The Relationships Between Physical Habitat Factors and Benthic Diversity in Southeastern Oklahoma Streams

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In the early 1970's, the U.S. Fish and Wildlife Service developed the instream Flow Incremental Methodology and the Habitat Evaluation Procedures for providing quantitative estimates of flow needs of fish and wildlife and evaluating habitat losses associated with federal construction respectively (1, 2). The underlying assumption of both these methods is that animals are constrained in the environment, and that it is possible to develop quantitative relationships between physical factors and population characteristics such as biomass or frequency of occurrence.

The use of these two procedures has become widespread but concomitantly has come under increased scrutiny and criticism (3-5). Most individuals are willing to concede that animal populations are constrained by their environment but question the general applicability of the models developed. We reasoned that the general applicability of a model for benthic insects could be measured by the degree to which the same physical factors were correlated with population parameters in different sections of the same drainage.

Forty-three single benthic samples (10 from Upper Little River, 6 from Lower Little River, 15 from Glover Creek, and 12 from Mountain Fork River) were taken from riffles with a circular depletion sampler between July 20 and August 11, 1982 and identified to family. Shannon Weaver diversity indices were prepared for each site. At each sampling point, water temperature, specific conductivity, pH, depth, velocity, substrate type, gradient, altitude, stream order, and the percentage of the upstream area in clear cuts 1, 2, 3, and 4 (CC1, CC2, CC3, and CC4) years old were determined.

Water temperature and specific conductivity were measured with a Yellow Springs Instrument (YSI) combination temperature and conductivity meter and pH was measured with a YSI pH meter. Velocity was measured at 0.6 of the depth with a Pygmy Gurly current meter, and substrates were classified with a modified Wentworth particle scale (6). Stream gradient, stream order, altitude, and percentage of the upstream drainage covered with age one through age four clear cuts were estimated from basin maps.

The correlations between benthic diversity and natural and man-caused physical factors in the environment were used to develop Statistical Analysis Procedure 'Stepwise' models (7) for benthic populations in the entire drainage and each of four subdrainages.

Direct correlations between diversity and physical variables were low (Table 1). There was no significant Stepwise model when the data from the Little River System were considered as a whole. When data from each section were considered separately, significant models were developed, but they were different from each of the sections (Table 2).

Several authors have failed to show correlations between actual and predicted standing crops, diversity or frequency of occurrence, and physical factors for vertebrate species (3-5), but others have reported relatively good correlations (1). Other authors have found that even though the suggested relationships between physical factors and standing crops proved to be correct that

TABLE 1. Correlation coefficients between diversity and physical variables in the Little River system (sample sizes given in parentheses).

Variable	Little River System	Upper Little River	Lower Little River	Glover Creek	Mountain Fork
Altitude	0.02 (42)	0.16 (7)	0.13 (9)	0.00 (15)	0.03 (11)
CC1	− 0.11 (39)	− 0.14 (7)	0.72 (9)	0.02 (15)	0.00 (12)
CC2	− 0.05 (39)	0.38 (6)	0.08 (8)	0.20 (15)	− 0.09 (10)
CC3	0.07 (39)	0.38 (6)	− 0.21 (8)	0.17 (15)	− 0.09 (10)
CC4	0.18 (39)	0.09 (6)	0.32 (8)	0.25 (15)	− 0.16 (10)
Conductivity	0.18 (43)	− 0.30 (6)	0.19 (8)	0.43 (15)	0.40 (10)
Depth	0.17 (43)	0.22 (7)	0.15 (9)	0.17 (15)	0.23 (12)
Gradient	− 0.05 (42)	0.16 (7)	− 0.01 (9)	0.03 (15)	− 0.24 (11)
Order	0.28 (43)	0.10 (7)	0.08 (9)	0.39 (15)	0.55 (12)
pH	0.14 (43)	− 0.17 (7)	0.48 (9)	0.15 (15)	0.11 (12)
Substrate	0.10 (43)	0.18 (7)	0.38 (7)	− 0.14 (15)	− 0.19 (12)
Velocity	0.13 (43)	0.69 (7)	0.17 (9)	0.39 (15)	0.20 (12)

TABLE 2. Stepwise models for all segments of Little River drainage; LR = Little River, ULR = Upper Little River, LLR = lower Little River, GLC = Glover Creek, and MFR = Mountain Fork River. X indicates where a variable was used in the model.

Loc. Model #	R^2 %	Variables Altitude	Conductivity	CC1	CC2	CC3	CC4	Depth	Gradient	Order	pH	Substrate	Velocity
LR													
1.										X			
2.										X		X	
3.			X							X		X	
4.*			X							X		X	X
5.			X				X			X		X	X
6.		X	X				X			X		X	X
7.		X	X				X		X	X		X	
8.		X	X				X	X		X		X	X
8.		X	X		X		X		X	X		X	X
9.		X	X		X		X	X	X	X		X	X
10.		X	X		X		X	X	X	X	X	X	X
11.		X	X	X	X		X	X	X	X	X	X	X
12.		X	X	X	X	X	X	X	X	X	X	X	X
ULR													
1.												X	
2.		X										X	
2.		X	X										
3.		X	X				X						
4.		X	X			X	X						
5.*	100	X	X			X	X				X		

TABLE 2. Continued.

Loc. Model #	R^2 %	Altitude	Conductivity	CC1	CC2	CC3	CC4	Depth	Gradient	Order	pH	Substrate	Velocity
LLR													
1.			X										
2.			X									X	
3.			X	X								X	
4.			X	X					X			X	
4.			X		X				X			X	
5.			X		X				X	X		X	
6.			X		X				X	X		X	X
6.			X	X	X				X	X			X
6.		X	X	X	X				X	X			
7.*	100	X	X	X	X				X	X			X
GCL													
1.							X						
2.			X				X						
3.			X				X				X		
4.			X	X			X				X		
5.			X	X			X			X	X		
6.			X	X			X			X	X	X	
7.			X	X		X	X			X	X	X	
7.			X	X		X	X	X			X	X	
8.*	86		X	X		X	X	X			X	X	X
MTF													
1.										X			
2.			X							X			
3.			X	X						X			
3.*				X			X			X			
4.*			X	X			X			X			
5.*			X	X			X			X		X	
6.*		X	X	X			X			X		X	
7.*		X	X	X			X		X	X		X	
7.*			X	X			X	X		X	X	X	
8.*			X	X	X		X	X	X		X	X	
9.*	100		X		X	X	X	X			X		X

* sig. at $p < 0.05$

models are predictive only if one bases them on data collected during the period when habitat is actually limiting (8, 9) and over a limited geographic area (10).

A single significant diversity habitat relationship in our data would tend to support the basic assumption, that the same physical factor limits benthic populations in similar areas. Our analysis failed to support this conclusion, and would suggest caution in the use of general benthic insect models outside the area for which they were developed.

Although our efforts by no means constitute a rigorous test of Habitat Evaluation Procedures and Instream Flow Incremental Methodology, they do present evidence that these approaches require careful application if predictability for benthic populations is to be obtained.

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