Species composition, distribution, and summer emergence phenology of stoneflies (Insecta: Plecoptera) from Catamaran Brook, New Brunswick

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Abstract: Stonefly (Plecoptera) emergence was investigated between May and September of 1993 and 1994 in Catamaran Brook, New Brunswick, as part of a base-line study to evaluate the effects of timber harvest on Atlantic salmon habitat in Atlantic Canada. Thirty-one stonefly species representing seven families were identified from Catamaran Brook, of which 8 were new provincial records. Eight species, all in the families Chloroperlidae and Leuctridae, were common in both years. The cone-type emergence traps used in this study appeared to adequately sample most stonefly species except the Perlidae. There was a pronounced seasonal progression of species emerging from the brook that was generally constant for both years. However, the abundance and timing of stonefly emergence were related to both temperature and discharge patterns. Generally earlier emergence in 1994 than 1993 was probably related to warmer water in 1994 than 1993, and lower abundance in 1994 was probably related to a reduction in habitat due to unusually low water in that year.

Résumé : L'émergence des plécoptères a été étudiée de mai à septembre, en 1993 et 1994, dans le ruisseau Catamaran, au Nouveau-Brunswick, dans le cadre d'une étude de l'impact de l'exploitation forestière sur l'habitat du Saumon atlantique dans les provinces maritimes. Trente-et-une espèces de plécoptères appartenant à sept familles ont été identifiées dans le ruisseau; 8 n'avaient jamais été rencontrées dans la province auparavant. Huit espèces, des familles Chloroperlidae ou Leuctridae, ont été abondantes au cours des 2 années de l'étude. Les cages d'émergence de type conique utilisées au cours de l'étude semblaient permettre l'échantillonnage adéquat de toutes les espèces, sauf des Perlidae. Nous avons observé une succession saisonnière marquée des espèces dans le ruisseau et cette succession s'est avérée généralement constante au cours des 2 années. Cependant, l'abondance et la date d'apparition des plécoptères étaient reliées à la fois à la température et au débit du ruisseau. L'émergence généralement plus hâtive en 1994 qu'en 1993 est probablement reliée à l'eau plus chaude de l'eau en 1994 et l'abondance plus faible des insectes en 1994 est vraisemblablement attribuable à la réduction de l'habitat par diminution importante du niveau d'eau en 1994.
[Traduit par la Rédaction]

Introduction

Catamaran Brook, New Brunswick, is currently the focus of several multidisciplinary studies evaluating logging impacts on Atlantic salmon (*Salmo salar*) habitat and productivity (Cunjak et al. 1993). Aquatic insects, including stoneflies, are an important component of the food of many juvenile salmonids, including Atlantic salmon (Scott and Crossman 1973), and benthic populations have been monitored in the brook since 1991 (Cunjak et al. 1993).

Little is known about the Plecoptera of the Canadian Maritime provinces, particularly with respect to seasonal emergence patterns (Kondratieff and Baumann 1993). Emergence studies on aquatic insects yield important information on species diversity, distribution, and life-history timing (Davies 1984; Friesen et al. 1984), and can provide comparative data for evaluating responses to natural and anthropogenic disturbances (Flannagan and Cobb 1991).

Seasonal studies of Plecoptera emergence in Canada have been carried out in Alberta (Radford and Hartland-Rowe 1971; Donald and Anderson 1977), Saskatchewan (Dosdall and Lehmkuhl 1979), Manitoba (Friesen et al. 1984; Flannagan and Cobb 1991), Ontario (Sprules 1947; Harper 1973*a*, 1973*b*; Harper and Hynes 1972; Singh et al. 1984), and Quebec (Harper and Magnin 1969; Harper and Pilon 1970; Harper 1990), but no emergence studies of Plecoptera have been published for the Maritimes. The objective of this research was to monitor stonefly emergence from three habitat types (riffle, flat or run, and pool) in each of three study reaches in Catamaran Brook in 1993 and 1994. Emergence sampling was implemented to aid in larval species identifications from ongoing benthic studies and to confirm the timing of emergence periods, in order to provide base-line information about aquatic insects in Catamaran Brook prior to logging.

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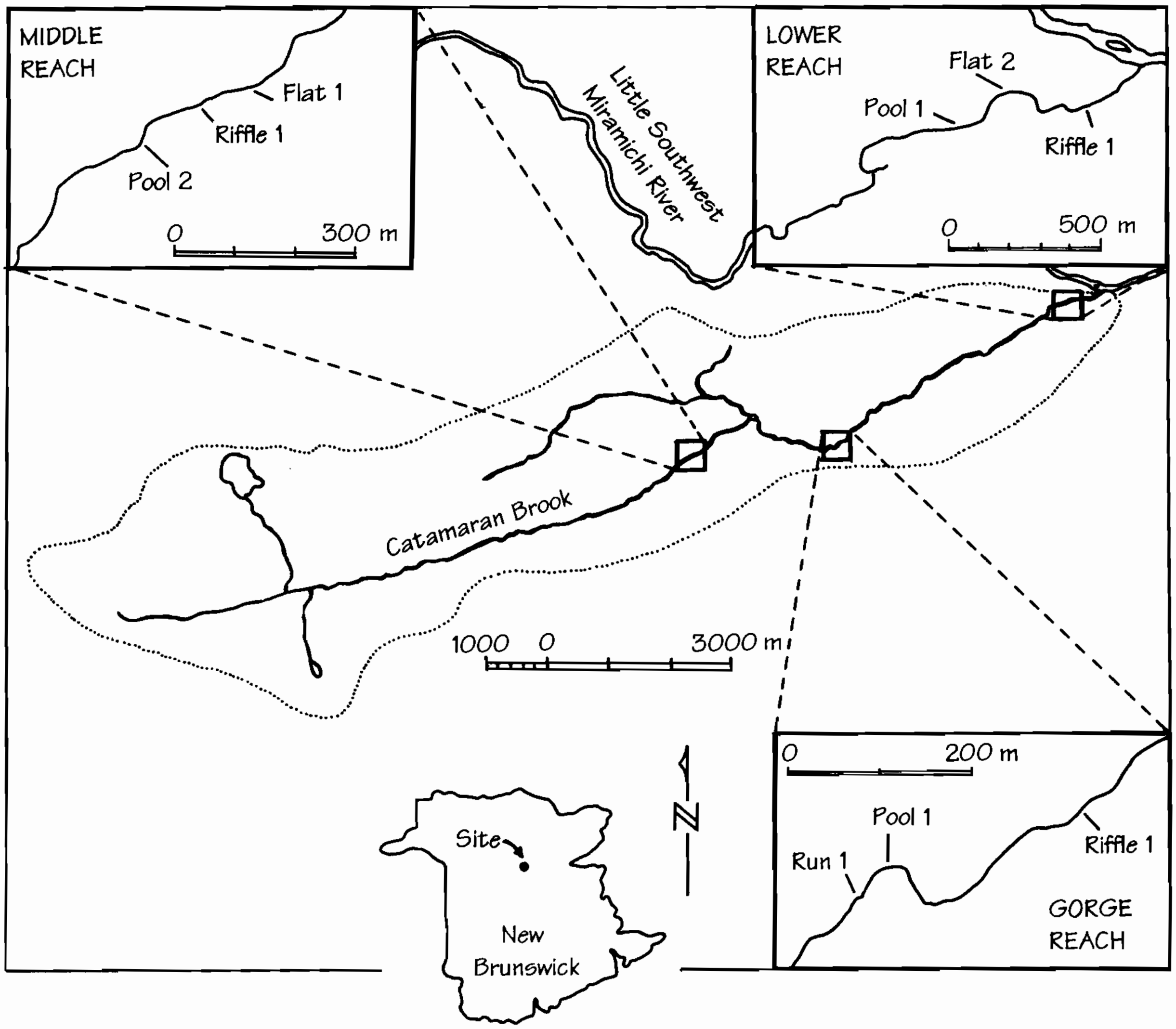
Study area

Catamaran Brook is a third-order tributary of the Little Southwest Miramichi River in central New Brunswick, Canada (Fig. 1). The brook is approximately 25 km in length and drains an area of 50 km^2 in a mixed coniferous–hardwood forest. Specific details on geochemistry, hydrology, and other physical and biotic factors can be found in Cunjak et al. (1993). Four study reaches have been surveyed in the brook, and sites representing replicated habitat

Fig. 1. Catamaran Brook, New Brunswick (46°52.7′N, 66°06.0′W), showing study sites (dotted lines indicate the watershed boundary).



types have been permanently established in each reach. Three reaches (middle, gorge, and lower; Fig. 1) were monitored for insect emergence.

The middle reach was located about halfway down the stream (Fig. 1), just upstream from a forestry road that bisects the catchment. Stream width was 4−5 m and the stream gradient in riffle zones in this reach was 2−2.1%. Substrates ranged from mainly gravel and cobble in the riffles to silt and sand in the pools. The gorge reach (Fig. 1) was located downstream of the forestry road, below a tributary and a beaver dam, about 5 km upstream from the mouth. Stream width varied from 5 to 8 m, substrates were dominated by bedrock outcrops, and the riffle gradient approached 3%. The lower reach included the lower 2 km of the brook (Fig. 1). Stream widths here varied from 7 to 12 m, riffle gradients ranged from 1 to 1.75%, and the substrate consisted of gravel, cobble, and boulder in the riffles and sand and silt in the pools.

Habitats were defined on the basis of water flow and have been described in detail in Cunjak et al. (1993). Riffles were characterized by high water velocity and a broken and turbulent water surface, runs had rapid flow but a smoother water surface and greater depth than riffles, flats had slow flow and a smooth water surface under summer flow conditions, and pools were characterized by still water at summer flow.

Materials and methods

Emergence was sampled using cone-shaped emergence traps (Chmielewski and Hall 1993) constructed with sheer white fabric to minimize darkening (area 0.07 m^2; mesh size 300 μm). The traps were suspended over the stream, and insects were directed upwards by the cone shape into a collecting bottle containing 70% ethanol. This design was chosen over box or cage designs (Davies 1984) because of its portability, because several replicates could be used, and because it could be used to sample all types of habitats, including the fast-water zones.

Three of the permanently established study sites (Cunjak et al. 1993) were chosen in each reach (Fig. 1) to represent a habitat range covering rapid-flow (riffles), moderate-flow (runs or flats), and no- or low-flow (pool) conditions. Five traps were suspended in a transect across the stream in each of the three sites in each reach, giving a total of 45 traps. The traps were adjusted as necessary so that the bottom of the trap rested directly on or just below the water surface, and were anchored in place in the current by attaching the bottom rings to pieces of reinforcement bar driven into the stream bed. Therefore, emergence data reflected the location where insects emerged from the stream water and not necessarily where they spent their larval period.

Table 1. Species composition and distribution in study sites in Catamaran Brook, New Brunswick, 1993 and 1994.

Family and species	LRi1	LF2	LP1	GRi1	GRu1	GP1	MRi1	MF1	MP2
Capniidae									
Capnia probably *vernalis*									x
Allocapnia pygmaea					x				
Paracapnia angulata or *opis*			x						
Leuctridae									
Leuctra tenuis	x	x	x	x	x	x	x	x	x
Leuctra tenella	x	x		x	x		x	x	x
*Leuctra truncata**	x	x	x	x	x		x	x	x
Leuctra ferruginea	x						x	x	
Nemouridae									
Paranemoura perfecta							x		
Amphinemura sp.				x					
Amphinemura wui			x						
Zapada sp.*			x				x		
Chloroperlidae									
Alloperla banksi									x
Alloperla concolor	x	x	x	x	x	x	x	x	x
Alloperla caudata	x	x	x		x	x		x	
*Alloperla imbecilla**	x	x	x	x	x	x		x	x
*Alloperla vostoki**		x	x	x		x		x	x
*Alloperla chloris**	x	x	x	x	x	x	x	x	x
Sweltsa naica						x		x	
Sweltsa mediana	x	x	x	x	x		x	x	x
Suwallia marginata	x		x	x					
Perlidae									
Acroneuria abnormis			x						
Perlodidae									
Helopicus probably *subvarians**							x		
Isoperla lata					x				
Isoperla–Clioperla sp.				x	x	x		x	
Isoperla transmarina	x								
Isoperla cotta or *orata*			x						
Isoperla holochlora		x							
*Clioperla clio**			x						
Cultus probably *decisus*								x	
Yugus sp.*						x			
Pteronarcyiidae									
Pteronarcys biloba							x		

Note: LRi1, lower riffle 1; LF2, lower flat 2; LP1, lower pool 1; GRi1, gorge riffle 1; GRu1, gorge run 1; GP1, gorge pool 1; MRi1, middle riffle 1; MF1, middle flat 1; MP2, middle pool 2.

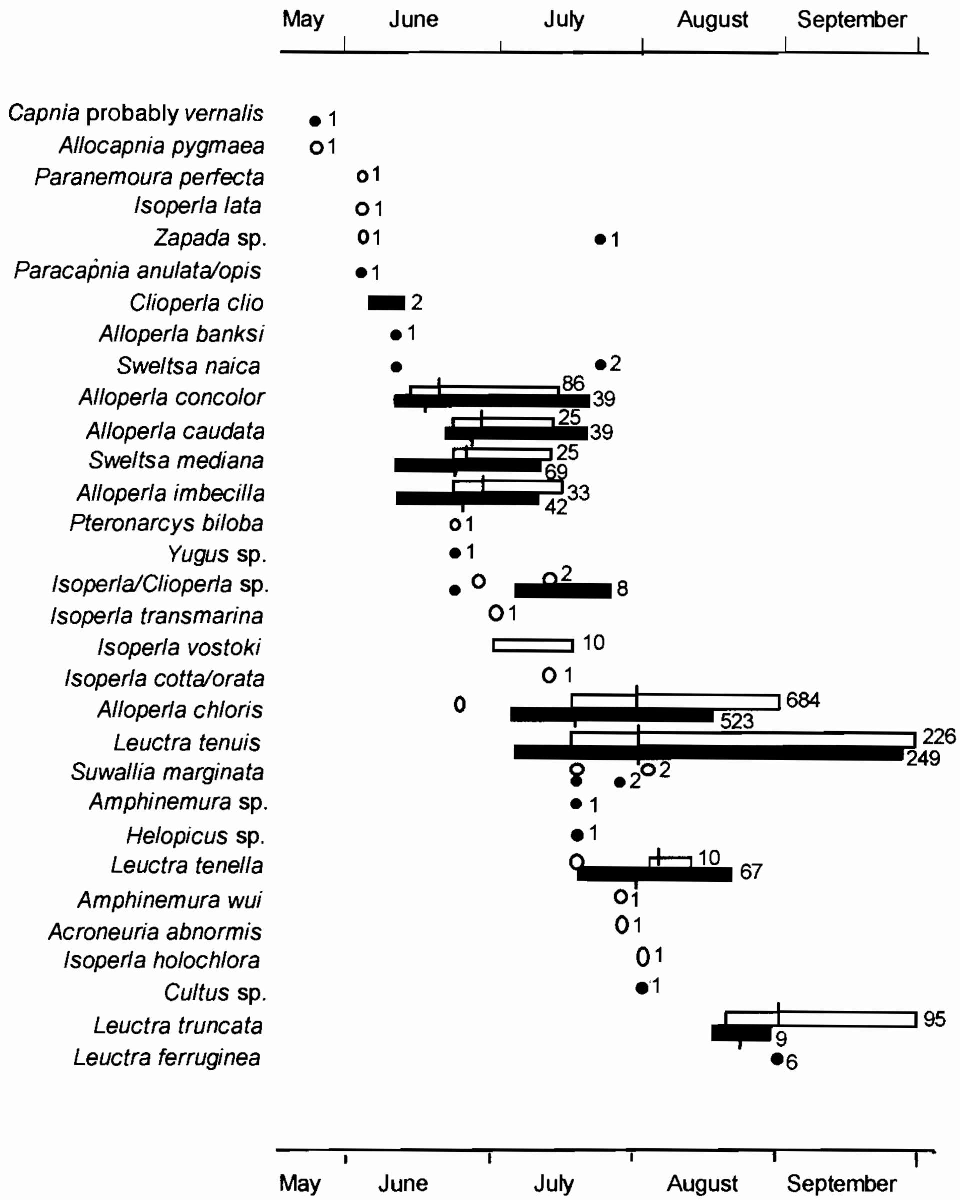
*New record for New Brunswick.

Traps were monitored weekly from the beginning of May, when water temperatures were $<5°C$, to the end of September in both years. Substrate classification (Platts et al. 1983) and water depth and velocity were recorded below each trap on all sampling dates. Water depths were subsequently grouped into 10 cm depth categories, and water velocity under traps was categorized as zero (no water under trap), still (no flow), slow (0–0.15 m/s), moderate (0.15–0.4 m/s), fast (0.4–1 m/s), and very fast (>1 m/s).

During the latter part of the season, particularly in 1994, some of the traps near the stream banks became "stranded" over apparently dry gravel as the water level fell. Stoneflies continued to emerge into these traps (as shown by the presence of exuviae on the gravel or clinging to the trap fabric), which rested directly on the dry gravel at the stream bank, and they continued to be monitored. Water temperature, air temperature, and discharge were recorded continuously in the brook at a permanent gauging station operated in the middle reach by Fisheries and Oceans Canada and Environment Canada.

Samples were sorted to order immediately after collection, and Plecoptera were identified using the keys of Frison (1935), Ricker (1952), Gaufin (1964), Harper and Hynes (1971*a*), Hitchcock (1974), Baumann (1975), Stark and Gaufin (1976), Stewart and

Fig. 2. Emergence phenology of Plecoptera from Catamaran Brook, New Brunswick. □, 1993; ■, 1994. Vertical lines indicate peak emergence; numbers beside the bars indicate the total number emerged.



Stark (1988), and Nelson and Baumann (1989). In some cases (e.g., *Alloperla*), females could not be identified to species, although they could be assigned to a species group. Where identified males of a particular species group emerged concurrently with such females, the females were assumed to belong to the same species. Where no males were captured, the specimens have been recorded using the possible names (e.g., *Isoperla cotta* or *orata*), or simply with "sp." (e.g., *Isoperla* sp.). Abundance patterns were compared with physical factors associated with the traps for the eight most common species using one-way ANOVA to determine whether trap captures of certain species were most associated with certain types of substrate or habitat.

Results and discussion

One thousand, two hundred and ten stoneflies were captured in 1993 and 1064 in 1994. Thirty-one species of Plecoptera were identified from the samples, representing seven families: Capniidae (3 species), Nemouridae (4 species), Perlodidae (9 species), Chloroperlidae (9 species), Perlidae (1 species), Leuctridae (4 species), and Pteronarcyiidae (1 species) (Table 1). Only eight species were common in both years (Fig. 2) and all of the common species belonged to two families, the Chloroperlidae and Leuctridae. Eight species represent new records for the Province of New Brunswick (Table 1). This number of species is likely an underestimate. Traps could not be placed in the brook until after the spring snowmelt flood, which was too late in both years to adequately sample the winter stoneflies (including *Taeniopteryx* sp., which has been collected in benthic samples; Cunjak et al. 1993). In addition, the Perlidae may also have been underrepresented, since their numbers were low relative to those in benthic samples (Cunjak et al. 1993). All other stoneflies were found in similar proportions to those found in benthic samples collected concurrently (Cunjak et al. 1993; D.J. Giberson, unpublished data).

Emergence periods and patterns

Capniidae

Capniidae were rare in the emergence traps, only appearing in the earliest samples (Fig. 2). Capniids generally emerge in early spring, prior to the spring flood (Harper and Magnin 1969; Harper et al. 1991). *Paracapnia* sp. was listed as a new record for New Brunswick by Kondratieff and Baumann (1993); however, *Paracapnia* sp. larvae were recorded from the St. Croix River in New Brunswick by Peterson and van Eeckhaute (1990).

Leuctridae

Four species of Leuctridae were found in emergence traps, and three of these species were common (Fig. 2). All were mid- to late-season emergers, with emergence extending from July to September. This pattern is consistent with that recorded for these species in Ontario (Sprules 1947; Harper 1973*b*) and Quebec (Harper and Magnin 1969; Harper and Pilon 1970). However, the emergence in northern New Brunswick was generally later than that reported in central Canada. *Leuctra truncata* represents a new record for New Brunswick (Table 1).

The emergence of *L. tenuis* overlapped temporally with all other species of *Leuctra* in the brook, but *Leuctra* spp. may have been spatially segregated. *Leuctra tenuis* was commonest in the lower reach in traps over low water velocities and fine substrates (ANOVA, $p < 0.05$). *Leuctra tenella* and *L. truncata* showed no statistically significant reach preference, but were commonest in traps in riffle habitats over coarse substrates and did not overlap temporally (Fig. 2).

No significant trap preference was seen for any *Leuctra* species (ANOVA, $p > 0.05$), indicating that they emerged fairly randomly across the stream. However, *L. tenella* and *L. truncata* continued to emerge into traps that had become "stranded" over dry gravel late in the summer as water levels declined. These were the only species to show consistent emergence in these traps, suggesting that they may reside in the damp substrates below the traps or migrate through the substrates before emerging.

Nemouridae

At least three species of Nemouridae were encountered in emergence traps, but all were too rare to allow emergence patterns to be adequately characterized (Fig. 2). *Zapada* sp. is generally considered to have a western North American distribution (Stewart and Stark 1988), but Harper and Hynes (1971*b*) described, on the basis of several female and larval specimens, a *Zapada* species from eastern North America. Both specimens found in Catamaran Brook were female; their presence in Catamaran Brook represents a new provincial record (Table 1).

Chloroperlidae

Chloroperlids were well represented in emergence samples, with a total of nine species, five of which were very common (Fig. 2) and three of which are new provincial records (Table 1). As found for the Leuctridae, the emergence patterns were similar to those reported for other northeastern locations, but emergence tended to be 2–4 weeks later (Ricker et al. 1968; Harper and Magnin 1969; Harper and Pilon 1970; Hitchcock 1974).

Three of the common chloroperlid species (*Alloperla concolor*, *A. caudata*, and *A. imbecilla*) emerged early in the season and were most abundant in the lower reach in traps over slow water (ANOVA, $p < 0.05$), suggesting little temporal or spatial segregation. *Alloperla chloris* also preferred the lower reach and slow-water traps, but emerged in mid to late summer, 4–6 weeks later than other *Alloperla* species. All of the common chloroperlids except *Sweltsa mediana* showed a tendency for higher emergence from traps located near the banks, but this was not statistically significant for any species ($p > 0.05$, ANOVA).

Perlidae, Perlodidae, and Pteronarcyidae

Individuals in these families were too rare in emergence traps (Table 1) to allow their emergence patterns to be adequately characterized. These stoneflies are generally larger than the members of the previous four families, and many may have migrated to stream edges to emerge (Hynes 1976). Perlodids and pteronarcyids, however, were found in similar proportions to those in benthic samples (Cunjak et al. 1993), suggesting that they may simply be rare in the brook. Only the perlids appeared to be underrepresented relative to benthic densities.

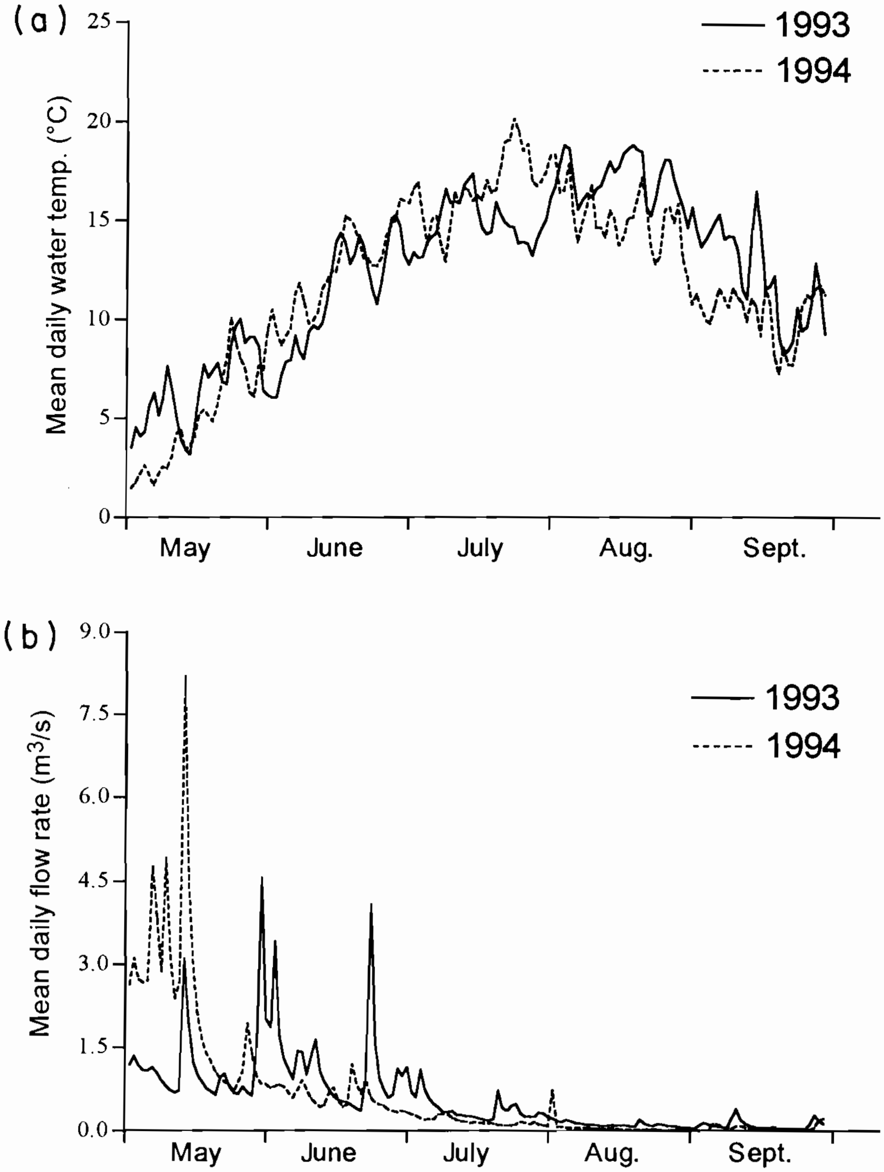
Overall patterns

The general patterns of emergence were similar in the 2 years, although the magnitude and timing of emergence varied, both between years and among sites. Most taxa emerged earlier in 1994 than in 1993 (Fig. 2), which was probably related to the higher midsummer temperatures in the brook in 1994 (Fig. 3*a*). Several researchers have noted earlier emergence in warm years than in cold ones and at lower altitudes than at high-altitude sites (Hynes 1976; Harper and Pilon 1970).

Overall Plecoptera abundance was slightly lower in 1994 than in 1993, although many of the common Plecoptera species were more abundant in emergence traps in 1994 than in 1993 (Fig. 2). These patterns may have been related to differences in discharge between the 2 years; in 1993, the brook experienced three major flood peaks in May and June, whereas in 1994 there was only one major flood peak in early May, followed by a decline to unusually low summer levels (Fig. 3*b*). The two commonest stoneflies, *A. chloris* and *L. truncata*, declined in abundance between 1993 and 1994, and both of these species emerged in mid to late summer, when water levels in the brook declined drastically in 1994 relative to 1993. The low water levels may have had detrimental effects on the populations by reducing the available habitat.

Similar numbers of taxa occurred in each study reach, although taxonomic composition varied (Table 1). However, significantly more emergence occurred in the lower reach in both years than in the gorge or middle reach (ANOVA, $p < 0.05$; Fig. 4). There was also a tendency for higher stonefly emergence in traps located over sites categorized as having slow-water conditions with sand and gravel substrates than in fast-water sites with coarser substrates (Fig. 4). Some

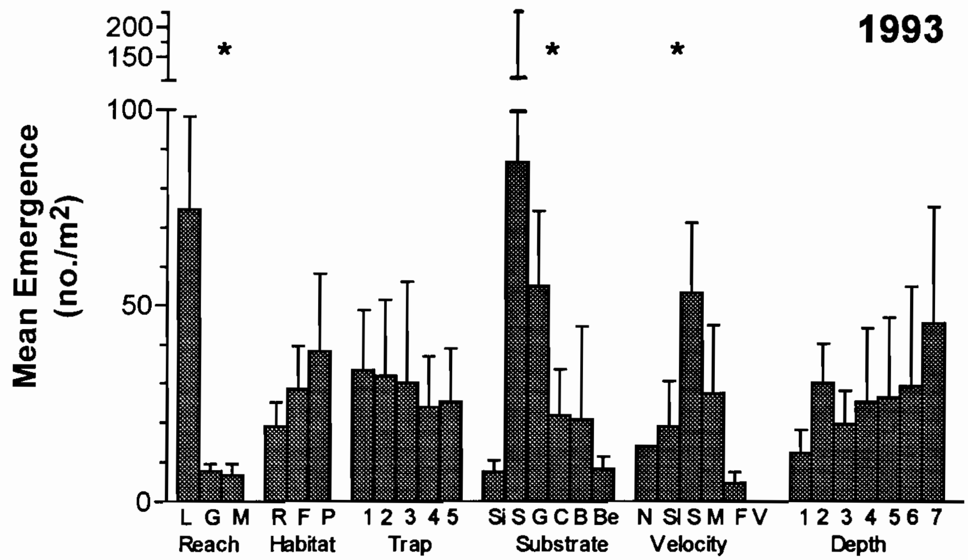
Fig. 3. Mean daily water temperatures (*a*) and discharges (*b*) in Catamaran Brook in 1993 and 1994, from the permanent gauging station in the middle reach.

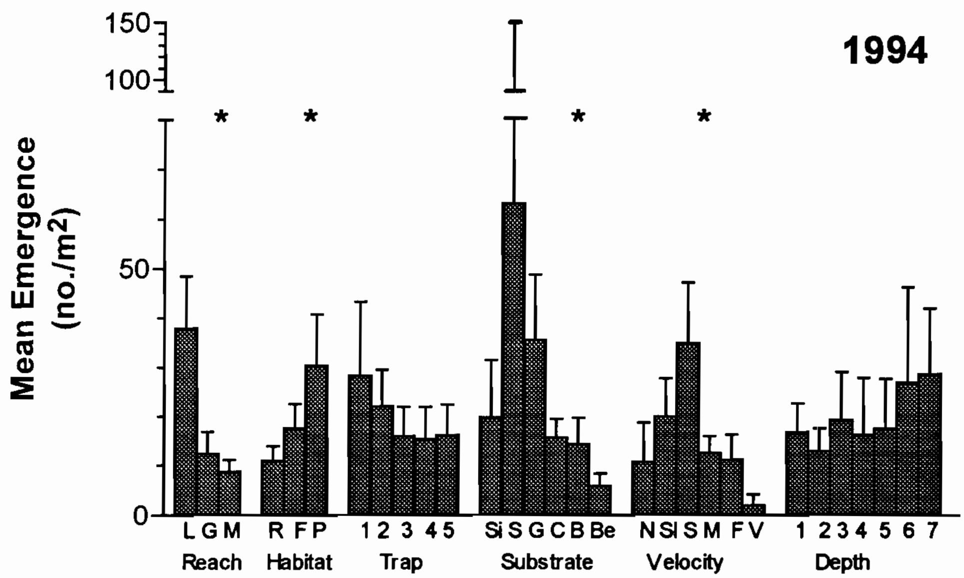


stoneflies may drift or migrate to slower water sites (pools, flats) before emergence; benthic studies in the same sites (D.J. Giberson, unpublished data) show that, for the immatures, the greatest larval abundance was generally found in riffle and run sites. Hynes (1976) suggested that many stoneflies migrate to the slower edges of streams to emerge, and therefore we expected to see significantly higher emergence from traps located at the stream edges than from traps in the middle of the stream. Trap location across the transect and water depth below traps had no statistically significant effect on overall Plecoptera emergence (ANOVA, $p > 0.05$), and although a few species showed a pattern of higher emergence from traps near the banks than from midstream, these patterns were not significant (ANOVA, $p > 0.05$). Further, several of the large species were collected from midstream traps.

The emergence trap used in Catamaran Brook was based on the cone trap used by Chmielewski and Hall (1993) in similar streams in central Ontario. Many types of traps have been used or proposed for use in running-water habitats, including cage traps (a screen cage built over the stream bed), funnel traps (a funnel-shaped frame set into the stream bed that funnels insects into a net), floating traps (generally used only in larger rivers), and suspended traps (Davies 1984). No trap design is suitable for all insect groups or habitat types, although any design should provide comparable results between sites and years (Davies 1984). Problems occur because some insects migrate before emergence, cage and funnel traps may clog with leaves and debris and are difficult to install in very fast water, and floating or suspended traps tend to tip in high-flow conditions (Davies 1984; Chmielewski and Hall 1993). The size of trap is also important; large traps sample large or rare insects more effectively, but can be unwieldy, whereas several small traps provide better statistical replicability and are more portable (Davies 1984; Chmielewski and Hall 1993). The suspended

Fig. 4. Numbers of Plecoptera emerging from Catamaran Brook, New Brunswick, from mid-May to late September from different reaches, habitat types, trap locations, substrate types, water-velocity classes, and water-depth classes. Vertical lines represent 95% confidence intervals. An asterisk indicates a significant effect of the parameter on abundance (ANOVA, $p < 0.05$). Reach: L, lower; G, gorge; M, middle. Habitat: R, riffle; F, flat–run; P, pool. Trap: 1, right bank; 5, left bank (facing downstream). Substrate: Si, silt; S, sand; G, gravel; C, cobble; B, boulder; Be, bedrock. Velocity: N, no water beneath trap; S, still; Sl, slow; M, moderate; F, fast; V, very fast. Depth: 1, 0–10 cm; 2, 11–20 cm; 3, 21–30 cm; 4, 31–40 cm; 5, 41–50 cm; 6, 51–60 cm; 7, >60 cm.





cone trap used in this study was anchored in place to reduce tipping in high flow, and was small and portable enough that several could be transported into isolated sites. In addition, it allowed us to sample in sites where a bedrock substrate or very high flows made it impossible to anchor box or cage traps. Chmielewski and Hall (1993) compared the suspended cone trap with box and pyramid traps and concluded that it was effective for sampling black flies and some other groups, but tended to underestimate groups that migrate to the stream banks or to slow-water sites to emerge, as was likely with the large predatory Perlidae in this study.

The pattern of stonefly emergence also indicated that a number of closely related congeneric species were on the wing at the same time. It is unusual to find closely related species emerging together, since temporal segregation is one way for congeners to reduce competition and remain genetically isolated (Hynes 1976). Grant and Mackay (1969) also noted this pattern, suggesting that temporal segregation was more important than habitat segregation in insects in a stream on Mount St. Hilaire, Quebec. Some habitat segregation was noted between *Leuctra* species emerging at the same time, at least with respect to emergence, but not in the chloroperlids. It is not possible to identify larval Chloroperlidae to species, so larval habitat preferences are not known, and it is difficult to speculate on the anticompetitive mechanisms of these species. In terms of genetic isolation, some mechanism besides temporal segregation, such as differences in mating behaviours or morphology of the genitalia, must keep them isolated.

Little work has been done on the aquatic insects of the Maritime provinces, especially recently or at the species level of identification. The stonefly assemblage found in Catamaran Brook generally represents an eastern North American assemblage, as indicated by Hitchcock (1974) and Stewart and Stark (1988). In a recent trip to Atlantic Canada, Kondratieff and Baumann (1993) increased the number of stonefly species known from New Brunswick from 39 to 64, of which 31 have been recorded from Catamaran Brook. Seven of the species listed as new records by Kondratieff and Baumann were also found in Catamaran Brook, plus an additional eight species that represent new records for the province.

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Erratum: *Alloperla imbecilla* should read *A. atlantica*

(Baumann, R.W. 1974. What is *Alloperla imbecilla* (Say)? Designation of a neotype and a new *Alloperla* from eastern North America (Plecoptera: Chloroperlidae). Proc. Biol. Soc. Wash. 87:257-64