IRA-International Journal of Applied Sciences
ISSN 2455-4499; Vol.04, Issue 03 (2016)
Institute of Research Advances
Pg. no. 460-470
http://research-advances.org/index.php/IRAJAS

Monitoring of adult aquatic insect activities and ecological role in the riparian zone of streams in the Western Ghats, India

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Type of Review: Peer Reviewed.
DOI: http://dx.doi.org/10.21013/jas.v4.n3.p10

How to cite this paper:
Kubendran, T., & Ramesh, M. (2016). Monitoring of adult aquatic insect activities and ecological role in the riparian zone of streams in the Western Ghats, India. *IRA-International Journal of Applied Sciences* (ISSN 2455-4499), 4(3), 460-470.
doi:http://dx.doi.org/10.21013/jas.v4.n3.p10

ABSTRACT

The Western Ghats, running parallel to the west coast of India between 8° N and 21° N is a prominent feature of the peninsular India. In freshwater biodiversity hotspots like the Western Ghats, no information is available on activates and ecological role of adult aquatic insect in the riparian zone of streams. Most adult aquatic insects that emerge from streams live briefly in the nearby riparian zone. Adult activities, such as mating dispersal and feeding influence their distribution in the terrestrial habitat. An observation at Kurangani streams, Western Ghats, India has shown that both numbers and biomass of adult aquatic insects are greatest in the near stream vegetation; however, adult insects can be relatively common 1 to 10 feet from the stream. Why because, adult aquatic insects are abundant and they are primary food resource for many riparian insectivores. The role of adult aquatic insects in the riparian zone must be better understood for riparian and aquatic food chain to be complete.

Keywords: aquatic insects, Western Ghats, riparian vegetation, insect activity

Introduction

The adult stages of most aquatic insects found in riparian zone (Anderson and Wallace, 1984; Erman, 1984). Although adult insects are generally short life span starts from one day to a week, they frequently exhibit morphological characteristics and life history traits that facilitate their survival in the terrestrial ecosystem and their reproductive success (Bulter 1984; Jackson 1988). Such adaptations suggest that the brief interaction between stream adult insects and the riparian habitat has been, and presumably continues to be, important to their survival. At the same time, stream insects can influence the distribution and abundance of riparian insectivores because the adult of aquatic insects represent an important primary food sources (Jackson and Fisher 1986; Jackson and Resh, 1989). The use of benthic macroinvertebrates is widespread and constitutes the basis for most aquatic biomonitoring programs currently in use (Metcalfe 1989; Rosenberg & Resh 1993). The present study is to explain some ecological activities and roles of adult stream insects in riparian zones in Kurangani streams of Western Ghats, India.

Description of study area

The Western Ghats, running parallel to the west coast of India between 8° N and 21° N is a prominent feature of the peninsular India. In freshwater biodiversity hotspots like the Western Ghats, no information is available on activates and ecological role of adult aquatic insect in the riparian zone of streams. Such information is very important to understand the impact of ongoing degradation of the biodiversity of streams in general and insect communities in particular. This information will also aid in developing conservation strategies for the riverine ecosystems of tropical biodiversity hotspots such as the Western Ghats (Sivaramakrishnan *et al*., 1990). There is a high probability that anthropogenic activity will also result in a change in the composition of the benthic community (Plate 1).

Riparian vegetation

Along the banks of the stream are thick stands of trees, shrubs, whose leaves are the stream's principal source of organic detritus. Among the taller plants *Bischofia javanica, Pongamia pinnata, Clerodendrum arboreum*, *Terminalia arjuna*, *Bombax sp*, *Mangifera indica* and *Lantana camera* dominate the stream banks. Because of the leaf canopy cover, the stream formed by branched and leaning trees, there is a feeble exposure to direct sunlight even in midday. Most of the tree species lose leaves throughout the year, with increase in leaf litter fall in spring resulting from nutrient translocation of the vegetation (Rathinakumar *et al*., 2013).

Materials and Methods

Collection and field survey of adult emergence by visual observation and light trapping

The aquatic insect samples were preserved in 80% Ethyl alcohol and stored in labelled vials. Collected samples were brought to laboratory and identified under steriobinocular microscope using standard taxonomic literature. Samples were assigned to family and genus using keys for that particular group. Following keys were used for identification; Ephemeroptera (Dudgeon, 1999 Sivaramakrishnan, 1990; Selvakumar *et al*., 2013; Kubendran *et al* 2014; 2015); Trichoptera (Wiggins, 1975).

Sampling method suggested by Sivaramakrishnan (1990) and Jackson *et al*., (1988) was followed for adult survey. The time of emergence, flying direction and flying height were determined before light trapping. The emergency light was placed near stream banks from19.00 to 20.00 hours. The emerged insects from the stream were attracted towards light and collected by using fine forceps and brushes without morphological damage (Plate 1).

Results and Discussion

Physico-chemical characteristics

The variation in physico-chemical parameters were analyzed from Kurangani stream, Western Ghats during May 2012 to April 2013 (Table 1 and Table 2). The third order Kurangani stream is clear and odourless. The sampling site had substrate index 7.00 which consists of 20% bed rocky, 25% boulders, 25% cobbles, 15% gravels, 10% sand integrated with 5% silts. Rathinakumar *et al* (2013) observed the average substrate index was 6.15 in Kurangani stream of Western Ghats, India. The stream averaged 5.5m wide. Maximum depth was 25 cm. The average water temperature was 20.5°C and Air temperature goes upto 27°C. The lowest water temperature 19°C observed during the study period. Air temperature and Water temperature showed large fluctuation because of different seasons in Kurangani stream of Cardamom hills (Balasubramanian *et al*., 1992). The average pH was 7.04. The dissolved oxygen of Kurangani stream ranged 9.3 to 9.8. Sivaramakrishnan *et al*., (1995) reported While studying in tributaries of Kaveri river in Karnataka with different stream orders by have dissolved oxygen level between 4-8 mg/L. Rathinakumar *et al*., (2013) recorded range of dissolved oxygen 7.1 to 8.3 mg/L was recorded by from streams of southern Western Ghats.

Adult aquatic insects taxa analysis

A total of 15 genera, 10 families and 3 orders of adult aquatic insects were collected during investigational period. At the order level, (EPT) Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) were predominant. Caddisflies found in more numbers followed by Mayflies and Stoneflies. At family level, Hydropsychidae, Baetidae, had contributed significantly to total abundance during light trapping. Perlidae also contributes maximum number of individuals followed by Leptophlebiidae and Caenidae. Genus *Neoperla biseriata, Notophlebia jobi,* and *Caenis sp*. were found to be high density followed by *Baetis sp* and *Hydropsyche sp*. The taxa *Neoperla biseriata* and *Caenis sp.* were collected throughout the experimental period.

Adult aquatic insect activities in streams

The adult aquatic insects are involved in several activities, the most common of which are reproduction, dispersal and feeding. Adult insects must select mate location followed by oviposition in the stream or overhanging vegetation by females for reproduction. It is also essential for the initiation of the next generation in the aquatic environment. The reproductive activities are often well defined with respect to time of the day and location in the riparian zone. Some species form mating swarms like mayflies (Ephemeroptera), caddisflies (Tricoptera) and stoneflies (Plecoptera) at specific times of the day, distances from the stream and heights above the ground (Edmunds *et al* 1976; Lesage and Harrison 1980).

The previous studies in the northern California demonstrated that cadisflies of some male species locate conspecific females by following sex pheromones like chemicals that mediate reproductive activities between males and females are released by females (Wood and Resh 1984; Resh and Wood 1985). The similar to swarming, pheromone induced mating occurs at a specific time of the day. Jackson and Resh observed pheromone induce mating period for *Gumaga nigricula* (Trichoptera: Sercostomatidae) is in the early morning and lasts only 3-6 hours.

Dispersal is also a key activity for most adult aquatic insects. The short lived adult stage in many species like mayflies, stoneflies and caddisflies would appear to limit the distance that they can potentially disperse, either passively or actively. However, long distance i.e. greater than 8-10 feet movements both within stream corridors (Coutant 1982) and across land (Sevensson 1974; Edmunds *et al* 1976). Jahnson (1969) recorded for some species in these groups not surprising, long distance movements have been commonly observed in species that have relatively long-lived adults like blackflies, mosquitoes and dragonflies (Johnson 1969).

Predators like Long lived adults often feed blood meal for egg development and prey or host availability may contribute to the distance travelled. The effect that limited feeding activities like stoneflies feeding on young leaves and buds or on algae on tree trunks (Harper and Stewart 1984), caddisflies feeding on nectar or honeydew (Burtt *et al* 1986) and some aquatic insects dispersal distance has not been examined (Jackson and Resh 1988). The above activates contribute to the distribution and abundance of adults in the riparian zone. In a recent study of the distribution of adult aquatic insects in the evergreen forest of Kurangani stream (Western Ghats, TN, India), authors found that the abundance of adult aquatic insects was greatest near the stream and decreased as distance from the stream increased by using XY Plot graph analysis for single light trap (Fig. 1). The rate of decrease in abundance varied among species. Caddisflies, *Hydropsyche sp. Potamiya sp. Macronema sp. Leptonema sp. Stenopsyche sp.* (Trichoptera: Hydropsychidae, Stenopsychidae) were very abundant in the trees next to the stream. However, *Macronema sp.* was almost absent 10 feet from the stream whereas *Hydropsyche sp.* was still common 3-4 feet form the stream. Mayfly and stonefly *Baetis sp, Caenis sp, Choroterpes sp, Notophlebia sp, Epeorus sp, Tricorythodes sp, Ephemera sp and Neoperla sp* (Ephemeroptera and Plecoptera) were very abundant in the same area. By flying more than 4 feet form the stream, adult aquatic insects would be outside of most riparian zones that are recommended to protect water quality and aquatic life in streams (Brinson *et al* 1981).

Within the forest, most of the species observed in the Kurangani stream study exhibited one of two distribution patterns: adults were either equally abundant at all heights observed like 2,3,4,5,6,7 &8 feet above the ground level or they were more abundant near the tree tops (above 6 feet) than at the tree bases (1 to 2 feet). Some of the undescribed species of the mayfly and caddisfly abundant near the tree bases than the tree tops.

Ecological role of adult aquatic insects

Larvae of aquatic insects are the secondary production of aquatic insectivores were reported in various studies have shown that between 5 percent and 60 percent of the biomass. The emerges from the aquatic system in the form of adult insects. Because many of these adults die in the riparian zone, much of this biomass does not return to the aquatic habitat. This export of biomass reduces the organic matter and nutrients that are available to aquatic insectivores like fishes, amphibians and other macroinvertebrates and increases organic matter and nutrients that are available to riparian insectivores like birds and bats. For riparian insectivores, the importance of this export of aquatic biomass depends on the abundance of adult aquatic insects as prey relative to the abundance of terrestrial insects as prey (Jackson and Fisher 1986).

Adult aquatic insects represented 75 percent of total arthropod numbers and 50 percent of total arthropod biomass captured by emergency light traps placed in stream rock bed in trees 4 meter from stream. Adult aquatic insects are often major components in the diets of riparian birds (Clark 1984) and bats (Herd and Fenton 1983; Swift *et al* 1985), which suggests that this aquatic-terrestrial interaction may have contributed to the abundant insectivore faunas that characterize riparian systems. The potential importance of adult aquatic insects to riparian insectivores is greatest in arid region such as Kurangani because terrestrial insects may be less abundant in upland areas (Rathinakumar *et al* 2013).

Implications for Management of Riparian Zones

The consequence of the interaction between adult aquatic insects and the riparian zone are more important. However, adults have not been considered in the management of riparian systems. The anthropogenic activities on riparian zone can directly affect adult aquatic insects by interfering with the reproductive activities of adults. Some times abiotic changes like atmospheric temperature, wind velocity also affect the reproductive activities. In some times the biotic factors like insectivore density also affect the same. These conditions are exposed to in the riparian zone in the stream ecosystem. Indirect effects can include changes in the survival and growth of the immature stages of aquatic insects (i.e. larvae found in the stream) which in turn affects the abundance of adult aquatic insects in the riparian zone (Subramanian *et al* 2005).

The direct and indirect effect increases the complexity of management decisions. The availability of opening of stream canopy can increase the production of the immature stages of aquatic insects in the stream. As a result, larvae of aquatic insects would be more available as prey for stream insectivores, such as trout and adults would be more available as prey for riparian insectivores such as birds and bats. However, such type of alterations of the riparian zone may actually have a negative effect on stream biota because other essential stream parameters like water temperature, salinity, fee carbon dioxide, dissolved oxygen total solid suspended particles, stream width and breath, water velocity, substrate and index would also change (Hawkins *et al*, 1983). Birds and bats may be adversely affected as well if the survival and reproductive success of adult aquatic insects decrease because of alteration of the riparian zone due to anthropogenic activities (subsequently numbers in subsequent generations decrease (Jackson and Fisher 1986).

The factors that affect the distribution, abundance and function of the aquatic insects larvae in aquatic ecosystems have been examined extensively (Resh and Rosenberg 1984). In this context, very limited information only available for the adult stages of aquatic insects. If management plans for riparian zones are to be complete, further studies that implement the role of adult aquatic insects in riparian systems are needed in Western Ghats, south India.

Acknowledgements

We thank Prof. Dr. K. G. Sivaramakrishnan for constant support and encouragement for constructive criticism in preparation of this manuscript. The authors gratefully acknowledge DST-Science Engineering Research Board (SERB), Government of India, New Delhi, for the award of National Post Doctoral Fellowship (F. No.PDF/2015/000945).

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Table1. Physical characteristics of evergreen forest Kurangani stream of Western Ghats during experimental study May 2012 to April 2013

S.No	Physical characteristics	Kurangani stream
1	Latitude (N)	11°.00"N
2	Longitude (E)	77°.50"E
3	Altitude (m.a.s.l)	650
4	Stream order	III
5	Appearance	clear
6	Colour	colourless
7	Odour	odourless
8	Canopy cover	Partially canopy cover
9	**Substrate composition Percentage (%)**	
	a. Bed rock	20
	b. Boulders	25
	c. Cobbles	25
	d. Gravels	15
	e. Sandy	10
	f. Silt	5
10	Substrate Index	7.0

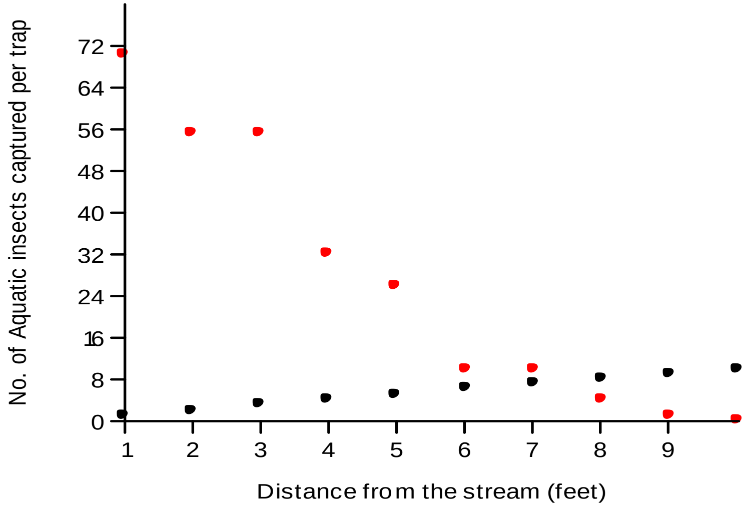

Fig1. XY Plot graph between distance from the stream and total number of adult aquatic insects captured per light trap set in the evergreen forest of Kurangani stream, Western Ghats, India.

Table 2. Showing Physico-chemical parameters of Kurangani stream of Western Ghats during experimental study May 2012 to April 2013

Parameters	May	June	July	Aug	Sep	Oct	Nov	Dec	Jun	Feb	Mar	April
Water Temperature (^{0}C)	21±0.47	23±0.47	23±0.47	22±0.94	21±0.47	22±0.47	22±0.94	21±0.47	21±0.47	21±0.47	23±0.47	22±0.47
Air Temperature (^{0}C)	26±0.94	26±0.47	27±0.47	25±0.94	24±0.47	24±0.47	24±0.47	25±0.47	25±0.94	25±0.94	25±0.94	26±0.94
Water velocity (M/Sec)	7.0±0.47	7.4±0.12	7.85±0.47	8.0±0.47	7.65±0.47	8.2±0.47	6.83±0.94	7.2±0.47	6.8±0.47	7.9±0.47	9.0±0.47	6.5±0.21
Width (M)	8.7±0.12	7.4±0.12	6.9±0.47	7.5±0.47	7.8±0.47	7.5±0.12	7.9±0.94	8.0±0.47	8.2±0.21	8.0±0.47	7.5±0.47	7.5±0.21
Depth (M)	0.3±0.12	0.5±0.08	0.6±0.12	0.8±0.47	0.8±0.47	0.8±0.47	0.6±0.12	0.8±0.47	0.8±0.21	0.9±0.21	1.0±0.07	0.5±0.21
Dissolved oxygen (mg/L)	7.64±0.27	9.07±0.03	7.79±0.12	7.28±0.12	8.5±0.47	7.9±0.12	8.2±0.12	8.0±0.47	9.0±0.47	9.1±0.47	8.9±0.47	8.2±0.47
Free CO_2	1.1±0.21	1±0.04	1±0.47	1±0.47	1±0.47	1±0.21	1±0.21	1±0.21	1±0.21	1±0.21	1±0.07	1±0.07
pH	7.63±0.27	7.93±0.06	7.8±0.12	7.85±0.12	7.8±0.470.12	7.5±0.12	7.8±0.47	7.2±0.21	7.7±0.47	7.5±0.21	7.5±0.47	7.4±0.47
Total Solids	0.4±0.21	0.56±0.06	0.55±0.21	0.75±0.21	0.6±0.21	0.02±0.21	0.5±0.21	0.09±0.21	0.03±0.02	0.41±0.21	0.01±	0.56±0.21
Dissolved Solids	0.04±0.07	0.1±0.04	0.05±0.07	0.09±0.07	0.04±0.07	0.02±0.07	0.02±0.07	0.01±0.07	0.04±0.07	0.06±0.07	0.02±0.07	0.02±0.07
Suspended Solids	0.36±0.07	0.46±0.04	0.45±0.21	0.06±0.07	0.56±0.07	0.18±0.07	0.06±0.07	0.08±0.07	0.05±0.04	0.07±0.07	0.06±0.07	0.06±0.07

Table 3. Order, Family and Genera of the adult aquatic insects (EPT) collected from Kurangani stream of Western Ghats during experimental study May 2012 to April 2013

Order	Family	Genera	May	June	July	Aug	Sep	Oct
Ephemeroptera	Beatidae	*Beatis sp*	13±0.81	16±0.81	18±0.5	13±0.81	18±0.81	10±0.81
	Leptophlebiidae	*Choroterpes sp*	24±0.47	23±0.47	12±0.47	16±0.47	18±0.47	12±0.47
		Notophlebia sp	1±0.47	6±0.81	6±0.47	3±0.47	4±0.94	4±0.47
	Caenidae	*Caenis sp*	7±0.47	9±0.47	5±0.47	6±0.47	10±0.47	8±0.81
	Heptageniidae	*Epeorus sp*	10±0.81	5±0.47	9±0.47	5±0.47	11±0.47	2±0.47
	Tricorythidae	*Tricorythodes sp*	8±0.47	14±0.99	11±0.47	10±0.47	7±0.47	15±0.99
	Ephemeridae	*Ephemera sp*	8±0.47	10±0.47	10±0.47	9±0.47	4±0.47	4±0.47
Plecoptera	Perlidae	*Neoperla sp*	8±0.47	12±0.47	5±0.5	8±0.81	2±0.47	8±0.47
Trichoptera	Hydropsychidae	*Homoplectra sp*	1±0.47	0±00	0±00	5±0.47	0±00	1±0.94
		Hydropsyche sp	6±0.47	15±0.94	14±0.81	18±0.47	13±0.47	12±0.94
		Potamiya sp	12±0.47	8±0.47	0±00	7±0.47	9±0.47	1±0.47
		Macronema sp	6±0.47	12±0.47	0±00	11±0.47	0±00	1±0.47
		Leptonema sp	1±0.47	0±00	1±0.47	0±00	1±0.47	1±0.94
	Polycentropodidae	*Polycentropus sp*	2±0.47	3±0.47	4±0.47	3±0.47	1±0.47	1±0.47
	Stenopsychidae	*Stenopsyche sp*	8±0.47	10±0.47	2±0.5	10±0.47	5±0.47	2±0.47

Order	Family	Genera	Nov	Dec	Jun	Feb	Mar	April
Ephemeroptera	Beatidae	*Beatis sp*	15±0.81	10±0.81	11±0.81	14±0.81	15±0.81	15±0.81
	Leptophlebiidae	*Choroterpes sp*	4±0.47	2±0.47	1±0.47	10±0.81	7±0.81	3±0.81
		Notophlebia sp	8±0.81	4±0.81	15±0.81	3±0.47	8±0.81	10±0.81
	Caenidae	*Caenis sp*	18±0.81	10±0.47	15±0.81	18±0.47	10±0.81	5±0.81
	Heptageniidae	*Epeorus sp*	2±0.47	4±0.47	5±0.47	4±0.47	18±0.81	4±0.81
	Tricorythidae	*Tricorythodes sp*	3±0.47	1±0.47	4±0.47	2±0.47	2±0.47	3±0.47
	Ephemeridae	*Ephemera sp*	2±0.47	1±0.47	1±0.47	4±0.47	7±0.81	2±0.81
Plecoptera	Perlidae	*Neoperla sp*	10±0.81	5±0.81	3±0.81	10±0.81	25±0.81	10±0.81
Trichoptera	Hydropsychidae	*Homoplectra sp*	1±0.47	0±0	1±0.47	1±0.47	1±0.47	0±0
		Hydropsyche sp	10±0.81	15±0.81	10±0.81	11±0.47	18±0.81	16±0.81
		Potamiya sp	1±0.47	0±0	1±0.47	0±0	1±0.47	2±0.47
		Macronema sp	0±0	0±0	0±0	1±0.47	1±0.47	1±0.47
		Leptonema sp	1±0.47	0±0	1±0.47	0±0	1±0.47	1±0.47
	Polycentropodidae	*Polycentropus sp*	2±0.47	1±0.47	0±0	1±0.47	1±0.47	1±0.47
	Stenopsychidae	*Stenopsyche sp*	8±0.81	4±0.81	15±0.81	3±0.47	8±0.81	10±0.81