Cohort dynamics of an over-wintering *Caenis latipennis* population in Honey Creek, Oklahoma, U.S.A

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Abstract

Eggs were collected from a south-central Oklahoma population of *Caenis latipennis* and reared at three different temperatures: 15, 20, and 25ºC. Eggs took 132 degree-days on average to hatch. Nymphs were reared to adults at 20ºC and emerged on average in 1709 degree-days. Degree-day estimates were applied to fall and winter stream temperatures to predict hatching and emergence times. These predictions indicate that the long overwintering generation is the combination of three different developmental strategies influenced by decreasing temperatures during the fall emergence period.

Keywords: life history, Ephemeroptera, *Caenis latipennis*, degree-days.

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2003, E. Gaino (Ed.), University of Perugia, Perugia, Italy.

Introduction

Life cycles for the caenid mayflies of southern North America are difficult to interpret due to extended emergence periods resulting in considerable cohort overlap. For this reason life history information is limited for southern populations. *Caenis amica* (HAGEN, 1861), *C. diminuta* (WALKER, 1853), *C. hilaris* (SAY, 1839), and *C. latipennis* (BANKS, 1907) all have extended emergence periods and more than likely are multivoltine at lower latitudes (Baumgardner, 1995; Berner, 1977; Berner and Pescador, 1988; Jacobi and Benke, 1991; Unzicker and Carlson, 1982). Multivoltine life cycles are difficult to understand without the combination of laboratory and field data (Brittian, 1982).

As part of a larger life history study, this paper attempts to interpret the winter cohort dynamics of *C. latipennis* from Honey Creek in south-central Oklahoma. The Honey Creek *C. latipennis* population exhibits an extended emergence period and is represented by all size classes throughout most of the year. During the winter months the population falls into a period of synchronization typical of most temperate species. Throughout the rest of the year the population is asynchronous (Taylor, 2001). Undoubtably this shift into a synchronous mode during the winter is due to temperature but by what mechanisms? Laboratory rearing data may provide additional insight into this question.

Material and Methods

A mercury vapor light run in front of a white sheet was used to attract adult *Caenis latipennis* from Honey Creek. Fertilized females extruded egg masses while resting on light trap. Eggs were collected with soft touch forceps and deposited in 4 dram vials with stream water and returned to the lab. Caps were removed and vials were placed in 1L plastic containers filled with stream water. Egg batches were maintained in Precision incubators under a 12-hour light regime and at temperatures of 15, 20, and 25ºC. These temperatures were comparable to temperatures for Honey Creek reported by previous investigators (Reisen, 1976; Wagner, 1995; Wang, 1997). Vials were recapped and inspected under a dissecting microscope (model SZ30, Olympus Optical, Tokyo) daily. Number of days from oviposition to hatching was recorded.

After hatching from eggs, nymphs were maintained in plastic containers and fed detritus decanted from substrate in Honey Creek. Head

capsule widths of nymphs were measured weekly with an Olympus series Cue-2 image analyzer (Olympus, Tokyo) and Olympus SZH dissecting microscope. Number of days from hatching to emergence was recorded.

Degree-day estimates were calculated using the following equation:

$DD = \sum t_{min} + t_{max} / 2 - ctm$ (Pedico and Zeiss, 1996)

Where t_{min} = minimum temperature, t_{max} = maximum temperature, and *ctm* = critical thermal minimum threshold for development. The critical thermal minimum threshold for development was determined by a regression of development rate against incubation temperature. If *ctm* culd not be determined it was set to 0 for a conservative estimate of developmental degree days (Pedico and Zeiss, 1996).

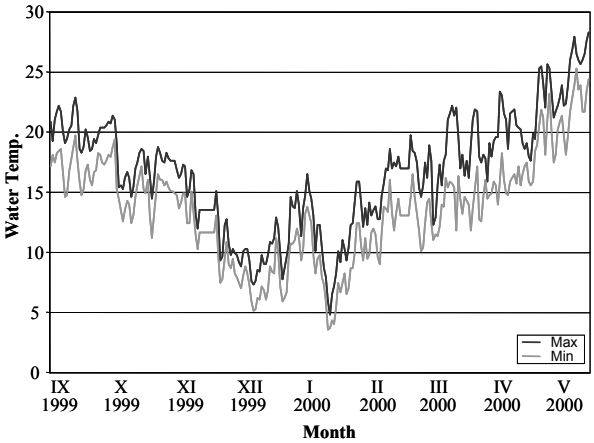

Fig. 1 - Maximum and minimum water temperatures for Honey Creek during study period (26 August 1999 – 31 May 2000).

Development curves were predicted for *C. latipennis* eggs and nymphs in Honey Creek by applying laboratory derived degree day estimates to field temperatures. Temperature was monitored in Honey Creek on an hourly basis using an Onset Stowaway Cap. Datalogger®. Daily minimum and maximum temperatures throughout the study period were used to determine developmental degrees for each day (Fig. 1). These were cumulatively added forward from the fall emergence peak and backward from spring emergence peaks until they totaled laboratory degree-day estimates to determine when eggs should hatch and adults should emerge.

Results

Egg broods incubated at 14 – 15ºC first hatched on day 28 (*n*=3). Eclosion for egg broods occurred in 12 to 14 days at 19 – 21ºC (*n*=6). At 25ºC, egg broods hatched in 8–10 days (*n*=7) (Fig. 2). The minimum critical threshold for egg development was 9.9ºC determined by the following regression model: Developmental Rate = 0.00763(Temperature) – 0.07596 (r^2 = 0.9515, F test, n = 16, p < 0.0001) (Fig. 3). On average, eggs took 132 degree-days to develop.

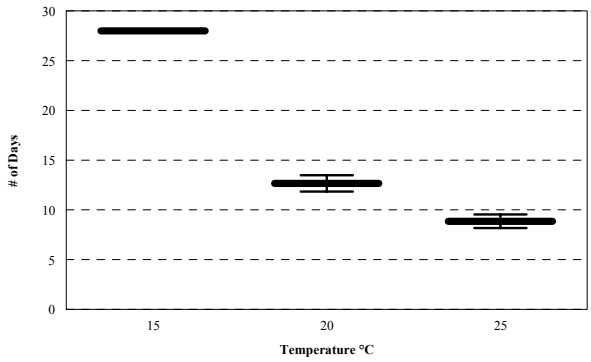

Fig. 2 - Mean # of days for eggs to hatch at 15, 20, 25ºC.

Nymphs were successfully reared at 20ºC. Mean number of days to emergence was 85 days (n = 11) (Fig. 4). Nymphs reared at 15ºC did not pass through the 1st instar. No live nymphs were observed after one week in rearing chambers.

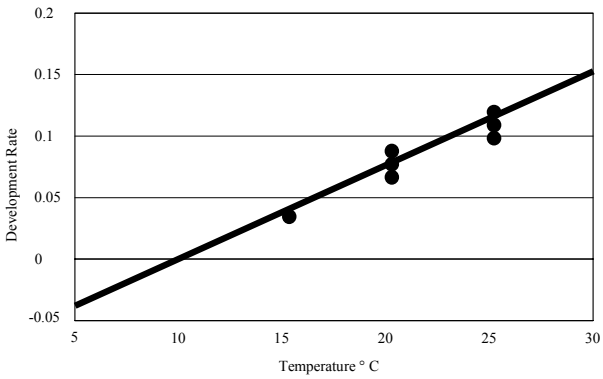

Fig. 3 - Critical thermal minimum threshold for egg development (9.9°C).

Nymphs were not successfully reared through complete lifecycle at 25ºC due to incubator malfunction. Therefore, no *ctm* was derived and a conservative estimate of 1709 degree-days was determined for nymphal development at 20ºC.

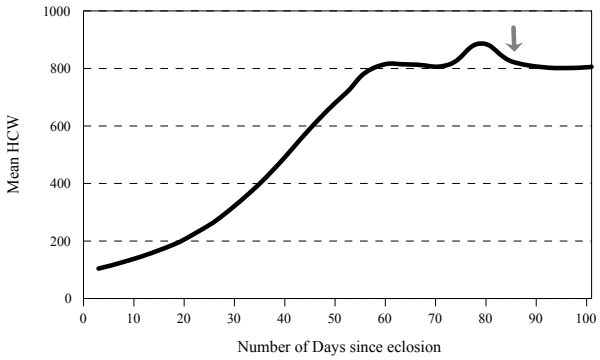

Fig. 4 - Mean number of days for nymphal development at 20ºC (n = 12).

Egg and nymph development rates based on degree-day estimates from continuous field water temperature data (Fig. 5) indicate that eggs oviposited by the fall generation (Cohort 1) hatched throughout the fall and winter. Eggs oviposited during the beginning of the fall emergence (water temperature = 16ºC – 25ºC) had a fast development rate and nymphs hatched almost immediately. As temperatures decreased throughout the fall emergence, egg development slowed resulting in an extended recruitment of nymphs. This hatching regime resulted in three different development strategies derived from the fall emergence. Nymphs recruited early during the fall emergence were able to develop quickly before temperatures dropped and over winter in late development classes. These nymphs are referred to as subcohort 2a. Eggs oviposited later in the fall developed slower and nymphs recruited from these eggs over wintered in earlier development classes. As water temperatures increased in the spring these nymphs continued to develop emerging in April as sub cohort 2b. Eggs oviposited at the end of the fall emergence period developed even slower with hatching beginning in late winter (February). These nymphs developed with rising temperatures to emerge in mid May (Cohort 2c).

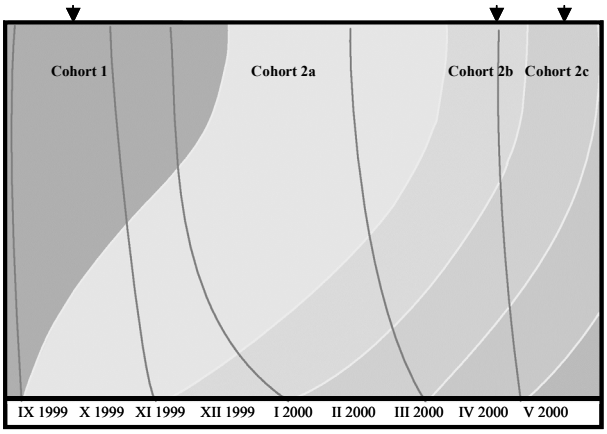

Fig. 5 - Egg and nymph developmental degree-day estimates applied to continuous water temperature data in Honey Creek, OK. Arrows indicate peaks in emergence. Lines represent egg development, and color blocks represent nymphal development periods for cohorts and subcohorts.

Discussion

Applying egg and nymphal degree-day estimates to field temperatures enables the researcher to predict eclosion and emergence times. While laboratory data cannot be relied on alone to determine aquatic insect life cycles it can provide valuable insight for interpreting field data, especially in species having multiple generations. Development class frequency data suggests a long over-wintering generation for *Caenis latipennis* in Honey Creek (Taylor, 2001). Predictions for eclosion and emergence derived from laboratory data suggest that this long over-wintering generation is a combination of three different development strategies occurring concurrently. These different development strategies within the over-wintering cohort provide for an extended spring emergence.

Air temperatures during the spring are highly variable at Honey Creek. The ability of a cohort to spread individuals among development stages and emerge continuously through variable conditions provides a selective advantage for *C. latipennis* populations. This bet hedging mechanism insures that some individuals will emerge under favorable conditions and successfully reproduce even though many are lost to premature emergence. This mechanism also provides for resource partitioning during annual peaks in density of *C. latipennis*.

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