REGULATED RIVERS: RESEARCH AND MANAGEMENT, VOL. 2, 155–166 (1988)

THE IMPORTANCE OF STREAMLINING IN INFLUENCING FISH COMMUNITY STRUCTURE IN CHANNELIZED AND UNCHANNELIZED REACHES OF A PRAIRIE STREAM*

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ABSTRACT

Channelized and unchannelized sections of a prairie stream in northwestern Iowa were compared to determine how differences in microhabitats affected fish species abundance and diversity and the incidence of streamlined species. Channelized sections had significantly more fish per unit area ($P < 0.05$) but significantly less biomass ($P < 0{\cdot}05$). Green sunfish (*Lepomis cyanellus*) and stonecats (*Noturus flavus*) were common in the unchannelized sections but rare or absent in the channelized ones. Small native minnows (Cyprinidae), especially the bigmouth shiner (*Notropis dorsalis*), dominated channelized sections. Species diversity was lower in channelized sections, but differences were not statistically significant ($P \doteq 0{\cdot}06$). Family diversity was significantly lower in channelized sections ($P < 0{\cdot}05$). Channelized sections exhibited less heterogeneity of widths, velocities and substrates and contained more streamlined forms than did unchannelized sections. Unchannelized sections, characterised by greater diversity of velocities and substrate types, supported more centrarchids and ictalurids, fishes that are not optimally streamlined. Although many other factors besides streamlining influence the fish community structure in streams, in reaches without refuges from the current, streamlining may be a factor determining which species persist there.

KEY WORDS: Channelization fishes streams

INTRODUCTION

Channelization, the artificial straightening and dredging of streams and rivers, has been widely practiced in the United States (Schneberger and Funk, 1971). Watercourses are channelized to increase land drainage and agricultural production, and to provide flood control (Best *et al.*, 1978). Channelization commonly involves clearing banks and channels of vegetation, removing large boulders and cobbles from channels, and depositing the dredge spoils along the banks for levees. Fish habitat in a channelized reach is commonly characterized by a reduction in total area (Chapman and Knudsen, 1980), higher stream gradients and velocities, finer and less stable substrates (Zimmer and Bachmann 1978), an absence of alternating pools and riffles, and an overall reduction in heterogeneity of habitats (Hortle and Lake, 1983).

The effects of channelization on game and nongame fish populations and communities are well documented (Etnier, 1972; Huet and Timmermans, 1976; Chapman and Knudsen, 1980; Hortle and Lake, 1983; Portt *et al.*, 1986). The prevailing conclusion in these studies was that channelized streams had less diversity of habitats and less cover, and thus lower densities and biomasses of fish, and fewer species. Artificial structures have been installed in some channelized streams to provide cover, and some have been partially successful (Carline and Klosiewski, 1985).

Many of the channelization studies had insufficient replication to ascertain the effects of the channelization (e.g. Huet and Timmermans, 1976; Portt *et al.*, 1986). The reduction of habitat diversity in

*Journal Paper No. J-12856 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2815.

0886–9375/88/020155–12$06.00

Received 5 October 1987
Revised 21 December 1987

channelized reaches has rarely been quantified, nor have specific mechanisms been identified for explaining changes in fish species diversity or fish community structure.

The higher and more uniform current, coupled with the generally homogeneous physical structure of channelized reaches, greatly reduces the number of available refuges from the current. Current should then be a stronger force in influencing fish community structure in channelized reaches than in unchannelized reaches. Given the virtual absence of refuges from the current in a channelized stream, are streamlined fish species favored, and does this account for differences in species composition between channelized and unchannelized reaches?

The objectives of this study were: (1) to determine how differences in microhabitats between channelized and unchannelized sections of a small stream affect fish abundance, biomass, and community structure; (2) to determine how the diversity of fish streamlining in the channelized and unchannelized sections relates to the diversity of physical habitats; and (3) to assess if streamlining can in some cases be a significant factor influencing species composition in channelized streams.

THE PHYSICAL SIGNIFICANCE AND MEASUREMENT OF STREAMLINING

For organisms such as fish with high or moderate Reynold's numbers, streamlining is beneficial in reducing drag (Vogel 1981). Webb (1975) reviewed the hydraulics of streamlining. As described by Vogel (1981): 'If the object is endowed with a long and tapering tail, fluid gradually decelerates in the rear, little or no separation [of flow] occurs, and the object is literally pushed forward by the wedge-like closure of the fluid behind it' (Figure 1).

Streamlining is usually described by the Fineness Ratio (FR) = l/d, where l is the total length of the body (excluding fins) and d is the maximum diameter of the body, or body depth (excluding fins). For fish, the optimal FR is about 4·5; such an FR gives minimum drag for maximum body volume (Webb, 1975). Webb noted, however, that 'FR can vary between about 3 and 7 and result in only a 10 per cent change in drag from the optimum value.'

Aleev (1969) characterized streamlining differently by first calculating the Index of Trunk Shape Y = y/SL, where y is the distance along the body to the line of maximum diameter and SL is the standard length. He then plotted Y against a function of maximum diameter d as a percentage of SL. His empirical results indicated to him that for the fastest swimmers, d constituted 12–27 per cent of SL, which is comparable to the 3 to 7 range of Fineness Ratios mentioned by Webb (1975).

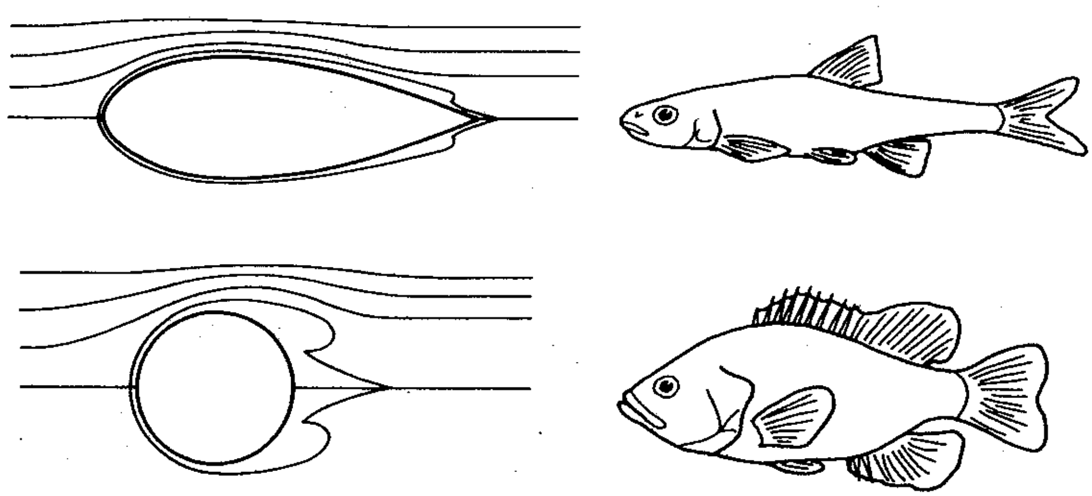

Figure 1. Flow patterns around circular and streamlined profiles (adapted from Webb, 1975), and fish analogues

STUDY SITE

The study was conducted in Pillsbury Creek, a tributary of the Little Sioux River, Iowa (Latitude 43° 20′ N, Longitude 95° 10′ W; Figure 2). The drainage area of the creek is approximately 43 km^2. The creek lies near the edge of the Des Moines Lobe landform region, which was last glaciated in the Pleistocene epoch by the Wisconsin glaciation 14,000–13,000 yr BP (Prior, 1976). The landscape immediately north of the creek is covered with glacial till, has poor natural drainage characteristic of many morainal areas, and was until early this century replete with shallow lakes and wetlands (McBride, 1899; Prior, 1976). Soils along the creek are loams formed by glacial till (Dankert, 1983).

The creek originally drained Pratt, Sylvan, and Pillsbury Lakes, three shallow interconnected glacial lakes. About 1915, these lakes were drained, drainage tiles installed on the surrounding land, and agricultural crops were grown in the dry lake beds (Hungerford, 1969). The upper portion of the creek flowing through the Pillsbury lake bed was channelized. as was a previously unchannelized portion downstream from the former lake, so that of the approximately 3·2 km of creek originally between the lower portion of Pillsbury Lake and the Little Sioux River, only about 2·4 km remain unchannelized. In 1983, the channelized portion of the creek was thoroughly cleaned of debris and restraightened. The channelized portion of the drainage is adjacent to agriculture in the upper portions and grazed by cattle in the lower portions. The land adjacent to the unchannelized portion is also grazed by cattle, but is not used for grain crops.

The water entering Pillsbury creek from the drainage tiles is cool compared with the Little Sioux River; creek temperatures in late afternoon the first week in August were commonly 18–22° C, compared to about 30° C in the Little Sioux River.

MATERIALS AND METHODS

Eight 40m long study sections were sampled for physical characteristics and fishes; four from the channelized portion and four from the unchannelized portion (Figure 2). At least one pool and one riffle were included in each unchannelized section. Channelized sections had no distinct pool-riffle character. Two sections of each type were sampled from August 4 to 8 in 1986 and two more sections of each type were sampled from July 29 to August 7 in 1987.

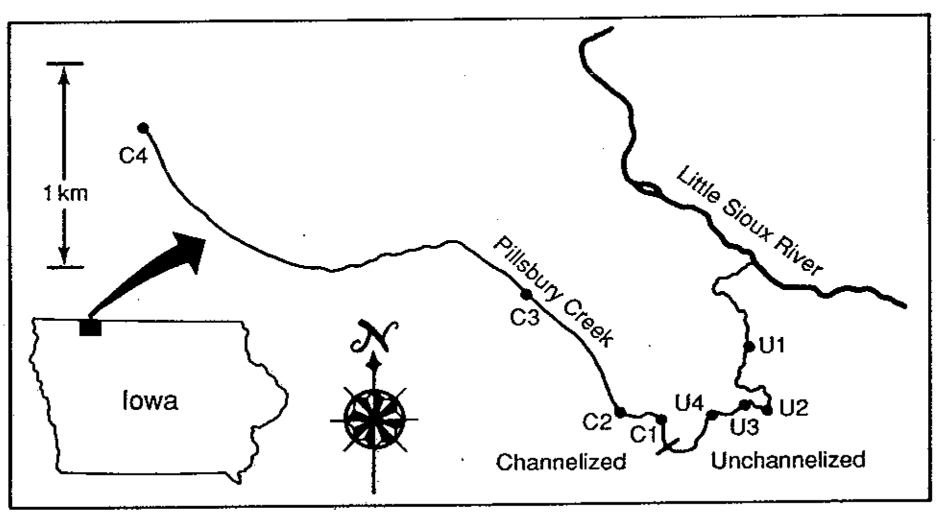

Figure 2. Location of study site showing unchannelized (U1–U4) and channelized (C1–C4) sections

Table 1. Characteristics of fishes and physical habitat in four channelized (C1–C4) and four unchannelized (U1–U4) sections of Pillsbury Creek. CV = coefficient of variation.

Characteristic	Section							
	Unchannelized				Channelized			
	U1	U2	U3	U4	C1	C2	C3	C4
Number of Species	17	17	10	10	10	12	9	11
Species Diversity	0·83	0·78	0·68	0·67	0·66	0·76	0·62	0·71
Family Diversity	0·54	0·54	0·59	0·47	0·12	0·26	0·13	0·55
Species evenness (J)	0·70	0·65	0·73	0·91	0·68	0·74	0·65	0·68
Family evenness (J)	0·70	0·69	0·75	0·37	0·16	0·38	0·21	0·80
Number per square meter	2·27	2·53	0·73	0·76	3·02	2·22	2·55	3·45
Biomass per square meter	12·9	11·8	20·3	25·8	8·6	14·7	5·8	19·0
Mean Fineness Ratio	3·92	3·74	3·98	4·14	4·46	4·42	4·42	4·52
CV Fineness Ratio	0·24	0·27	0·30	0·20	0·05	0·12	0·06	0·10
Percent *Notropis dorsalis* in catch	4	4	1	1	30	27	54	22
No. Ictaluridae (all species)	9	6	18	4	0	0	0	0
No. *Campostoma anomalum*/100m^2	12	1	0	0	13	23	0	1
Percent *Lepomis cyanellus* in catch	31	42	38	19	1	6	0	3
Percent of biomass in Cyprinidae	63	50	38	20	89	88	93	82
Substrate diversity	0·49	0·50	0·43	0·39	0·23	0·44	0·21	0·24
Mean velocity (m/s)	0·40	0·39	0·20	0·29	0·28	0·48	0·28	0·22
CV velocity	0·58	0·58	0·98	0·92	0·50	0·26	0·32	0·30
Mean depth (cm)	34·5	52·0	31·8	32·0	13·2	36·9	17·9	45·8
CV depth	0·45	0·26	0·42	0·36	0·35	0·14	0·34	0·12
Mean width (m)	4·90	3·37	2·98	3·31	4·58	3·69	4·30	4·54
CV width	0·20	0·18	0·25	0·16	0·06	0·11	0·08	0·08
No. substrate sites with boulders	10	5	8	8	0	0	0	0
Percent of substrate sites with boulders	48	24	38	38	0	0	0	0
No. substrate sites with sand or fine gravel	8	9	10	21	21	9	21	21
Percent of substrate sites with sand or fine gravel	38	57	43	48	100	43	100	100

Fish populations

Each section was blocked off with fine-meshed (3·175 mm) seines, and fish were sampled with battery-powered backpack electrofishing gear. Population estimates and 95 per cent confidence intervals were estimated in aggregate by the three-pass removal method (Zippin, 1958) with a maximum likelihood estimator (Carle and Strub, 1978; summarized in Cowx, 1983); the total estimate for all species in each section was then partitioned back into species according to their respective percentages, by number, of the total catch. In this approach, equal catchability of different species was assumed. In section U2, excessively hot weather and turbid water from cattle activity prevented a third sample from being taken, so population estimates and diversity indices for this section were based on just two samplings.

Table 2. Analysis of variance probability values for comparisons of treatment (channelized and unchannelized) means, yearly means, their interactions. $P < 0.05$ implies significance at the 95% level of confidence, $P < 0.01$ at the 99% level of confidence, and so on. CV = coefficient of variation.

Characteristic	Probability value		
	Treatment	Year	Treatment × Year
Species Diversity	0·06	*0·005*	0·40
Family Diversity	*0·03*	0·13	0·16
Species evenness (J)	0·30	0·39	0·13
Family evenness (J)	0·17	0·13	0·40
Number per square meter	*0·02*	0·06	0·07
Biomass per square meter	*0·04*	0·79	*0·005*
Mean Fineness Ratio	*0·002*	0·20	0·12
CV Fineness Ratio	*0·003*	0·32	0·40
Percent *Notropis dorsalis* in catch	*0·007*	0·30	0·17
No. Ictaluridae (all species)	0·06	0·65	0·65
No. *Campostoma anomalum*/100m²	0·43	0·43	0·95
Percent *Lepomis cyanellus* in catch	*0·006*	0·34	0·73
Percent of biomass in Cyprinidae	*0·002*	0·14	*0·05*
Substrate diversity	*0·03*	0·11	0·73
Mean velocity (m/s)	0·93	0·19	0·98
CV velocity	*0·001*	*0·007*	0·07
Mean depth (cm)	0·14	*0·02*	0·23
CV depth	0·06	0·07	0·15
Mean width (m)	0·32	0·50	0·21
CV width	*0·01*	0·85	0·46
No. (and %) substrate sites with boulders	*0·003*	0·85	0·85
No. (and %) substrate sites with sand or fine gravel	0·06	0·43	0·37

Lengths of all fishes were measured. Larger fish of each species were weighed individually, but specimens under 3g were weighed in aggregate to obtain biomass and mean weight estimates for each species. Additionally, approximately 20 fish of each of 14 species were measured for Fineness Ratios (Webb, 1975). Samples of 10 of these species came exclusively from Pillsbury Creek. For four other species rarely found there (*Cyprinus carpio, Lepomis humilis, Notropis cornutus,* and *Notropis stramineus*), samples were mixed from the creek and nearby rivers and natural lakes. Ratios for nine rare species were estimated from ratios of the most morphologically similar species for which ratios were calculated. In all, the 13 rare species constituted a small percentage of the total catch (less than 4 per cent in 1987). Weighted mean Fineness Ratios were calculated by multiplying population estimates for each species by its mean Fineness Ratio, summing for all species in the section, and dividing by the total population estimate for all species in the section.

Physical variables

Within each section, seven transects were established perpendicular to the flow at 5 meter intervals. Along each transect, 3 stations were established, one station at the center of the stream and one station between the center and each edge of the stream, so that the 40m sections each had 21 stations.

Width of the streams was measured at each transect. At each station, depth was measured and substrate evaluated by size according to a modified Wentworth classification. Substrate types were boulder (> 25·6 cm), cobble (6·4–25·6 cm), coarse gravel (1·6–6·4 cm), fine gravel (0·2–1·6 cm), sand (·0062–0·2 cm), silt (·0004–·0062 cm). Velocity was measured at 0·6 of the depth with a pygmy-type current meter.

Measures of diversity and variation

Brillouin indices of diversity (H) were calculated for fish species, families, and substrate type in each of the eight sections according to the following expression:

$$H = (\log N! - \Sigma \log n_i!)/N$$

where N = total number of individuals and n_i = number of individuals in the ith species, family, or substrate class. Evenness (J) was calculated as $J = H/H_{max}$ where H_{max} is calculated by:

$$H_{max} = [\log N! - (s - r) \log c! - r\log (c + i)!]/N$$

where S is the number of species, c is the integer portion of N/S, and r is the remainder (Brower and Zar, 1977). Variation in width, depth, velocity, and weighted mean Fineness Ratio for each of the eight sections was estimated by the coefficient of variation, the standard deviation divided by the mean.

Statistical analyses

Thirteen fish-related and eleven habitat related-attributes were calculated for the four channelized and four unchannelized sections and subjected to one way analyses of variance. Treatments were channelized and unchannelized, and the four sections of each type were treated as replicates. Data were also analysed by year, and for treatment x year interactions. Means were compared by employing the method of Least Significant Differences (Snedecor and Cochran, 1967). Regression methods were used to investigate relations between habitat variables, fish populations, and community attributes.

RESULTS

Effectiveness of electrofishing

Backpack electrofishing gear effectively sampled fish in this small stream, but despite the assumption of equal species catchability, it seemed that shoaling minnows, particularly bigmouth shiners (*Notropis dorsalis*), were skilled at escaping the gear and less susceptible to capture than other species. Total biomass estimates should be considered minimum, as should abundance estimates of bigmouth shiners in the channelized sections in particular.

Numbers and biomass of fish

Channelized sections had significantly more fish per square meter than unchannelized sections ($P < 0{\cdot}05$), but significantly less mean biomass per square meter ($P < 0{\cdot}05$). The presence of large creek chubs (*Semotilus atromaculatus*) and large white suckers (*Catostomus commersoni*) in unchannelized sections accounted for the greater biomass (Table 3, Figure 3). The statistical differences in biomass between channelized and unchannelized sections were strongly influenced by the 1986 data, but data for 1987 were inconclusive. A significant treatment × year interaction was found for biomass. Numbers of fish were particularly low in unchannelized sections U3 and U4, where one northern pike (*Esox lucius*) was captured in each section. These two sections also had substantial areas of undercut banks, and were inhabited by large creek chubs and white suckers.

Table 3. Population ($\hat{N}$) and Biomass ($\hat{B}$) estimates by species in 4 channelized and 4 unchannelized of Pillsbury Creek.

	Unchannelized								Channelized							
Family Species	U1		U2		U3		U4		C1		C2		C3		C4	
	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$	$\hat{N}$	$\hat{B}$
ESOCIDAE																
Esox lucius					1	148	1	140	1	69						
CATOSTOMIDAE																
Moxostoma macrolepidotum	8	11	5	6												
Catustomus commersoni	52	87	46	67	5	1000	9	2474	20	80	2	94	3	9	20	185
CYPRINIDAE																
Cyprinus carpio	1	12														
Semotilus atromaculatus	125	1024	58	665	19	900	43	645	209	836	102	1177	35	294	121	2322
Rhinichthys atratulus	14	52	18	43	4	24			35	81	34	126	31	78	6	14
Notropis cornutus	5	68														
Notropis dorsalis	19	44	15	34	1	1	15	16	163	293	89	250	235	423	135	444
Notropis lutrensis			1	2												
Notropis stramineus			4	8												
Hybognathus hankinsoni	2	1	19	33			1	1	88	79			59	65		
Pimephales notatus	1	1	3	5			3	4			8	13	46	69	1	4
Pimephales promelas	17	18	3	3							3	3	1	4	12	32
Campostoma anomalum	24	376	1	1					23	101	35	345			1	22
ICTALURIDAE																
Ictalurus melas			1	12	15	98	4	12								
Noturus flavus	8	497	5	240	3	144										
Noturus gyrinus	1	3														
CENTRARCHIDAE																
Lepomis cyanellus	140	308	143	441	33	102	19	108	6	23	20	100			16	125
Lepomis humilis	1	4	1	7											1	5
PERIDAE																
Perca flavescens							3	8								
Etheostoma nigrum	14	20	13	15							26	49	23	44	110	172
Etheostoma exile					4	4	4	5	2	2	1	2				
GASTEROSTEIDAE																
Culaea inconstans	14	6	5	4	1	1			5	5	9	8	6	17	205	127
TOTALS	446	2532	341	1586	87	2422	101	3413	552	1569	328	2167	439	1003	628	3452

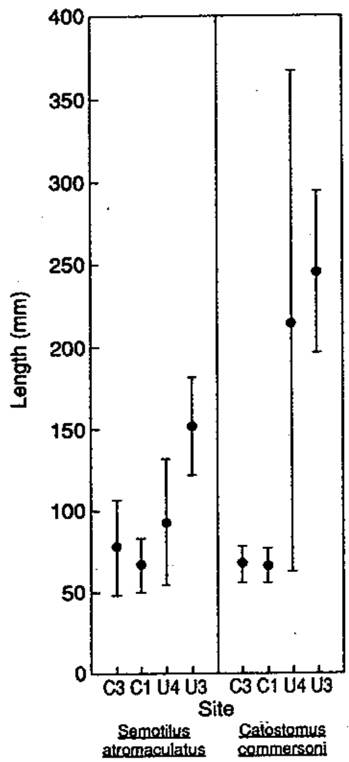

Figure 3. Mean lengths of white suckers (*Catostomus commersoni*) and creek chubs (*Semotilus atromaculatus*) from channelized and unchannelized sections

Species composition

Species composition clearly differed between channelized and unchannelized sections. Green sunfish (*Lepomis cyanellus*) were common in unchannelized sections, constituting between 19 and 42% of the fish there, whereas in channelized sections, they constituted only 0–6% of the fish ($P < 0{\cdot}05$). In addition, either stonecats (Ictaluridae: *Noturus flavus*) or black bullhead (*Ictalurus melas*) or both were found in all unchannelized sections (4–18 individual fish per section), but no ictalurids were found in any of the four channelized sections ($P < 0{\cdot}05$).

In contrast, small native minnows (Cyprinidae) dominated in channelized sections (82–93% of total biomass), but not in unchannelized sections (20–63%; $P < 0{\cdot}05$). Large numbers of shoaling minnows seemed to feed effectively in mixed species assemblages over the open, exposed, current-swept sandy bottoms. Bigmouth shiners constituted 22–54% of the fish in channelized sections but only 1%–4% in unchannelized sections ($P < 0{\cdot}05$).

Central stonerollers (*Campostoma anomalum*) were found in some channelized and unchannelized sections over coarse gravel and cobble substrates. Their presence in a section seemed to be more a function of suitable cobble substrate than of channelization per se. Brook sticklebacks (*Culaea inconstans*) were found in all but one section, but were most abundant in channelized section C4 where they were closely associated with extensive submerged aquatic vegetation along the stream edges. None of the other 7 sections had this vegetation, and sticklebacks were uncommon or absent (Table 3).

Species and family diversity and evenness

Species diversity was not significantly different between channelized and unchannelized sections, but was close to significance ($P = 0{\cdot}06$). Channelized sections had between 9 and 12 species, whereas two unchannelized sections had 10 species and two had 17. However, several of these 17 species were represented by one or two fish (Table 3), so that their contribution to diversity indices was small. Channelized and unchannelized sections did not differ in species evenness ($P > 0{\cdot}05$).

Family diversity, however, was significantly different between channelized and unchannelized sections ($P < 0{\cdot}05$). Cyprinidae predominated in the channelized sections, whereas the families Ictaluridae, Catostomidae, and Centrarchidae were important contributors to the unchannelized sections (Table 3). Family evenness did not differ between channelized and unchannelized sections ($P > 0{\cdot}05$).

Physical characteristics of sections

Channelized sections had significantly less diversity of widths ($P < 0{\cdot}01$), velocities ($P < 0{\cdot}01$), and substrates ($P < 0{\cdot}05$) than unchannelized sections. Depths may have been less diverse in channelized sections as well ($P = 0{\cdot}06$). Mean depth and mean velocity did not differ for channelized and unchannelized sections. Channelized sections had significantly fewer sites with boulders ($P < 0{\cdot}01$) and instead seemed to have more sand and fine gravel in their substrate ($P = 0{\cdot}06$).

Streamlining and Fineness Ratios

Weighted mean Fineness Ratios were consistent and near optimal within channelized sections, ranging from 4·42 to 4·52. These mean ratios were significantly different from those of unchannelized sections, which were less than optimal, and ranged from 3·74 to 4·14 ($P < 0{\cdot}01$). Variations in mean Fineness Ratios were also significantly lower in channelized sections than in unchannelized ones ($P < 0{\cdot}01$). Streamlined, shoaling fishes such as bigmouth shiner, creek chubs and other minnows (Figure 4) that use sandy bottomed streams with steady velocities were common in channelized sections. In unchannelized sections, less streamlined stonecats and territorial green sunfish (Figure 4) used gravel and cobble riffles and slow backwater areas, respectively. Variation in Fineness Ratios was related to variations in velocities among the 8 sections ($r = 0{\cdot}724$; $P < 0{\cdot}05$). Variation in Fineness Ratios was lowest in sections with uniform velocities and substrates; coefficients of variation of velocities and substrates together in a multiple regression equation explained 88% of the variation in the ratios ($P < 0.01$).

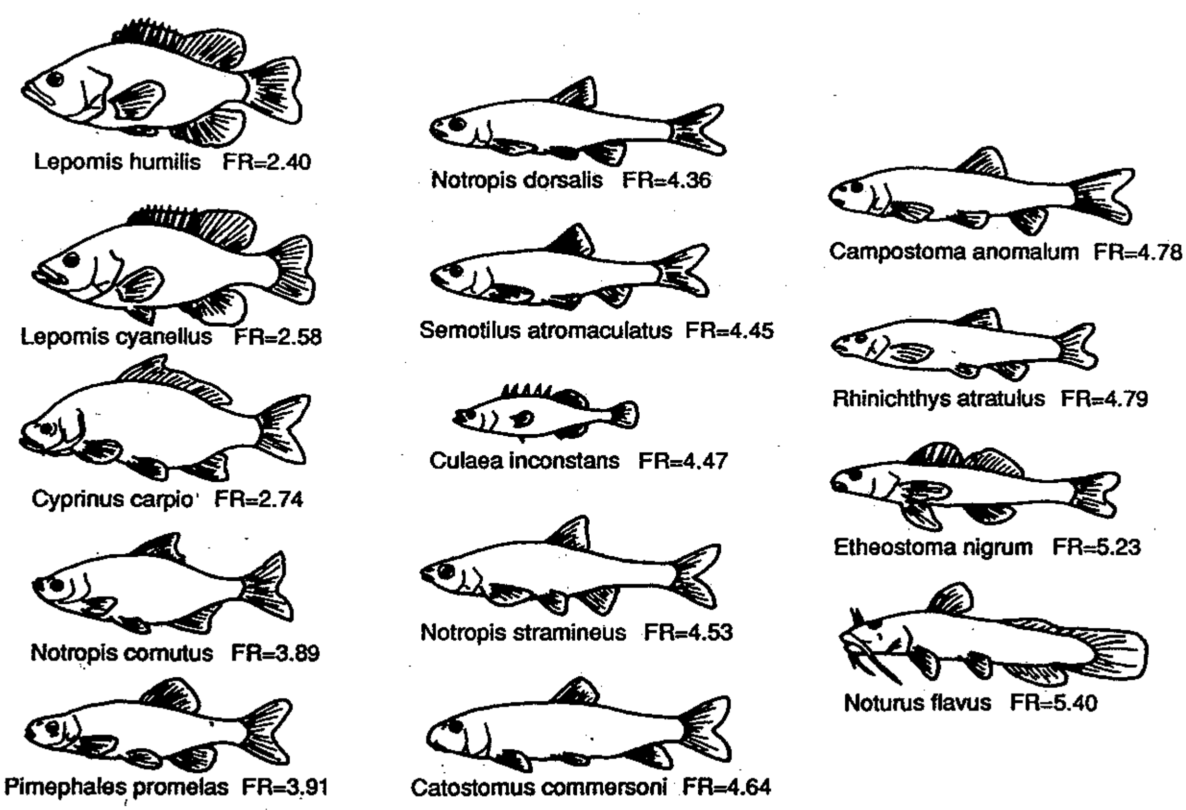

Figure 4. Body shapes and associated Fineness Ratios for 14 species sampled

DISCUSSION

Effects of channelization

The lack of statistically significant differences in species diversity between channelized and unchannelized sections and the higher density of fish in channelized sections contrasts with studies by Huet and Timmermans (1976), Hortle and Lake (1983) and several other investigators, who found that channelized streams were less diverse and had fewer fish. Several factors could account for this difference.

First, treatment means were just outside the 0·05 level of significance ($P = 0{\cdot}06$). There were 17 species found in each of two of the four unchannelized sections, which is five more than were found in the most speciose channelized section. Nonetheless, several of these species were rare enough (1–2 specimens/section) that overall diversity indices were not substantially higher than in channelized sections.

Second, Pillsbury Creek was channelized long ago (1915–16) and merely cleaned recently (1983). Despite the extensive disruption associated with debris and cover removal, perhaps the fish community in the stream as of the early 1980's was already adapted to some habitat conditions associated with channelization. If so, the fish community would suffer less disruption than if it was an unchannelized stream that had recently been channelized.

Third, Pillsbury Creek is fed by cool water from drainage tiles, so thermal conditions in summer are favorable for many minnows. Even though the stream is channelized in its upper portion, unpublished data indicate that water temperatures remain well below those of the Little Sioux River. Severe thermal problems often associated with channelization are absent.

Fourth, much of the emphasis in channelization studies has been on the effects on larger fishes, whereas Pillsbury Creek is small, with mostly small, nongame fish. Although the channelized sections provided little habitat for large fishes, and as a result, large fishes were rare there, the section did provide habitat for small schooling minnows suited to the sand and fine gravel substrates. The effects on density and diversity would be expected to be greater on large fishes than on these small minnows, because the large fishes would often require the deep pools, cover, and larger substrates eliminated by channelization.

Finally, the unchannelized reaches in Pillsbury Creek, which were downstream of the channelized reaches, were undoubtedly influenced by sedimentation and related effects of the channelization upstream. Observed differences between channelized and unchannelized sections were probably less than if the channelized reaches had been downstream from the unchannelized reaches.

Physical characteristics and fish

Channelized sections were characterized by low diversity of widths, depths, velocities, and substrates, by moderate depth, by steady and ubiquitous velocities, and by substrates of predominantly sand and fine gravel. Unchannelized sections were diverse in widths, depths, velocities and substrates; all sizes of substrate from silt to boulder were found. In the channelized sections, the transect data support the observation that there was virtually no habitat unexposed to the current: no backwater areas, little unevenness of depth, and little cobble and boulder substrate for shelter. The only significant protection from the current in these sections was in section C4, where submerged aquatic vegetation along the banks afforded protection to sticklebacks, which are weak swimmers. Becker (1983) noted that sticklebacks are invariably associated with vegetation cover, and the margins of the section provided that cover. With this exception, the only fishes that had any significant habitat in the channelized sections were those adapted to feeding in assemblages over sand and fine gravel bottoms, and requiring little if any cover. Several streamlined minnow species in northwestern Iowa streams can exist or even thrive under such circumstances, and this accounts for the reasonably high species diversity in these sections. The omnivorous bigmouth shiner was particularly abundant. Becker (1983) found them in Wisconsin to be primarily associated with gravelly and sandy substrates. Paloumpis (1958) and Harlan *et al.* (1987) indicate that bigmouth shiners are particularly well adapted to sandy bottomed, channelized streams. The blacknose dace also prefers areas of current and was found by Becker (1983) predominantly over gravel and sand. The creek chub was found in all sections, consistent with reports by Becker (1983) and Trautman (1981) that it is an opportunist able to exist under a wide variety of environmental conditions. The white sucker (*Catostomus commersoni*) is also adaptable to many conditions. The Johnny darter (*Etheostoma nigrum*) is more tolerant of degraded environments than many darters (Trautman, 1981) and can exist under the channelized conditions in Pillsbury Creek by feeding over sandy bottoms (Harlan *et al.* 1987). Selection for streamlining was strong in the fishes existing in this environment, and mean Fineness ratios were near optimal (Webb, 1975), and little variation from optimal streamlining occurred. Species in the channelized sections tended to be environmentally tolerant and morphologically adapted to the current.

In contrast, the unchannelized sections, which were more physically diverse, not only supported more species, but accomodated significantly more fish families, including species that were not optimally streamlined. Slow-flowing areas with cobble and boulder substrates supported large numbers of green sunfish and a few orangespotted sunfish (*Lepomis humilis*). This result agrees with Harlan *et al.* (1987) who characterized green sunfish habitat as slower, quieter water, and with Becker (1983), who found them to be sedentary, territorial fish found over a variety of substrates. Stonecats were found in riffles among coarse gravel, cobble, and small boulders, where they could feed without being subjected to a continuous current. In Pillsbury Creek, stonecats were captured in riffle areas with cobble and boulder substrates, which agrees with Trautman's (1981) report that the stonecat is predominantly a riffle species but intolerant of strong currents. The shoaling minnows were also found over sand and gravel substrates but in lower numbers than in channelized sections. In the unchannelized sections, the current was more easily avoided, and not as strong a selection for streamlining occurred.

Gatz (1979) and Mahon (1984), building on the observations of Hora (1922), Hubbs (1941), and others, attempted with moderate success to use diverse aspects of fish morphology to explain fish community structure. However, they did not evaluate the importance of streamlining as a primary mechanism affecting fish community structure in altered streams. For a channelized stream, other factors besides streamlining clearly are important in affecting fish community structure. Available species, their various tolerances, species interactions (Gatz, 1979), food supplies (Schlosser, 1982), and many other factors ultimately affect community structure. However, in streams where cover is scant and relief from the current scarce, streamlining may be a significant factor determining which species persist there.

ACKNOWLEDGEMENTS

Thanks are due to R. Huisman for measurements on the fishes and field assistance, and to C. Clark, J. Gude, D. Hurt, W. Jensen, R. Schulte, J. Sieler, and J. White for additional field assistance. S. White helped with the statistics. This work was conducted while the author was in residence at the Iowa Lakeside Laboratory, Milford, Iowa. I thank the Lab Director, R. Bovbjerg, and the Wehrspann family for support and assistance. G. J. Atchison, K. D. Fausch, and an anonymous reviewer provided valuable suggestions on drafts of this paper.

REFERENCES

Aleev, Y. G. 1969. *Function and Gross Morphology in Fish.* Israel Program for Scientific Translations, Jerusalem, p. 268.

Becker, G. C. 1983. *Fishes of Wisconsin.* University of Wisconsin Press, Madison, p. 1052.

Best, L. B., Varland, K. L. and Dahlgren, R. B. 1978. 'Effects of stream channelization on land-use practices in Iowa'. *Iowa State Journal of Research*, **52**, 411–423.

Brower, J. E., and Zar, J. H. 1977. *Field and Laboratory Methods for General Ecology.* Wm. C. Brown Company Publishers, Dubuque, IA, p. 194.

Carle, F. L., and Strub, M. R. 1978. 'A new method for estimating population size from removal data', *Biometrics*, **34**, 621–630.

Carline, R. F., and Klosiewski, S. P. 1985. 'Responses of fish populations to mitigation structures in two small channelized streams in Ohio'. *North American Journal of Fisheries Management*, **5**, 1–11.

Chapman, D. W., and Knudsen, E. 1980. 'Channelization and livestock impacts on salmonid habitat and biomass in western Washington', *Transactions of the American Fisheries Society*, **109**, 357–363.

Cowx, I. G. 1983. 'Review of the methods for estimating fish population size from survey removal data', *Fisheries Management*, **14**, 67–82.

Dankert, W. N. 1983. 'Soil survey of Dickinson County, Iowa', *U.S. Department of Agriculture, Soil Conservation Service*, p. 152.

Etnier, D. A. 1972. 'The effect of annual rechanneling on a stream fish population', *Transactions of the American Fisheries Society*, **101**, 372–375.
Gatz, A. J. Jr. 1979. 'Community organization in fishes as indicated by morphological features, *Ecology*, **60**, 711–718.
Harlan, J. R., Speaker, E. B. and Mayhew, J. 1987. *Iowa Fish and Fishing*. Iowa Department of Natural Resources., Des Moines, p. 323.
Hora, S. L. 1922. 'Structural modifications in the fish of mountain torrents', *Records of the Indian Museum (Calcutta)*, **24**, 31–61.
Hortle, K. G., and P. S. Lake. 1983. 'Fish of channelized and unchannelized sections of the Bunyip River, Victoria', *Australian Journal of Marine and Freshwater Research*, **34**, 441–450.
Hubbs, C. L. 1941. 'The relation of hydrological conditions to speciation in fishes', p. 182–195 in *A Symposium on Hydrobiology*. University of Wisconsin, Madison.
Huet, M., and Timmermans, J. A. 1976. 'Influence sur les populations de poissons des amenagements hydrauliques de petits cours d'eau assez rapides', *Travaux Station de Recherches Eaux et Forets (Belgique)*, Series D, No. 46, p. 27.
Hungerford, J. J. 1969. 'Lacustrine sediments of a drained lake in northwest Iowa. Part 1', *Iowa State Journal of Science*, **43**, 253–260.
Mahon, R. 1984. 'Divergent structure in fish taxocenes of north temperate streams', *Canadian Journal of Fisheries and Aquatic Sciences*, **41**, 330–350.
McBride, T. H. 1899. 'Geology of Osceola and Dickinson counties'. *Iowa Geological Survey*. **10**, 187–239.
Paloumpis, A. A. 1958. 'Responses of some minnows to flood and drought conditions in an intermittent stream', *Iowa State Journal of Science*, **32**, 547–561.
Portt, C. B., Balon, E. K., and Noakes, D. L. G. 1986. 'Biomass and production of fishes in natural and channelized streams', *Canadian Journal of Fisheries and Aquatic Science*, **43**, 1926–1934.
Prior, J., C. 1976. 'A regional guide to Iowa landforms', *Iowa Geological Survey Educational Series* **3**, p. 72.
Schlosser, I. J. 1982. 'Fish community structure and function along two habitat gradients in a headwater stream', *Ecological Monographs*, **52**, 395–414.
Schneberger, E., and Funk, J. L., (eds). 1971. *Stream channelization, a Symposium*. American Fisheries Society North Central Division Special Publication 2, p. 83.
Snedecor, G. W., and Cochran, W. G. 1967. *Statistical Methods*. Sixth edition. Iowa State University Press, Ames, p. 593.
Trautman, M. B. 1981. *The Fishes of Ohio*. Revised edition. The Ohio State University Press, Columbus, p. 782.
Vogel, S. 1981. *Life in Moving Fluids*. Princeton University Press, Princeton, New Jersey, p. 352.
Webb, P. W. 1975. 'Hydrodynamics and energetics of fish propulsion', *Fisheries Research Board of Canada Bulletin*, **190**, p. 158.
Zimmer, D. W., and Bachmann, R. W. 1978. 'Channelization and invertebrate drift in some Iowa streams', *Water Resources Bulletin*, **14**, 868–883.
Zippin, C. 1958. 'The removal method of population estimation', *Journal of Wildlife Management*, **22**, 82–90.