FACTORS CONTROLLING THE SPECIES DIVERSITY AND DENSITY OF MAYFLIES (EPHEMEROPTERA) EMERGING FROM AN UNSTABLE RIVER IN MANITOBA, CANADA

John F. Flannagan and Donald G. Cobb

Department of Fisheries and Oceans
Central and Arctic Region, Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6, Canada

ABSTRACT

A total of 7,845 mayflies representing 7 families, 10 genera and 21 species, was collected from 10, 1 m^2 emergence traps, set in pairs at 5 stations along the length of the Ochre River, Manitoba.

No significant correlations were found between species diversity or density and water temperature, pH, conductivity, % slope, bankfull water depth, tractive force or substrate diameter size or substrate instability under the traps. Mayfly density and diversity were negatively correlated with the degree of substrate instability in the reach of the river in which the traps were set. Positive, although less significant, correlations were found between mayfly density and diversity and the mean diameter size of the substrate in the reach.

The correlation coefficients for mayfly densities described above increased markedly when the data for station 5, the furthest downstream, and most anthropogenically impacted station, were omitted from the analyses.

INTRODUCTION

The large decline of walleye (*Stizostedion vitreum*), perhaps the most valuable commercial and sports fish in Manitoba, has been attributed to the effects of land clearing and channelization for agricultural purposes on their spawning rivers (Gaboury 1985).

These agricultural practices have resulted in changes in sediment loads, substrate stability and the quality and peak flow quantity of the water in many prairie streams (Newbury and Gaboury 1987). A walleye rehabilitation experiment in Dauphin Lake, Manitoba attempted not only re-establishment of significant fish populations in the lake but also re-establishment of spawning habitat (Flannagan *et al.*, unpublished). The first step in this latter process was to find out whether or not density or diversity of aquatic insects in the streams of the Dauphin Lake catchment would be useful indicators of the stable substrate required for successful walleye spawning, as the literature suggested (Flannagan and Cobb, 1991).

In 1983 and 1984, an emergence trap programme was carried out to survey the aquatic insects of the Ochre River, one of the major walleye spawning streams of the Dauphin Lake basin. It was hoped that this survey and the attendant physical and hydrological data collected would confirm the value of aquatic insects as indicators of disturbances in streams. This paper presents the mayfly results from 1983.

MATERIALS AND METHODS

The Ochre River has a drainage area of 450 km^2, most of which is protected within the Riding Mountain National Park. The part of the basin outside the Park is farmed and has been modified (straightened, dyked) to allow fast runoff of spring meltwater.

Both inside and outside the Park the river bed is largely composed of shale, varying in size from bedrock to gravel or smaller particles, with scattered boulders derived from the glacial till overburden. Interspaced within the shale are steep riffle areas of large boulders where the river cuts into relict Glacial Lake Agassiz beach ridges. In the lowest reaches of the river the boulder reaches alternate with sandy reaches.

Five sampling stations were selected along the length of the river to provide as wide a range as possible of physical and chemical conditions.

Emergence of aquatic insects was monitored using two, 1 m^2 box emergence traps (Flannagan 1978) at each station. The traps were emptied on Monday, Wednesday and Friday of each week from early May until mid-September. Insects were preserved in 70% ethanol for identification in the lab. Water and air temperatures, pH, dissolved oxygen, and conductivity were measured on each sampling. Water temperature was continuously monitored using Ryan submersible thermographs located at stations 1, 2, 3, and 5. Total suspended solids (TSS) was measured weekly at each station, and daily TSS and mean daily discharge at station 3 were obtained from Environment Canada (1983, 1984).

Median substrate diameter was measured under each trap, and at each station (reach). Slope, bankfull (bf) depth and width were measured at each station following the survey techniques recommended by Newbury (1984). Tractive force (shear stress), which is approximately equal to the mean diameter of the substrate in incipient motion was calculated for each station using the formula: tractive force = mean depth bf x slope x 1,000 (Newbury 1984). Tractive force was divided by the measured median substrate diameter at each reach and beneath each trap to give the instability index of Flannagan et al. (1990). This index provides a measure of the potential or sensitivity of the substrate in question to move. A high value indicates an unstable substrate with the likelihood of the substrate to be set in motion even at relatively low discharges.

To examine the relationship between the measured hydrological, physical and chemical factors and the density and diversity of Ephemeroptera, correlation coefficients were calculated using "Lotus 1,2,3" on $\log_e$ transformed data.

RESULTS

A total of 7,845 specimens of mayflies representing 7 families, 10 genera, and 25 species was collected. Four species occurred at two or less stations and in very small numbers and were thus not included in the analyses.

A summary of the biological, chemical, hydrological and other physical results is presented in Table 1. It should be noted that two apparent trends appear: 1) a more or less gradual increase or decrease in values in a downstream direction, e.g. dissolved oxygen and TSS conductivity; and 2) higher values at the midlength of the river and lower upstream and downstream, e.g. mayfly density, mayfly diversity, reach instability index, substrate size, etc. This suggests, even without any statistical analysis, that mayfly density and species composition are strongly influenced by hydrological factors.

Significant correlations were not found with any of the environmental factors except negative correlations with the reach instability index (density, $P<0.05$; diversity, $P<0.025$) and to a less significant extent, positive correlations with the reach median substrate size (density, $P<0.05$; diversity, $P<0.05$) (Table 2). A good positive correlation was additionally found between the number of mayfly species and the density of mayflies ($P<0.025$).

The analyses were rerun without the data from station 5 as this station because of its low slope is thought to be highly influenced by deposition of fine sediments eroded from upstream (Cobb and Flannagan, 1990). The results (in brackets, Table 2) show that elimination of station 5 has little effect on the analyses involving diversity of mayflies, but substantially decreases the probability of error in those analyses involving mayfly densities. This suggests that Ephemeroptera densities but not diversity are affected by sedimenting conditions.

DISCUSSION

Ochre River mayfly densities averaged $784.5/m^2$ (Table 1). Clifford (1980), in a review of the Holarctic literature on larvae mayfly abundances, reported that 93% of the records of yearly average abundance values were $<700/m^2$, that the mean was $375/m^2$ and that 21% of all reported values were $<100/m^2$. The range in reported densities compares favorably with the range collected from the various traps in the Ochre River (Table 1), suggesting, perhaps, that we met our goal of sampling as wide a range of environmental conditions as possible. Both the mean and range of densities of mayflies collected from the Ochre River were about twice that reported from the South Duck River and Cowan Creek, the only other Manitoba streams from which quantitative mayfly emergence results have been published

(Flannagan *et al.* 1990). The species diversity in all three streams is similar. The Ochre River, because of its much larger size, might be expected to be more diverse in species than either of these other streams. However, the wide range in water temperatures available in the two smaller streams probably compensates since it provides a wider range of habitat variables (Brittain 1982).

The strong positive correlation found between density and numbers of species (Table 2) was somewhat surprising, since in unstable streams a species that has evolved or possesses a life cycle strategy that can accommodate periods of instability often dominates. For example, the stonefly fauna of this river is dominated (75-83% of specimens collected and almost 100% of the stonefly fauna at the most unstable station) by one hyporheic species *Haploperla brevis* (Flannagan and Cobb, 1991b). Since even the most unstable areas (stations 1 and 2) had 7-10 mayfly species and since these species were well represented at other stations, we conclude that many mayfly species are able to survive periods of instability, perhaps through life history strategies (Cobb *et al.*, this volume).

The reach instability index but not the trap index, was significantly negatively correlated with both density and diversity of mayflies. Cobb and Flannagan, 1990) report similar results with Trichoptera and postulate that in unstable areas the abrasion from moving substrate is more important than the actual stability of the substrate under the trap. The median substrate size in the reach was significantly positively correlated with both mayfly density and diversity although the probabilities of error were higher. These two factors are obviously intercorrelated since the index is the tractive force divided by substrate; thus the correlations might be expected.

As previously mentioned, station 5 is subjected to sedimentation. Sedimentation has been usually reported to be detrimental to stream benthos (Rutherford and Mackay 1986; Rosenberg and Wiens 1978; Hynes 1973; Nuttall 1972). Thus, the improved relationships with elimination of station 5 from the analyses were also expected. What was surprising was that the correlations with numbers of mayfly species either dropped or did not substantially improve in significance. This perhaps suggests that all of the species present in the Ochre River are to some extent resistant to the effects of sedimentation.

In conclusion, it appears that both density and diversity of mayflies are useful indicators of stream substrate stability, although their usefulness may be limited in situations of settling sediment. Studies on other streams and using other mayfly communities are required to substantiate these results.

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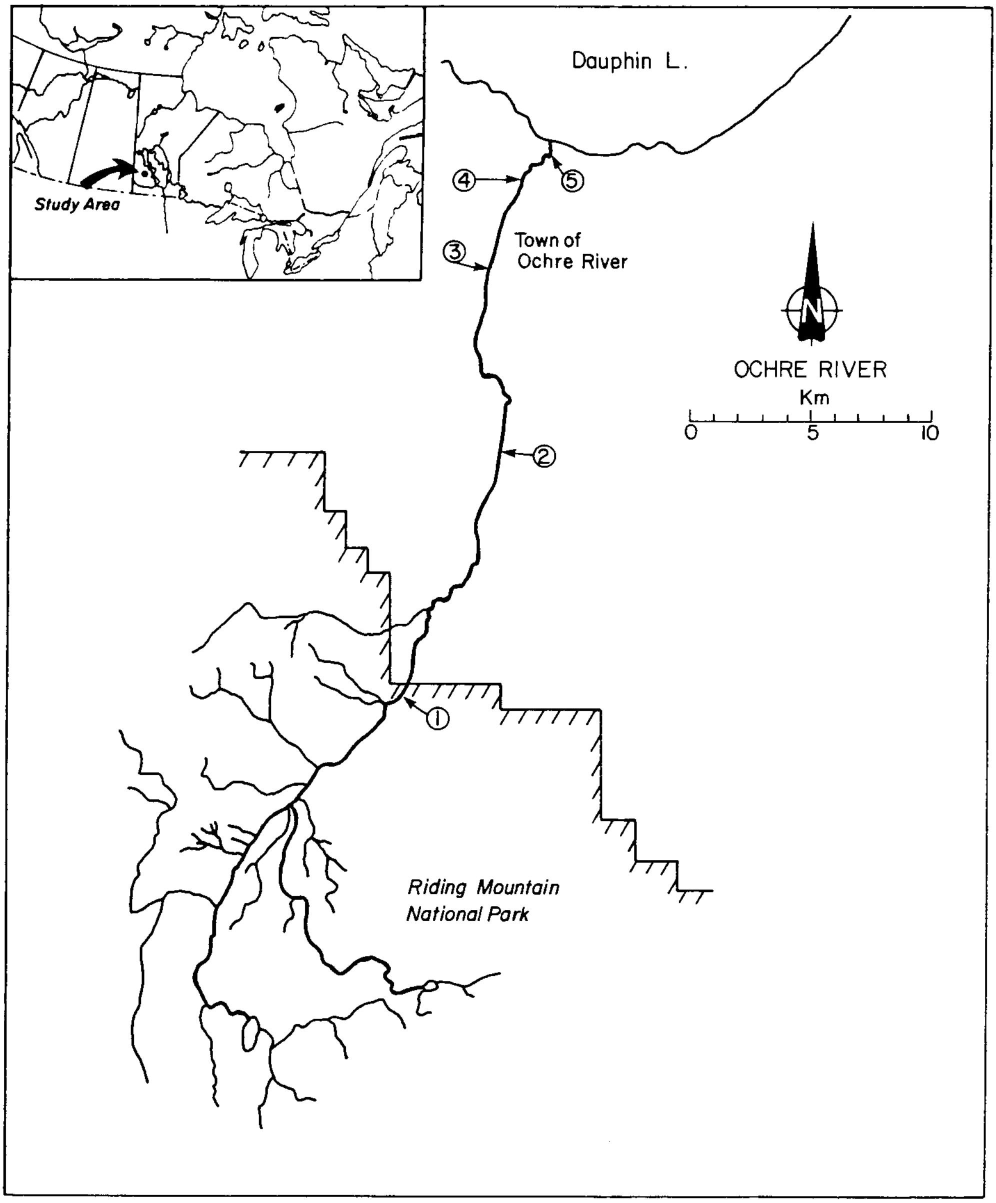

Figure 1. The location of the Ochre River and our sampling sites.

Table 1. Summary of physical, hydrological and chemical results.

Station	# Species	Density no/m^2	% Slope	Depth, bf (m)	Median substrate size (reach) (cm)	Median substrate size (trap) (cm)	Tractive force (kg·m^2)	Instab. index reach	Instab. index trap	Temp (degree days)	pH mean	Conduct. mean	TSS mean	oxygen % (mean)
1.1	7	256	0.5	0.55	12.6	37	2.75	0.218	0.073	1925	7.97	435	55	101
1.2	9	318				7			0.393					
2.1	10	551	0.4	0.41	7.3	7.3	1.64	0.23	0.23	1925	7.98	446	61	101
2.2	8	249				7.3			0.23					
3.1	12	1425	0.65	0.54	41.5	57	3.51	0.085	0.062	1980	8	463	74	101
3.2	11	1437				21.3			0.17					
4.1	16	1043	0.3	0.95	30	46	2.85	0.095	0.062	2076	7.98	478	76	98
4.2	13	2161				42			0.069					
5.1	10	186	0.3	1.1	26.3	32.5	3.3	0.125	0.102	2076	8	486	80	98
5.2	9	220				35			0.094					

Table 2. Correlations between number of Ephemeroptera species, density of Ephemeroptera and substrate size and stability in Ochre River (n=10). Probabilities in brackets are correlations without station 5 data (n=8).

	Ephemeroptera density ($\log_e$ no/m^2)	Reach instability index	Reach median substrate size (cm)
$\log_e$ number of Ephemeroptera species	** (**)	** (**)	* (NS)
Reach instability index	* (***)	-	-
Reach median substrate size (cm)	* (**)	-	-

* = $P \leq 0.05$

** = $P \leq 0.025$

*** = $P \leq 0.01$

N.S. = not significant