12-15	15-18	18-24	>24	Species Totals
	June, 2006 number of fish per length class								
Blackside darter	24	11	0	0	0	0	0	0	35
Brown Trout	**0**	**0**	**9**	**0**	**0**	**5**	**0**	**0**	**14**
Carp	0	0	0	0	0	1	1	7	9
Central mudminnow	22	40	0	0	0	0	0	0	62
Grass pickerel	3	4	1	0	0	0	0	0	8
Johnny darter	76	2	0	0	0	0	0	0	78
Largemouth bass	3	37	3	0	0	0	0	0	43
Logperch	0	2	0	0	0	0	0	0	2
Northern pike	0	0	1	0	1	0	1	1	4
Pirate perch	1	6	0	0	0	0	0	0	7
Rock bass	0	3	1	0	0	0	0	0	4
Round goby	28	24	0	0	0	0	0	0	52
Spottail shiner	1	0	0	0	0	0	0	0	1
Sunfish spp.†	101	74	3	0	0	0	0	0	178
White sucker	0	8	3	2	9	13	2	0	37
Yellow perch	0	1	0	0	0	0	0	0	1
Length Class Totals	259	212	21	2	10	19	4	8	535‡
	August, 2006 number of fish per length class								
Banded killifish	1	0	0	0	0	0	0	0	1
Blackside darter	30	24	0	0	0	0	0	0	54
Brown trout	**0**	**0**	**4**	**0**	**0**	**3**	**0**	**0**	**7**
Central mudminnow	103	47	0	0	0	0	0	0	150
Grass pickerel	1	25	2	1	0	0	0	0	29
Johnny darter	112	1	0	0	0	0	0	0	113
Largemouth bass	4	30	4	0	0	0	0	0	38
Smallmouth bass	0	2	0	0	0	0	0	0	2
Logperch	0	6	0	0	0	0	0	0	6
Pirate perch	0	8	0	0	0	0	0	0	8
Rock bass	0	1	1	0	0	0	0	0	2
Round goby	17	20	0	0	0	0	0	0	37
Shiner spp.	1	1	0	0	0	0	0	0	2
Sunfish spp.†	82	87	0	0	0	0	0	0	169
White sucker	0	2	9	4	1	5	0	0	21
Length Class Totals	351	254	20	5	1	8	0	0	639‡

† Sunfish species include green, bluegill, and pumpkinseed sunfish and their hybrids.
‡ Total fish measured during each survey period.

Figure 1. Average Daily Stream Temperatures at Four Stations on the Pigeon River, Ottawa County, Michigan, During the Summer of 2006

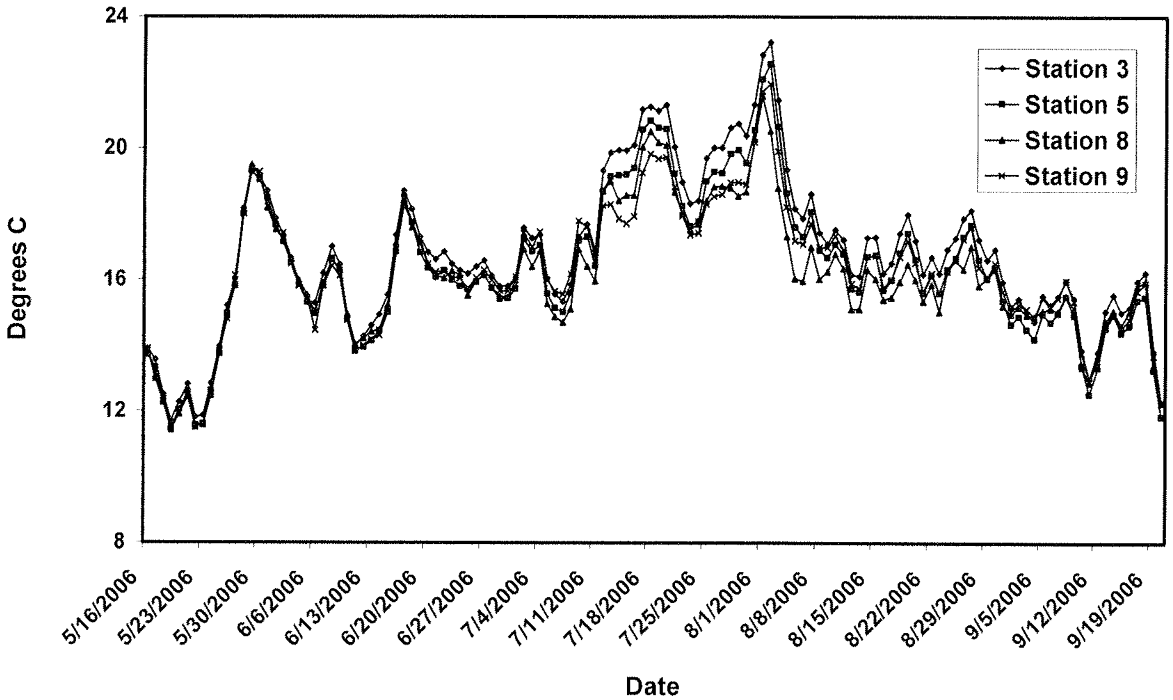

Figure 2. Stream Habitat Types in the Pigeon River, Ottawa County, Michigan.

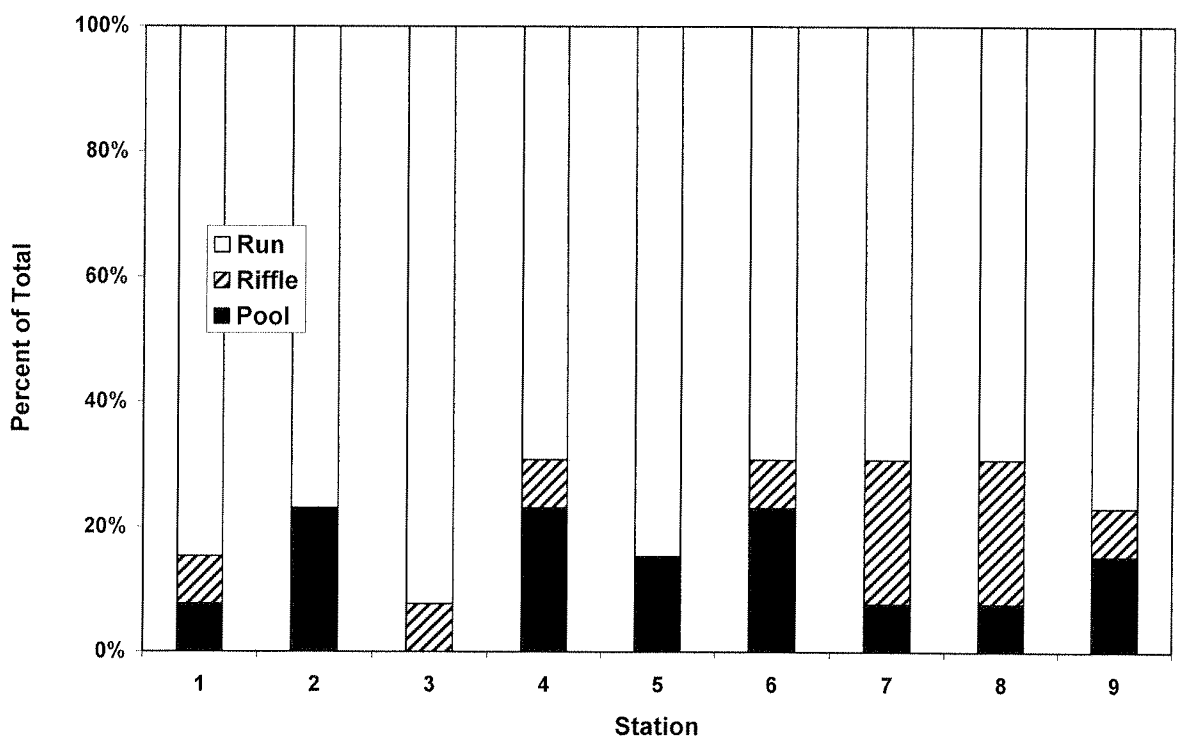

Figure 3. Stream Bottom Substrate Types in the Pigeon River, Ottawa County, Michigan.

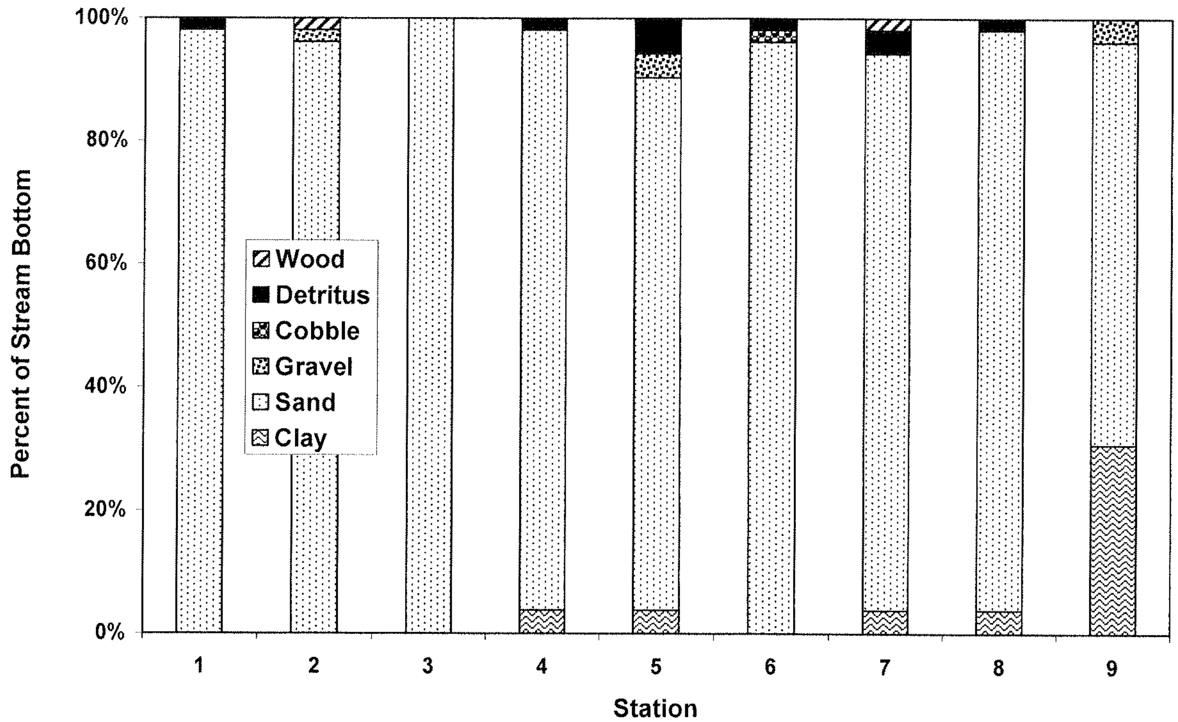

Figure 4. Large Woody Debris in the Pigeon River, Ottawa County, Michigan.

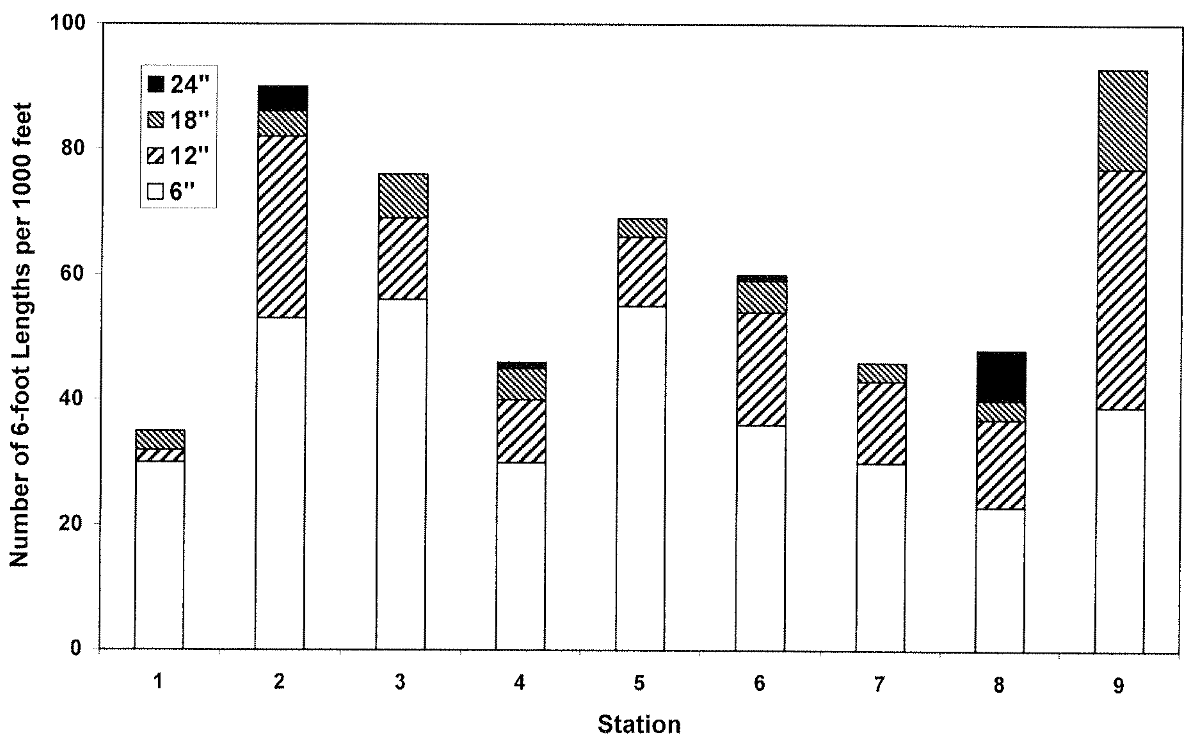

Figure 5. Natural and Artificial Habitat Elements in the Pigeon River, Ottawa County, Michigan.

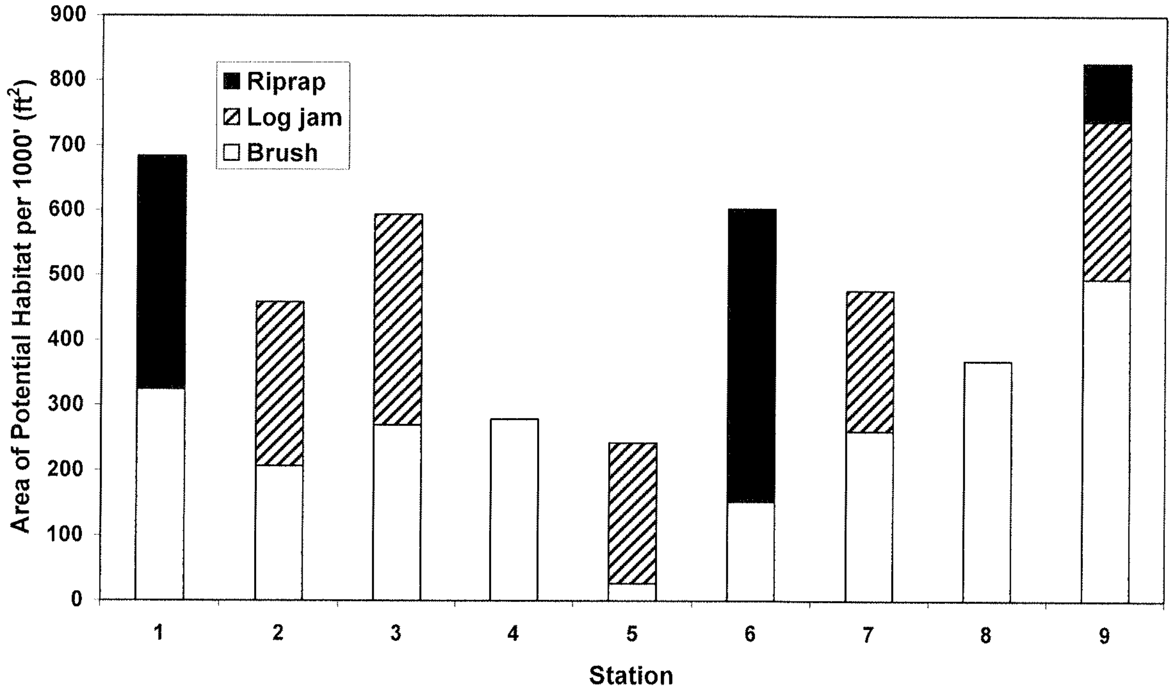

Figure 6. Riparian Vegetation Classes along the Pigeon River, Ottawa County, Michigan.

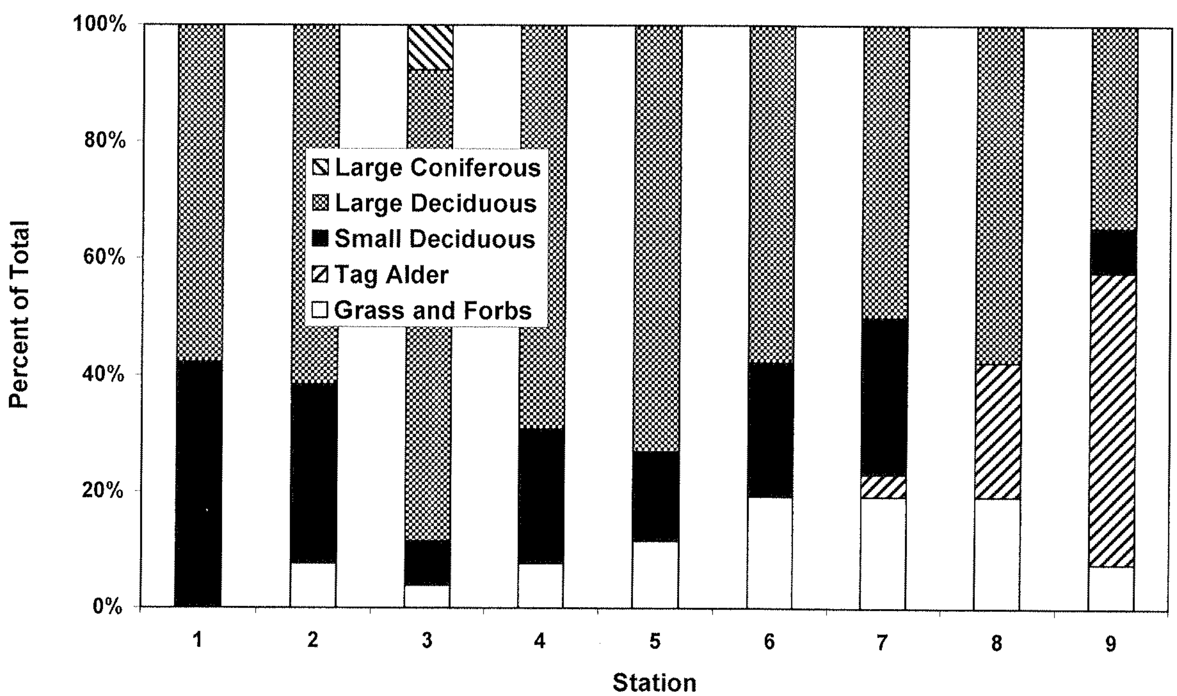

Figure 7. Bank Stability Classes along the Pigeon River, Ottawa County, Michigan.

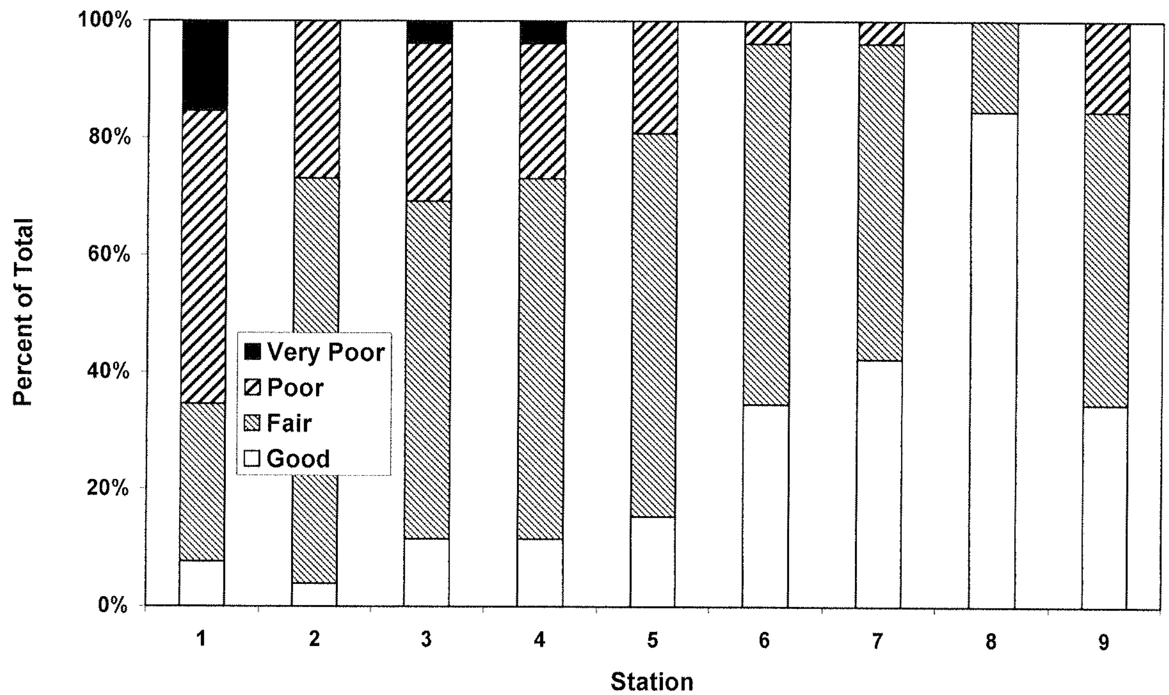

Figure 8. Principal Components Plot of Pigeon River Habitat Variables.