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COLONIZATION OF MACROBENTHIC COMMUNITIES ON ARTIFICIAL SUBSTRATES

by

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ABSTRACT

A series of 30 artificial substrates were anchored in the North Fork of the Roanoke River for 30 days to check the hypothesis that the colonization of artificial substrates for macrobenthos in a freshwater stream follows the MacArthur-Wilson Equilibrium equation as proposed for island faunas. Immigration rates and extinction rates followed the simple exponential as proposed by MacArthur-Wilson. Extinction rate equaled colonization rate on approximately day 22. Diversity indices decreased throughout the study period and suggested that the community stability on the artificial substrates was precluded by the lack of diverse habitats. Colonization of Diptera larvae increased with time, while colonization of Trichoptera, Plecoptera and Coleoptera reached a maximum on day 10. This sequence appeared to be affected by the siltation of the substrates through time.

INTRODUCTION

MOON (1935; 1940) and WENE and WICKLIFF (1940) were the first to use artificial substrates to collect macrobenthos (in: HOCUTT, 1974). Since then, many other authors have used various types of substrates to sample stream invertebrates (BRITT, 1955; CAUTHRON, 1961; DICKSON, CAIRNS and ARNOLD, 1971; DICKSON and CAIRNS, 1972; FULLNER, 1971; HENSON, 1965; HESTER, and DENDY, 1962; HOCUTT, 1974; HOLT, 1962; SIMMONS and

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WINFIELD, 1971). For a description of the different types of substrates used, see HOCUTT (1974) and SIMMONS and WINFIELD (1971).

The purpose of this study was threefold. First, we attempted to fit colonization of artificial substrates to the equilibrium model proposed by MACARTHUR and WILSON (1963) for island faunas. In so doing, we were duplicating the work of DICKSON and CAIRNS (1972) who found the colonization of artificial substrates fit the model at $p < .25$ with 7 df. Secondly, we wanted to determine if this relatively poor fit was due to some other process controlling colonization (i. e. another model) or whether it was due to the lack of diverse habitat offered by the artifical substrates. Finally, an attempt was also made to determine trends of colonization for the most abaundant aquatic insect orders.

METHODS AND MATERIALS

Thirty artificial substrates were anchored in a riffle section of the North Fork of the Roanoke River, Montgomery County, Virginia. Each substrate consisted of a Bar-B-Q chicken basket filled with 20 4×4 inch sections of 3M Corporation's 200 conservation webbing. The substrates differed from those used by DICKSON and CAIRNS (1972) in that their substrates were not enclosed by a basket. We had hoped that the use of the chicken basket would stabilize the habitat offered by the conservation webbing. All samples were anchored on 11 April, 1974. Five substrates were removed every five days for a period of 30 days. After removal, the entire substrate was preserved in 40 percent isopropanel and taken to the laboratory. On each sampling day, one three minute kick sample was taken with a standard D-frame kick net. All organisms were sorted and identified to taxa.

The total number of species, the number of new species, the number of recurring species, and the number of species eliminated were recorded for each sampling period. New species were defined as those which had never occurred before; recurring species, as those which were eliminated, but subsequently reappeared; and species eliminated as those which occurred in the previous sample, but were now absent. Colonization rate was calculated as the number of new species plus the number of recurring species divided by the time in days between sampling periods. Extinction rate was calculated by dividing the number of species eliminated by the time in days. Since it is impossible to continually observe colonization and extinction, the five artificial substrates for each sampling period had to be grouped for the calculation of colonization and extinction rate. The above definitions and methods follow those used by DICKSON and CAIRNS (1972).

In addition, diversity indices were calculated for each sampling period ($\bar{d}$, WILHM and DORRIS, 1968). Diversity indices were plotted against time to determine how diversity changed with time. Finally, the most abundant aquatic insects were grouped by taxonomic order (to increase sample size) for each period and their abundance was plotted against time to determine any group specific trends of colonization.

RESULTS AND DISCUSSION

The artifical substrates resulted in the collection of a total of 5372 individuals represented by 40 taxa (Table 1). Kick samples produced a total

TABLE 1 — Number of specimens of each taxa captured with artificial substrates from 11 April — 11 May, 1974

Subsample	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Day			5					10					15		
Taxa															
Annelida															1
Ephemeroptera															
Ephemera															
Stenonema	1	1	1	3	1	2	1			5	2	2		1	3
Iron										1					
Heptagenia															
Isonychia	1	9	5	10	8	1	8	1	2	9	5	1		11	9
Ephemerella	9	30	10	27	26	19	35	27	39	26	25	11	16	17	44
Pseudocloeon															
Paraleptophlebia		1													
Baetis		9		1	2	4	5	8	7	7	11	1			9
Ameletus		2				1		2	4						
Plecoptera															
Pteronarcys														1	
Peltoperla	1		1	1	3		5	3		1					1
Memoura	6	49	3	47	10	7	65	42	46	26	7	1		5	45
Isoperla								1			1				
Isogenus	1	9		14	6		15	8	6	13	2				3
Chloroperla		1	1	3	1		3		2	3	2			2	
Alloperla		1			1						1				
Paraperla		5		4	2	1	7	5	2						4

TABLE 1 (continued)

Subsample	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Day			5					10					15		
Taxa															
Trichoptera															
Hydropsychidae		4		9	6		12	5	17	19	1	1	1	7	13
Rhyacophilidae		3	1	1	1	1				1					
Philopotamidae				1				1							
Psychomyiidae			1				1			1					
Limnephilidae															
Coleoptera															
Elmidae		6	1	3	2		2	1	1	1	30	3	1	13	33
Dryopidae		1				1					1				
Hydrophilidae			1												
Diptera															
Tipulidae															1
Chironomidae		113	4	52	13	26	49	52	49	46		2	30	11	131
Empididae			1												
Simuliidae		1			1		1	1							3
Odonata															
Agrion					1										1
Megaloptera															
Corydalus															
Gastropoda															
Gonibasis								1							
Physa															
Amphipoda															
Gammarus							1	2		1					
Decapoda															
Cambarus															
Pisces															
Cottus Bairdi															
Noturus															
Amphidia															
Eurycea		1				1									1

TABLE 1 (continued)

Subsample	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Day			20					25					30		
Taxa															
Annelida								1							
Ephemeroptera															
Ephemera											1				
Stenonema	1		3	1		12	3	6	4	3	5	7	6	10	10
Iron															
Heptagenia										1					
Isonychia	4	1	3		2	1		4	1	7		5	1		1
Ephemerella	3	3	14	13	8	27	46	51	37	63	46	48	47	56	28
Pseudocloeon									2						
Paraleptophlebia								3	1	1	2		1	1	
Baetis		1	7	4	4	28	35	37	10	11	1	14	1	1	8
Ameletus															
Plecoptera															
Pteronarcys															
Peltoperla	1	2		1					2	3				2	
Nemoura	1	3	12		1			1	32	99	3	4	4	1	
Isoperla		1		1				1	1						
Isogenus	4	3	5	10	1			2	3	7	3		1	2	
Chloroperla		1	2	4	2		1	4	5	7		1	2	6	1
Alloperla			2	2					1						
Paraperla			3	1		1	3	4	5		3	7			2
Trichoptera															
Hydropsychidae			2	1			1	3	9	12	1	1	1		1
Rhyacophilidae										1					
Philopotamidae															2
Psychomyiidae															
Limnephilidae						2			1			1			
Coleoptera															
Elmidae			1			3	7	8	1	10	2	11	1	5	2
Dryopidae							1								
Hyarophilidae															

TABLE 1 **(continued)**

Subsample	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Day			20					25					30		
Taxa															
Diptera															
Tipulidae	1							1							
Chironomidae	26	26	84	67	39	235	267	267	178	275	159	269	242	238	166
Empididae					2	1	1	6			4				1
Simuliidae	1						1					1			
Odonata															
Agrion					1						2				
Megaloptera															
Corydalus											1				
Gastropoda															
Goniobasis						1	1					2	4		
Physa					1							2	4		
Amphipoda															
Gammarus						2	1	1		1		7		1	
Decapoda															
Cambarus			1												
Pisces															
Cottus bairdi			1	1		2	7	5	2		1		5	3	
Noturus									1					1	
Amphidia															
Eurycea								1	2		2	1			

of 1646 organisms represented by 35 taxa (Table 2). FROST *et al.* (1971) showed that three one-minute kick samples yield an excellent estimate of the number of species present. A qualitative comparison of the kick samples and artificial substrate samples showed no drastic difference in the kinds

TABLE 2 — **Number of specimens of each taxa captured with a D-frame kick net from 11 April — 11 May, 1974**

Day	5	10	15	20	25	30
Taxa						
Ephemferoptera						
Ephemera	1		1	1	1	
Stenorema	13	7		15	5	12
Iron	2	2	1			
Heptagenia					1	
Isonychia	2	22	26	27		4
Ephemerella	37	81	47	195	46	
Pseudocloeon	1		5			21
Paraleptophelia	2	6				
Baetis	2	20	14	72	7	
Ameletus		1				
Plecoptera						
Pteronascys						1
Peltoperla						1
Nemoura		4	1	1		
Acroneuria	1	1				
Isoperla			1	2		
Isogenus				4	1	1
Chloroperla		2	3	1		
Alloperla		1				
Paraperla						3
Trichoptera						
Hydropsychidae	20	28	17	69	23	17
Rhyacophilidae				2		
Philopotomidae		1	1	5		
Limnephilidae						1
Coleoptera						
Elmidae		35	29	19	54	19
Psephenidae					1	
Diptera						
Tipulidae	1	6	3	21	31	4
Chironamidae	26	56	38	37	323	20
Empididae	2		3	11	5	1
Simulidae		1		2	1	

TABLE 2 (continued)

Day	5	10	15	20	25	30
Taxa						
Hydracarina					1	
Mollusca						
Goniobasis ssp.	1	2	3		2	
Goniobasis ssp.	1					
Physa					1	
Pisces						
Cottus bairdi		1	3		1	
Rhinichthys atralatus			1			

and numbers of organisms collected. All invertebrate taxa collected in the kick samples were represented in the artificial substrate collection. Four Dryopidae (Order: Coleoptera) were found on the substrates but did not appear in any of the kick samples. Other invertebrates not found in the kick samples included *Corydalus* (Order: Meyaloptera), *Cambarus* (Order: Decapoda), Hydrophilidae (Order: Coleoptera), and Annelida.

The total number of species, new species, recurring species and species eliminated are summarized in Table 3. Colonization rates (Figure 1) and extinction rates (Figure 2) were regressed against the logarithm of time in days as suggested by MACARTHUR and WILSON (1963, 1967) and DICKSON and CAIRNS (1972). Colonization rate equaled extinction rate on approximately day 22. Both regression lines were more significant ($p < 13$, $df = 4$) than the values found by DICKSON and CAIRNS (1972), ($p < 25$, $df = 7$). A linear regression, second degree polynomial, third degree polynomials fitted to the data for extinction rate, and colonization rate all had a value less significant than 13. Again, these results agree with those of DICKSON and CAIRNS (1972).

Regression analysis of diversity indices versus time in days (Figure 3) indicated that diversity decreased with time ($p < .01$, $df = 4$). If diversity indices are assumed to be an indication of community «health» PATRICK, (1949), it would appear that the «health» of the artificial substrate decreased through the study period. DICKSON and CAIRNS (1972) showed that stabi-

TABLE 3 — **Total number of species, number of new species, recurring species, and species eliminated, captured from 11 April — 11 May, 1974**

Day	Total No. of Species	New Species	Recurring Species	Species Eliminated
5	23	23		
10	24	5		4
15	23	4	1	6
20	21	3	1	6
25	30	4	7	2
30	27	2	3	

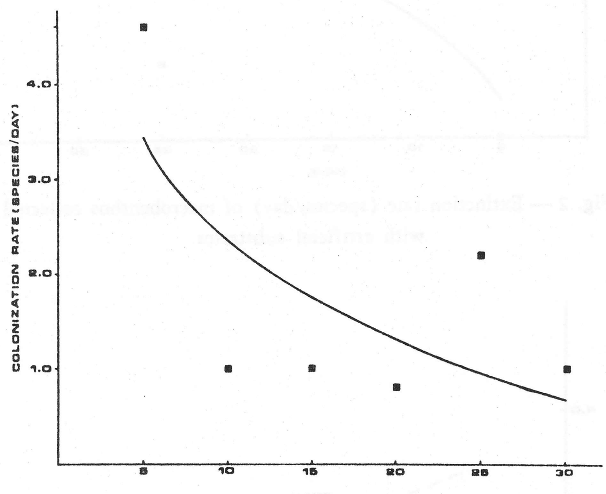

Fig. 1 — Colonization rate (species/day) of macrobenthos colected with artificial substates.

lity of the macroinvertebrates on the substrates was transitory. They postulated that the lack of stability was caused by the lack of diverse habitats in the artificial substrates. They related this colonization pattern to an «old-field sucession». A similar hypothesis (i. e., lack of diverse habitat) may also be used to explain a decrease in community health. Therefore, an artificial substrate offering a more varied habitat may be more useful in quantitative analysis of macrobenthic communities.

The five abundant groups of aquatic insect (Order: Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Diptera) were grouped by order and analyzed for colonization trends. An analysis of variance ($p < .05$, $df = 5$)

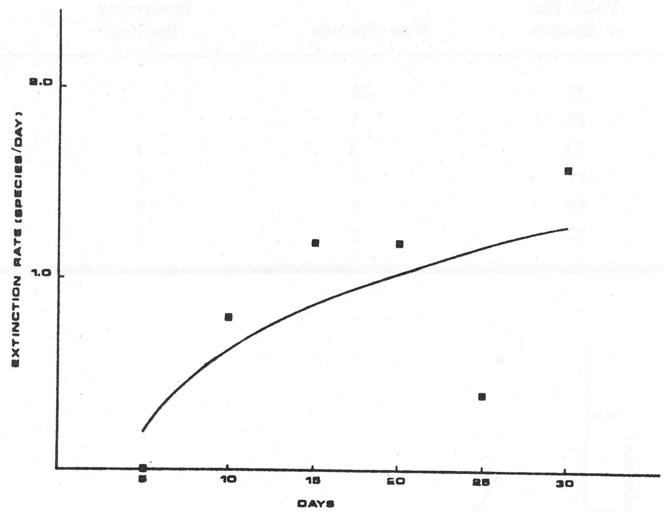

Fig. 2 — Extinction rate (species/day) of macrobenthos collected with artificial substrates.

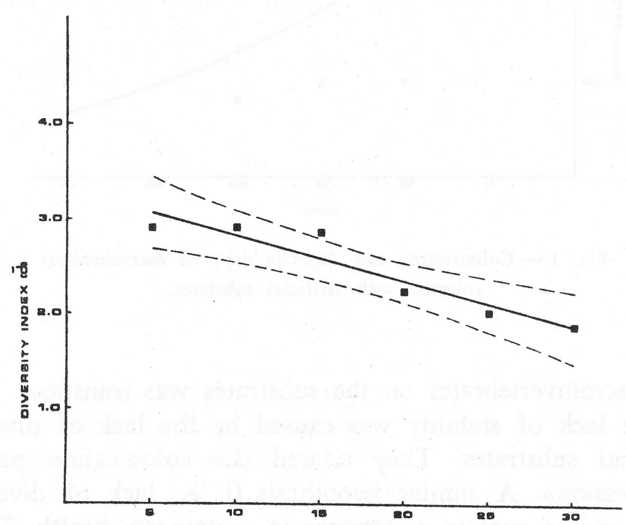

Fig. 3 — Plot of diversity indices versus time showing 95 percent confidences limits for macrobenthos collected with artificial substractes.

showed that the second sampling period (day 10) produced the highest number of both Plecoptera and Trichoptera. Ephemeroptera were most abundant in sampling periods five and six (days 25-30). Sampling period three (day 15) accounted for the highest numbers of Coleoptera. The cononization of Diptera (mostly Chironomid larvae) followed a linear regression (Figure 4) ($p < .05$, df $= 4$). Simmons and WINFIELD (1971) showed a similar pattern of colonization for chironomid larvae.

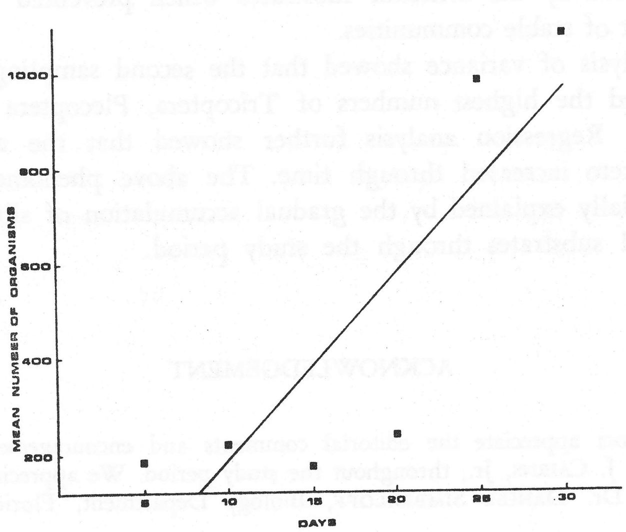

Fig. 4 — Colonization of Diptera larvae on artificial substrates.

Field observations indicated that there was a gradual silting of the substrates with time. This increase in silt may account for the large numbers of Diptera and decreasing numbers of Trichoptera, Plecoptera and Coleptera. Variability between replicate substrates was observed (Table 1). This variability was probably caused by predation, different sampler orientation to current, and/or kind of primary invader. It is highly likely that if the primary invader of a substrate was a predador such as a stonefly *(Peltoperla)* it retarded the succeful colonization of other species.

CONCLUSIONS

1. The sampling of macrobenthic faunas with articial substrates reconfirmed that colonization followed the MACARTHUR-WILSON equilibrium equation for island faunas, as previously shown by DICKSON and CAIRNS (1972).
2. Diversity indices, and, therefore, «health» decreased trough time. This phenomenon may be related to the lack of diverse habitats offered by the artificial substrates which prevented the establishment of stable communities.
3. Analysis of variance showed that the second sampling period produced the highest numbers of Tricoptera, Plecoptera and Coleoptera. Regression analysis further showed that the abundance of Diptero increased through time. The above phenomenou may be partially explained by the gradual accumulation of silt on the artificial substrates through the study period.

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