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Macro-invertebrate Colonization of Artificial Substrata II: Weeds and Plant Stems

J.O. Olomukoro and O.C. Nduh Tochukwu
Department of Animal and Environmental Biology (Zoology),
University of Benin, P.M.B. 1154, Benin City, Nigeria

Abstract: Colonization of submerged artificial substrates by macrobenthic invertebrates in Ogba River Benin City, Nigeria was examined. Investigation involves the use of local traps over an exposure periods of 4, 10, 21 and 40 days. 1074 benthic organisms were recorded of which the weeds and plant stems substrates recorded density of 61.64 and 38.36%, respectively. Thirty-two macro-invertebrate taxa were recorded. The dominant groups were Ologochaeta and Diptera. Colonization of the substrates occurred at different rates. Early colonizers include the families Chironomidae, Naididae and Bufanidae in the 4 and 10 days exposure periods, while the late colonizers were mollusc and crustacean in the 21 and 40 days experiments. High species diversity (species richness and number of taxa) was recorded in the weeds substrate. The use of artificial substrate for sampling has shown to great significance in the bioassessment of unwadeable streams and rivers.

Key words: Macro-invertebrate, substrate colonization

INTRODUCTIOIN

The use of colonization samples for benthic macrofauna studies may have its advantages and disadvantages and is of great significance in the bioassessment of unwadeable streams and rivers. Some benthic groups have strong preference for or may be attracted by special artificial or natural substrates for immediate colonization. Colonization of macro-invertebrates following changes to the stream environment occurs rapidly through drift, oviposition, lateral movement and vertical migration (Fowler, 2002). Lakes (2000) observed that ability of invertebrates to colonize available habitats is influenced by disturbance type and also by the abundance and type of taxa present in the system (Death, 1996, 2000).

Colonization according to Mayr (1964) is defined as the invasion of species into disturbed and newly created habitats. Williams and Hynes (1979) discovered that the colonization of a disturbed habitat will be certainly be by an amount of original species which have been wiped out by perturbations or by new colonizers. Also, it has been discovered that the rate of colonization of invertebrates varies between taxa, as shown in the study carried out on the effects of shoot age on colonization of an emergent macrophyte (*Typha latifolia*) by microinvertebrates (Oertli and Lacharanme, 1995). Colonization studies lasting less than a week have distinguished early and late colonizers (Shaw and Minshall, 1980; Clifford *et al.*, 1992). Macarthur and Wilson (1963) pointed out that a new habitat has a high invasion rate of species that have become established and a relatively stable equilibrium would be reached. Both authors proposed an equilibrium model for island faunas to describe patterns of species diversity amongst relatively homogeneous habitat "patches". Minshall and Peterson (1985) developed the MacArthur-Wilson model further with respect to non-equilibrium phase as proposed in the colonization process where the number of species and individuals are less than or exceed the equilibrium number.

Artificial substrates have been employed and found to be attractive for sampling the macro-invertebrates of freshwater (Pearson and Jones, 1975; Boothroyd and Dickie, 1991) and many types have been used like the trays of substratum described by Moon (1935) and Egglishaw (1964) and the basket samplers used by Jacobi (1971) and Fowler (2002). These authors have recorded large number of the invertebrates colonizing the substrates, but little attention has been paid to the temporal pattern of colonization. Pearson and Jones (1975) have described the study of the benthic communities of the River Hill, East Vorkshire by using metal boxes.

The main objective was to evaluate the relationship between habitat and macro-invertebrate community and the colonization of 2 types of artificial substrates with emphasis on early and late colonizers and factors that may influence their colonization.

MATERIALS AND METHODS

Sampling technique: Ogba River is located at the southwest region of the outskirt of Benin City in Edo

Corresponding Author: Dr. J.O. Olomukoro, Department of Animal and Environmental Biology (Zoology), University of Benin, P.M.B. 1154, Benin City, Nigeria Tel: +2348023411935

State. It lies between lat 6.5 °N and long. 5.5 °E. The River, which is about 42 km in length, takes its source at Ekenwan and flows in a South East direction through Ogba village and empties into Benin River, which in turn empties into the Atlantic Ocean. The municipal drains of Benin metropolis flow into the river at Ogba prison catchment area (Ezemonye and Kadiri, 1998).

The study area has the tropical wet and dry climate primarily regulated by rainfall. The rainfall season, which occur between April and October and the dry season, which occur between November and March, do not conform to any regular pattern. The selected sampling site is up and down streams of Ogba village (Ogbaneki station) that has a characteristic of narrow and shallow riffle.

Fifteen local trap artificial substrates were deployed in the Ogba River from June to December 2002. The Traps made with interwoven cane materials (from *Raphia hockerii* and *Lacosperma secundiflorum*) were used for sampling (Fig. 1). Fresh weeds and plant stems were used as artificial substrates. The trap has an opening at the base through which benthic organisms have access to the substrates. While the other end serves as opening through which materials are introduced into the trap. Each trap was half filled with substrate and closed by tying with an attached string and consequently anchored with a peg to the river bed. Recommended deployment period for artificial substrates are 4, 10, 21 and 40 days, respectively. This is a similar length of time to previous experiments using artificial substrates (Downes *et al*., 1998; Zimmermann and Death 2002; Fowler, 2002). Three replicate samples were collected per artificial substrate.

The traps were removed by hand picking and placed immediately in a polypropylene bucket containing water. Substrate materials were dusted and rinsed with water and were closely examined to ensure that no organism was still attached to them. The medium inside the bucket was sieved through a set of tyler sieves of varying mesh-sizes: 2 mm, 1 mm, 150 and 100 μm. The sieved contents were preserved in the field in labeled sampling bottles containing 10% formalin.

In the laboratory, sorting was done using the American optical dissecting microscope model 570 with magnification of 25-40x and HM-Lux 3 microscope. Sorted organisms were preserved in 4% formalin.

Identification of organisms was carried out using appropriate keys and works of Mellanby (1963), Macan (1963), Pennak (1978), Ward and Whipple (1958), Needham and Needham (1978) and Powell (1977, 1980) Olomukoro (1996). Due to the insufficiency of our taxonomic knowledge of the riverine fauna of Nigeria, some specimens have been assigned only to the lowest taxon within which they can be placed with certainty. In some cases identification can be carried out at generic level.

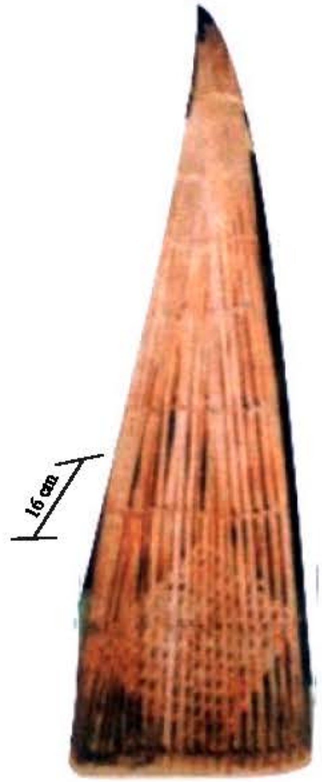

Fig. 1: Trap used for sampling

Estimation of total fauna diversity: Benthic Community diversity was determined in both substrates using biological indices such as Margalef, Shannon and Weaver (1949) and Evenness indices. Sorensen's quotient (Q/S) and Jaccard Co-efficient (Sj) (Boothroyd and Dickie, 1991) were also used for the estimation of faunal similarities.

RESULTS

Physical and chemical parameters: Results of Table 1 shows that highest values of parameters were recorded in July, August and October, while the lowest values were obtained for Water temperature, Suspended solid, dissolved Solids and Conductivity in June and November, respectively. Other parameters had their lowest values between June and August.

MACROBENTHIC FAUNA

The total number of taxa recorded was 32 with 1070 individuals. These comprise 5 species of Oligochaeta, 3 species of Crustacea, 4 species of Odonata and 2 species

Table 1: Physical and chemical parameters of the study area, Ogba River from June 2002-Dec, 2002

	Months							
Parameters	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Water temp.	27.3	27.0	27.2	27.2	30.00	27.0	27.1	27.83
pH	6.47	6.39	6.64	5.90	6.11	6.16	6.87	6.36
Dissolved oxygen	10.89	11.60	7.20	7.50	7.61	7.80	7.60	8.60
Phosphate	0.10	0.20	0.21	0.34	1.81	1.12	1.18	0.71
Nitrates	0.39	0.40	0.07	0.14	0.95	0.97	0.96	0.55
Total dissolved solids	25.13	33.42	32.49	18.39	25.15	24.00	25.15	26.22
Suspended solids	10.40	11.60	14.50	6.20	6.40	6.50	6.35	8.85
Conductivity	64.00	89.32	90.00	80.30	62.10	68.00	62.35	73.72

Note: Parameters are in mg L^{-1} except temperature in °C and conductivity in µs cm^{-1}

Table 2: The overall composition, distribution and abundance of macrobenthic invertebrate fauna in the substrate weeds and plant stems

	Artificial substrates	
Taxa	Weeds	Plant stems
Oligochaeta		
Aulophorus vagus Leidy	39	32
Nais sp. A	32	22
Nais sp. B	48	73
Nais communis	39	52
Nais simplex	35	49
Crustacea	2	
Sudanonautes africanus	-	-
Sudanonautes aubryi	1	2
Potamalpheops monodi Solland		-
Odonata		
Coenagrion sp. Rambur	3	-
Enallagma sp. Chanpenthier	10	-
Libellula sp.	14	4
Plathemis sp.	2	8
Hemiptera		
Notonecta sp.	2	2
Ilyocoris sp.	-	2
Diptera		
Chironomus sp.	15	35
Chironomus fractilubus	17	11
Pseudochironomus sp.	18	5
Clinotanypus maculatus	23	26
Pentaneura sp.	28	20
Tanytarsus sp.	19	10
Tanypus sp. Meigen	17	8
Cricotopus sp.	16	-
Culex sp.	18	15
Psychoda sp.	1	-
Antocha sp.	8	-
Arachnida		
Argyronecta aquatica	3	1
Amphibia (Tadpoles)		
Bufo maculatus	184	39
Gstropoda (Mollusca)		
Hydrobia sp.	38	-
Potamopyrgus ciliatus	20	-
Total	659	411

of Hemiptera. Other groups are Arachnida (1 specie), Diptera (II), Mollusca (2) and Amphibia (Tadpole) (I). Hemiptera and Arachnida had the lowest population density of 0.30 and 0.24% in substrate weeds and plant stems, respectively. Of all the taxonomic groups identified, mollusca had no record in plant stems. Consequently, some groups e.g., Ephemeroptera, pleroptera, Coleoptera, Trichoptera, Lepidoptera etc, were not represented in the two artificial substrates. The number of individuals in weeds and stems substrates were 61.27 and 38.36%, respectively (Table 2).

Table 3: Relative percentage composition/abundance of the Macrobenthic Invertebrate of the submerged artificial substrates

	Weeds		Plant stem	
Taxa	Taxas NO.	Occurrence (%)	Taxas No.	Occurrence (%)
Oligochaeta	5	29.15	5	55.34
Diptera	11	28.85	8	30.34
Odonata	4	4.38	2	2.91
Hemiptera	1	0.30	2	0.97
Crustacea	2	0.45	1	0.49
Arachnida	1	0.45	1	0.24
Mollusa	2	27.80	1	9.47
Amphibia (Tadpoles)	1	8.76	-	
Total	27	100.00	20	100.00

The relative percentage composition of the macrobenthic organisms in the artificial substrate (Table 3), shows that *Oligochaeta* has the highest record of 29.15% in the substrate weeds and 55.34% in the plant stem

Table 4 and 5 show the relative colonization rate of individuals groups of organisms in each exposure periods in the substrate weeds and plant stems. Rapid invasion of substrates by the organisms occurred within the first four days of the experimental observation. The pattern of substrate colonization varied between the two substrates as few organisms e.g., Diptera and Amphibia attained their peak at 10 days exposure period in the trap containing plant stems. Consequently, in weeds all organisms except Odonata attained their peak at 21-day period before leveling off at 40-day period.

DOMINANT AND SUB-DOMINANT GROUPS

Taxonomic groups or genera comprising 15% or more of the total individuals collected are considered as "dominants" while those comprising 5-14% are considered as "subdominants" (Slaek *et al.*, 1977). All other groups below 5% are regarded as the rare groups.

In all the submerged artificial substrates, the dominant invertebrates were the Oligochaeta, Diptera

Table 4: The number of individuals recorded in each exposure periods in the substrate weeds and plant stems

	4 Days		10 Days		21 Days		40 Days	
Taxa	W	PS	W	PS	W	PS	W	PS
Oligochaeta	35	69	9	9	128	3	21	147
Odonata	17	10	2	2	8	-	2	-
Hemptera	2	4	-	-	-	-	-	-
Diptera	38	30	42	89	98	-	13	6
Crustacea	-	-	-	-	2	2	-	-
Mollusa	-	-	3	-	-	-	85	-
Arachnida	-	-	3	1	-	-	-	-
Amphibia	41	13	3	25	135	-	15	1

W-Weeds, PS -Plant Stems

Table 5: Pattern of colonization of artificial substrate by macro-invertebrate in each exposure period

	No. of individuals	
Sampling days	Weeds	Plant stem
4	133	126
10	62	126
21	373	5
40	96	155
Total	662	412

Table 6: The variations in Taxa richness and evenness (E), indices of macro-invertebrate in the substrates

Index	Weeds	Plant stems
Total number of individual (N)	662.00	412.00
Total number of taxa (S)	29.00	21.00
Margalef's Index (D)	4.31	3.32
Shannon - Wiener's Index (H)	0.42	0.06
Evenness Index (E)	0.29	0.05

and Amphibia in Weeds substrate, Diptera 28.85% and Oligochaeta 29.15% occurred as the most dominant group. Amphibi 9.47% was the subdominant group, while the rare groups were Hemiptera 0.97%, Crustacaens 0.49% and Arachnida with 0.24%, respectively.

DIVERSITY AND FAUNA SIMILARITIES

Table 6 presents the taxa richness (D), general diversity (H) and Evenness (E) for the submerged artificial substrates.

In the plant stems, Oligochaeta 55.34% was the most dominant group, followed by Diptera with 30.34% density. Amphibian 9.47% was the subdominant group, while the rare groups were Hemiptera 0.97%, Crustaceans 0.49% and Arachnida 0.24%.

Weeds substrate had high taxa richness 4.31% than plant stem. with 3.32 index, respectively. Simultaneous increase was also reflected in general diversity (H) and Evenness index (E) in weeds than plant stems.

Similarity indices estimated for the fauna of the artificial substrates, using Sorensen's quotient (Q/s) and Jaccard's Co-efficient (Sj), revealed that Q/S of 66.45% and Sj of 1.95 indicated that there was significant similarity in fauna abundance of the artificial substrates.

DISCUSSION

Three groups dominated the macroinvertebate communities of the submerged artificial substrates: the diptera (Chironmidae), Oligochaeta (Naididae) and Tadpole (Amphibia). In the submerged weeds and stems, the Oligochaetes (such as *Nais* sp. and *N.simplex*) had the highest record of 29.15 and 55.34%, while the Dipteran larvae followed closely with density of 28.85 (weeds) and 30.34% (stems), respectively. The percentage occurrence of Tadpoles (Amphibia) was relatively higher in weeds (27.8%) than in plant stems (9.47%). Few organisms are considered to be rare groups, which are Odonata, Hemiptera, Crustacea and Arachnida, having relatively less than 5% density in both artificial substrates. The rate of substrate colonization clearly demonstrates habitat preference and variation in the abundance of various taxonomic groups. It is interesting to note that the clean water representatives like Ephemeropteran, Coleopteran, Plecopteran and Trichopteran larvae were conspicuously absent in the artificial substrates used. The water quality may not be a limiting factor in this case. Substrate types may have restricted the groups from immediate colonization of the available substrates. Other synergistic conditions may have contributed to the choice of a suitable nitche.

Within the first four days, the number of benthic organisms that colonized the artificial substrates varies considerably. The rapid invasion of the substrate weeds and stems apparently occurred at the 4 - day period the submerged materials were still relatively fresh and could be of great significance to the organisms. Such new substratum may serve as a source of food, refuge from fish predation as well as a substrate for breeding, grazing and hunting (Fowler, 2002; Soszka, 1975). The early colonizers were the Oligochaeta, Odonata, Diptera and Tadpoles (Amphibia), which attained their peak numbers or 21 days period in traps containing weeds. But in plant stems, Diptera and Tadpoles were observed to attain their peak numbers at 10 days period. It is interesting to also note that the substrate type may determine the peak numbers in individual organisms as in the case of Mollusca: *Hydrobia* sp. and *Potamopyrgus ciliatus* (observed in traps with weeds) and Oligochaete (in plant stems), respectively. The former appeared as late colonizer in the said substrate but absent in traps containing plant stems. Mollusca are deposit feeder and may prefer a heavily silted artificial substrate for colonization. Oligochaeta in the other hand had its peak numbers, which occurred at 40 day period. A period the substrate materials must have gathered sufficient particulate organic matters and algae growth. Some species, which appeared after a long exposure period, might normally require muddy substrata to thrive (Pearson and Jones, 1975; Boothroyd and Dickie, 1991; Soszka, 1975).

These results are comparable with other studies (Death, 2000; Boothroyd and Dickie,1991; Fowler and Death, 2000) indicating that although all taxa colonize rapidly, a more stable community composition may not be achieved within 1 month. Rapid invasion rate for new substratum by the benthic organisms decreased after 21 days in traps with weeds and 12 days with stem until a relatively stable equilibrium was reached. This trend agrees with MacArthur and Wilson (1963) equilibrium model which predicts that the rate of colonization or immigration will be high initially and become progressively slower until finally an asymptote is neared. This occurs because the chances of a new species arriving decease overtime. As more species arrive, so the chances of some leaving, or becoming extinct, increases until the community reaches a state of dynamic equilibrium when the colonization and extinction rates are equal and the situation stabilizes with a constant species number. Stabilization of the substrate over a longer period could possibly eliminate opportune species not usually, associated with natural water as earlier reported (Soszka, 1975; Boothroyd and Dickie, 1989; Zimmermann and Death, 2002). Dickson and Cairns (1972) pointed out that a new habitat has a high invasion rate of new species and a low extinction rate of species that have become established. Colonization of water body depends on animals with wide distributional capacities (Green, 1979) and varied amongst the various taxa as earlier observed by previous workers (Clifford *et al.*, 1992; Macarthur and Wilson, 1963; Pearson and Jones, 1975; Peckarsy, 1980; Cummins *et al.*, 1989). Once colonization begins, it proceeds rapidly until the macrobenthic organisms have fully colonizes three quarters of the time for which the habitat is exposed.

Application of Sorensen's quotient (Q/S) indicated similarly between species of both artificial substrates where Q/S of 66.45% was estimated. This was also confirmed by Jaccard's coefficient (Sj) with estimated index of 1.95. The substrate weeds recorded higher species richness than the stems. This indicated that species diversity (richness, dominance and number of taxa) varied in the treatments. Diversity has been considered as a measure of community stability (Downes *et al.*, 1998). Fowler (2002) observed that species diversity is highly variable in streams in response to disturbance, resource availability and the presence of suitable habitat.

The distribution of the macroinvertebrates community appears to have been influenced by the habitat preference of the species for food, shelter and protection and the various taxa recorded are representatives of some major groups in Ogba River.

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