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Richard P. Narf
Wisconsin Department of Natural Resources

AQUATIC INSECT COLONIZATION AND SUBSTRATE CHANGES IN A RELOCATED STREAM SEGMENT

Richard P. Narf[1]

ABSTRACT

A section of Bear Creek in northwestern Wisconsin was relocated to accommodate new highway construction. The 850-m section of the stream was shortened to 650 m and fashioned with five broad bends and a uniform width and depth. Sandy substrate and lack of coarse particulate organic matter within the new channel delayed colonization by aquatic insects. The absence of snags, boulders, and cobbles in the design of the new channel reduced available habitat. Substrate stabilization and colonization of available habitats was determined to be complete 5.5 years after channelization, when the 22 dominant insect taxa were similar to the control sites. The changes in insect population and substrate type during the six year study are addressed.

Stream alterations to improve navigation and drainage are conducted in many areas of the United States (Wilkinson 1973), and are considered detrimental to aquatic populations because of habitat disturbance (Henegar and Harmon 1973). Channelization usually replaces natural cobble and coarse gravel substrate with small particulates. Flow also becomes more laminar as the natural riffle-pool complexes common to many lotic habitats are lost during channelization. The elimination of varying substrates and currents prevents establishment of the diverse benthic population that inhabited the substrate prior to alteration (Etnier 1972, Congdon 1973, Simpson et al. 1982).

Simpson et al. (1982) summarized the effects of channelization and suggested the need for additional information on benthic community response. The Bear Creek project provided an opportunity to evaluate the channelization of a third order warm water (non-trout) stream in the northern Midwest, a region lacking in the study of channelization impacts. This paper describes substrate type following channelization and addresses changes in the composition and density of the 22 dominant insect taxa.

STUDY LOCATION AND METHODS

The Bear Creek channelization is located 6 km north of the city of Rice Lake, Barron County, in northwestern Wisconsin. Bear Creek is a third order stream, 4–15 m wide with a base flow of 0.35 m^3/sec at the study location. The stream habitat is primarily a run with occasional pools and riffles.

The natural stream bed (Fig. 1) was composed of sand, gravel, and cobbles as large as 20 cm in diameter and some snags; boulders were infrequent. Silt was present along the streambank and in the pools. Instream vegetation was sparse, consisting of scattered patches of *Potamogeton crispus* L. (curlyleaf pondweed), *Vallisneria americana* Michx.

[1]Wisconsin Department of Natural Resources, Bureau of Research, 3911 Fish Hatchery Road, Madison, WI 53711

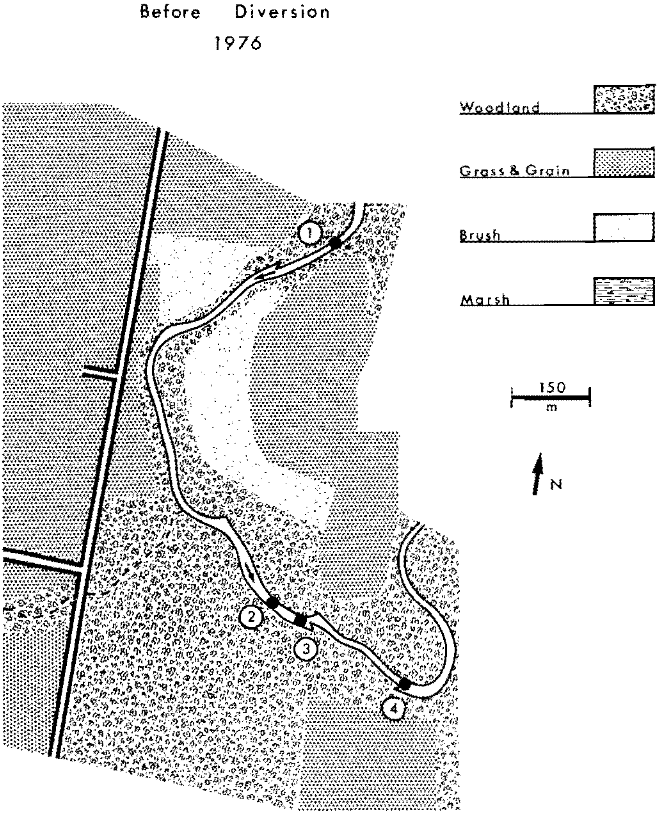

Fig. 1. Bear Creek sampling site locations and vegetation types before construction of the new channel and highway corridor.

(wild celery), and filamentous algae. Leaf mats were common under cobbles and on snags. The floodplain contained a buffer strip of hardwoods and shrubs along most of the creek's length.

An 850-m section of Bear Creek was relocated and channelized in June and July of 1976 to accommodate construction of the new U.S. Highway 53 corridor. Sand and gravel from the immediate area were used for new channel construction. The completed channel has parallel sides, a flat bottom, and five broad bends riprapped with boulders on the outside curves (Fig. 2). No riffle-pool complexes, boulders or snags were provided. All trees and brush were removed from the vicinity of the channel and the disturbed soil was seeded to retard erosion. The original 850-m stream length was reduced to 650 m and the natural irregularity of width was made a nearly uniform 10 m.

Four sampling sites were selected (Figs 1, 2). Sites 1 and 4 acted as controls. Site 1 was located 150 m above the new channel and site 4 was located 250 m below the channel. Sites 2 and 3 in the old channel had to be relocated after construction. Their replacements were sites 2B and 3B; located 50 m upstream and 50 m downstream from the end of the

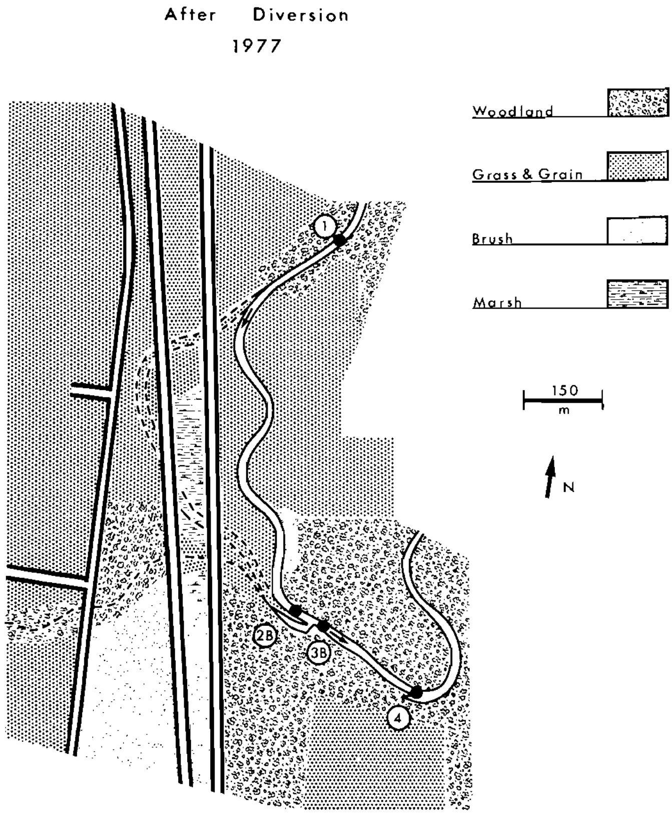

Fig. 2. Bear Creek sampling site locations and vegetation following stream channel relocation and establishment of the new highway corridor.

new channel. The replacement sites (2B and 3B), as well as original sites 1 and 4, were used for postconstruction sampling.

Sampling began in June 1976, immediately before channel construction. Postconstruction samples were taken in November 1976 and again in March of 1977, 1978, and 1982. Observations were made on the relative abundance of substrate type and presence of coarse particulate organic matter (CPOM) within the stream channel. Late notice of the construction start precluded sampling prior to June 1976.

Benthic samples were collected via Surber sampler (0.09 m^2) equipped with a 210 /μm mesh net. Two samples were taken at each site, one sample each from a point one-third the stream width from either bank. Samples were preserved in 95% ethyl alcohol and organisms were later identified and enumerated in the laboratory. Sample totals were combined and expressed in mean number per square meter for each site. The dominant insect taxa found for the study period (i.e. those numbering $>10/m^2$) were used to determine colonization.

RESULTS

PRECONSTRUCTION. Substrate at the four sampling sites was dominated by gravel and cobble before channel construction except for site 2, which had fewer cobble and more sand (Fig. 3). CPOM and periphyton were plentiful at all sample locations.

Based on the occurrence of the dominant insect taxa prior to construction (Tables 1, 2), sites 2 and 4 had the greatest diversity with 10 dominant taxa each. The greatest chironomid diversity (six taxa present) occurred at site 2. A community composed of more scrapers and net spinners, namely *Helicopsyche borealis* (Hagen), *Hydropsyche simulans* Ross and *Symphitopsyche bifida* (Banks), was found at site 4.

POSTCONSTRUCTION. Sediment Conditions. Substrate particle diversity and relative abundance remained nearly constant at sites 1 and 4 during the postconstruction sampling period (Fig. 3). The channelization had no apparent impact on the sediment at these two sites. Periphyton and CPOM were "common" to "abundant" throughout the study period at sites 1 and 4 except for CPOM, which was "rare" at site 4 in November 1976. Site 2B within the new channel was dominated by silt and fine sand in November 1976, 2.5 months after construction. Periphyton was not observed at site 2B or elsewhere in the newly constructed channel.

Eight months after channel completion (in March 1977) the silt and fine sand of the new channel had shifted, producing large areas of deposition which were easily moved by changing water currents. Several pools were forming along the riprapped bends. The amount of silt and fine sand at site 2B had decreased, exposing areas of gravel. Periphyton and CPOM were still rare in the new channel.

Observations of the substrate in March 1978, showed no basic changes in the amount of sand and gravel present nor any increase in the quantity of CPOM. The finer particles of substrate continued to be easily disturbed and subject to movement by changing water currents.

The substrate in the new channel (site 2B) changed between March 1978 and March 1982 (5.5 years after construction). Gravel was the dominant substrate in 1982 and areas of silt and sand were still present, but they were not easily shifted by normal stream flow. This was due to the growth of periphyton that had developed upon them. Cobbles, boulders, and snags were not present, due to their absence in the channel design and construction. Riffles were absent, but several pools were now well established in the new channel. CPOM was commonly found in the gravel interstices where the fine sand and silt had been removed by water currents.

A portion of the stream directly downstream from the new channel (site 3B) was also affected by the construction. In November 1976, (only 2.5 months after construction) the natural interstices were being filled with silt and sand from the new channel, thus eliminating places that entrap CPOM and provide habitat for the periphyton and invertebrates.

During the March 1977 survey (8 months after construction) the substrate of site 3B was nearly covered with sand washed out of the new channel. A small area of filamentous algae and CPOM was present among the remaining exposed gravel substrate, but periphyton and CPOM were generally rare at this location.

Periphyton and CPOM were still uncommon at site 3B in March 1978, 1.6 years after construction. However, the covering of sand over the gravel was reduced and some cobbles were exposed once again.

By 1982 the stream flow had exposed additional gravel and cobbles at site 3B, although the amount of exposed cobble was still less than found in the natural stream bed. CPOM and periphyton were commonly found within the coarser sediments present at site 3B.

Insect Colonization. Insect density and diversity increased at sites 1 and 4 between the June and November 1976 sample periods (Tables 1, 2). This increase is attributed to typical autumnal increases that occur within lotic habitats. Samples in June 1976 can only be used to show faunal similarity between sites prior to construction. The March samples provide better consistency for annual comparison because this period has the least fluctuation from faunal recruitment.

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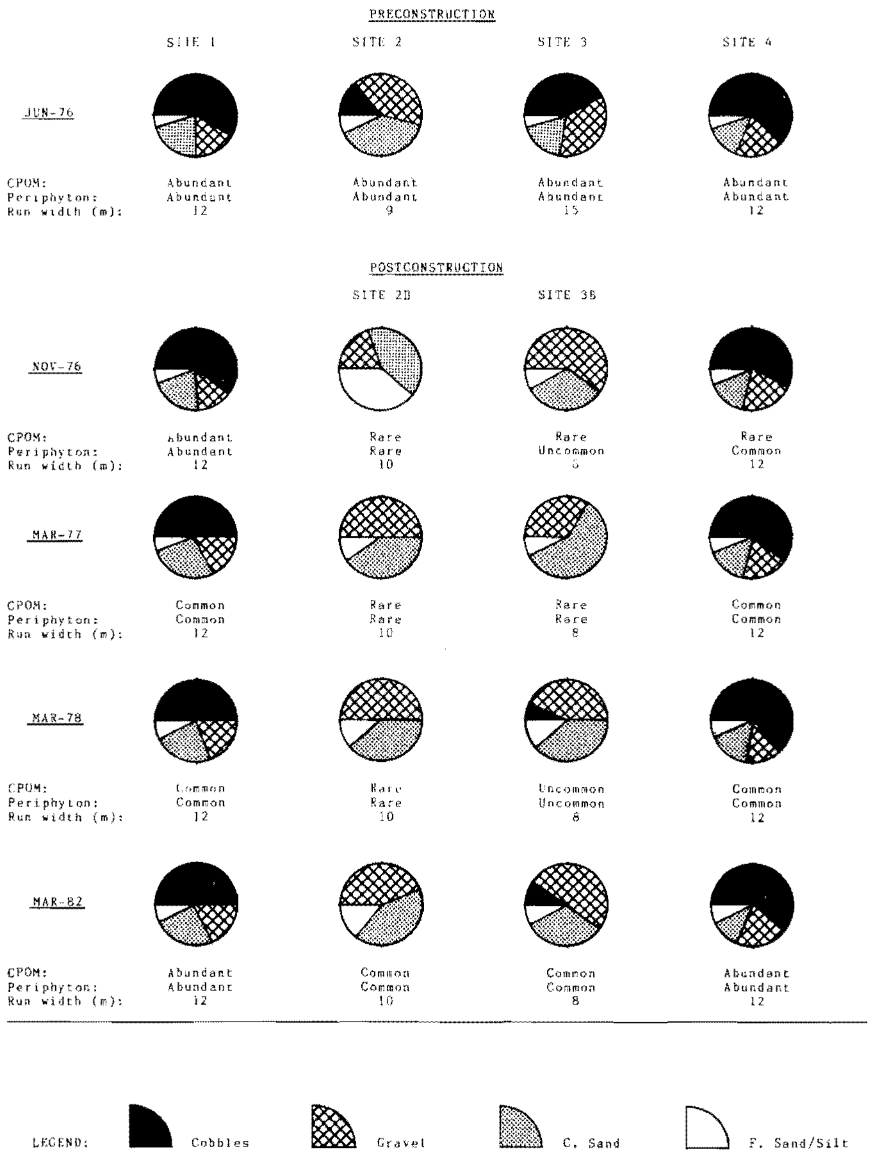

Fig. 3. Observations on relative abundance of substrate type, associated periphyton and occurrence of coarse particulate organic matter (CPOM) at the sampling sites.

Table 1. Relative abundance of the dominant benthic insect taxa (those numbering $>10/m^2$) found in the samples taken from sites 1, 2 and 2B at Bear Creek.

	Site 1					Site 2	Site 2B			
						Precon.	Postconstruction			
TAXA	6-76	11-76	3-77	3-78	3-82	6-76	11-76	3-77	3-78	3-82
PLECOPTERA										
Hastaperla brevis		●	•		•		•			•
Isopela signata		•			•					•
Taeniopteryx nivalis							•			
EPHEMEROPTERA										
Ephemerella rotunda		•		•	•				•	⬤
E. subvaria					●					•
Stenonema mediopunctatum	•	•			•	•				•
TRICHOPTERA										
Cheumatopsyche spp.				•	⬤					•
Helicopsyche borealis	●			•		•			⬤	
Hydropsyche simulans		•				•				
Symphitopsyche bifida group					●					●
S. sparna					⬤					•
COLEOPTERA										
Dubiraphia spp.		•	•	•						•
Optioservus spp.		⬤	•	●	⬤	•			•	●
Stenelmis spp.		•	•		•				•	
DIPTERA										
Conchapelopia spp.		•				•				⬤
Corynoneura spp.					●	•				⬤
Eukiefferiella spp.	•			•	●	•			•	•
Micropsectra spp.				•	⬤					
Microtendipes spp.								•		⬤
Orthocladius spp.	⬤	•		•	•	•	•		•	⬤
Palpomyia spp.	•	•				•				
Polypedilum spp.	•			•		•				
Number of Taxa:	6	11	4	9	14	10	3	1	6	15
Number per m^2:	470	856	167	297	1367	318	121	50	473	3079

LEGEND: • $>10 - <100/M^2$; ● $>100 - <200/M^2$; ⬤ $>200/M^2$.

Eight months after construction (March 1977), density and diversity of insects within the stream were reduced at site 1 above the new channel (Table 1). Ephemeroptera, Trichoptera, and chironomids were not present in the dominant taxa at that time, but were present in March of 1978 and 1981. The suspected cause of this March 1977 decrease at site 1 is the loss of insects by migration and drift, compounded by the lack of upstream migration through the new barren channel.

The new channel, as represented by site 2B, contained few organisms (Table 1) in November 1976, 2.5 months after construction. Ephemeroptera, Trichoptera, and Coleoptera were absent from the dominant fauna. *Hastaperla brevis* (Banks) and *Taeniopteryx nivalis* (Fitch) were found in a small leaf mat, and *H. brevis* and *Orthocladius* spp. were present in a small area of gravel and sand. These two places were the only refuges deemed capable of providing suitable habitat within the area designated as site 2B.

Eight months after construction (March 1977), the density and diversity of the dominant taxa at site 2B were the lowest observed throughout the study, a condition similar to site 1 during the same sampling period. *Microtendipes* was the only genus present in numbers $> 10/m^2$. A moderate increase in diversity and density was observed from March 1977 to March 1978 (1.5 years after construction); however, the only taxa present in densities similar to preconstruction were the common chironomids *Orthocladius* spp. and *Eukiefferiella* spp.

Insect numbers and taxa had increased at site 2B by March 1982, 5.5 years after construction. A few deep pools had developed in the new channel and quantities of CPOM had accumulated to provide a foodchain base. In addition, the substrate was covered by a growth of periphyton which helped to stabilize the finer particulates. Winter stoneflies,

Table 2. Relative abundance of the dominant benthic insect taxa (those numbering > $10/m^2$) found in the samples taken from sites 3, 3B and 4 at Bear Creek.

TAXA	Site 3 Precon 6-76	Site 3B Postconstruction 11-76	Site 3B 3-77	Site 3B 3-78	Site 3B 3-82	Site 4 6-76	Site 4 11-76	Site 4 3-77	Site 4 3-78	Site 4 3-82
PLECOPTERA										
Hastaperla brevis	•			•	•	•	•	•	•	•
Isopela signata			•				⬤		•	
Taeniopteryx nivalis							⬤			
EPHEMEROPTERA										
Ephemerella rotunda				•			•		•	•
E. subvaria										•
Stenonema mediopunctatum	•						•		•	•
TRICHOPTERA										
Chemotopsyche spp.				•	•					•
Helicopsyche borealis	•	•	•	•		⬤	•	●	•	
Hydropsyche simulans						•	•	•	•	•
Symphitopsyche bifida group				•	●	•	•	•		•
S. sparna					•					•
COLEOPTERA										
Dubiraphia spp.			•	•	•		•		•	
Optioservus spp.	•	•	●	•	⬤	•	⬤	⬤	⬤	●
Stenelmis spp.		•	●		•	•	•	•	●	•
DIPTERA										
Conchapelopia spp.					•		•			•
Corynoneura spp.	•				•					•
Eukiefferiella spp.				•	•	•		•		●
Micropsectra spp.					●					●
Microtendipes spp.				•	•					•
Orthocladius spp	•	•		•	•	•	•		•	•
Palpomyia spp.	•	•				•				
Polypedilum spp.	•	•	●			●				•
Number of Taxa	8	6	6	9	13	10	13	7	10	17
Number per m^2	383	258	518	296	1158	782	1387	684	548	964

LEGEND: • >10 - <100 M^2; ● >100 - <200/M^2; ⬤ >200/M^2.

Allocapnia frisoni Ross and Ricker and *T. nivalis* were observed emerging near areas of riprap.

The number of taxa at site 3B was reduced in the November 1976 samples, because of a major disturbance created immediately downstream by drifting silt and sand from the new channel. Plecoptera and Ephemeroptera were absent from the dominant taxa. This reduction in organism diversity at site 3B was still evident during the March 1977 survey, when Ephemeroptera and several common chironomids were still absent. The taxa present, including the trichopteran *H. borealis* (Hagen), and the larval elmids *Optioservus* spp. and *Stenelmis* spp., were found in a sample that contained a small amount of algae.

Insect numbers and taxa increased substantially at all sites from 1978 to 1982. Sites 1, 2B, and 4 contained similar dominant taxa, with sites 1 and 2B having greater densities. Site 3B contained similar taxa except for the absence of Ephemeroptera from the dominant group. *H. borealis* was absent from all sites in the 1982 survey. The presence of similar taxa at all of the sites in 1982 indicates a stabilized substrate and food chain able to support most of the insects present in the stream.

DISCUSSION

The recovery time for channelized stream segments is highly variable and interrelated with the substrate and riparian vegetation. Recovery rates of over 52 years have been reported (Simpson et al. 1982).

The upstream reaches of Bear Creek remained unchanged. However, allochthonous material does not travel far from its source (Hesser et al. 1975), and the upstream sources of organic material had a reduced influence upon the channelized segment. The absence of trees and brush from the channelized riparian area of Bear Creek reduced the availability of CPOM. This greatly influenced the input of allochthonous material to provide a nutrient base for the food chain. The insects that inhabit first to fifth order streams are predominately detritivores and omnivores that feed heavily upon allochthonous materials and their breakdown products (Cummins 1975, Minshall 1967, Shapas and Hilsenhoff 1976, Wiggins and MacKay 1978). The lack of this source of organic material restricted insect colonization.

Substrate particle size also determines biomass and numbers of benthos (Cummins and Lauff 1969, Karr and Schlosser 1977, Lynch et al. 1977, Williams and Mundie 1978). Biomass and density of insects are higher in medium-sized gravel (25-mm d); however, the number of taxa is greater in larger gravel and cobbles since this size allows for attachment by various filter feeding organisms such as Hydropsychidae (Williams and Mundie 1978). Production is the lowest in sand substrates due to their shifting nature and lack of interstices for CPOM entrapment and biotic activity (Egglishaw 1969, MacKay 1969, Sanders 1976, Sprules 1947).

The effect of sand substrate was demonstrated by the faunal reduction at site 3B for two years following construction. Sand washed out of the new channel covered nearly all of the natural substrate at site 3B. A coarser substrate was exposed in the last years of the study and provided the necessary habitat for increased insect diversity and density. The reduction in fauna was a function of habitat disturbance and lack of recruitment from the channel. The control site farther downstream was generally stable throughout the study and capable of providing recruitment through upstream migration.

Inhibition of upstream migration through the new channel was indicated during the first winter following construction. Site 1 experienced a reduction in faunal numbers, likely due to upstream migration from site 1 by some organisms and compounded by drift out of this area by others. The high sand content and absence of food in the newly constructed channel and immediately downstream created a barrier for upstream migration, as well as unsuitable habitat for colonization by drifting organisms. Normal forms of migration (i.e., vertical migration from the substrate, drift, upstream migration, and aerial dispersion) (Williams and Hynes 1976) were reduced to drift and aerial dispersion before the channel was fully colonized. The presence of a few taxa in the new channel during November 1976, 2.5 months after the channel was opened, shows that the water quality of the channel was suitable for habitation. The main obstacle to colonization was the absence of a stabilized substrate with its associated CPOM and periphyton.

The presence of similar insect diversity and density at all sites 5.5 years after construction shows that the new channel habitat supported the dominant insects found in this study, even though some of the channel substrate and pool riffle complexes did not appear to be completely stabilized. Based on the presence of the dominant taxa in these samples from March 1982, the channel was considered to have completed colonization and was able to support higher trophic levels.

SUMMARY

The Bear Creek channelization created a major localized disturbance to the aquatic insect community. Colonization was influenced by the elimination of habitat, absence of a food chain base, and reduced sources of insects. The greatly reduced number of insect taxa and individuals indicates that all habitats normally available in a natural system were not present during the first 1.5 years after construction.

The absence of large substrates (i.e. snags, boulders, and cobbles) from the new channel increased the time necessary for stabilization and colonization. Providing snags, brush, cobble, and gravel free of sand in newly constructed channels like Bear Creek is highly recommended. In addition, the replacement of woody vegetation along the streambank would provide a supply of CPOM. This would enhance colonization by immediately providing most of the attributes of natural stream ecosystems.

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A diverse faunal community was established in the channel 5.5 years after construction. The diversity of insects in the sample sites below the channel indicates that overall stream water quality was not affected by the channelization.

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