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ABSTRACT

From 1984 to 1986, the Arkansas Highway and Transportation Department reconstructed and upgraded a portion of St. Hwy. 123 west of St. Hwy. 7 at Pelsor, Arkansas. As a result of the construction, portions of Haw Creek, Johnson County, Arkansas, a third order stream in the Boston Mountains Ecoregion, were straightened and channelized. In reconstructing specific stream reaches, stream banks were riprapped and vegetated, gabions constructed and positioned, stream substrates and pool-riffle ratios altered. Instream and riparian habitat and fish biomass and diversity in altered reaches were radically altered. Channelized reaches became wide and shallow, lacking overstory cover and pools. Substrate particle size changed from boulder/rubble to rubble/gravel/sand and velocity increased. Fish communities in channeled reaches simple; ***Campostoma anomalum, Notropis boops,*** and ***Etheostoma spectabile*** accounted for more than 80 percent of all fish captured. This represented a shift from piscivore and insectivore-piscivore to herbivore and insectivore dominated feeding guilds. Natural channel reaches had more complex fish communities and greater abundance of centrarchids and ictalurids, primarily deeper water groups. Immediately after channelization, altered reaches had a larger biomass than natural reaches (0.43-0.26 g/m²). The summer following alteration, channeled segments were basically dewatered, and biomass decreased dramatically (0.06-0.11 g/m²). One year post channelization, altered reaches had eroded, scoured and deepened at their headwaters, and embedded.Fish community composition in altered reaches s stabilizing to a riffle-type assemblage dominated by the herbivore ***Campostoma anomalum.***

INTRODUCTION

Stream channelization is one of the most destructive activities that man imposes on riparian ecosystems. Over 300,000 km of stream channels have been modified in the United States (Schoof, 1980). Specific impacts of channelization upon stream ecosystems are multidimensional and interrelated. Two aspects of channelization of prime importance are habitat changes due to channelization and the resulting biological response.

Hubbard *et al.* (1988) in their review of channelization listed gradient, velocity, depth, channel meander, flow regime, substrate, instream structure, temperature, turbidity, water chemistry, and terrestrial and riparian habitats as being affected by channel alteration. Immediate impacts on instream and riparian biota result from the physical destruction of the biota and their habitat. Delayed impacts may occur as habitats continue to be altered due to land use changes or unstable conditions. The magnitude and duration of particular impacts depend on the type of stream system involved, length and timing of channelization, and the impacted biological species.

Early studies of channelization effects on fishes were conducted by Schneberger and Funk (1971), Barton *et al.* (1972), Wilkienson (1973), and Moyle (1976). More recently, channelization impacts on fish have been well documented, but mitigation of losses has not been adequately addressed (Edwards *et al.*, 1984).

Channelization and subsequent shifts in fish species composition were identified as early as the 1900's (Shelford, 1911; 1917). Trautman and Gartman (1974) reported that during an 86-year period, relative abundance of fishes in Gordon Creek, Ohio, decreased and the fish fauna reverted from smallmouth bass associations to typical headwater or brook associations comprised of beach-nosed dace, red-sided dace, creek chub and silver-jawed minnow. The decrease was attributed to dredging, channelizing and clearing that occurred before the turn of the century. Smith (1960, 1971) reported similar results from Illinois. Biomass and number of fish species have been found to be reduced in channelized streams. Golden and Twilley (1976) reported downstream reduction in game and fish species and biomass, especially centrarchids, while greater numbers of nongame fish were evident where channelization removed riffles and instream cover. Schlosser (1982) noted more stable trophic structure, biomass, and age structure in fish communities of a natural headwater stream when compared with a similar modified stream. He noted that seasonal and annual variations in fish biomass and trophic structure occurred in the modified stream because of shifts in both amounts and types of instream production. Large pools in the natural stream increased habitat volume and stability relative to the modified stream. This resulted in a trophic structure of predominately large insectivore-piscivore and benthic insectivore fish species. Trophic structure, age structure, and recruitment were stable in the natural stream.

Bayless and Smith (1964) evaluated fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina. Comparisons indicated that reductions in the magnitude of 90 percent occurred both in weight of game fish per acre and in number of game fishes over six inches total length per acre, and following channelization no return towards natural stream populations had occurred within a 40 year period.

Spawning of fishes dependent on bottom substrate can be severely altered by channel modification. Bowman (1970) showed that slight differences in bottom grain distribution resulted in marked segregation of spawning distribution of three species of redhorse. Grain size has been considered a spawning stimulus, and lack of suitable grain size or proper spatial grain configuration may result in lack of egg maturation, behavior alterations impeding spawning, and egg resorption (Simpson *et al.*, 1982).

Flow or substrate alteration due to channelization may cause reduced spawns of species utilizing bottom material to deposit their eggs. Darters and sculpins actively use substrate for reproduction. Channel modification may remove suitable spawning sites, thereby forcing substrate spawners to move either up or downstream, use less suitable substrate, or not to spawn at all and to resorb eggs (Simpson *et al.*, 1982).

This investigation tested the hypothesis that stream fishes inhabiting a third order stream in the Boston Mountains Ecoregion of Arkansas are reduced in biomass and diversity by channel alteration; that fish biomass and diversity will change in altered reaches over time; and that altered reach instream habitat will return to prechannelization conditions.

STUDY AREA

Haw Creek lies in northwestern Arkansas, draining an area of approximately 200 km². The stream, located in the Boston Mountains Ecoregion, flows in a southeasterly direction for 13 km, attaining third order before entering Big Piney Creek. The majority of the drainage basin is sandstone substratum covered by oak-hickory forest and pasture. Continuous flow in the headwater reaches is dependent on extended rainfall. Intermittent flow is characteristic from July through November.

Stream channels in Haw Creek are fluvially-formed, alluvial, riffle-pool structure from headwaters to third order. Shallow, slow flowing pools alternate with short, shallow swift riffles. Gravel is concentrated in riffle areas and slopes of pools, while pool bottoms are predominately bedrock-rubble.

MATERIALS AND METHODS

Quantitative fish samples were collected in third order reaches of Haw Creek, Johnson County, Arkansas. Pools and riffles were visually inspected, measured, then partitioned based on depth, flow, and substrate. Small mesh block nets were placed at the ends of each areas to prevent fish movement in and out of the study area. Fishes were captured by electroshocking with a generator coupled to a variable voltage pulsator (Coffelt VVP-2C) and hand held electrodes. A minimum of three electroshocking runs was conducted at each site. Specimens were preserved in 10% formalin in the field. Upon return to the laboratory, fishes were identified to species utilizing taxonomic identification keys of Buchanan (1973), weighed, measured, preserved in 50% isopropanol and catalogued.

Population size for each species was estimated. Areas were compared for fish community distribution and partitioning. All species were grouped by feeding guilds based on Pflieger's (1975) general description of food habits. Structure of the fish community at each site and habitat type was summarized using percentage composition of biomass by species and by feeding guild.

Quantitative habitat analysis were performed using methods developed by Ebert *et. al.* (1987b) and Platts *et al.* (1987). Water quality and velocity analyses and channel typing were conducted at each sample site following the methods of Standard Methods (1975), Patton (1987), and Rosgen (1985).

RESULTS

A total of 1826 individuals comprising six families and fourteen species was represented in electrofishing samples (Table 1). Although channelized reaches had fewer species (6-10/10-15), biomass was greater immediately after channelization compared with that of natural reaches (0.57-0.69/0.47-0.59 g/m²). Fish biomass in altered reaches did not show an increase with time, but returned to approximate natural reach levels 2 years after channelization (0.43-0.58/0.44-0.51 g/m²) (Table 2). Mean length and weight per individual was also greater in natural reaches. Darters (Percidae), and stonerollers-shiners (Cyprinidae) dominated altered reaches (67-98%) and comprised a substantial percentage, by number, of natural reaches (48-77%). Sunfishes (Centrarchidae) and catfishes (Ictaluridae) were abundant in natural reaches (23%).

Dominant feeding guilds in altered reaches were herbivores and insectivores, while natural areas were dominated by insectivores, insectivores-piscivores, and omnivores (Table 1). *Campostoma anomalum*, a herbivore, was the most numerous species collected at all sites, and was primarily concentrated in natural riffles and altered reaches. *Etheostoma blennoides, E. spectabile* and *Noturus exilus*, insectivores, were also abundant in natural riffles. Smaller individual sizes of *E. spectabile* were consistently collected in altered riffles. *Lepomis cyanellus, L. megalotis,* and *Micropterus dolomieui*, insectivores-piscivores; *Notropis boops*, insectivore; and *Pimephales notatus*, omnivore; dominated natural areas.

Study areas differed greatly in channel and water width, depth, substrate particle size, and length (Table 3). Channelized reaches were smaller in area, shallower, swifter, and had a more homogenous substrate than did natural reaches. Channel water width was similar in all areas. Size of substrate was substantially less in altered reaches. Dissolved oxygen and specific conductance values were similar among study sites. Stream bank erosion was moderate, and canopy closure and instream cover were lacking in altered reaches.

Table 1. Species list for 3rd order reaches of Haw Creek, Johnson County, Arkansas (1 = herbivore-detritivore; 2 = omnivore; 3 = insectivore; 4 = insectivore-piscivore).

Cyprinidae	Cyprinodontidae
Campostoma anomalum (1)	Fundulus olivaceous (3)
Notropis boops (3)	
Pimephales notatus (2)	Centrarchidae
Catostomidae	Lepomis cyanellus (4)
	Lepomis megalotis (3)
Hypentilium nigricans (3)	Micropterus dolomieui (4)
Erimyzon oblongus (3)	
	Percidae
Ictaluridae	
	Etheostoma blennioides (3)
Ictalurus natalis (3)	Etheostoma spectabile (3)
Noturus exilis (3)	Etheostoma whipplei (3)

Table 2. Fish biomass (g/m²) and numbers for channelized and natural sample reaches of Haw Creek, Johnson County, Arkansas.

	CHANNELIZED		NATURAL	
	Reach 1	Reach 2	Reach 1	Reach 2
Spring 1986	0.57-0.69 132	0.51-0.55 105	0.47-0.59 109	0.39-0.42 137
Summer 1986	0.06-0.11 63	0.10-0.12 49	0.23-0.27 78	0.26-0.34 87
Fall 1986	0.41-0.51 105	0.39-0.46 117	0.48-0.63 113	0.39-0.70 120
Spring 1987	0.46-0.56 98	0.56-0.71 101	0.49-0.56 165	0.37-0.42 219
Summer 1987	0.11-0.19 45	0.16-0.19 67	0.26-0.28 109	0.22-0.27 64
Fall 1987	0.43-0.58 121	0.44-0.67 112	0.44-0.51 134	0.41-0.51 143

* fish biomass (g/m²) (top) and numbers (bottom) determined by area of wetted perimeter (available habitat) per sample.

DISCUSSION

Stream fish biomass, species number and species composition have been found to decrease with channelization (Bayless and Smith, 1964; Smith, 1968 and 1971; Trautman and Gartman, 1974; Golden and Twilley, 1976; and Schlosser, 1982). Increase in species number in streams, attributed to addition rather than replacement of species, occurs as a stream progresses from its headwaters to its mouth. Increase in species diversity has been found to be directly related to habitat variability (Horwitz, 1978). When channelization alters a stream, decreases in both number and diversity of fishes are characteristic. In biologically diverse streams, such as Haw Creek, distribution of fish has been found to be correlated with instream habitat (Schlosser, 1982; Ebert *et al.*, 1987) and constrained by environmental tolerances (Smith and Powell, 1971) and habitat and foot preferences (Matthews and Hill, 1979a. 1979b; Orth and Maughan, 1984). In our investigation altered reaches failed to provide the habitat requirements of numerous species, primarily centrarchids and ictalurids. This compares with results documented by Lotrich (1973). Populations of sport fish, such as larger centrarchids, have been directly related to stream reaches with a higher proportion of pools (Wydoski and Helm, 1980). Shallow riffle species, characterized by *C. anomalum* and *E. spectabile,* were more abundant in altered reaches of Haw Creek than in natural channels. Todd and

Table 3. Physical and chemical parameters for channelized and natural reaches (3rd order) of Haw Creek, Johnson County, Arkansas.

		Channelized		Natural	
		Reach 1	Reach 2	Reach 1	Reach 2
Channel Width (m)	S*	18.2	18.9	23.4	30.1
	S	18.0	18.2	23.1	29.7
	F	19.3	17.9	22.8	29.3
Water Width (m)	S*	16.3	17.0	14.5	16.2
	S	8.3	10.1	13.6	15.2
	F	14.9	16.6	14.7	15.9
Max. Depth (ft)	S*	0.5	0.6	2.9	2.1
	S	0.3	0.3	1.9	1.0
	F	0.4	0.6	2.8	1.9
Substrate		gr/cb	gr/cb	cb/bd	cb/bd
Length (m)		82.5	63.4	72.7	71.1
Dissolved Oxygen (mg/l)	S*	9.9	9.8	9.9	9.9
	S	7.9	8.1	8.1	8.1
	F	10.0	9.6	9.6	9.6
Specific Conductance (umhos)	S*	34.0	34.0	34.0	34.0
	S	42.0	42.0	42.0	42.0
	F	29.0	29.0	29.0	29.0
Canopy Closure (%)	S*	0.0	0.0	54.6	62.5
	S	0.5	1.1	72.1	89.0
	F	0.5	1.1	70.9	88.1

(S* =Spring; S=Summer; F=Fall)
(gr=gravel; cb=cobble; bd=bedrock)

Stewart (1985) found primary food items of *E. spectabile* to be mayflies, chironomids, amphipods and crustaceans, all of which are plentiful in shallow riffle areas. Abundance of *C. anomalum* has been suggested by Brown and Todd (per. comm.) to be influenced by abundance of periphyton on shallow riffle substrate in the Illinois River, Washington County, Arkansas. This species is considered to be herbivorous (Pflieger, 1975; Sewell *et al.*, 1980; Orth and Maughan, 1984). Channelized reaches of Haw Creek had abundant periphyton coverage on all instream substrate due to shallow depth and lack of overhead cover, both of which allow more solar radiation to reach the stream substrate. *C. anomalum* was the most abundant fish collected in channelized reaches, accounting for 56 to 67 percent of total numbers of individuals.

In our investigation, is appeared that channelization not only reduced fish biomasses and numbers in altered reaches (Table 2), but also reduced species composition and biased altered reach fish populations towards smaller individuals which are capable of withstanding shallow water conditions. Trautman and Gartman (1974), reporting on Gordon Creek in Ohio, and Schlosser (1982), reporting on a natural headwater stream in east central Illinois, noted total population shifts and apparent size reductions of groups resulting from channel modifications. It is important to note that altered reaches of Haw Creek were bounded by natural areas, thus offering refugia to many species, especially centrarchids and ictalurids. Ebert *et al.* (1987a), in their quantification of habitat requirements for eight species of Ozark fishes in streams within the Ozark-St. Francis National Forests, noted that *E. spectabile, C. anomalum,* and *N. exilus,* and juvenile life stages of *L. megalotis, L. cyanellus* and *M. dolomieui* preferred shallow, fast/slow riffles with a gravel dominated substrate. In their investigation, *N. boops* was primarily a shallow pool species and adult *L. megalotis, L. cyanellus,* and *M. dolomieui* preferred deep, moderately flowing pools with bedrock/boulder substrate. Channel alteration in Haw Creek resulted in shallow, slow/moderate flowing gravel dominated reaches which offered preferred habitat to darters and stonerollers. Natural stream reaches with an abundance of debris and boulder dominated pools were preferred by centrarchids and ictalurids.

During low summer flows in 1986 and 1987, altered reaches of Haw Creek were practically dewatered. This occurrence is common in many Ozark streams. Fish biomasses in altered reaches during these periods are greatly reduced (0.12-0.21 g/m^2) compared to natural reaches (0.22-0.26 g/m^2). This may be a result of suitable instream cover loss and an overall reduction of wetted area in altered reaches. Ebert *et al.* (1987a) found a strong correlation between wetted area (m^2) and total fish weight ($r^2 = 0.94$) and wetted area (m ±) and total fish numbers ($r^2 = 0.61$) in 10 streams in the Boston Mountains Ecoregion of Arkansas, sampled from 1985 to 1987. Their investigation indicated that fish numbers and weight would increase with wetted area until an inflection point was reached, based on channel form, where water levels above the point would result in no significant additional usable fish habitat. This is one of the basic tenants of many instream methods used to reserve water for stream fisheries and aquatic ecosystems (Filipek *et al.*, 1987). Two years after channelization altered channels were scouring. Rubble/boulder material that moved into the altered reaches during storm events had diversified the bottom substrate, and fish populations during normal flows were comparable to those of natural channels (Table 2). In two altered reaches scour pools were formed where natural reaches entered the areas. However, this is often offset by silt deposition downstream of the scoured, channelized area (Yearke, 1971). It is apparent that with time the altered reaches will return to a natural state. This is due in part to the altered reaches being bounded by natural areas and to the small overall length of each altered reach (>1 km). Previous long term studies have indicated an irreversible destruction of stream habitat and fish populations in channelized streams. Tratuman and Gartman (1974) reported that after 86 years relative abundance of fish in Gordon Creek, Ohio, was decreased and diversity altered. Bayless and Smith (1964) reported fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina had reductions in the magnitude of 90 percent in number and weight of game fish following channelization, with no return towards natural stream populations over a 40 year period. Also, the physical loss of habitat and loss in ecotone, both aquatic and terrestrial, can occur above and below the channelized section, expanding the area impacted by channelization (Simpson *et al.*, 1982).

This investigation indicated that small Ozark stream fish populations and habitat can recover from channelization if altered reaches are short in overall length and bounded by natural undisturbed areas. There was a direct tendency for darters and stonerollers to seek the shallow, slow/moderate flowing, gravel substrate of altered reaches. The stimulus for the new habitat colonization may be related to preference for that type of habitat or for abundant food organisms. Large size fishes were excluded from altered reaches due to depth and cover limitations. Channelization of natural stream reaches should be avoided in highway construction and improvement if possible because of major impacts, not only to the aquatic system, but also to the terrestrial environment and its associated wildlife (Hedrick, 1975). Further, upstream channelization has caused engineering problems, such as increased bank and bottom erosion, increased frequency of floods, and a higher incidence of downstream bridge repair due to the above factors (Emerson, 1971).

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