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THE INFLUENCE OF STREAM ORDER AND SELECTED STREAM BED PARAMETERS ON FISH DIVERSITY IN RAYSTOWN BRANCH, SUSQUEHANNA RIVER DRAINAGE, PENNSYLVANIA

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SUMMARY

Consistent relationships among certain physical parameters with stream order have been shown (summarized in Platt 1974). These parameters in combination are significant in influencing fish population densities and species diversity. Diversity of fishes in Raystown Branch was correlated most highly with stream order; other physical data were significantly correlated with both diversity and stream order. Data from Raystown Branch support the hypothesis that stream order represents a multidimensional network of the physical parameters which comprise it and, as such, can be used as a satisfactory composite index.

INTRODUCTION

Stream classifications based on various physical, chemical and biological parameters have been advanced to explain changes in faunal diversity within streams. Shelford (1911) originally described the longitudinal distribution of fishes in temperate stream habitats in terms of the geologic age of stream beds. The concept of ranking streams based on bifurcation ratios, drainage density and stream length was advanced by Horton (1945) and applied by Kuehne (1962) to the fish distribution of Doe Run, a tributary of Kentucky River. Strahler (1957) extended the use of this dimensionless number system for geomorphic basin studies. The physiological effects of temperature on longitudinal fish distribution were included by Burton & Odum (1945) but no attempt was made to separate the effects of temperature and basin morphometry (Sheldon 1968). Trautman (1942) investigated the importance of gradient in distribution, abundance and stocking potential. Huet (1959) discussed the effects of both gradient and width as applied to Western European streams. Hocutt & Stauffer (1975) studied the effect of gradient and other physical features on the longitudinal distribution of fishes in Conowingo Creek, Maryland/Pennsylvania. Harrel & Dorris (1968) showed a high correlation between stream order and numerous stream basin dimensions. Platts (1979) used stream size obtained by interpolative width and depth from stream order to predict fish population structure. Correlation between the presence and absence of fish species was used by Gorman & Karr (1978) to illustrate the influence of habitat on fish populations of small streams. Horwitz (1978) tested the relationship between diversity gradients and variability patterns by studying gradients of variability of discharge.

The purpose of this paper was to study the influence of stream order and selected stream

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bed parameters as a technique in determining fish diversity in Raystown Branch of the Susquehanna River drainage.

BASIN DESCRIPTION

Raystown Branch of the Susquehanna River drainage originates at an elevation of 56·3–25·5 m (U.S. Geological Survey Maps 1:24 000) in Somerset County of south central Pennsylvania and flows through Bedford and Huntingdon counties to its confluence with Juniata River near Smithfield, Pennsylvania. Stream length is approximately 165 km with gradient ranging from 32·4 to 0 km/m from source to mouth. Stream bed composition is primarily bedrock and gravel, with riffles and relative shallow pools predominating. The uppermost reaches drain the eastern edge of the Appalachian Plateau with most drainage in the Ridge and Valley physiographic province (Rizza *et al.* 1975). It flows east, roughtly perpendicular to Tussey Mountain, with major tributaries flowing parallel to Wills and Evitts mountains to the south and Dunning Mountain to the north (Fig. 1). After crossing Tussey Mountain, it turns north-east and continues between Tussey and Sideling Hill to its mouth at Huntingdon. The region drained by Raystown Branch is composed primarily of Devonian and Mississippian deposits (Rizza, Hughes & Smith 1975).

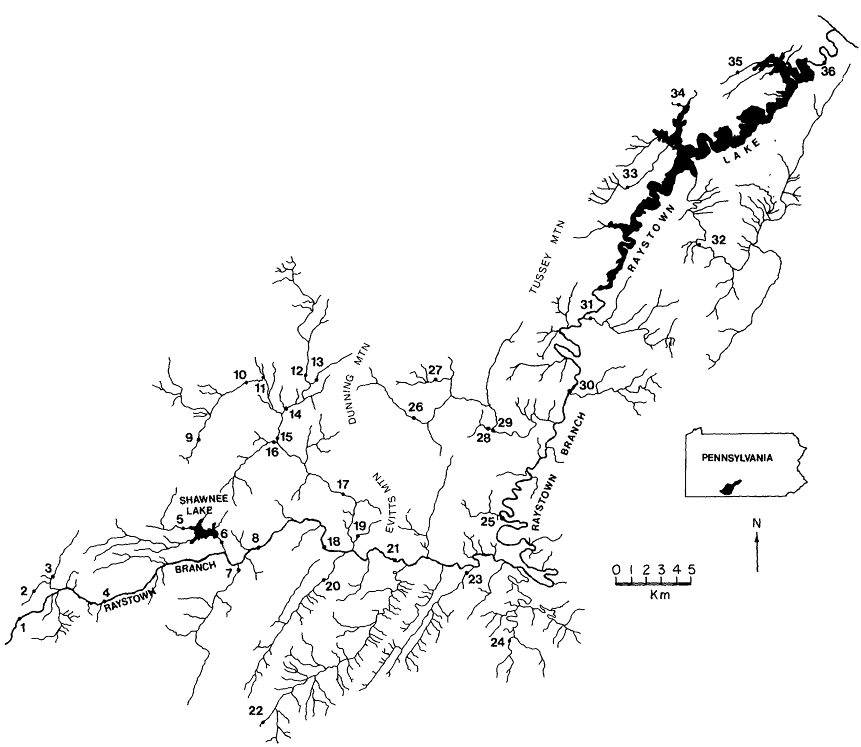

FIG. 1. Collecting stations in Raystown Branch, Susquehanna River drainage, Pennsylvania.

METHODS

Thirty-six stations were sampled in Raystown Branch between August and October, 1978 (Fig. 1). Fish collections were made with a 1·5 m × 3 m × 0·3 cm seine and/or a 220 V AC–DC electroshocker depending upon flow and substrate. Collecting continued in each habitat until a representative qualitative sample was obtained and it seemed unlikely that further effort would produce additional species (Hocutt 1978). Fish were preserved in 10% formalin, washed after 2 weeks, placed in 40% isopropanol for permanent storage in the Appalachian Environmental Laboratory Fish Museum, University of Maryland, Frostburg, Maryland.

Collection sites were chosen to allow a complete survey of the Raystown fish fauna and to insure that at least three collections were made for each stream order. Stream order (Horton 1945; Strahler 1957) and altitude for each station were determined with U.S. Geological Survey maps (1:24 000). Streams indicated as being seasonal on these maps were not considered in stream order designation.

Gradient at each locality was measured over a 33 m section using standard surveying techniques. Widths were measured perpendicular to stream flow at top, midpoints, and bottom of the 33 m gradient stretch; the narrowest and widest points were also determined. Depths were taken at 3 m intervals across the top, bottom and midpoint widths. Deepest and shallowest points were determined for each area sampled.

Brillouin's (1962) diversity index (in Pielou 1977) was calculated for each station. Diversity indices, stream order, gradient, maximum width, narrowest width, mean width, mean depth, maximum depth, altitude, total species, total individuals and the six most commonly occurring species were tabulated by station and correlated using Spearman's Rank correlation coefficient. Station 18 (artificial impoundment) and station 31 (no fish collected due to acid mine influx) were not included in the analysis.

RESULTS AND DISCUSSION

A total of 7795 fish represented by forty-five species distributed among ten families was collected from thirty-six localities on Raystown Branch (Fig. 1; Table 1). Minnows (Cyprinidae) and sunfish (Centrarchidae) were the dominant forms with respective totals of seventeen and nine species. *Rhinichythys atratulus*, *R. cataractae*, *Etheostoma olmstedi*, *Semotilus atromaculatus* and *Notropis cornutus* were the five most abundant species. *Rhinichthys atratulus* was the most commonly occurring species in first order streams, *R. cataractae* in second order streams, *Catostomus commersoni* in third, *Notropis rubellus* in fourth and *Noturus insignis* and *Lepomis auritus* in fifth order streams. Six species were found in all five stream orders: *Campostoma anomalum*, *Pimephales notatus*, *Rhinichthys cataractae*, *Micropterus dolomieui*, *Etheostoma blennioides* and *E. olmstedi*. First through fifth order contained the following number of species, respectively: 16, 25, 37, 25, 24.

Eight components correlated using Spearman's Rank correlation coefficient are presented in Table 2. The component, diversity index, was most highly correlated with number of species [0·9351, ($P \leqslant 0{\cdot}001$)] and number of organisms [0·6993, ($P \leqslant 0{\cdot}001$)] as would be expected since Brillouin's index is based on information theory (Pielou 1977). Certain biological correlations are also predictable. Number of organisms, number of species and diversity would be significantly correlated with maximum width [0·3591, ($P \leqslant 0{\cdot}019$); 0·5605, ($P \leqslant 0{\cdot}001$); 0·5825, ($P \leqslant 0{\cdot}001$); respectively] since increased volume and wider basin structure would allow more available habitat. The biological

TABLE 1. Number of species and individuals collected from Raystown Branch, 1978, by stream order[1]

Species collected	Stream order 1 Station no.					Stream order 2 Station no.							
	1	2	22	34	35	3	11	13	20	23	26	27	28
Anguilla rostrata													
Salmo gairdneri						2		1					
Salmo trutta								10	3			4	
Salvelinus fontinalis						5							
Esox americanus							7						
Campostoma anomalum					2		30		19	7			
Ericymba buccata							57						
Exoglossum maxillingua									2	2	1		5
Nocomis micropogon													
Notemigonus crysoleucas					2				1				
Notropis cornutus					3		26		28				
Notropis hudsonius									2		3		
Notropis procne													
Notropis rubellus									3				
Notropis spilopterus													
Pimephales notatus				11	2		1		1	3	2		
Pimephales promelas													
Rhinichthys atratulus	38	22	33	43	7	31	88		53	3	51		62
Rhinichthys cataractae	5		5			8	31	3	16	34	129		28
Semotilus atromaculatus		1		54	120		18	19	9	114	8		6
Semotilus corporalis							67		14	8	2		2
Semotilus margarita											16		
Catostomus commersoni				8	21			10	8	5	39	1	1
Erimyzon oblongus								1					
Hypentelium nigricans							1	2		2			
Ictalurus natalis					6								
Ictalurus nebulosus					2								
Nocturus insignis													
Fundulus diaphanus													
Ambloplites rupestris									6				
Lepomis auritus													
Lepomis gibbosus				1	4		6		2				
Lepomis macrochirus													
Lepomis megalotis									1				
Micropterus dolomieui	1			2			1		2	5			
Micropterus salmoides							3						
Pomoxis annularis													
Pomoxis nigromaculatus													
Etheostoma blennioides			5						6	26	1		
Etheostoma olmstedi				1	17		12		4	43	4		4
Etheostoma zonale[2]													
Perca flavescens					3								
Percina peltata													
Cottus sp.	6	4	4			16	9	21	27	31	8	46	

[1] Stations 18 (artificial impoundment) and 31 (acid mine flow: no fish collected) were not included in analysis and do not appear in table.
[2] First record of *Etheostoma zonale* (Cope) in the Juniata system.

components (diversity, number of species and number of organisms) were more highly correlated with stream order than any individual physical parameter. Of the biological components, diversity was most highly correlated with stream order [0·6415, ($P \leqslant 0{\cdot}001$)]. Similar results were published by Harrel, Davis & Dorris (1967), with a correlation coefficient of 0·96 between species diversity of fishes and stream order in the Otter Creek drainage basin of north-central Oklahoma.

Diversity indices increased with first through fourth order streams (Table 3). Increasing diversity with increasing stream order has been documented in previous studies (Kuehne 1962; Harrel & Dorris 1968; Whiteside & McNatt 1972; Platts 1979), and may be due to increased environmental fluctuations or increased available habitat. The mean diversity index for fifth order stations (25, 30, 36) was slightly lower than for fourth order stream stations. Whiteside & McNatt (1972) reported a decrease in diversity in fifth order streams, and suggested migration of fishes into lower order streams for spawning purposes,

Stream order 3 Station no.															Stream order 4 Station no.			Stream order 5 Station no.			Compilation of species occurrence by stream order				
4	5	6	7	9	10	12	15	16	17	19	24	29	32	33	8	14	21	25	30	36	1	2	3	4	5
																				2					x
																						x			
	12																					x	x		
																						x			
		1				6	4	1	6		2				3	3	2					x	x	x	
19		1	103	31	58	4	16	8	18	8			1	10		4	2	6		1	x	x	x	x	x
11		3	66	161	24	25	13	17			50					3						x	x	x	
10	1		5	4	10	12	4		16	10	1	18			9	21	4	12				x	x	x	x
17							7		6	15						1	19	16	5				x	x	x
		12																			x	x	x		
40		45	42	112	52	4	15	14	63	1		37				16	43				x	x	x	x	
1		18	9	18	16	11	6	1	20	2	1	7			61	9	26	1		13		x	x	x	x
																1								x	
26		2	14	1	28		29		12	4	23	1			7	16	150	5		1		x	x	x	x
			6				2				4				54		4	10					x	x	x
7	1	9	28	1	9	6	43	5	18		44		11			6	10	19		3	x	x	x	x	x
				1																			x		
109	66	1	26	55	28	13		79	61			25	1			37					x	x	x	x	
30	33	6	109	2	50	29	20	59	3	5		117		8		21	11	5	14		x	x	x	x	x
11	4	3	33	36	40	18	12	22	14			16	7			10	4				x	x	x	x	
12		20	14	12	7	6	14	24	4	11	7	13	12	9		6	10	23	1	19		x	x	x	x
																						x			
3	10	22	15	21	13	2	18	14	15	23	7	16	3			19	8				x	x	x	x	
						7										1						x	x	x	
3	3		12	5	4	2	6	1	14	21	5			10	1		6	27	4			x	x	x	x
		1	1				2		1				3			1	7	3			x		x	x	x
		1		1		6			1	1					1	1					x		x	x	
						9	6	2	2	8	1	3		10	4	9		15	5	3			x	x	x
																	1							x	
	3		1	13	2	4	1	3	7	1	8		1	15	11	3	7	18	32	28		x	x	x	x
			1						1		2		2		2		2	13	6	1			x	x	x
	1				3	14		3	1		5		7		1	3	3				x	x	x	x	
		1					2		3		6						1						x	x	
																						x			
5	1	2	30	2	6	1	1	2	1	6	7			5	1		6	16	30	2	x	x	x	x	x
	3	3		2	1	1		1	2	5			5							1		x	x		x
		12										1					4	1					x	x	x
		12															5		2				x	x	x
2			5		2		3		5	8		1			2	4	16	21	11		x	x	x	x	x
13	4		132	39	28	35	60	73	39	10	7	14	1	2	12	19	20	6		8	x	x	x	x	x
																				11					x
	16	21											17		2					3	x		x	x	
						1	14	2	19	48		1		14	1	13	11	6					x	x	x
50	34		17		20	3										16					x	x	x	x	

escape from high waters, or reduced seining efficiency due to increased depth and obstacles, as possible causes for the decrease. In this particular example, certain mitigating circumstances existed: station 30 may have been influenced by an acid mine effluent into its mainstream from nearby Six Mile Run, and station 36 was probably influenced by decreased collecting efficiency caused by the deep rocky channel, and the resultant swift current.

The correlation of mean depth to maximum [$0{\cdot}5582$, ($P \leqslant 0{\cdot}001$)] is a predictable association based on the change in basin structure from headwaters to mouth. Similarly, mean depth and maximum width are inversely correlated with gradient [$-0{\cdot}5765$, ($P \leqslant 0{\cdot}001$); $-0{\cdot}5361$, ($P \leqslant 0{\cdot}001$)]. Stream gradient, mean depth and maximum width showed consistent relationships with stream order [$-0{\cdot}5171$, ($P \leqslant 0{\cdot}001$); $0{\cdot}6294$, ($P \leqslant 0{\cdot}001$); $0{\cdot}8360$, ($P \leqslant 0{\cdot}001$)]. Platts (1974) stated similar relationships for certain structural variables with stream order.

TABLE 2. Spearman's rank correlation coefficient, with levels of significance in parentheses

		1	2	3	4	5	6	7	8
1	Stream order	1·000 (·000)							
2	Gradient	−0·5171 (·001)	1·000 (·000)						
3.	Maximum width	0·8360 (·001)	−0·5361 (·001)	1·000 (·000)					
4.	Altitude	−0·3913 (·011)	0·0811 (·324)	−0·3013 (·042)	1·000 (·000)				
5	Mean depth	0·6294 (·001)	−0·5765 (·001)	0·5582 (·001	−0·4182 (·007	1.000 (·000)			
6	No. of organisms	0.3787 (·014)	−0·3011 (·040)	0·3591 (·019)	−0·0689 (·349)	−0·0792 (·328)	1·000 (·000)		
7	No. of species	0·6202 (·001)	−0·4199 (·007)	0·5605 (·001)	−0·1677 (·172)	0·2207 (·105)	0·7856 (·001)	1·000 (·000)	
8	Diversity index	0·6415 (·001)	−0·3751 (·014)	0·5825 (·001)	−0·1947 (·135)	0·2370 (·089)	0·6993 (·001)	0·9351 (·001)	1·000 (·000)

TABLE 3. Station number, physical data, diversity indices and dominant species listed with corresponding stream orders

	Stream order 1	Stream order 2	Stream order 3	Stream order 4	Stream order 5
Station number	1, 2, 22, 34, 35	3, 11, 13, 20, 23, 26, 27, 28	4, 5, 6, 7, 9, 10, 12, 15, 16, 17, 19, 24, 29, 32, 33	8, 14, 21	25, 30, 36
Mean width (m)	2·71	4·64	11·07	16·86	42·25
Mean depth (cm)	4·91	12·35	14·55	22·11	37·38
Mean gradient (m/km)	17·42	12·08	5·58	3·57	3·9
Mean altitude (m)	422	361	336	329	242
Mean diversity index	0·985	1·463	2·208	2·214	2·061
Dominant species	*R. atratulus*	*R. cataractae*	*C. commersoni*	*N. rubellus*	*N. insignis* *L. auritus*

Physical parameters from first to fifth order showed decreasing mean gradient (17·4–3·9 m/km) and altitude (56·2–25·5 m), and increasing mean depth and mean width (4·9–37·4 cm; 2·7–42·3 m, respectively). These changes are predictable with increasing stream order and are attributable to increasing variables such as stream depth, velocity and surface area (Platts 1979). Horwitz (1978) stated that patterns of flow variability were correlated with gradients of species richness that fit the competition : trophic structure and extermination : colonization hypotheses, in which variability affects the habitat specialization, food specialization and extermination probabilities. Table 3 lists station numbers, physical data, diversity indices and dominant species for each stream order. The high degree of correlation between community structure and habitat structure in Raystown Branch, as expressed by stream order, supports the use of stream order system for lotic classification, and may prove more useful as a composite index in stream survey work than the individual physical parameters.

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