Influence of Gradient on the Distribution of Fishes in Conowingo Creek, Maryland and Pennsylvania

ABSTRACT: Twenty-seven fish species were collected from Conowingo Creek at eleven stations during the summer, 1970. Species most abundant were *Rhinichthys atratulus*, *Notropis cornutus*, *Exoglossum maxillingua*, *Semotilus atromaculatus* and *Catostomus commersoni*. A Spearman's rank correlation coefficient matrix was calculated for biological and physical parameters. Distribution of fishes appeared related to width and depth of the stream, but was most influenced by gradient.

Introduction

Ichthyological Associates since 1966 has conducted an intensive ecological investigation of Conowingo Reservoir, the lower Susquehanna River, in relation to the Peach Bottom nuclear generating facility and Muddy Run pumped storage unit. The study of Conowingo Creek was initiated during the summer of 1970 to provide information on fish populations representative of Conowingo Reservoir tributaries. Water quality in Conowingo Creek was similar to that of other streams in southern Lancaster County. The area was intensively farmed, thus contributed through runoff and erosion to eutrophication of the stream; however, water quality was not considered to be a significant factor limiting fish distribution. Industry was absent.

Numerous studies (Shelford 1911; Thompson and Hunt 1930; Luce 1933; Trautman 1942; Burton and Odum 1945; Huet 1959; Kuehne 1962; Larimore and Smith 1963; Ross 1969; and Lotrich 1973) have shown that the longitudinal succession of stream fishes may be correlated to a number of physical, chemical and biological factors. More recently, Moyle and Nichols (1973) applied multivariate analysis to determine which of 20 variables most influenced the distribution of fish associations in streams of the Sierra Nevada foothills. The latter study re-emphasized the fact that individual environmental variables do not necessarily act independently.

Study Area

Conowingo Creek originates from springs along the south slope of Mine Ridge, east of Buck, Pennsylvania, and flows approximately 24.9 km in Pennsylvania and 5.6 km in Maryland before its confluence with the Susquehanna River, Conowingo Reservoir, at Pilot Station, Maryland (Figure 1). Mine Ridge varies in elevation from 213–244 m above sea level while the confluence is at 33.5 m. An outstanding feature of the stream is the steep gradient, 6.25 meters per kilometer (m/km) average for the 30.5 km length, which dramatically increases to over 26.5 m/km for the last 1.0 km. Conowingo Creek winds through the rolling Piedmont Upland Province of the Appalachian Highlands, characterized by crystalline (metamorphosed) rocks of Precambrian or Paleozoic origin; schist, serpentine, gneiss and quartzite are common (Willard, 1970). Climax vegetation is oak-chestnut forest. Soils are podzolic.

Methods and Materials

Eleven stations were established along the course of the creek and sampled during the Summer, 1970 (Fig. 1): (1) Route 372 bridge, Buck, Pa.; (2) Deaver Road bridge, Old Buck School, Pa.; (3) Scotland Road bridge, Hopkins Mill Dam, Pa.; (4) Cardinal Road bridge, Old Conowingo School, Pa.; (5) Black Bear Road bridge, Bethel Church, Pa.; (6) Route 222 bridge, Goshen, Pa.; (7) Black Baron Road bridge, New Texas, Pa.; (8) Old Mill Road bridge, Pleasant Grove, Pa.; (9) Old Conowingo Road bridge, Oakwood, Md.; (10) 0.5 km upstream of mouth of Conowingo Creek, Pilot Station, Md.; and, (11) 90 m above first riffles from mouth of Conowingo Creek, Pilot Station, Md.

Stations were sampled once with seine and once using an electrofishing unit powered by a Honda Model 300 portable generator, except for Station 1 which was sampled only once by electrofishing. Collections were preserved in 10% formalin and stored in 40% iso-

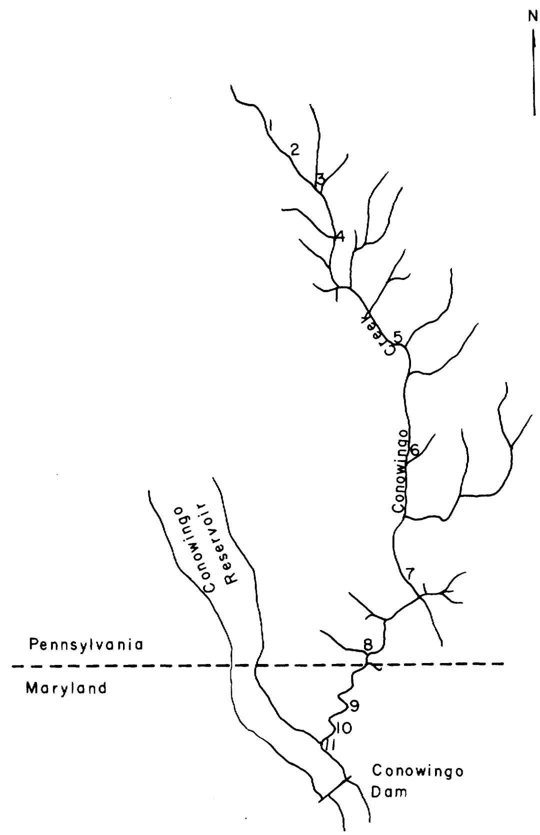

Fig. 1. Conowingo Creek drainage basin and location of stations 1–11.

TABLE 1. Numbers of fishes collected from Conowingo Creek.

Station	1	2	3	4	5	6	7	8	9	10	11	Total
Width (meters)	0.9	1.5	3.0	4.6	6.1	8.5	12.2	12.2	9.1	9.1	9.1	
Depth (meters)	0.08	0.15	0.6	0.9	0.9	1.4	0.9	1.7	1.2	1.5	0.9	
Gradient (m/km)	19.3	10.0	13.4	7.8	5.5	3.0	3.0	2.5	3.4	28.4	28.4	
Number of Collections	1	2	2	2	2	2	2	2	2	2	2	21
Number of Species	3	8	11	15	12	21	20	21	16	7	11	27
Diversity Index (I)	0.58	0.73	1.72	1.78	1.98	2.31	2.53	2..23	2.10	1.11	1.68	
Anguilla rostrata	—	—	3	1	—	—	—	—	1	—	—	5
Salmo trutta	—	—	—	—	—	1	—	—	—	—	—	1
Campostoma anomalum	—	—	1	8	8	19	25	2	7	—	—	70
Clinostomus funduloides	—	3	51	13	15	2	1	—	—	—	—	85
Exoglossum maxillingua	1	3	35	39	7	20	7	17	7	1	—	137
Nocomis micropogon	—	—	—	1	1	1	2	4	11	12	10	42
Notropis analostanus	—	—	—	—	—	—	23	1	20	—	—	44
N. cornutus	—	1	18	18	30	26	6	13	25	4	1	142
N. hudsonius	—	—	—	1	7	19	38	9	5	—	1	80
N. procne	—	—	—	—	—	3	24	8	1	—	—	36
N. rubellus	—	—	—	—	—	—	1	1	14	1	1	18
N. spilopterus	—	—	—	—	—	2	14	11	—	—	4	31
Pimephales notatus	—	—	—	—	—	—	6	74	1	—	—	81
Rhinichthys atratulus	17	110	178	168	24	15	22	1	6	—	1	542
R. cataractae	—	5	17	15	11	8	13	8	1	—	2	80
Semotilus atromaculatus	5	8	30	44	11	8	11	3	—	—	—	120
S. corporalis	—	—	—	—	—	1	—	—	—	—	—	1
Catostomus commersoni	—	3	25	14	1	3	21	18	13	2	3	103
Hypentelium nigricans	—	—	12	9	4	7	10	3	2	—	—	47
Ictalurus nebulosus	—	—	—	—	—	1	—	—	—	—	—	1
I. punctatus	—	—	—	—	—	—	—	—	—	1	4	5
Noturus insignis	—	—	—	2	—	1	4	15	—	—	3	25
Lepomis auritus	—	—	—	—	—	2	4	5	—	—	1	12
L. gibbosus	—	—	—	1	—	5	—	8	—	—	—	14
L. macrochirus	—	—	—	—	—	—	—	4	—	—	—	4
Micropterus dolomieui	—	—	—	—	—	1	2	3	1	1	—	8
Etheostoma olmstedi	—	2	14	36	3	3	23	2	1	—	—	84
Total specimens	23	135	384	370	122	148	257	210	116	22	31	1,818

TABLE 2. Spearman's correlation coefficients* for factors influencing fish distribution in Conowingo Creek.

	1	2	3	4	5	6	7
1. River km (Station)	1.00 (.0000)						
2. Width	.85 (.0012)	1.00 (.0000)					
3. Depth	.75 (.0080)	.78 (.0049)	1.00 (.0000)				
4. Gradient	−.03 (.9341)	−.45 (.1672)	−.43 (.1795)	1.00 (.0000)			
5. No. of Organisms	−.33 (.3272)	.00 (.9863)	−.07 (.8322)	−.52 (.0982)	1.00 (.0000)		
6. No. of Species	.31 (.6453)	.61 (.0437)	.60 (.0489)	−.90 (.0003)	.54 (.0817)	1.00 (.0000)	
7. Diversity Indices	.35 (.2985)	.67 (.0228)	.57 (.0664)	−.87 (.0008)	.51 (.1072)	.95 (.0001)	1.00 (.0000)

* Number in parenthesis is the probability > |R| under the $H_0: R = 0$ (d.f. = 11).

propanol. Stream gradients in meters per kilometer were calculated between elevation intervals on topographic maps scaled 1:24,000, 7.5 minute quadrangles.

Diversity indices were calculated using the formula:

$$H = \frac{1}{N} \times Log_e \left(\frac{N!}{N_1! \times N_2! \times N_3! \times \ldots N_s!} \right)$$

where:

N is the number of organisms in the collection; $N_1, N_2 \cdots N_i$ are the number of organisms in species one, two ..., etc.; and s is the number of species in the collection (Pielou 1969).

Because the data did not satisfy all of the assumptions of a normal distribution, a Spearman's rank correlation coefficient matrix (Conover, 1971) was determined for river kilometer (station locality), gradient, width, depth, number of specimens, number of species, and diversity indices.

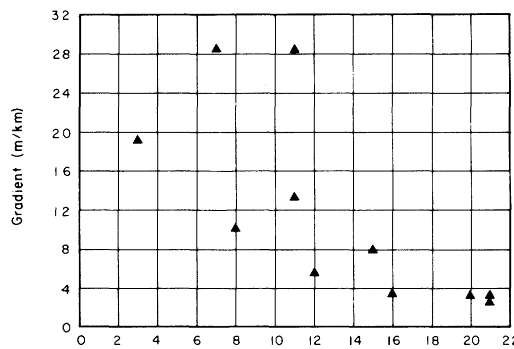

Fig. 2. Analysis of the number of fish species versus gradient in meters per kilometer for Conowingo Creek, Md.-Pa.

Results

Twenty-one collections yielded 27 species and 1,817 specimens (Table 1). No single species was common to all stations. *Exoglossum maxillingua*, *Notropis cornutus*, *Rhinichthys atratulus* and *Catostomus commersoni* were each present at ten sample sites. *Salmo trutta*, *Semotilus corporalis*, *Ictalurus nebulosus* and *Lepomis macrochirus* were each collected from a single locality. The most abundant species present was *R. atratulus* (542 specimens), followed by *N. cornutus* (142), *E. maxillingua* (137), *Semotilus atromaculatus* (120), and *C. commersoni* (103).

Gradient decreased in Conowingo Creek from the headwaters to the Maryland/Pennsylvania state line, but increased substantially to the mouth thereafter. Increased gradient in the lower course was caused by the creek flowing through high bluffs bordering the Susquehanna River, which has cut through the peneplain terraces of the surrounding piedmont to the present base level.

Results obtained by Spearman's rank correlation coefficient matrix (Table 2) when the total number of organisms, total number of species, and diversity indices were compared with the physical variables (river kilometer, width, depth and gradient), showed that the effects of physical parameters were interrelated. However, gradient was the parameter that most influenced the distribution of fish in Conowingo Creek. The greatest number of species in Conowingo Creek was found at gradients between 2.5 and 3.4 m/km.

Station locality (river kilometer) was correlated highly with width (0.85) and depth (0.75), but had little influence on the number of taxa (0.31) or specimens (−0.33) collected. Width and depth were highly correlated (0.78), but were of significantly less importance than gradient (−0.90) in influencing distribution of fish in Conowingo Creek (Fig. 2).

Numbers of each species collected per locality indicated that *Clinostomus funduloides* and *S. atromaculatus* were headwater species. In contrast, *Nocomis micropogon* and *Notropis rubellus* were most common in the lower course of Conowingo Creek. *Rhinichthys cataractae* and *R. atratulus* were collected in most of the survey area, but were more abundant in middle to headwater localities. Greatest numbers of *Campostoma anomalum*, *E. maxillingua*, *Notropis hud-*

sonius, *Notropis procne*, *Hypentelium nigricans*, and *Etheostoma olmstedi* were collected near the middle of the survey area. *Pimephales notatus* was abundant only at Station 8, location of lowest gradient.

Species succession in stream fishes is usually a factor of species addition rather than one of replacement (Sheldon, 1968; Lotrich, 1973). This was observed in Conowingo Creek where the number of species increased from three at Station 1 (headwaters) to 21 at Station 8. A sharp reduction in stream gradient occurred between these localities. Gradient increased and number of species decreased downstream from Station 8.

Larimore et al. (1952) depicted relative abundance of four species of darters in Jordan Creek, Illinois, by percent catch of each species per locality. This approach was applied to Conowingo Creek data for the four most abundant cyprinids: *R. atratulus*, *N. cornutus*, *E. maxillingua* and *S. atromaculatus* (Figure 3). In terms of relative abundance, *R. atratulus* decreased in abundance and *N. cornutus* increased in abundance from headwaters to mouth. *S. atromaculatus* distribution was similar to that of *R. atratulus* although its abundance was considerably lower. *E. maxillingua* showed preference for low gradient localities similar to those found at Stations 6–9.

Discussion

Additional species may occur in Conowingo Creek other than those collected. *Micropterus salmoides* has been reported (D. W. Daniels, pers. commun.). Also, the Pennsylvania Fish Commission has stocked *Salvelinus fontinalis* and *Salmo gairdneri* in the Pennsylvania portion of Conowingo Creek in recent years. It is likely that *Cyprinus carpio*, *Notropis amoenus*, *Notemigonus crysoleucas*, *Carpiodes cyprinus*, *Percina caprodes*, and *Percina peltata*, which have been taken in Conowingo Reservoir near the mouth of Conowingo Creek, may be found within the study area (particularly Station 11) at certain times of the year. *Ictalurus punctatus* entered Stations 10 and 11 from the reservoir in this manner, but has not successfully traversed the swift currents to populate upstream localities. *Etheostoma zonale* was recently collected from nearby Wissler's Run, a tributary of the lower Susquehanna River, Conowingo Reservoir. Its distribution was apparently enhanced by severe flooding that accompanied Hurricane Agnes (T. W. Robbins, pers. commun.); other upper Susquehanna taxa may have spread similarly in distribution.

Many physical factors have been shown to influence the longitudinal distribution of stream fishes. Most factors are inseparable, each playing a significant role in forming the specific microhabitat. However, as demonstrated by the results of this and other (Shelford 1968; Moyle and Nichols 1973) investigations, it is possible to distinguish those factors most important. As indicated by this investigation, gradient could help explain the distribution of many Pennsylvania fishes which have not been systematically studied since the early work of Fowler (1919).

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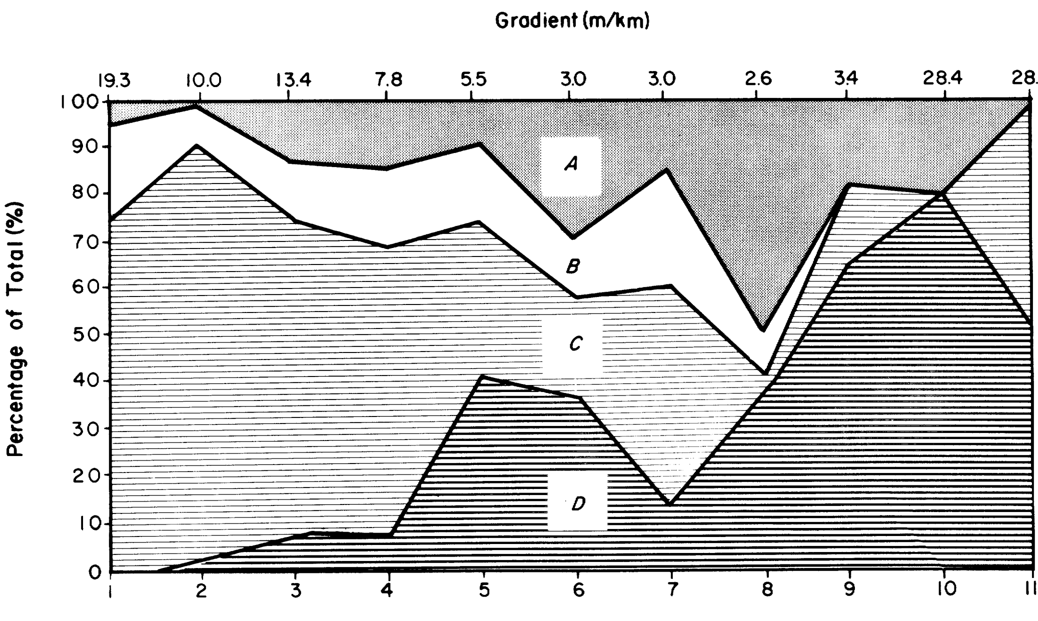

Fig. 3. Distribution (in percent) of the four most abundant minnows (Cyprinidae) collected in Conowingo Creek, stations 1–11, with gradients noted. (A: *Exoglossum maxillingua;* B: *Semotilus atromaculatus;* C: *Rhinichthys atratulus;* and D: *Notropis cornutus*).

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Abundance of Submerged Vascular Vegetation in the Rhode River from 1966 to 1973

ABSTRACT: Surveys on the distribution and abundance of submerged vascular plants in the Rhode River showed that there was an irregular decline in the amount of vegetation from 1966 to 1973, along with significant changes in species dominance. In 1966, redheadgrass (*Potamogeton perfoliatus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) were both very abundant with lesser amounts of widgeongrass (*Ruppia maritima*), horned pondweed (*Zannichellia palustris*), sago pondweed (*Potamogeton pectinatus*), and elodea (*Elodea canadensis*). In 1967, all of these species declined substantially, and elodea disappeared entirely. In 1968, redheadgrass and horned pondweed returned in substantial abundance, but they again declined in 1969 and virtually all submerged aquatics disappeared in 1970. In 1972, horned pondweed and sago pondweed reached an eight-year peak, but other species remained at very low levels. In 1973, all species were low, and a prominent lack of vegetation similar to 1967, 1970, and 1971 occurred again. Elodea has not been seen in the Rhode River since 1966. We believe these changes represent a decline in environmental quality in the Rhode River that may have serious long-range implications.

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Introduction

This report presents data on the abundance of five species of submerged vascular plants in the Rhode River (Fig. 1), a subestuary of Chesapeak Bay, seven miles south of Annapolis. Preliminary observations in the early 1960's indicated that the Rhode River had an abundant community of submerged macrophytes which was dominated in the mid-60's by Eurasian watermilfoil (*Myriophyllum spicatum*) and redheadgrass (*Potamogeton perfoliatus*). The former was part of an explosive growth of watermilfoil which occurred throughout the upper Bay in the early 1960's and displaced much of the native vegetation (Bayley, Rabin and Southwick 1968; Elser 1966).

We began accurate field surveys of submerged vegetation in Middle, Back and Rhode rivers in 1966. In this year, there was a prominent decline in the abundance and distribution of watermilfoil throughout the upper Bay, probably caused by the interaction of milfoil disease and increased turbidity (Bayley et al. 1968; Elser 1967). In 1967, virtually all submerged vegetation disappeared in the Rhode River, a phenomenon called the "Rhode River evanescence" by Elser (1967). We established an annual