Factors affecting the distribution and abundance of *Cloeon* and *Caenis* (Ephemeroptera) larvae in a tropical impounded river, Nigeria

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Abstract

Impoundment of rivers affects the mayfly (Ephemeroptera) fauna inhabiting such water bodies, especially with respect to their distribution and abundance. A two-year study of the mayfly fauna and some of the physicochemical parameters of the Opa stream–reservoir revealed that there are two mayfly genera inhabiting it, *Cloeon* and *Caenis*. The number of *Cloeon* larvae collected was 10,930 while the number of *Caenis* larvae was 450. It was observed that although both genera occurred at all the sampling stations, their numbers were reduced in the stream below the dam due to increased water current velocity. There were significant differences in the abundance of *Cloeon* among the stations, but none for *Caenis*. Submerged aquatic plants and water current velocity were found to be the major factors responsible for the significant differences. There were significant correlations between the number of *Cloeon* larvae and pH as well as between dissolved oxygen concentration and *Caenis*. These findings are discussed with reference to inter-specific differences in patterns of response to environmental parameters. A species-specific approach is suggested for studies on the strategies that enable mayfly species maintain their populations in stressed and unstable aquatic ecosystems.

Key words: abundance, distribution, Ephemeroptera, impounded, river, Nigeria

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Résumé

Les lachers d'eau de barrages affectent la faune d'éphémères (Ephemeroptera) qui habitent ces rivières, spécialement leur distribution et leur abondance. Une étude de deux années de cette faune et de certains de paramètres physico-chimiques du réservoir de Opa a révélé que deux genres d'Ephéméroptères y habitent, *Cloeon et Caenis*. On a récolté 10.930 larves de *Cloeon* et 450 de *Caenis*. On a observé que, bien que les deux genres étaient présents à toutes les stations d'échantillonnage, leur nombre était réduit dans le cours d'eau en aval du barrage en raison de la rapidité du courant. Il y avait des différences significatives dans l'abondance des *Cloeon* entre les stations, mais aucune pour les *Caenis*. On a trouvé que les plantes aquatiques et la rapidité du courant étaient les principaux facteurs responsables des différences significatives. On discute ces découvertes en regard des différences interspécifiques du schéma des réponses aux paramètres du milieu. On suggère une approche par espéce pour étudier les stratégies qui permettraient aux espèces d'éphémères de maintenir leurs populations dans des écosystèmes aquatiques perturbés et instables.

Introduction

Mayflies (Ephemeroptera) constitute a major order of aquatic insects in reservoirs and running waters. A greater part of their life cycle is spent as larvae in water, while their short terrestrial adult life is simply for reproduction. They are a major component of food webs, forming a link between primary production and secondary consumers such as fish (Brittain & Saltveit, 1988). They are often the most abundant taxa in macroinvertebrate drift (Brittain & Eikeland, 1988) and are sensitive to aquatic pollution. They are therefore useful in the assessment of water quality (Wilhm, 1972; Agnew, 1985).

Impoundment of rivers for hydroelectric power and water supply affects the mayfly fauna of such rivers. From the upper reaches to the dam and beyond, changes in environmental parameters occur, and they affect the community structure, microdistribution and abundance of mayflies inhabiting the system. These parameters may include temperature (Vannote & Sweeney, 1980), solar input (Vannote & Sweeney, 1980), flow regime (Gaschignard & Berly, 1987), substrate and water quality (Armitage, 1984). Reports exist of occurrence of afrotropical mayflies in many tropical freshwater systems (McLachlan, 1970; Petr, 1973; Gillies, 1977, 1980, 1985, 1988; Ogbogu, 1991), but few have dealt with the effect of environmental heterogeneity on the fauna. There is therefore the need for studies focusing on the influence of environmental parameters on microdistribution and abundance of mayfly species inhabiting tropical reservoirs and rivers.

The Opa stream–reservoir system is typical of such water bodies that exhibit seasonal changes in environmental parameters. It is a tropical freshwater body located at Obafemi Awolowo University, Ile-Ife, southwestern Nigeria. During the rainy season it receives water from feeder streams as well as run-off from adjoining farmlands. This water is capable of causing considerable seasonal fluctuations in the physicochemical parameters of the water body. It is against this background that changes in distribution and abundance of mayflies in the water body were studied for two years in relation to fluctuations in some environmental parameters. It is hypothesized that the variability in some of the parameters will influence the distribution and abundance of mayfly larvae in different ways.

Study area

The Opa reservoir is located in the eastern part of the University (latitude 7°24′ and 7°35′N, longitude 4°30′ and 4°35′E). It was formed by damming the Opa River to provide a potable water supply and for freshwater fisheries research. The dam has an embankment length of 233.3 m, crest width of 6.7 m and a mechanical spillway for occasional use. The reservoir has a maximum depth of 10 m, a surface area of 950 ha and holds 675 m^3 of water at maximum capacity. Some of its physicochemical parameters have been reported in Akinbuwa & Adeniyi (1996).

The general vegetation of Ile-Ife is typical of tropical rain forests, as described in Egborge (1971). The climate of this region exhibits two distinct seasons, dry and wet. During the wet season, increased rainfall causes a rise in water level in the reservoir, with increased water current velocity in the stream below the dam. In the dry season on the other hand, between December and January, the spillway is dry because of little or no discharge, and the stream below shrinks into stagnant pools of water.

There are at least 31 species of aquatic macrophytes in parts of the reservoir. They form up to seven associations (Isawunmi, 1989), in which *Pistia stratiotes*, *Polygonum senegalense*, *Ludwigia africana*, *Typha australis*, *Strichum sparganophora*, *Acroceras zizanioides* and *Cyclosorus striatus* are dominant species. In the upper reaches of the reservoir, *P. stratiotes* is dominant and virtually covers the surface of the slow-flowing water. At the margin of the upper reaches are the fern, *C. striatus*, in association with *Commelina diffusa*. The pelagic zone of the reservoir is devoid of aquatic plants while pure strands of T. australis with infrequent Scirpus cubensis and Ludwigia species dominate the margin of the lower reaches. Below the dam, there is a large stone bed at the upper portion, near the spillway, and a sandy substratum at the lower portion. *Acroceras zizanioides* dominates the vegetation of this station, which includes *Pentodon pentandrus* and *P. senegalense*.

Materials and methods

Samples of mayfly larvae were collected fortnightly from October 1993 to September 1995 from Stations 1 and 2 in the reservoir and Station 3 below the dam. In Stations 1 and 2 water was agitated by kicking over a time of 1 min (Frost *et al.*, 1971) and the water column was swept vertically upwards with a hand net (0.08 m^2, 200 μm mesh netting). At Station 3, a Surber-type sampler of the same area and mesh was used (Pringle, 1984). The samples were fixed in ethanol for sorting and identification in the laboratory. Although the samples were not quantitative, the abundance of larvae at various stations could be compared on the basis of total number of larvae collected each month. Using the key in Gillies (1980), larvae could not be identified beyond the generic level because taxonomic characters were not developed in many individuals. Besides, some species require information on adult morphology for accurate identification. For this reason larvae were grouped by genera. The total number of individuals of each genus collected at each station throughout the period of study were recorded, together with monthly mean and standard deviations. The studentized *t*-test was used to test the levels of significance of the differences in the abundance of larvae among the stations.

Data on some physical and chemical parameters of water were collected fortnightly at the three stations. Temperature was recorded to the nearest 0.1 °C. Water current velocity was estimated at Station 3 with a float (Schlosser, 1982). Water was collected in plastic jars from all stations for analysis. Conductivity and pH values were read off a Metrohm conductometer and a pH meter, respectively, while dissolved oxygen concentration (DO) was determined by titration (MacKereth, 1963) of water previously fixed in the field (APHA, 1976). The data obtained for these parameters are summarized in Table 1.

The relationships between mayfly larvae and the physicochemical parameters were investigated using product moment correlation coefficients (r). The values of r were calculated using the data from all the stations combined. This is because the parameters did not vary much through time or at different stations (except for current velocity).

Results

The mayfly fauna of the reservoir belong to two families, Baetidae and Caenidae, which are represented by two genera, *Cloeon* Leach and *Caenis* Stephens, respectively. Of the two, *Cloeon* was more abundant. A total of 10,930 *Cloeon* and 450 *Caenis* larvae were collected throughout the study period (Table 2). The stations can therefore be rated for abundance of larvae as Stations 2 > 1 > 3 for *Cloeon* and Stations 3 > 1 > 2 for *Caenis*. In other words, the number of *Cloeon* collected at Station 2 is much higher than at other stations while the reverse is the case with *Caenis*. There were significant differences in the abundance of *Cloeon* ($P < 0.05$) among the three stations, but none in the abundance of *Caenis* ($P > 0.05$).

Table 1 Some physicochemical parameters of the three study stations in the Opa stream–reservoir system, October 1993 to September 1995

	Station 1					Station 2					Station 2				
Parameter	*n*	min.	max.	mean	SD	*n*	min.	max.	mean	SD	*n*	min.	max.	mean	SD
Water temperature (°C)	24	23.0	30.5	26.9	1.9	24	23.8	31.65	28.41	1.91	24	21.4	30.1	27.26	1.86
Current velocity ($m\ s^{-1}$)	–	–	–	–	–	–	–	–	–	–	24	0	6.25	1.98	2.28
pH	24	5.75	6.8	6.22	0.72	24	6.4	7.70	6.98	0.33	20	6.2	7.2	6.63	0.27
Conductivity (Ohm mm^{-1})	24	0.260	0.465	0.344	0.039	24	0.245	0.4	0.327	0.029	20	0.285	0.416	0.352	0.046
Dissolved oxygen ($mg\ l^{-1}$)	24	0	3.18	3.18	2.96	24	2.64	11	6.78	1.89	20	4.4	14.33	6.76	2.55

n, number of samples; SD, standard deviation.

Table 2 Distribution and abundance of *Cloeon* and *Caenis* (Ephemeroptera) larvae in the Opa stream–reservoir system, October 1993 to September 1995

Station	Genus	Total no. of larvae collected	Monthly mean with SD	Total no. of individuals at each station
1	*Cloeon*	4505	187.81 ± 132.24	4619
	Caenis	114	4.75 ± 7.29	
2	*Cloeon*	5378	224.08 ± 126.55	5481
	Caenis	103	4.29 ± 7.17	
3	*Cloeon*	1047	43.63 ± 64.21	1280
	Caenis	233	9.71 ± 14.53	
Total	*Cloeon*	10,930		
	Caenis	450		
Grand total		11,380		11,380

Low numbers of larvae of both genera were collected from Station 3 at the peak of the rains (between May and October), when higher current velocities were recorded (Fig. 1). As a result, the lowest total number of larvae (1280) was collected at this station (Table 2). This number was accounted for by *Cloeon*, because more *Caenis* larvae were collected at this station than at the other two. The larvae negatively correlated with water current velocity (Table 3). There were significant correlations also between the abundance of *Cloeon* and pH, as well as between *Caenis* and dissolved oxygen concentration (Table 3).

Table 3 Correlation coefficients (r) between the abundance of mayfly (Ephemeroptera) larvae and physicochemical parameters at the Opa stream–reservoir system

	Genus	
Parameter	*Cloeon*	*Caenis*
Current velocity (m s^{-1})	−0.4727*	−0.3672*
Temperature (°C)	−0.0248	−0.0521
pH	0.2733*	-0.0612
Conductivity (Ohm mm^{-1})	0.1938	−0.0084
Dissolved oxygen (mg l^{-1})	−0.0004	0.2548*

*Values significant at 5% level ($P < 0.05$).

Discussion

Plants usually provide food and shelter and so larvae are restricted to the shallows in the study area, where aquatic macrophytes are abundant. Some of these macrophytes (e.g. the torpedo grass, *Panicum laxum*) were common at Station 2. They adapt readily to varying water level and can withstand prolonged periods under water (Mitchell, 1969; Thomson, 1985). Apart from food and shelter, the plants produce oxygen, which adds to the DO of water at this station. *Cloeon* larvae can cling to the plants and utilize these resources. *Cloeon* survives better in areas of high water quality, as pointed out in Brooker & Sweeting (1991). This may explain why *Cloeon* larvae were more abundant at Station 2 than at the other stations. This corroborates many reports on the influence of plant materials (fresh, dead and decomposing) on the microdistribution of mayfly species in ponds and streams (McLachlan, 1970; Corbet *et al.*, 1973; Petr, 1973; Bidwell, 1979).

In the same way, the high incidence of *P. stratiotes* at Station 1 provides the larvae with a substratum for attachment and feeding. However, the number of larvae collected from this station was less than that from Station 2. The Opa River and Amuta stream are the sources of water to Station 1. They drain many residential areas and farmlands, bringing sediment and effluents with run-off. As such the water frequently appeared turbid at Station 1, indicating a high level of silt in suspension. Besides, *P. stratiotes* can reduce photosynthetic activ-

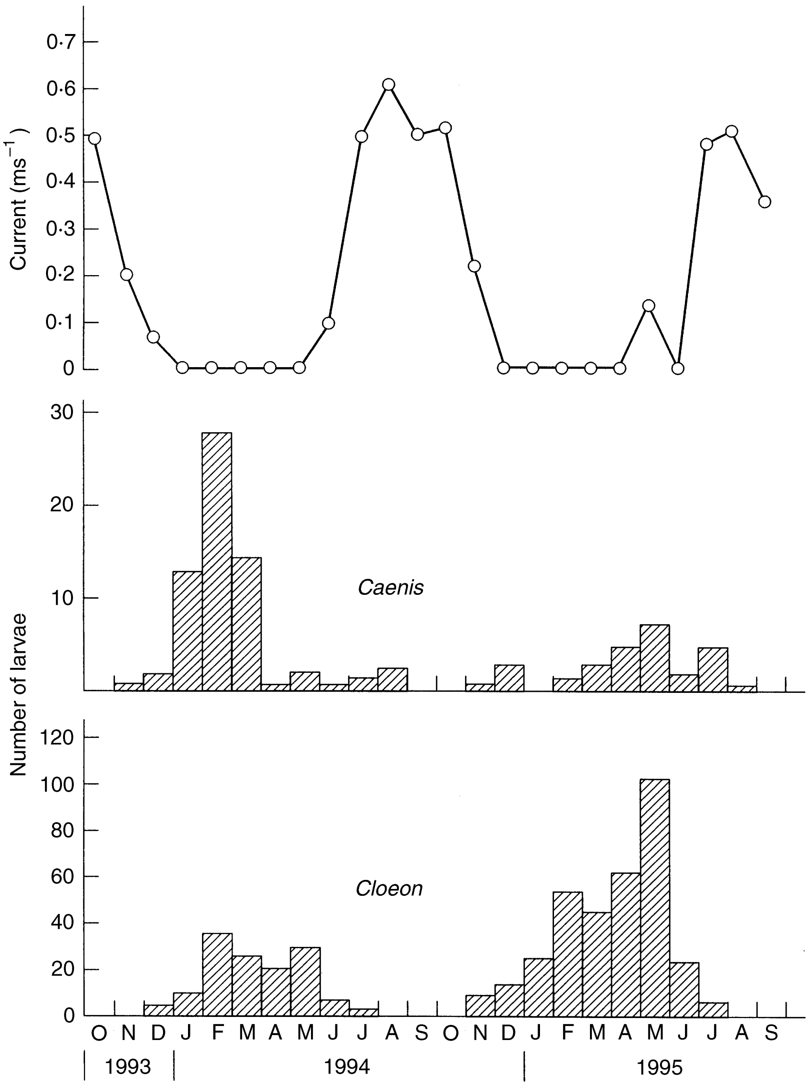

Fig 1 Monthly mean number of *Cloeon* and *Caenis* (Ephemeroptera) larvae and monthly fluctuation in water current velocity at Station 3 in the Opa stream–reservoir system, October 1993 to September 1995

ities in water by reducing light penetration. This will in turn cause reduced DO, a condition that is intolerable to *Cloeon*. This may account for the significant difference in the number of *Cloeon* larvae between Stations 1 and 2. As for *Caenis*, the lack of significant difference between the numbers of larvae collected from all the stations suggests that its distribution is not influenced by aquatic macrophytes.

Like food and shelter, water current has been implicated in limiting the distribution of aquatic insects, but this depends on species (Hynes, 1963; Maitland, 1965). Most species of *Cloeon* avoid lotic areas (Brittain & Saltveit, 1988); hence the higher number of larvae in the reservoir (Station 2) than Station 1, where there was low current, and at Station 3 where there were wide fluctuations in water current. This effect is further accentuated by the significant negative correlation between the abundance of *Cloeon and* current ($r = -0.4727$, Table 3). The significant differences in the abundance of *Cloeon* larvae in all the stations also support this assertion.

As is the case with *Cloeon*, current is limiting to the distribution and abundance of *Caenis* ($r = -0.3672$, Table 3). It can therefore be said that both genera occur in the same macrohabitats and are adversely affected by spates of current (Fig. 1). However *Caenis* generally prefers stream areas, and the highest number of larvae was collected at Station 3 (Table 1) where there was high water current, the absence of significant differences in its abundance among the stations notwithstanding. *Cloeon* on the other hand prefers lentic areas. The difference in preference is explained by the fact that mayflies have certain preferential and absolute limits with respect to current velocity (Gore, 1978; Gaschignard & Berly, 1987). The observed highest number of *Caenis* at Station 3, and the lowest number of *Cloeon* at the same station in the present study agrees with the explanation above.

Low pH has been found to limit the distribution of *Povilla adusta* Navas (Petr, 1973) and abundance of *Ephemerella funeralis* McD (Fiance, 1978). Low pH can also induce elevated hydrogen sulphide levels (Petts, 1984), which is intolerable to *Baetis* (Oseid & Smith, 1974) but not to *Hexagenia* (Oseid & Smith, 1975). In the present study there was a significant positive correlation between pH and *Cloeon* ($r = 0.2733$). The significant correlation ($r = 0.2548$) between *Caenis* and DO also shows that *Caenis* positively responds to variability in dissolved oxygen concentration in the water body. It prefers conditions in which oxygen concentration is high with reduced water current velocity. These findings support the assertion that responses to environmental parameters are species-specific (Rabeni & Minshall, 1977).

The responses may also vary with changes in geographical location and climatic regions. It is therefore pertinent to note that the previous findings are from other climatic regions. A few species of both genera in this study that have been described from Africa seem to be endemic to the afrotropical region. They may as well have their common and species-specific patterns of response to these parameters.

To conclude, aquatic macrophytes and water current velocity were the major factors affecting the distribution and abundance of the two mayfly genera in the water body in this study. Although they occur in many types of water body, *Cloeon* has a predilection for aquatic macrophytes in areas devoid of water current while *Caenis* is more abundant in streams than reservoirs. Other parameters may be acting in various combinations to affect (through pH and DO) *Cloeon* and *Caenis* larvae in the water body. These findings provide considerable support for the hypothesis. To determine how these parameters achieve this requires further investigation. Further studies on the strategies employed by individual mayfly species to persist and maintain their populations in the water body are suggested. It will enhance our knowledge of how they survive unstable and stressed conditions such as spates of current and wide fluctuations in pH and DO.

Acknowledgements

I am immensely grateful to the National Geographic Society (NGS), Washington, D.C., for funding this study through research grant #4944–92 and 5585–95. I am indebted to Steve S. Stettes of NGS for his assistance with logistics in release of funds, as well as his suggestions for enhancing the quality of the study. I also thank the two anonymous reviewers for their useful comments on the manuscript.

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(Manuscript accepted 21 June 2000)