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Research Article
FPOM Feeding Mayflies (Ephemeroptera: Insecta) from South India: Life History and Secondary Production

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Abstract

Objective: We analyzed the lifecycle pattern and secondary production of FPOM feeding three dominant mayfly species from a tropical stream of Southern Eastern Ghats, India. **Methodology:** Month-wise sampling for a period of a year was done. The collected specimen were stored and reared. The size frequency and cohort production methods were used for analyzing life histories and secondary production. **Results:** The present study showed that *C. alagarensis* and *L. silambarensis* had asynchronous nymphal development with a continuous emergence in a year while, *C. grimiensis* had asynchronous pattern but mass emergence with two seasons. The cohort P/B ratio was analyzed for measuring secondary production. **Conclusion:** These findings address the need for more quantitative accounts of population dynamics (life cycle patterns, fecundity, development rates, production and P/B) of aquatic insect species in streams across environmental gradients.

Key words: Fine particulate organic matter, collector, mayfly, stream, CPOM, production, *Choroterpes*, *Caenis*, *Labiobaetis*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Coarse Particulate Organic Matter (CPOM) is transported to streams from allochthonous and autochthonous sources. Allochthonous carbon inputs comprise mainly terrestrial plant litter which has been characterized as a dominant input of energy source into stream ecosystem[1]. This CPOM provides two distinct sources such as food and substrate or habitat for a variety of aquatic organisms. Entry of CPOM in stream, there are two mechanisms occur in stream to convert Fine Particulate Organic Matter (FPOM) that microbial colonization, which leach the input of litter, consequently change into palatable for macroinvertebrate colonization[1-3]. The FPOM is an amorphous collection of particles <1 mm, originating from instream CPOM breakdown, sloughed cells of algae, invertebrate fecal pellets and fragments derived from the terrestrial environment[4].

In general, aquatic macroinvertebrates play a very important role in the litter processing and nutrient cycling, which are belong to several specialized feeding groups such as filter-feeders, collectors, scrapers (sometimes called grazers), shredders and predators[5]. Shredders are commonly found where there are large accumulations of CPOM in forested headwater streams and the mouthparts of this group adapted for maceration of the CPOM particles, which they tear and shred while feeding. Their feeding results in the initiation of the conversion of CPOM to FPOM by physically breaking up the CPOM and by production of FPOM in the form of fecal pellets. The FPOM accumulates in many places on the streambed wherever the current slackens enough to permit it to settle from the water column and accumulate in these deposition zones. Mayflies (*Baetis*, *Labiobaetis*, *Caenis* and Leptophlebiids) are a common example of this functional group[6].

Life cycle information on collectors is a fundamental importance for nutrient cycling[7]. Secondary production is a useful measure associated with life histories because it combines individual growth with population survivorship. Mayflies have the ability to adopt different life cycle strategies ranging from a single generation to two or more generations per year, which is reported worldwide[8-10]. Mayflies have generally similar trophic roles (they feed principally by scraping or collecting food from surfaces), therefore, when resources are limited, we may expect them to segregate either by food type, habitat or space[9].

In India, lifecycle pattern of mayflies was recorded as multivoltine with asynchronous development of Leptophlebiidae (*Petersula courtallensis* and *Notophlebia jobi*), Ephemeridae (*Ephemera nadinae*), Heptageniidae (*Thalerosphyrus flowersi*, *Afronurus kumbakkaraiensis* and *Epeorus* sp.) Baetidae (Baetis) in the hill streams of South India[11-14]. Similar study was observed on *Cloeon* sp. (Baetidae) in Northern India[15]. Some pioneering studies have been confirmed that temperature is one among the main factors disturbing from the early stage of nymphal growth to the fecundity of adult[16,17]. Other factors regulating the growth and development of aquatic insects are determined by food quality and quantity, habitat and competition[18,19]. These factors have a direct influence on the nymphal size before emergence, on emergence timing, population densities and consequently on secondary production. Mainly, the study of the life history of a single species is essential in order to achieve a full knowledge of the ecosystem itself and the relations within it. Hence, the present study was aimed to inventorize the lifecycle pattern and secondary production of FPOM feeding three dominant mayfly taxa: *Choroterpes alagarensis* (Leptophlebiidae), *Labiobaetis silambarensis* (Baetidae) and *Caenis grimiensis* (Caenidae) from a tropical stream of Southern Eastern Ghats, India.

MATERIALS AND METHODS

Study area: The present study was carried out in Alagar hills. It forms a discontinuous minor range in the Deccan plain and appears as an extension of Eastern Ghats. It comes under Natham range in Dindigul forest division and located 22 km North East of Madurai city (10°00'-10°30' N and 75°55'-78°20' E). The deciduous forests of Alagar hill is composed of both disturbed and protected vegetation, which are varies due to change in topography of the area (Sriganesan 1984, 1987). The famous Alagar kovil, the temple of 'The God of Beauty' is situated at the foot of the hills (275 m). There are three streams: Hanuman theertham (350 m), Silambar odai and the Nooburagangai (425 m). The specimen was collected from the Nooburagangai stream. The rainfall regime is erratic. This area comes under dissymmetric rainfall regime with the bulk of the rains during the retreating Northeast monsoon (October-November). Some rain is also received during the Southwest monsoon (April-May).

Sampling: In this study, the specimen of *C. alagarensis*, *L. silambarensis* and *C. grimiensis* were collected once in a month from September, 2008 to August, 2009, using 'D-net' and hand picking methods according to Sivaramakrislman[20]. In each study site, three replicate samplings were done. The pool and riffle areas were chosen for sampling. In riffle, 1 m^2 areas were randomly selected. In pool habitat, specimens were collected with the help of D-net, bearing mesh size 300 µm. The collected specimens were carefully removed with the help of a fine and soft brush. The collected specimens were separated in two sets. First set was preserved in the field using 70% ethanol and second set was brought to the laboratory for rearing purposes.

Laboratory analysis: In the laboratory, both samples were segregated at species level and labeled each group of species with the help of a binocular stereo-microscope, Leica, Germany, Model. The growth pattern was analyzed based on the total length measurements. Each nymph was measured to the nearest 0.1 mm of length of a nymph (from the anterior margin of the labrum to the posterior margin of the last abdominal segment) and width of the head, using a micrometer. Assessing the degree of nymphal developments and different stages were recognized according to morphological features based on wing pad size and length of nymph[21,22]. Hatching periods were determined by the presence of small-sized nymphs, while the emergence periods were recognized by the presence of dark wing pads in mature nymphs and from observations of imagoes in the field[23-25]. The dark wing pad of respective nymphs were also collected from field and reared in the laboratory for 1 day in a BOD incubator adjusted to stream water temperature to identify the respective species. Estimates of secondary production were established using the size frequency method[26]. Values were corrected for Cohort Production Interval (CPI) according to Benke[27]. The relationship between length and width of mayflies were measured by regression analysis with 95% of confidential intervals.

RESULTS

***Choroterpes alagarensis*:** The nymphal stages of *C. alagarensis* are typically found underside of the pebbles than accumulation of plant material. The population of *C. alagarensis* was abundant in March with densities about 254±32.2 individuals m^{-2}, while very low abundance was recorded in June and November. The size frequency histograms showed that *C. alagaresnsis* have asynchronous pattern, overlapping generation with the continuous emergence in a year (Fig. 1).

***Labiobaetis silambarensis*:** The nymph of *L. silambarensis* inhabits a wide range of stream substrates. Typically, they are more abundant in leaf litter rather than other substrates. The abundance of *L. silambarensis* population was high in

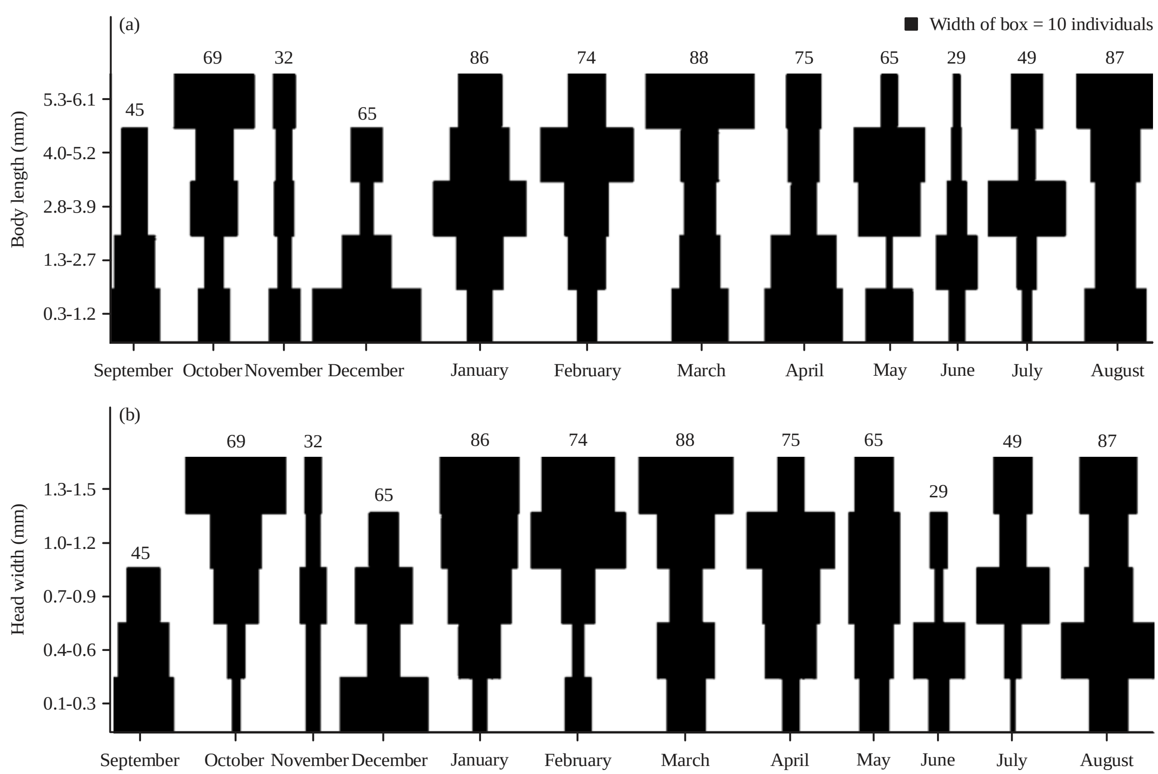

Fig. 1(a-b): Size frequency histogram of (a) Body length and (b) Head width of *Choroterpes alagarensis*

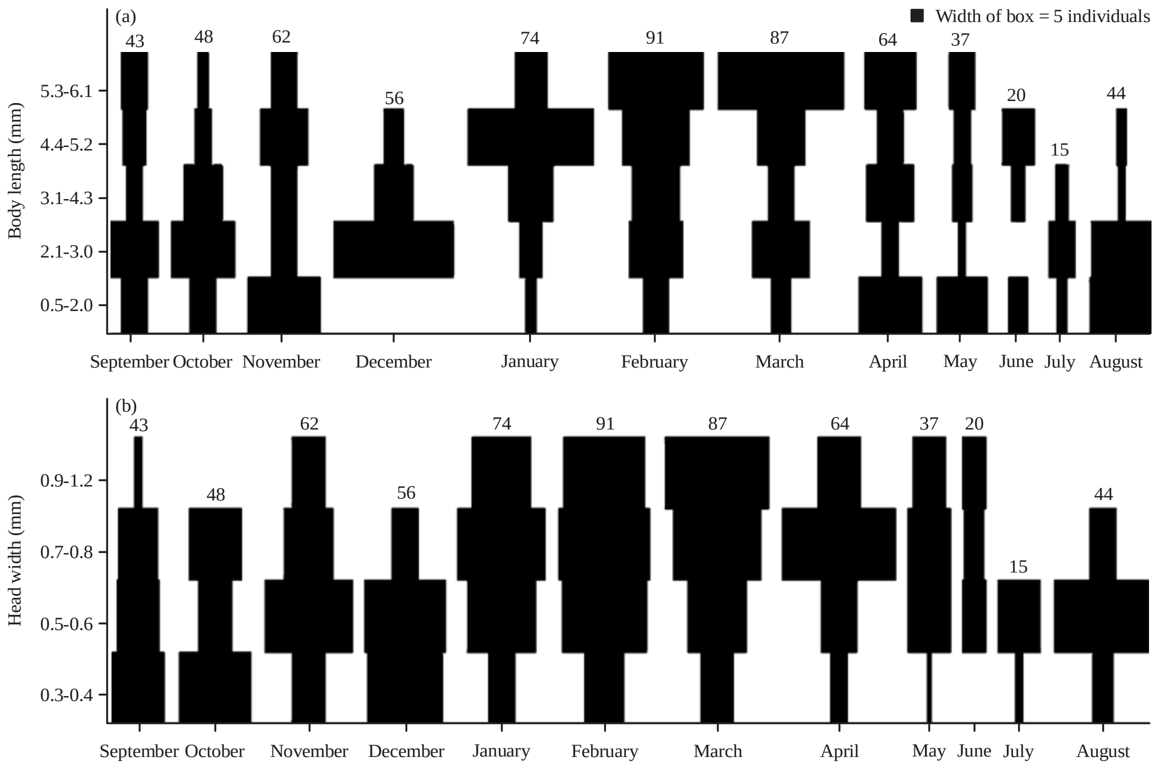

Fig. 2(a-b): Size frequency histogram of (a) Body length and (b) Head width of *Labiobaetis silambarensis*

Table 1: Relationship between body length and head width of three mayfly taxa

Taxa	Regression equation	n	r^2	p-value
Caenis grimiensis	HW = 0.2444 (BL)+0.0988	12	0.9102	<0.0001
Labiobaetis silambarensis	HW = 0.1658 (BL)+0.3044	15	0.7683	<0.0001
Caenis grimiensis	HW = 0.312 (BL)-0.2046	17	0.7368	<0.0001

February with a density of 185±22.7 individuals m^{-2}, while very low mean abundance was recorded in the month of June and July with density 20.7±5.1 and 15.8±4.7 individuals m^{-2}, respectively. The size frequency histograms for body length and width of head capsule of *the L. silambarensis* (Fig. 2), explained the asynchronous nymphal development with a continuous emergence in a year.

***Caenis grimiensis*:** Nymphs of *C. grimiensis* occur frequently in organic rich plant debris area of stream pool and they are quite tolerant of organic pollution. Maximum abundance of *C. grimiensis* was recorded in February and September, with density of about 72±6.3 and 70±12.7 individuals m^{-2}, respectively, while minimum abundance during July and November with density of 15±2.1 and 20±3.6 individuals m^{-2} respectively. The size frequency histograms for body length and head capsule width of the *C. grimiensis* (Fig. 3) revealed that the nymphal development was two generations in a year. There was a long winter generation, the newly hatched young nymph appeared in May and their growth continued till October. The eggs laid by the adult of the winter generation yield the individuals of a short summer generation, which developed from December-April. The first generation was emerged in October, similarly the second generation in April.

Production dynamics: Linear regression analysis was used to correlate between the body length and head width of three analyzed species. Result of this analysis was significantly correlated with 99.99% confidence interval for three species (Fig. 4, Table 1). Production dynamic details (densities, biomass and secondary production (P) and ratio of cohort production and biomass) of *C. alagarensis*, *L. silambarensis* and *C. grimiensis* were given in the Table 2. The maximum production of above mentioned three mayfly taxa was observed in March (657.07 mg m^{-2}), whereas, minimum production was recorded in November (360.86 mg m^{-2}). The annual secondary production and cohort production/biomass ratio (P/B) of *C. alagarensis* (2158 and 8.17 mg m^{-2} $year^{-1}$) was higher than the *L. silambarensis* (2056.02 and 7.34 mg m^{-2} $year^{-1}$) and *C. grimiensis* (1196.23 and 6.41 mg m^{-2} $year^{-1}$).

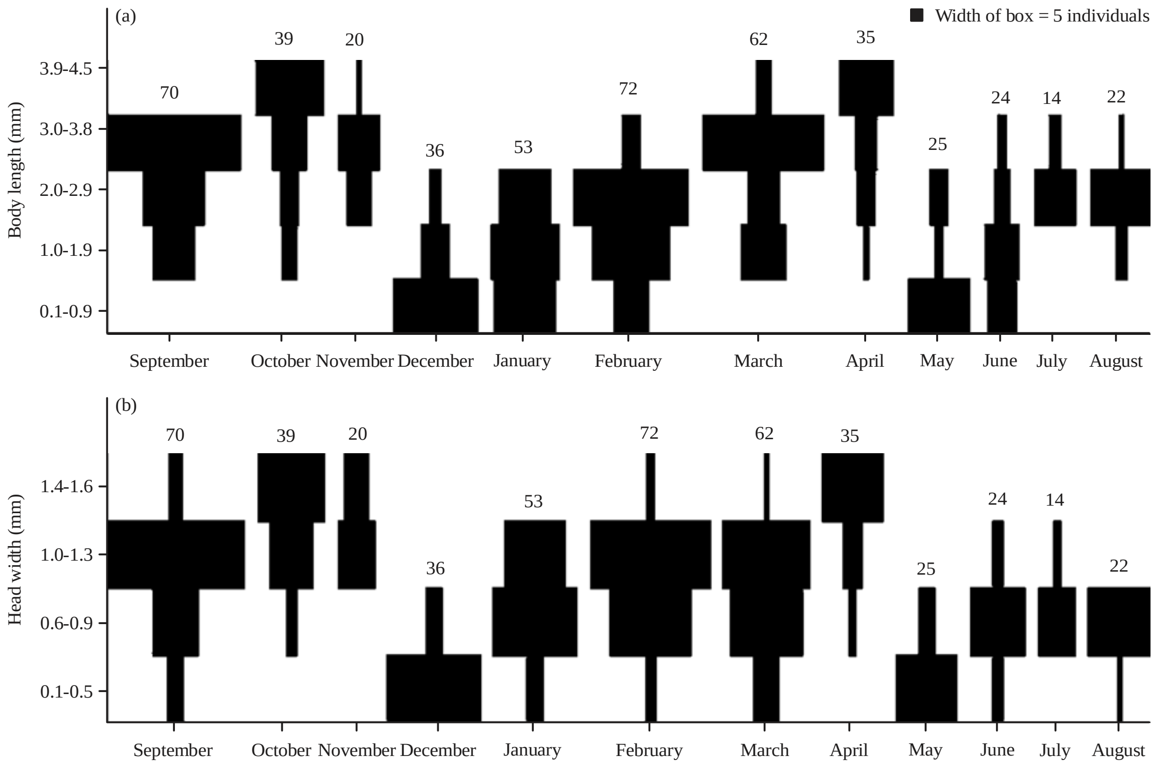

Fig. 3(a-b): Size frequency histogram of (a) Body length and (b) Head width of *Caenis grimiensis*

Table 2: Production values of three mayfly species from Southern Eastern Ghats

Taxa	Density No. (m^{-2} $year^{-1}$)	Biomass (mg m^{-2} $year^{-1}$)	Production (mg m^{-2} $year^{-1}$)	P/B ratio
Choroterpes alagarensis	820	263.87	2158.35	8.17
Labiobaetis silambarensis	900	280.10	2056.02	7.34
Caenis grimiensis	426	186.30	1196.23	6.41

DISCUSSION

The classification of the mayfly life cycle patterns were categorized based on the number of generation per year and also each life cycle into periods of slow and fast growth[28]. This pattern varies from species to species or within species in a different environment, e.g., *Baetis alpinus* showed high plasticity, being bivoltine at lower altitudes and univoltine at higher altitude[29]. Mayfly population almost multivoltine life cycles in temperate and tropical region[30-32], while cold-temperate and subarctic region have univoltine with hatching, growth and emergence restricted to a very short part of the year[33]. McClure and Stewart[34] reported that the *Choroterpes mexicanus* was multivoltine with three relatively distinct generations in the Brazos river, Texas. In contrast, *C. alagarensis* (Leptophlebiidae) had multivoltine with 8 distinct generations. Several researchers[31] suggested a wide range of life cycle types in the Ephemeroptera, claims that the water temperature is a major factor determining the egg development and nymphal growth. Campbell[35] reported that the water temperature remained above 18°C for most of the year in Queensland, supports occurrence of three or more generations of *Jappa* spp. (Leptophlebiidae). This report supports the increasing number of generations of *C. alagarensis* in tropical stream. The production of species is directly related to consumption, it represents a quantification of a population's resource utilization (food and space) in a given time interval[36]. The present study estimated that annual production of *C. alagarensis* were higher (2158 mg m^{-2} $year^{-1}$) than the following species: *Choroterpes* species (202.7 mg m^{-2} $year^{-1}$) in Hong kong stream[9], *C. mexicanus* in the Brazos River, Texas[34], *Thraulodes* sp. and *Leptohyphes* sp., from Costa Rica[37].

The genus *Labiobaetis* has a wide distribution; it appears to be present all over the world except in Australia, Central and South America[38]. Life cycle pattern of this genus is not reported elsewhere so far. The newly described species, *L. silambarensis* had an asynchronous nymphal development

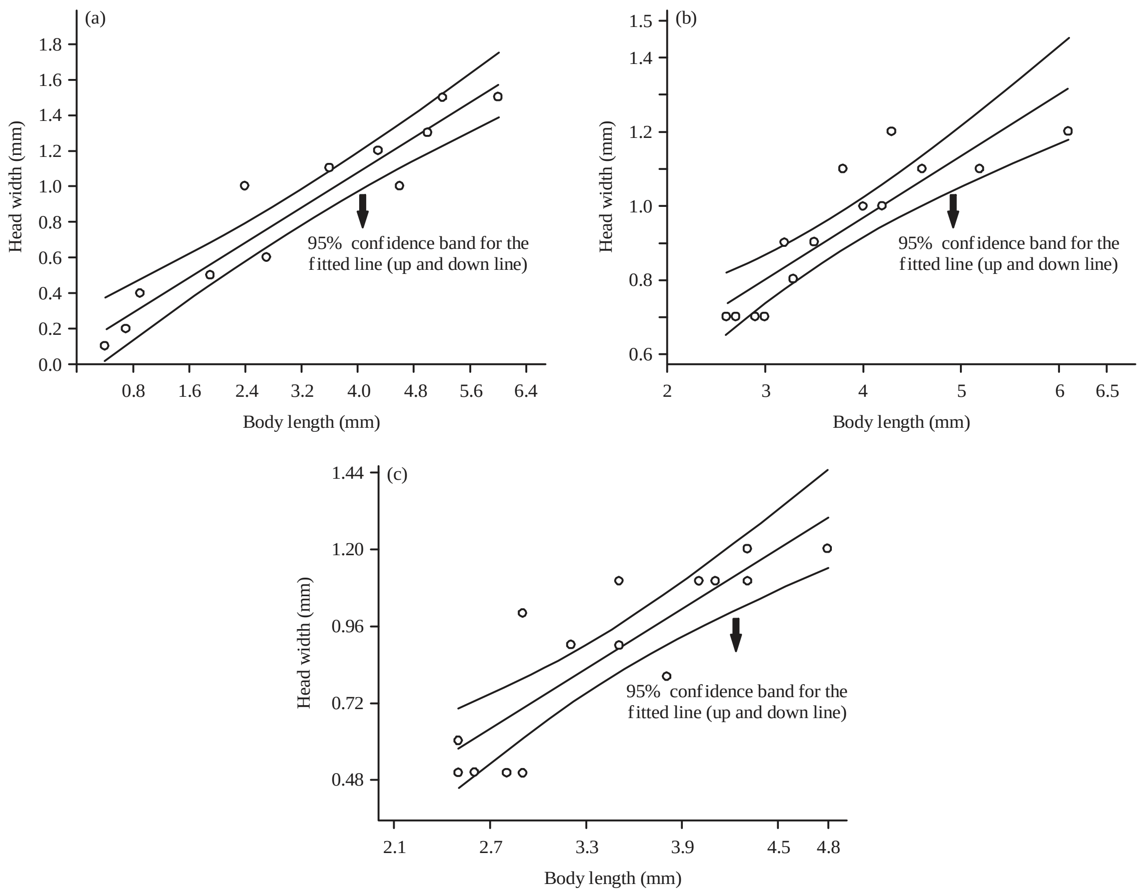

Fig. 4(a-c): Regression analysis shows the relationship between body length and head width of mayflies with 95% confidence line for each regression line, (a) *Choroterpes alagarensis*, (b) *Labiobaetis silambarensis* and (c) *Caenis grimiensis*

with multiple generations in a year. The peak emergence was observed in the month of February and March. Similar findings were observed on the life cycle patterns of *Baetis* sp. and *Cloeon* sp., in the Umkhrah stream, Shillong, India[39,40].

Caenis grimiensis sp. nov., had two distinct generations and emergence during October and April, which coincides with some European *Caenids* like *C. horaria* and *C. latipennsis* species[41]. Similar result was reported in various studies[30,31,42-45]. The estimated annual production of *C. grimiensis* is lower than *C. luctuosa* (6349.81 mg m^{-2}), while the production of *C. grimiensis* was higher than *C. horaria*, *C. amica* and *C. rivulorum*[46]. According to Benke and Jacobi[47] the most important factor limiting production in the riverine ecosystem where food is not a limiting factor than habitat characteristics, so production would be optimal when the functional habitat per unit area is high. Cid *et al.*[19] documented the production of *Ephoron virgo* were determined the proportion of habitat than the availability of foods. Now-a-days, the present study area of Nooburagangai stream in Alagar hill is highly impacted by anthropogenic an activity which leads to the destruction of stream habitat and accumulation of wastes. Further enhances the habitat destruction and leads stressful life history patterns of mayfly population. Government should concern over this problem and ensure to prevent the entry of pilgrim's wastes into stream. If it happens over a period of time there would be a chance for the extinction of sensitive species. For example, Dinakaran and Krishnan[48] reported that *Isca* sp., was found missing in the same region and this species may be under threatening/disappeared[49].

CONCLUSION

Basic autecology studies, including describing life histories of aquatic insects are fundamental to the understanding of stream ecology. The present study showed that *C. alagarensis* and *L. silambarensis* had asynchronous nymphal development with a continuous emergence in a year, which indicate that both the species belong to multivoltine. *Caenis grimiensis* had only two generation in a year. The cohort P/B ratio was 6.41, 7.34 and 8.17 in

C. grimiensis, *L. silambarensis* and *C. algarensis*, respectively. It clearly shows that, the studied mayfly populations play a major role in energy transfer within stream ecosystems. These findings emphasize the need for more quantitative accounts of population dynamics (life cycle patterns, fecundity, development rates, production and P/B) of aquatic insect species in streams across environmental gradients.

SIGNIFICANT STATEMENTS

- The present study revealed that mayfly populations play a major role in energy transfer within stream ecosystems
- Life cycle pattern of mayfly would be used to assess the water quality in stream
- Secondary production is addressing to nutrient cycling of stream ecosystem level and also used indicate climate change

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