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# REPLACEMENT BY CAENIS DIMINUTA WALTER (EPHEMEROPTERA: CAENIDAE) IN THE MAYFLY COMMUNITY STRUCTURE OF A THERMALLY-STRESSED, SOUTHEASTERN STREAM

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REPLACEMENT BY *CAENIS DIMINUTA* WALKER (EPHEMEROPTERA:CAENIDAE) IN THE MAYFLY COMMUNITY STRUCTURE OF A THERMALLY-STRESSED, SOUTHEASTERN STREAM[1]

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Abstract. Mayfly community structure on sycamore (*Platanus occidentalis*) and sweetgum (*Liquidambar styraciflua*) leaf packs in a thermally-stressed, post-thermal and an unstressed stream were compared. Leaves were colonized over an 11 wk (77 d) period from December 1982 to March 1983. Temperatures ranged from 7-31°C in the thermally-stressed stream and from 4-14°C in both the post-thermal and unstressed streams. Degree-days (>0°C) accumulated were 1014, 638 and 608 for the thermally-stressed, post-thermal and unstressed streams, respectively. Significant differences in mayfly community structure were found between the thermally-stressed *vs*. the post-thermal and unstressed streams with respect to both *Stenonema* spp. and *Caenis diminuta* Walker. No significant differences in community structure were found between the two leaf species. *Stenonema* spp. dominated the mayfly fauna over the sampling period for both the unstressed (68%) and post-thermal (98%) streams; however, *C. diminuta* replaced *Stenonema* spp. as the dominant mayfly (88%) within leaf packs from the stream receiving thermal effluent. Additional data suggest *C. diminuta* may be tolerant of rapidly fluctuating thermal regimes ($\Delta T$ of up to 11°C in 1 hr) and high temperatures (up to 40°C).

Changes in lotic macroinvertebrate community structure have been used frequently to investigate impacts of thermal stress (Benda & Proffitt 1974, Dahlberg & Conyers 1974; Howell & Gentry 1974; Langford 1971; Obrdlík, Adámek & Zahrádka 1979; Rodgers 1980). However, these findings have often appeared contradictory, probably due to the differing intensity, duration and seasonal timing of the thermal perturbations under examination. Benda & Proffitt (1974) found macroinvertebrate taxa decreased, while total numbers increased, below electrical power plant cooling water discharge in Indiana. Dahlberg & Conyers (1974) found both number of taxa and individuals increased below a power plant in Virginia. Macroinvertebrate biomass, however, can either increase or decrease in response to artificially elevated temperatures, depending on season (Rodgers 1980, 1982).

Mayflies (Ephemeroptera) are potentially good indicators of thermal stress because of their general sensitivity to pollution (Hynes 1974; Sloan 1956). Thermally-induced changes in mayfly community structure reported in the literature are in relatively close agreement. Obrdlík et al. (1979) found reduced mayfly diversity below a power plant in Czechoslovakia, and mayfly numbers decreased downstream of power plant effluent in Indiana (Benda & Proffitt 1974). Reduced mayfly abundance and diversity were also reported by Howell & Gentry (1974) in a thermal stream. Langford (1971) reported that, although heated effluent from a power plant did not affect numbers of mayflies collected from an English river, relative abundances of major mayfly taxa shifted.

The objective of this research was to investigate the influence of temperature on macroinvertebrate utilization of allochthonous leaf material in a large, Southeastern coastal plain river and three of its major tributaries. In this study, we found total mayfly abundance, particularly abundance of the predominant species, Stenonema spp., to be significantly reduced in a thermally-stressed stream. However, C. diminuta occurred regularly and with significantly greater abundance in the thermally-stressed stream than in both the post-thermal and unstressed streams. This finding raises interesting questions about the thermal tolerance of this species.

There are relatively few studies involving temperature effects on Caenis in North America. Rodgers (1980) reported density reduction and life cycle acceleration for Caenis sp. (since identified as C. simulans, Elizabeth Rodgers pers. com.) in artificial streams maintained at seasonally elevated temperatures. Rodgers (1982) found that density, fecundity and annual production rates of C. simulans were reduced in the artificial streams at temperatures exceeding 30°-35°C. Caenis diminuta has not been reported to occur at temperatures greater than 30°C (Hubbard & Peters 1978). However, Caenis sp. nymphs have been found at temperatures approaching 40°C in Par Pond, a thermal cooling resevoir on the SRP (Thorp & Bergey 1981).

*Caenis diminuta* has been reported from several locations in South Carolina, including the Upper Coastal Plain (Berner 1977). The nymphs may be found in stream vegetation and leaf debris where current is reduced or in lentic habitats such as ponds and roadside ditches (Berner 1950; Hubbard & Peters 1978). *Caenis* sp. nymphs are rarely abundant in undisturbed streams in South Carolina, but where they are, *Stenonema* spp. are also generally common (Paul Carlson pers. com.). *Caenis diminuta* has been reported as tolerant of various environmental stresses, including low D.O., high temperatures, organic enrichment and unstable pH (Berner 1950; Sloan 1956). In this study, we present data that suggest *C. diminuta* is a species tolerant not only of high temperatures, but also of dramatically fluctuating temperature regimes.

## MATERIALS & METHODS

### Study Sites

This project was conducted on the Savannah River Plant (SRP), a facility operated for the Department of Energy by E.I. du Pont de Nemours & Co., Inc. The SRP occupies 778 $km^2$ (300 $mi^2$) on the South Carolina Upper Coastal Plain adjacent to the Savannah River (Fig. 1). Production reactors in operation at the plant use once-through cooling, and two of the three operating reactors release hot water (>70°C) to onsite streams. Temperatures decrease as receiving streams flow through riverine, floodplain swamps toward the Savannah River; however, ambient temperatures are not attained until mixing with the river occurs. Two streams on the SRP have received reactor thermal discharges since 1954; two no longer serve as effluent streams; and, one has never received thermal discharges.

Three streams with distinct thermal regimes were chosen for this study: Upper Three Runs Creek (U3RC), Steel Creek (SC) and Four Mile Creek (4MC). Sampling was conducted in each stream within 0.1 km of its confluence with the Savannah River (Fig. 1). Leaf pack placement in the streams was delayed until late December in order to take advantage of the scheduled discharge of cooling water at elevated temperatures from an upstream reactor into 4MC throughout the winter and spring of 1983.

Upper Three Runs Creek is an Upper Coastal Plain, blackwater stream that has never received thermal effluent. It drains a watershed of 490 $km^2$, is 39 km long, and flows mostly through bottomland hardwood (McFarlane 1976). Average discharge at the mouth has historically ranged between 5.5 and 15.0 $m^3/s$, with an estimated average of 7.5 $m^3/s$ (Brown, Jacobsen, Rabon & Tilly 1972). At its confluence with the Savannah River, U3RC is a well-canopied, sandy-bottomed, fourth order stream.

Steel Creek is about 20 km long and drains 90 $km^2$ watershed (Langley & Marter 1973). Prior to its confluence with the river, it flows through an extensive cypress-tupelo gum (Taxodium *distichum* - *Nyssa aquatica*) swamp, where it is joined by Pen Branch, a stream draining 90 $km^2$ along its 24 km length (see Fig. 1). Pen Branch (PB) has received cooling water effluent since 1954. Steel Creek, however, has received no elevated temperature discharges since 1968. The SC Swamp is presently characterized by open canopy and patchy, dense macrophyte beds. Most of the water (83%) discharging from the swamp into SC near its confluence with the river is actually river water that has been circulated through the operating reactor on PB. Steel Creek is 1-2°C above ambient at its point of discharge from the swamp due to the influence of PB Discharge at the mouth of SC has been estimated to range between 1.9 $m^3/s$ and 11.3 $m^3/s$ (Brown et al. 1972). At its confluence with the river, SC is a third order stream with a mostly sandy bottom.

Four Mile Creek drains 90 $km^2$ along its 24 km length (Langley & Marter 1973). A production reactor has discharged cooling water effluent into 4MC about 15 km upstream of the river from 1954 to the present. This hot water, about 89% of which is river water, flows through the 4MC Swamp and most re-enters 4MC about 2.5 km above the stream mouth. Because of the short hydrologic retention time and the paucity of macrophytic vegetation in the swamp, water in 4MC has a heavy sediment load like that of the river. Discharge rates at 4MC mouth are variable. Average discharge during periods of reactor operation is about 5.7 $m^3/s$; however, when the reactor is shut down for fuel replacement, discharge can drop to about 2.3 $m^3/s$ (Brown et al. 1972). Near its confluence with the river, 4MC is a well-canopied, third order stream.

Each of our sampling stations was subject to backflooding from the Savannah River. River water normally begins to invade the streams and flood the swamps at river elevations of about 27.4 m msl (90 ft mean sea level), as measured at the Corps of Engineers gauging station near U3RC (Brown et al. 1972). These high river levels generally occur in the early spring when water is released from upstream reservoirs on the Savannah River.

Methods

Leaves of sycamore (Platanus occidentalis) and sweetgum (Liquidambar styraciflua), common riparian species at the SRP, were collected just prior to abscission, air dried to constant weight and placed in labeled plastic peanut bags (maximum mesh size, 5 x 25 mm). Eight leaf packs of each species were placed in hand-crafted, chicken-wire baskets and secured to concrete blocks. Eight baskets, along with a continuously-recording thermograph (Peabody Ryan Model J) were placed near the stream bottom of each of the three sampling sites. One basket from each site was retrieved randomly following 12, 20, 27, 34, 48 and 77 days of exposure. Thermographs were pulled at the end of the study and degree-days (>0°C) were calculated numerically by fitting appropriate-sized trapezoids to the recorded temperature profile

(Stark 1970). Due to equipment difficulties, degree-days before day 41 at U3RC were calculated by extrapolating from six datum points.

Three randomly-selected leaf packs of each species were returned to the lab on ice, and each was separately washed through a Number 40 U.S. Standard Sieve (425-μm mesh). All retained material was stored in 75% EtOH. Macroinvertebrates were sorted by hand in a white enamel tray. Some samples required treatment with $CaCl_2$ to separate macroinvertebrates from accompanying debris (Anderson 1959). Mayflies were identified to genus using Brigham, Brigham & Gnilka (1982). Data were tested to conform to the assumptions of parametric ANOVA, then analyzed using the general linear models procedure (GLM) and Duncan's multiple range test (Goodnight, Sall & Sarle 1982).

## RESULTS

### Temperature

Continuously-recording thermographs placed at each site over the study period indicated that alternating periods of normal stream discharge and river water intrusion into the streams induced temporally unpredictable temperature fluctuations in the three stream mouths, particularly in 4MC (Fig. 2). Temperatures in 4MC were highest when hot water from the upstream production reactor discharged from the stream mouth into the river. Such discharge normally occurs when river stage is below approximately 27.4 m (msl), as was the case on only 14 of the 77 days of the study. However, all 14 of these days of normal stream-mouth discharge occurred before the fifth collection date (day 48), and 11 occurred before the third (day 27). Steel Creek and U3RC showed similar thermal regimes, with mid-January lows of about 4°C followed by general warming to about 14°C in March (Fig. 2). Temperatures in 4MC, however, ranged widely from 7-31°C, with the highest temperatures occurring in December and mid-January (Fig. 2). Approximate total degree-days accumulated were 1014 for 4MC, 638 for SC and 608 for U3RC. Four Mile Creek also accumulated 24 degree-days >15°C, 12 degree-days >20°C and 4 degree-days >25°C, while U3RC and SC had no degree-days >15°C.

Rapid temperature changes were not uncommon in 4MC over this period. For example, on day 21 the temperature dropped from 26°C to 13°C over a six hour period; on day 41 it climbed from 8°C to 23°C in 24 hours; and, on day 48 it dropped from 22°C to 11°C in just over one hour (see Fig. 2). Although river water intrusion into U3RC and SC also resulted in modified thermal regimes, recorded temperature fluctuations in these two streams were relatively small (Fig. 2).

Other physical-chemical characteristics fluctuated under the influence of river water intrusion. Generally, 4MC and SC were similar with respect to water chemistry, but river backflooding of

U3RC resulted in occasional overlaps in water quality between the three streams (Table I).

Fauna

No significant differences in numbers of mayfly taxa occurred between sycamore and sweetgum leaves. Therefore, numbers collected on both leaf types were pooled by site for each sampling date. Because no sample was recovered from 4MC after day 48, statistical comparisons between the three streams were restricted to the five dates on which samples were retrieved from all sites.

*Caenis diminuta* and *Stenonema* spp. represented the only mayflies that showed a significantly different abundance ($p \leq 0.05$) in the thermally-stressed stream when compared with both the unstressed and post-thermal streams (Table II). *C. diminuta* was significantly more abundant in 4MC than in both U3RC and SC. The species represented 88% of the mayfly fauna in 4MC. Only one nymph was taken from SC (day 77) and none were collected from U3RC (Fig. 3). Conversely, *Stenonema* spp. were significantly less abundant in 4MC (4%) than in either U3RC (68%) or SC (98%). Upper Three Runs and Steel Creeks were significantly different from each other with respect to *Stenonema* spp.; however, *Stenonema* was the dominant genus in both streams (Table II).

Upper Three Runs Creek had the most diverse mayfly fauna over the entire study period (Table II). It also supported the most genera on each collection date (Fig. 3). This was not unexpected, given that this stream has suffered relatively little perturbation. Post-thermal SC yielded fewer genera than did thermal 4MC, although differences were not pronounced. Because the sampling site in 4MC was nearer the confluence with the river than was the SC site, river water intrusion at higher river stages may have introduced occasional, transient taxa to leaf packs in 4MC. Mayfly abundance, however, was much higher in SC than in the other streams due to the great number of *Stenonema* spp. (Table II). Leaf packs from SC also produced the most mayflies on each collection date, followed by those from U3RC and 4MC (Fig. 3).

Thirteen drift samples taken from 11 March to 28 August 1982 (Specht & Painter 1983) showed a total of 201 *Caenis* sp. were collected in 4MC mouth, as compared with fewer than 10 for both U3RC and SC mouths (Table III). Based on our leaf pack collections, we suspect all *Caenis* collected in the drift from 4MC and SC to be *C. diminuta*; however, we are less certain about collections from U3RC, as *C. amica* reportedly occurs in the U3RC watershed (Morse, Chapin, Herlong & Harvey 1980). The Heptageniidae, mostly *Stenonema* spp. (Bill Painter, ECS, pers. com.), were relatively uncommon in the drift of all three streams (Table III). The relative abundances of the Heptageniids in the drift from SC and U3RC were particularly low when compared to collections from leaf packs (see Table II). Although total numbers are low, these data suggest that this sampling method does not accurately reflect actual mayfly community structure, especially in the non-thermal streams.

*Caenis* occurred regularly in the 4MC drift at temperatures ranging from 21-40°C (Table III). The most individuals collected at one time were 122 on 3 June 1982, when the water temperature in 4MC mouth was 40.4°C. Unfortunately, it is not known whether these organisms were viable at the time they were taken. However, the regular occurrence of *Caenis* in the 4MC drift throughout the summer months suggests either that the species is tolerant of elevated temperatures or that cooler refuges are available. One possible explanation for the peak on 3 June is that a temperature of about 40°C represents a thermal threshold, above which *Caenis* cannot maintain itself on the substrate and enters the drift in great numbers.

Monthly collections of Hester-Dendy multi-plate samplers from each of the stream mouths between October 1982 and March 1983 (ECS, unpub. data) also showed the presence of *Caenis* nymphs under elevated temperature regimes. Prior to the October collection, a high temperature of at least 39.2°C was recorded (Table III), and during the following month, a high temperature of at least 34.8°C was measured (O'Hara & Osteen 1983). Heptageniids (mostly *Stenonema* spp.) were relatively uncommon in 4MC (Table III). However, relative abundances of *Caenis* sp. and Heptageniids at each of the three sites were similar to those observed on our leaf packs (cf. Tables II & III).

# DISCUSSION

Our data indicate the thermal regime in 4MC is an important determinant of that stream's mayfly community structure; however, other factors may also contribute to C. diminuta abundance in 4MC. Because mayflies are held to be microhabitat specialists, substrate type and stream velocity should be considered (Edmunds, Jensen & Berner 1976). Four Mile Creek sediments are finer than those of either U3RC or SC, and stream velocity at the sampling site in 4MC is usually less than that at the sites in the other two streams. However, C. diminuta nymphs were also collected on leaf packs in SC (day 77) and in the Savannah River below the mouths of 4MC and SC where velocities are greater and substrates coarser. Moreover, siltier substrates and reduced flow should not so depress the occurrence of Stenonema spp., which also occur on leaf debris in streams (Berner 1950; Edmunds et al. 1977).

General water quality differences between the three streams do not account for the relative abundance of C. diminuta in 4MC (see Table I). Four Mile Creek and Steel Creek have similar water quality by virtue of the reactor cooling water flowing through each of these streams, but the mayfly fauna of these two streams are significantly different with respect to dominant species. Upper Three Runs Creek is typically a unit lower in pH and less alkaline than the other two streams. With respect to species dominance, however, U3RC is more similar to SC than SC is to 4MC.

Other factors possibly important in explaining *C. diminuta* abundance in 4MC could be reduced predation or competition pressure and enhanced nutrient supply. Rodgers (1982) found that numbers of *C. simulans* were reduced at elevated temperatures, in part due to increased bluegill predation. McFarlane (1976) reported fewer species of insectivorous fishes in 4MC than in either U3RC or SC. Recent electroshocking efforts in the Savannah River system indicate that fewer insectivorous fishes occur during the warm, summer months in 4MC than in U3RC or SC; however, in the winter this situation is reversed and fish move into the warm 4MC from the Savannah River (O'Hara & Osteen 1983). Our macroinvertebrate data also show the percentage of predators in the leaf pack fauna to be highest for 4MC. These data suggest that predation pressure, both vertebrate and invertebrate, was actually greater in 4MC during the leaf pack study than in either of the other two streams.

Warmed water in 4MC and upstream in 4MC Swamp accelerates decomposition of allochthonous materials (Paul, Benfield & Cairns 1983; Sadowski & Matthews, In Review). This could provide an enhanced food supply for *C. diminuta* in the form of fine organic particulate matter, as this nymph is a collector-gatherer (Merritt & Cummins 1978). Macroinvertebrates that perish after drifting into 4MC from side channels could also serve as a food source for the nymphs, which have been observed to feed opportunistically on such material (Lewis Berner pers. com.).

Nutrient availability in 4MC for C. diminuta should also increase because of the thermal exclusion of most other collector-gatherers (Poff & Matthews, In Review).

Caenis diminuta abundance in 4MC may be facilitated by the above factors (microhabitat, reduced predation/competition, nutrient availability); however, without the ability to tolerate the elevated temperatures and thermal fluctuations prevailing in 4MC, this species could not thrive. The rarity of C. diminuta in the post-thermal and unstressed, ambient streams at the SRP suggests that conditions are more favorable for this species in 4MC. The American Caenidae are of Lower Boreal derivation (Berner 1977), and their apparent preference for warm waters in the temperate zone probably reflects their more southerly origins. Caenis diminuta nymphs have most frequently been reported from warm water habitats, for example shallow lentic environments or slow-moving stream reaches (Berner 1950; Edmunds et al. 1976; Hubbard & Peters 1978). Sloan (1956) found C. diminuta abundant in warm water springs in Florida where temperature varied only between 20°-28°C annually. Caenis nymphs have also been found to be tolerant of elevated thermal regimes in lotic habitats. Rodgers (1980, 1982) reported that C. simulans can acclimate to temperatures up to 6°C above ambient (Tmax = 35°C), although biomass, production and fecundity are reduced. Langford (1971) and Obrdlík et al. (1979) found C. macrura nymphs at temperatures 0.2-4.0°C (Tmax = 24.8°C) and 5.5-14.6°C (Tmax = 35.4°C) above ambient, respectively, in European waters constantly warmed by electrical power plant discharges.

Sweeney & Vannote (1978) suggest that the "temporal predictability" of a river's or stream's thermal regime plays an important role in regulating the temporal distribution of aquatic insects in a given lotic habitat. They further state that lotic insects "show little ability to compensate or acclimate to environmental temperatures," beyond that temperature range in which they have evolved. Although C. diminuta is not solely a lotic insect, the same general evolutionary constraints would be expected to influence its distribution in the temperate zone. The semi-lotic habitats from which C. diminuta has been previously reported may be subject to great thermal variation. Such variation is diel and seasonal; it is also temporally predictable.

The thermal regime in 4MC, however, is not temporally predictable. This stream receives heated effluent from a nuclear production reactor which can cease operating for fuel replacement or maintenance at any time. The Savannah River can also inundate the stream with relatively cool water when discharges from upstream reservoirs are high. This complex interaction between reactor operation and river water intrusion results in a frequently non-seasonal and thermally-unstable environment in 4MC. Temperatures in this stream have been observed to range from about 5°C to 40°C on an annual basis. Under typical stream discharge conditions, temperature in 4MC can range up to 20°C above that in U3RC or SC. If the reactor shuts down or if Savannah River water inundates the stream, temperatures can drop to ambient levels within hours (see Fig. 2). Such temperature extremes and abrupt changes in the thermal environment (e.g., a drop of 11°C in 1 hr on day 21) would seem to preclude acclimation, and this probably explains why most mayflies do not occur in this stream. Caenis diminuta, however, appears capable of acclimating to the thermal regime of 4MC, as it has been consistently collected throughout the year from this stream.

This conclusion is supported by the research of Martin & Gentry (1974), who studied dragonfly nymphs of the genus Libellula collected from 4MC. They reported that nymphs maintained normal locomotor activity at temperatures ranging from 40-46°C following acclimation for 24 hr at 15-35°C. These authors also suggested that an acclimation period of only 8-10 hr would be sufficient for nymphal survival at >40°C. However, no data on Libellula acclimation to the rapidly decreasing temperatures common in 4MC were collected, although the nymphs reportedly survived such declines.

The occurrence of C. diminuta in 4MC is interesting in terms of this organisms's thermal tolerance alone; however, the mayfly's abundance in this stream also has broader ecological significance. The biota in stream ecosystems with fluctuating environments may help stabilize the stressed system by counteracting the forces contributing to system instability (e.g., temperature fluctuations) (Vannote, Minshall, Cummins, Sedell & Cushing 1980). One way in which stream ecosystem instability occurs is through downstream loss of nutrients and carbon (Elwood, Newbold, O'Neill & Van Winkle 1983). There is some evidence that the 4MC ecosystem is a relatively inefficient processor of detrital energy inputs and that nutrients are lost from this stream to the Savannah River (Poff & Matthews, In Review). If this is the case, then the occurrence of a tolerant species such as _C. diminuta_ can contribute to the stability, productivity and organic carbon retention within a thermally-stressed ecosystem.

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| | 4MC | SC | U3RC | n* |
|---|---|---|---|---|
| D.O. (mg/l) | 6-12 | 8-15 | 8-11 | 12 |
| Flow (cm/s)** | 0-10 | 0-57 | 0-67 | 12 |
| Conductivity (µmhos/cm) | 42-65 | 25-66 | 18-38 | 5 |
| Total Alkalinity (mg $CaCO_3$/l) | 13-31 | 25-37 | 3-18 | 4 |
| pH | 6.4-6.9 | 6.6-7.0 | 5.6-6.5 | 4 |

| | 4MC (thermal) | SC (post-thermal) | U3RC (unstressed) |
|---|---|---|---|
| *Caenis diminuta* | 61 | 0 | 0 |
| *Stenonema* spp. | 3 | 428 | 135 |
| *Stenacron* spp. | 1 | 1 | 1 |
| *Ephemerella* spp. | 1 | 0 | 35 |
| *Eurylophella* spp. | 1 | 5 | 1 |
| *Baetis* spp. | 2 | 3 | 2 |
| *Isonychia* spp. | 0 | 0 | 11 |
| *Neoephemera youngi* | 0 | 0 | 8 |
| *Paraleptophebia* sp. | 0 | 0 | 1 |
| Total | 69 | 437 | 194 |

| | *Caenis* sp. | | | Heptageniidae | | | Temperature (°C) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4MC | SC | U3RC | 4MC | SC | U3RC | 4MC | SC | U3RC |
| Drift Samples* | | | | | | | | | |
| 11 Mar 82 | 0 | 1 | 1 | 0 | 0 | 0 | - | - | - |
| 25 Mar 82 | 3 | 0 | 0 | 1 | 3 | 0 | 33.0 | 17.4 | 16.3 |
| 07 Apr 82 | 19 | 0 | 0 | 0 | 0 | 0 | 30.5 | 13.9 | 14.5 |
| 21 Apr 82 | 3 | 0 | 0 | 0 | 0 | 0 | 21.3 | 19.5 | 18.0 |
| 05 May 82 | 22 | 0 | 0 | 0 | 0 | 0 | 32.0 | 21.0 | 17.5 |
| 20 May 82 | 19 | 1 | 3 | 0 | 1 | 0 | 35.1 | 22.7 | 21.4 |
| 03 Jun 82 | 122 | 0 | 1 | 1 | 2 | 0 | 40.4 | 27.1 | 23.2 |
| 12 Jun 82 | 4 | 1 | 1 | 0 | 1 | 0 | 40.2 | 26.2 | 23.2 |
| 01 Jul 82 | 3 | 0 | 0 | 1 | 2 | 0 | 39.8 | 26.4 | 24.4 |
| 15 Jul 82 | 5 | 0 | 2 | 1 | 7 | 0 | 36.3 | 24.0 | 22.1 |
| 28 Jul 82 | 0 | 0 | 0 | 0 | 4 | 0 | - | - | - |
| 11 Aug 82 | 0 | 0 | 1 | 0 | 0 | 2 | - | - | - |
| 28 Aug 82 | 1 | 0 | 0 | 0 | 2 | 0 | 39.2 | 25.7 | 23.5 |
| Total | 201 | 3 | 9 | 4 | 22 | 2 | | | |
| Hester-Dendy Samples** | | | | | | | | | |
| 06 Oct 82 | 9 | 1 | 5 | 0 | 284 | 54 | | | |
| 12 Nov 82 | 24 | 0 | 0 | 1 | 112 | 50 | | | |
| 06 Dec 82 | 15 | 0 | 0 | 2 | 133 | 150 | | | |
| 13 Jan 83 | 9 | 0 | 0 | 3 | 180 | 43 | | | |
| 15 Feb 83 | 19 | 0 | 0 | 1 | 60 | 4 | | | |
| 17 Mar 83 | 0 | 0 | 0 | 5 | 112 | 7 | | | |
| Total | 76 | 1 | 5 | 11 | 881 | 308 | | | |

Table I. Physical-chemical data for thermally-stressed (4MC), post-thermal (SC) and unstressed (U3RC) streams.

* Number of observations over the study period (77 days).

** Values of 0 represent periods of site inundation by the river.

Table II. Total numbers of mayfly nymphs collected from five sampling dates between 29 December 1982 and 15 February 1983 (48 days). GLM and Duncan's Multiple Range test for taxon averages.*

* Numbers connected by a solid line are not significantly different ($p < 0.05$).

Table III. Numbers of Caenis sp. and Heptageniidae nymphs collected with drift nets and Hester-Dendy samplers in thermally-stressed (4MC), post-thermal (SC) and unstressed (U3RC) streams. Data provided courtesy of Environmental & Chemical Sciences, Inc., Aiken, South Carolina.

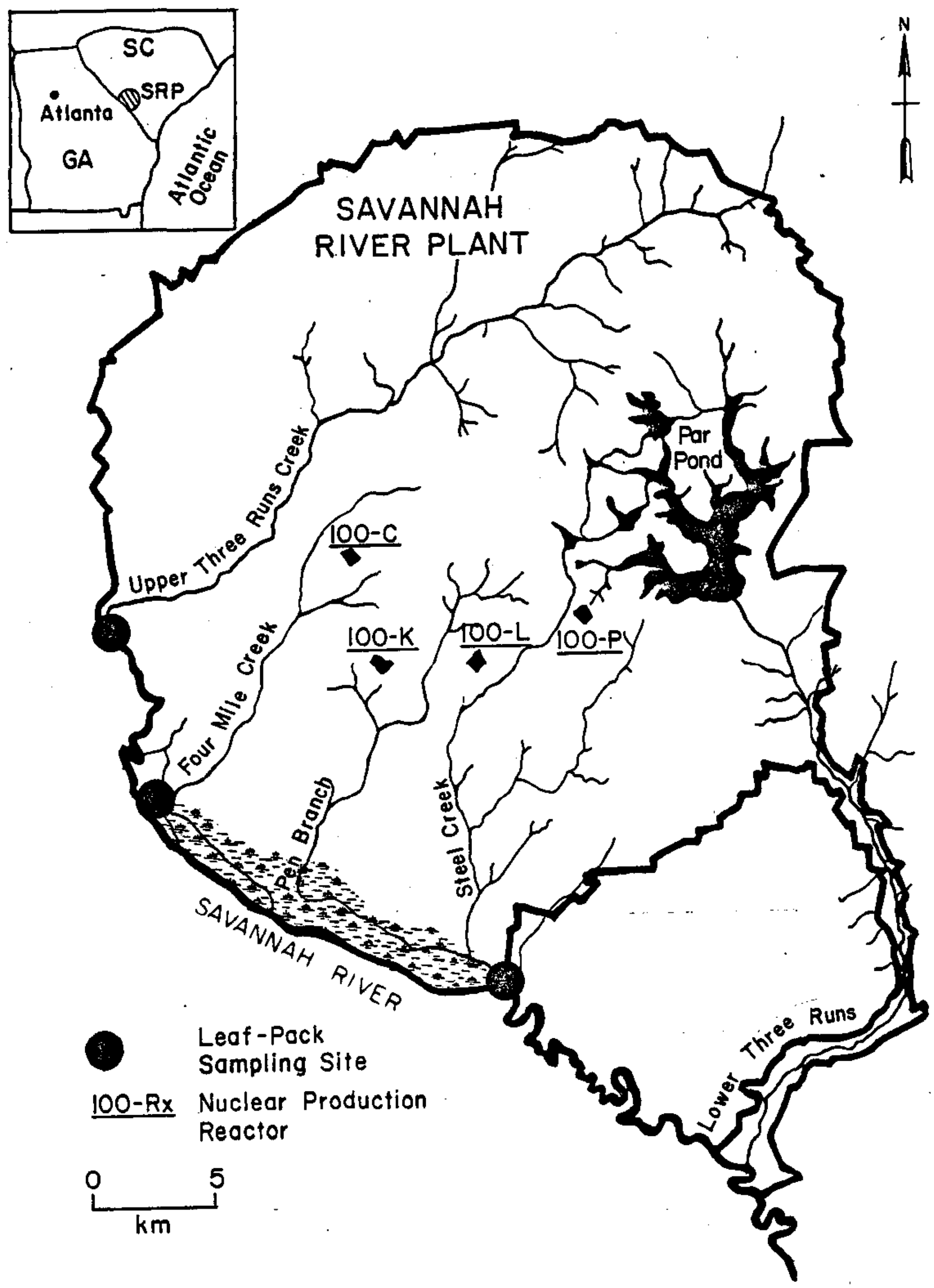
* Approximately 50 $m^3$ samples taken during daylight.

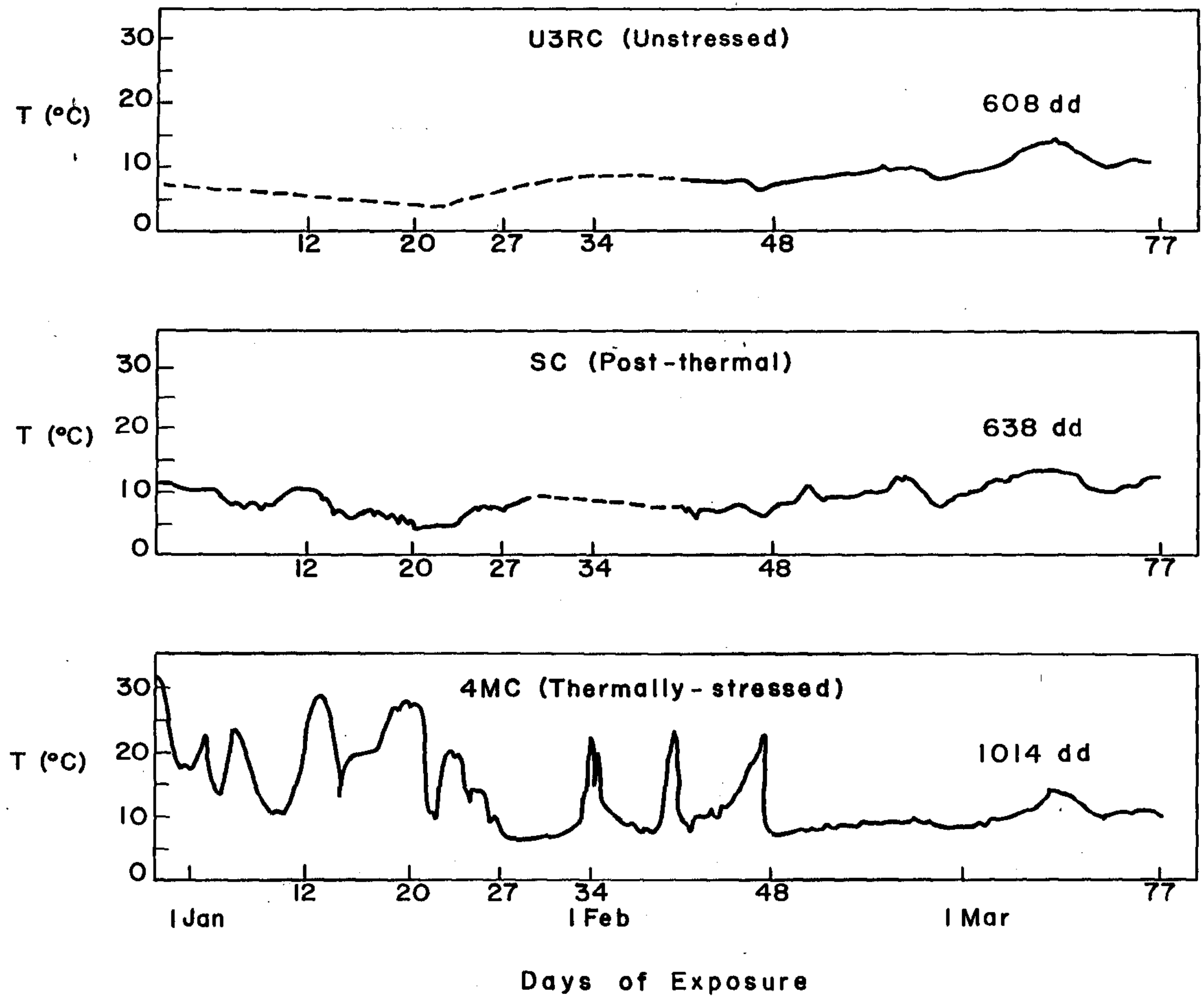
** Total from three samplers.

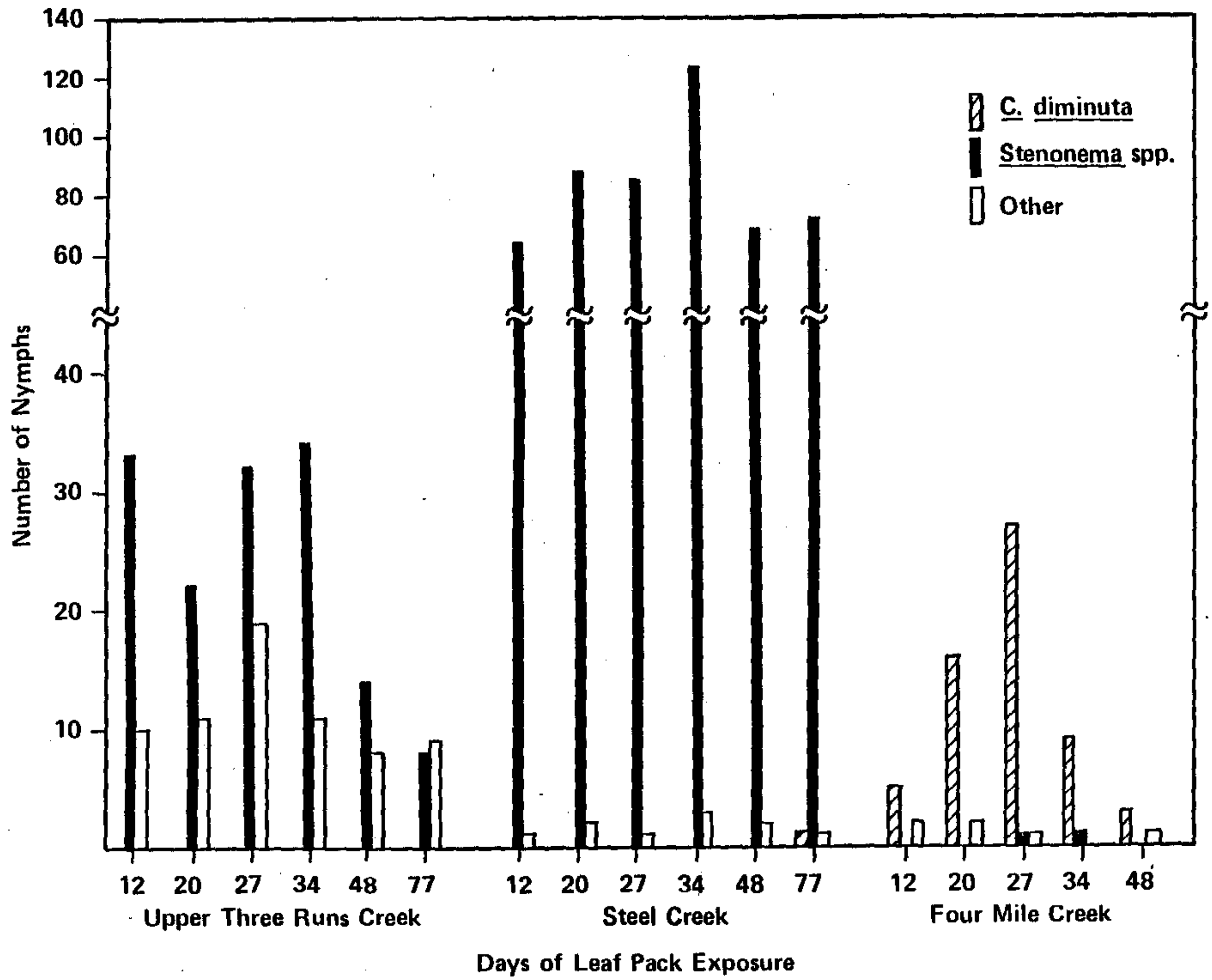
Figure 1. Map showing the location of the Savannah River Plant, sampling sites and nuclear production reactors.

Figure 2. Temperature profiles and degree-days (>0°C) accumulated for three stream sites from 29 December 1982 to 16 March 1983.

Figure 3. Number of Caenis diminuta, Stenonema spp. and other mayfly nymphs occurring on all leaf packs for each collection date (29 December 1982 to 15 February 1983).


SC
SRP
Atlanta
GA
Atlantic Ocean
N
SAVANNAH RIVER PLANT
Upper Three Runs Creek
Par Pond
100-C
100-K
100-L
100-P
Four Mile Creek
Pen Branch
Steel Creek
SAVANNAH RIVER
Lower Three Runs
Leaf-Pack Sampling Site
100-Rx Nuclear Production Reactor
0
5
km


U3RC (Unstressed)
608 dd
SC (Post-thermal)
638 dd
4MC (Thermally-stressed)
1014 dd
T (°C)
0
10
20
30
12
20
27
34
48
77
1 Jan
1 Feb
1 Mar
Days of Exposure



140
120
100
80
60
40
30
20
10
Number of Nymphs
C. diminuta
Stenonema spp.
Other
12
20
27
34
48
77
Upper Three Runs Creek
12
20
27
34
48
77
Steel Creek
12
20
27
34
48
Four Mile Creek
Days of Leaf Pack Exposure