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Baetidae (Ephemeroptera: Insecta) as Biological Indicators of Environmental Degradation in Tamiraparani and Vaigai River Basins of Southern Western Ghats, India

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A B S T R A C T

Biomonitoring of the Ephemeroptera (Family: Baetidae) was undertaken at species level in the Tamiraparani (Tirunelveli) and Vaigai (Theni) river basins of southern India. A total of 1,359 baetids were collected from three times from ten sampling sites, representing an environmental gradient. The mesohabitats of sixteen Baetidae species was described and their responses to environmental degradation and water chemistry were evaluated by means of species richness and abundance and the data was subjected to multivariate analysis (Canonical Correspondence Analysis), in order to assess their potential capacity as indicators of these impacts. Most species were found predominantly associated with stony substrates, but some were associated with grasses, and two species were found predominantly in lentic water bodies. Species distributions were influenced by the environmental gradient. Based on the CCA ordination, pristine and the most impaired areas were identified for each spices so as were found in therefore enabling us to establish the sensitivity of each species.

Keywords

Ephemeroptera, Baetidae, Bioassessment, Bioindicator, Western Ghats, India.

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Introduction

Freshwater habitats are being subjected to increased levels of human disturbance throughout the world (Saunders *et al.*, 2002). A recent assessment of the status of inland water ecosystems shows that globally most threatened river catchments are to be found in the Indian subcontinent. Biological monitoring is a central component of water resource management throughout the world (Rosenberg and Resh, 1993; Barbour *et al.*, 1999). The systematic development and testing of rapid bioassessment tools on river basins using benthic aquatic insects in Brazil is recent (Buss *et al.*, 2002; Buss, 2001; Callisto *et al.*, 1998; Silveira *et al.*, 2005) and due to limited knowledge of the taxonomy and distribution of mayflies in India, these studies have generally used supraspecific taxonomic levels.

Aquatic insects are ideal indicators of pollution (Dudgeon, 1999) aquatic insects also inhabit vital position in the food chain of aquatic systems and therefore can be used to make estimates of ecosystem health. Analysis of aquatic insect assemblages is also lot of time and cost efficient compared to chemical and physical assessments of water quality (Bode *et al.,* 1995; EEA, 2007).

In temperate streams it is very well documented that the changes in catchment land use results in the loss or a change in diversity of invertebrates and fishes (Corkum, 1989; Allan, 1995; Vinson and Hawkins, 1998). Similarly, in tropical Asia, though it is known that deforestation of the catchment affects fish populations (Dudgeon, 1992; 1999) the impact of catchment land use on the stream insect communities is poorly understood.

In freshwater biodiversity hotspots like the Western Ghats, no information is available on this topic. Such information is very important to understand the impact of ongoing landscape transformations on the biodiversity of rivers 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 (Subramanian *et al.,* 2005).

The purpose of this study was to determine the specific requirements of species of family Baetidae and evaluate their potential use as indicator species for assessing environmental degradation in the Western Ghats river systems and to describe the mesohabitat and to assess their responses to environmental degradation and hydro-chemistry by means of biological measures (richness and abundance) and multivariate analysis (Canonical Correspondence Analysis), in order to evaluate their potential capacity as indicators of these impacts.

Materials and Methods

Study area

This study was carried out at the Tamiraparani and Vaigai rivers, which is the two major river basins of the southern Western Ghats. Tamiraparani, a major east flowing river with catchment area of 5482 km2 is a medium sized river basin in India. It originates from the Pothigai hills of Kalakad-Mundanthurai Tiger Reserve (KMTR) of the Western Ghats (8° 42' N and 77.15° 24' E) at an altitude of 2074 m. Tamiaraparani river basin benefits from both the north-east and south-west monsoons (Martin *et al.,* 2000). The Vaigai river is one of the major river system in Madurai, Tamil Nadu state of southern India. It originates in the Periyar Plateau of the Western Ghats range, and flows northeast through the Cambam Valley, which lies between the Palni hills to the north and the Varushanad hills to the south (Martin *et al.,* 2000).

Larval forms of Baetidae species were sampled along with data on physical, chemical and other environmental variables at ten sites on Tamiraparani and Vaigai river basins. Two sites are third order streams and three sites are fourth order river, and all sites were at the altitudes between 60 and 150 m.a.s.l. Sites were chosen to represent an environmental gradient from a pristine area such as diversity of species (site A, B, F and G) to most impaired (site E and I). The four classes are: site A and B (Class 1), sites C, D and E (class 2), sites F and G (class 3), and sites H, I and J (class 4). Class 1 and 3 are located at upstream and class 2 and 4 are located in downstream from the Tamiraparani and Vaigai river basins. Class 1 and 3 are chosen as a reference sites because of its dense riparian vegetation (80% stream cover). Class 2 and 4 sites have disturbances caused by the tourists and pilgrims thronging them during festivals and ceremonies.

Field and laboratory procedures

Species collection and identification

The larvae of Baetidae species were collected by kick net (mesh size: 0.5 to 1.0 mm) sampling (Balasubramanian *et al.*, 1992). The duration of each kick net operation was 2 minutes. The substratum viz., bed rocks, boulders and cobbles was vigorously disturbed strictly restricted to one m^2 area. All specimens from the net surface were carefully collected without any morphological damage using fine forceps or brush and preserved in 80% Ethyl alcohol immediately. Sampling was performed on for two years 2010–2011. The collected samples were brought to laboratory and identified upto genus and species level was carried out by done using published taxonomical literature pertaining to of the Western Ghats, India (Sivaramakrishnan *et al.,* 2009; Selvakumar *et al.*, 2012; Kubendran *et al.*, 2014; 2015).

Analysis of physico-chemical factors

Recording of selected river characteristics like order of the stream, nature of the eco-region, substrate composition and a few physico-chemical parameters like wet width, depth, water current as well as water temperature were done at the sampling sites during sampling (Table 5). River characteristics were evaluated qualitatively by following visual observation and description.

Substrate index

Substrates were classified by using (Jowett *et al.*, 1991). The following criteria: <0.5 mm for mud/silt, 0.5–2 mm for sand, 2–64 mm for gravel, 65–256 mm for cobbles, and >256 mm for boulders. For statistical analysis, substrate composition was converted to a substrate index (Suren, 1996) as explained below: Substrate Index = (0.07 x % boulder) + (0.06 x % cobble) + (0.05 x % gravel) + (0.04 x % sand) + (0.03 x % mud/silt) (Jowett *et al.*, 1991).

Data analysis

The structure of the Baetidae assemblage was evaluated by species richness and abundance. CCA was performed to determine relationships between environmental variables and the respective biotic components. Diversity indices and CCA were performed carried out by the PAST software (Hammer *et al.*, 2001).

Results and Discussion

Total of 1,359 individuals corresponding belonging to nine genera belonging to sixteen species belonging to nine genera were recorded in this study (Tables 1 and 2).

The representation of physico-chemical variables of study sites are listed in table 5. The tropical structure of the baetid assemblage was varying among the sampling periods. The total number of individuals was appreciably more at the post-monsoon, intermediate at the end of the pre-monsoon and minimum at the dry season. The most abundant species are *LabioBaetis soldani* and *NigroBaetis paramakalyani* collected in the sites are 161 and 160 individuals respectively. *L. verum* and *L. pulchellum* represented with the least abundance during investigation period.

Substrate preference of Baetidae species

Most Species such as *Baetis acceptus, B. conservatus, B. frequentus, I. michaelohubbardi*, *LabioBaetis geminatus, L. pulchellum, L. soldani, L. jacobusi*, and *L. vera* were found predominantly associated with pebbles substrates, but *L. geminatus*, *L. pulchellum*, *L. soldani* and *N. paramakalyani* some were predominantly associated with grasses, (90), two species *C. ceylonensis* and *C. similis* were primarily attached with rocks and two species namely *C. bimaculatum* and *P. regularum* were found in pool litter substrate (40). Absence of all species in fine sediment substrate sites is a notable point (Tables 3, 4 and 7).

Site preference of Baetidae species

Baetid species richness followed the gradient of environment and water quality in the Tamiraparani and Vaigai river basins. Totally 14 baetid species were associated to sites of classes 1 and 3, and one species (46 individuals of *L. geminatus*) and two species of (*C. bimaculatum* and *P. regularum*) were found in the most impaired site. Class 4 site had species richness within this limit (five species). Simson and Shanon index were higher in site F (0.9061, 2.501) and H (0.9044, 2.496) compare to other sites of intermediate integrity (Table 6).

Canonical Correspondence Analysis (CCA)

In order to determine the specific environmental parameter that associated with *Baetid* species distribution and CCA was performed (Fig. 1). The diversity of the baetids of the analyzed communities was correlated with the physicochemical parameters. The most influencing factor was the concentration of dissolved oxygen. Obviously, species richness was high in the sampling sites towards upstream where the dissolved oxygen content was higher. Based on the CCA plot for the sites, the two River basins have been classified into four reaches among which the first reach had good water quality marked by the presence of higher species diversity, the second level of sites had disturbances caused by the tourists and pilgrims thronging them during festivals and ceremonies. The two sites in this reach were represented by two species *LabioBaetis* sp. and *NigroBaetis* sp. The third and fourth reaches had minimal baetid representation which clearly indicated the gradual increase in pollution load and the corresponding deteriorated water quality. Localities that were towards the last reach had only two species namely *C. bimaculatum* and *P. regularum* that usually inhabit localities impacted by some type of pollution.

Water temperature of Thalaianai and Valiparai is one of the most important physical characteristics of ecosystem. It affects a number of water quality parameters that is one of the concerns using for bathing, washing the clothes and pilgrims activities. The chemical and biological reaction rates increase with increased water temperature. The pH of water affects the normal physiological functions of aquatic organisms, including the exchange of ions with the water and respiration. Such important physiological processes operate normally in most aquatic biota under a relatively wide pH range (e.g. 6.5–8.5 pH units). The significant change in pH value is due to using the detergents and bathing soaps and also drastically changes in pH of time due to the exposure of air, biological activity and temperature. The higher values of pH recorded in Kurangani could be attributed to increased primary productivity wherein carbonates, sulfate, nitrates and phosphates are converted to hydroxyl ions. Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. The dissolved oxygen was less 6.2 mg/L^{-1} in Thiruvedakam and higher value 9.02 mg/L^{-1} in Kurangani. Dissolved oxygen levels change and vary according to the time of day, the weather and the temperature. Its presence is essential in aquatic ecosystem in bringing out various bio- chemical changes and its effect on metabolic activities of organism. CO_2 values are within the permissible limits.

Beyond permissible limit taste, corrosion and palatability of water is affected. Besides imparting salty taste water high level of total solids, total suspended solids and dissolved solids have deleterious effects on metallic pipes and structure as well as on agricultural plants are also reported (Balachandran *et al.*, 2011; Kubendran and Ramesh, 2016a,b).

In this study, out of 16 species of Baetidae, 14 were associated predominantly with pebble substrates, 9 species with grasses and wood debris, 8 species with leaf litter, 7 species with rocky substrate and 2 species with pool areas. This predominantly association with pebbles substrates may be explained by their main food source. Sivaramakrishnan and Venkataraman (1987) categorized the functional feeding groups of a few Baetidae species. The above mentioned species were assigned to the scraper functional feeding group. Studies exclusively on Baetidae in south-east Brazil indicate that these species have a strong negative effect on the quantity periphyton and sediment (Moulton *et al.*, 2004), suggesting that these species are important herbivores in this region.

Fig.1 Canonical Correspondence Analysis (CCA) based on the Baetidae diversity and physico-chemical parameters

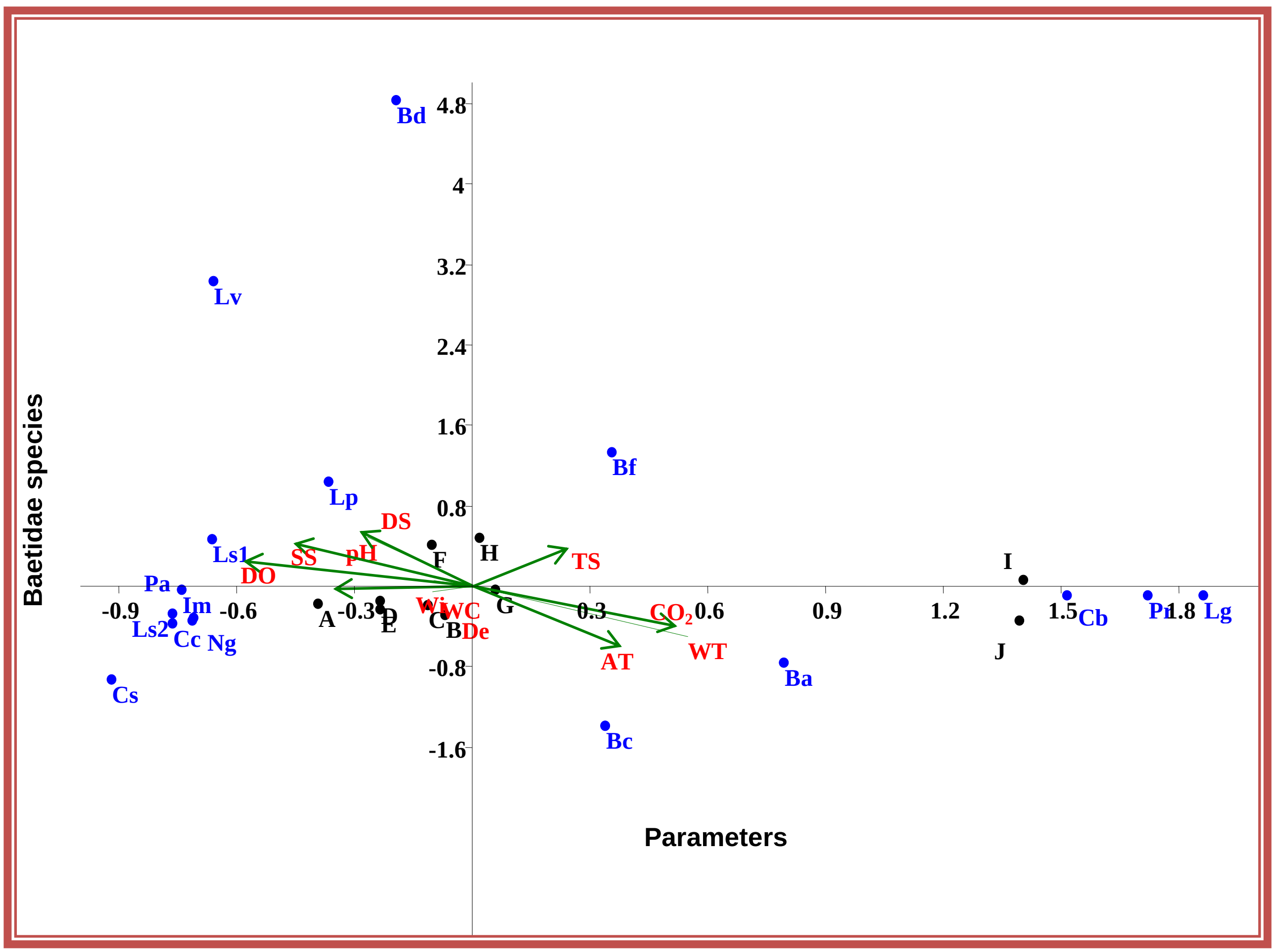

Table.1 Baetid species at each sampling site and total number of individuals collected in the southern Western Ghats during 2010-2011

Particulars	A	B	C	D	E	F	G	H	I	J	Total
Baetis acceptus	4	5	8	3	5	3	3	6	3	5	**45**
Baetis conservatus	2	3	4	1	5	2	2	2	0	3	**24**
***Baetis* sp.**	0	0	0	0	0	17	1	10	0	0	**28**
Baetis frequentus	1	3	4	1	5	48	22	30	5	0	**119**
Cloeon bimaculatum	0	0	6	4	12	11	7	5	10	7	**62**
Chopralla ceylonensis	21	15	8	4	19	24	9	8	0	0	**108**
Chopralla similis	11	4	5	2	22	15	6	1	0	0	**66**
IndoBaetis michaelohubbardi	20	12	15	7	25	28	1	22	0	0	**130**
LabioBaetis geminatus	1	8	4	1	2	4	4	8	9	5	**46**
LabioBaetis pulchellum	1	1	2	4	1	2	1	2	0	0	**14**
***LabioBaetis* sp.**	5	1	11	3	30	25	15	22	0	0	**112**
LabioBaetis soldani	18	11	24	22	40	21	6	19	0	0	**161**
Liebebiella vera	3	0	0	0	0	4	0	5	0	0	**12**
***NigroBaetis* sp.**	30	10	12	10	50	23	5	20	0	0	**160**
***Cloeon* sp.**	8	8	12	12	55	25	6	10	0	0	**136**
Procloeon regularum	10	5	3	5	5	22	4	20	30	32	**136**
										Total No of Individuals	**1359**

A- Panathertham; B- Kallar; C- Sorimuthu Ayyanar river; D- Agasthiar falls; E- Thalaianai; F- Kurangani; G- Suruli falls; H- Valiparai; I- Thiruvedagam and J- Peranai

Table.2 Percent of occurrence of each Baetid species at each sampling site in the southern Western Ghats during 2010-2011

Particulars	Percent of sampling site (%)									
	Class 1		Class 2			Class 3		Class 4		
	A	B	C	D	E	F	G	H	I	J
Baetis acceptus	8.88	11.11	17.77	6.66	11.11	6.66	6.66	13.33	6.66	11.11
Baetis conservatus	8.33	12.5	16.66	4.22	20.83	8.33	8.33	8.33	0	12.5
***Baetis* sp.**	0	0	0	0	0	60.71	3.57	35.71	0	0
Baetis frequentus	0.8	2.52	3.33	0.8	4.2	40.33	18.48	25.21	4.2	0
Cloeon bimaculatum	0	0	9.66	6.45	19.35	17.74	11.29	8.06	16.12	11.29
Chopralla ceylonensis	19.44	13.88	7.4	3.7	17.59	22.22	8.33	7.4	0	0
Chopralla similis	16.6	6	7.57	3.3	33.33	22.72	9.9	1.51	0	0
IndoBaetis michaelohubbardi	15.38	9.23	11.53	5.38	19.23	21.53	0.76	16.92	0	0
LabioBaetis geminatus	2.17	17.39	8.69	2.17	4.34	8.69	8.69	17.34	19.56	10.86
LabioBaetis pulchellum	7.14	7.14	14.28	28.36	7.14	14.28	7.14	14.28	0	0
***LabioBaetis* sp.**	4.46	0.89	9.82	2.67	26.78	22.32	13.92	19.69	0	0
LabioBaetis soldani	11.18	6.83	14.9	13.66	24.84	13.04	3.72	11.8	0	0
Liebebiella vera	25	0	0	0	0	33.3	0	41.6	0	0
***NigroBaetis* sp.**	18.75	6.25	7.5	6.25	31.25	14.37	3.12	12.5	0	0
***Cloeon* sp.**	5.8	5.8	8.82	8.82	40.44	18.38	4.4	7.35	0	0
Procloeon regularum	7.35	3.67	2.2	3.67	3.67	16.17	2.94	14.75	22.05	23.55

Table.3 Substrate preference and total number of Baetid individuals collected in the ten sampling sites in the southern Western Ghats

Particulars	Rock	Pebbles	Grasses	wood debris	leaf litters	Pool	TOTAL
Baetis acceptus	3	15	20	5	2	0	**45**
Baetis conservatus	0	12	9	2	1	0	**24**
***Baetis* sp.**	0	25	0	3	0	0	**28**
Baetis frequentus	10	44	35	16	14	0	**119**
Cloeon bimaculatum	15	0	27	0	0	20	**62**
Chopralla ceylonensis	44	64	0	0	0	0	**108**
Chopralla similis	33	33	0	0	0	0	**66**
IndoBaetis michaelohubbardi	0	70	0	33	27	0	**130**
LabioBaetis geminatus	0	10	36	0	0	0	**46**
LabioBaetis pulchellum	0	14	0	0	0	0	**14**
***LabioBaetis* sp.**	0	20	70	12	10	0	**112**
LabioBaetis soldani	0	40	80	20	21	0	**161**
Liebebiella vera	0	12	0	0	0	0	**12**
***NigroBaetis* sp.**	0	40	90	20	10	0	**160**
***Cloeon* sp.**	10	80	40	3	3	0	**136**
Procloeon regularum	96	0	0	0	0	40	**136**
						TOTAL	**1359**

Table.4 Baetid species percent per substrate and total number of individuals collected in the ten sampling sites in the southern Western Ghats

Particulars	Percent of substrates (%)						
	Rock	Pebbles	Grasses	wood debris	leaf litters	Pool	Total no of Individuals
Baetis acceptus	6.66	33.33	44.44	11.11	4.44	0	**45**
Baetis conservatus	0	50	37.5	8.33	4.16	0	**24**
***Baetis* sp.**	0	89.28	0	10.71	0	0	**28**
Baetis frequentus	8.4	36.97	29.41	13.44	11.76	0	**119**
Cloeon bimaculatum	24.19	0	43.54	0	0	32.25	**62**
Chopralla ceylonensis	40.74	59.25	0	0	0	0	**108**
Chopralla similis	50	50	0	0	0	0	**66**
IndoBaetis michaelohubbardi	0	53.84	0	25.28	20.76	0	**130**
LabioBaetis geminatus	0	21.73	78.26	0	0	0	**46**
LabioBaetis pulchellum	0	100	0	0	0	0	**14**
***LabioBaetis* sp.**	0	17.85	62.5	10.71	8.92	0	**112**
LabioBaetis soldani	0	24.84	49.68	12.42	13.04	0	**161**
Liebebiella vera	0	100	0	0	0	0	**12**
***NigroBaetis* sp.**	0	25	56.25	12.5	6.25	0	**160**
***Cloeon* sp.**	7.35	58.82	29.41	2.2	2.2	0	**136**
Procloeon regularum	70.58	0	0	0	0	29.42	**136**
						TOTAL	**1359**

Table.5 Physico- chemical parameters of selected sits of southern Western Ghats during 2010-2011

	A	B	C	D	E	F	G	H	I	J
Water Temperature (˚C)	21	23	21	22	21	21	22	21	22	23
Air Temperature (˚C)	26	27	24	24	25	23	24	24	26	26
Water Current (m/sec)	7	7.85	7.65	6.83	7.2	7.4	6.83	7.65	6.5	7.8
Width (M)	8.7	6.9	7.8	7.9	8	7.4	7.9	7.8	7.5	7.5
Depth (M)	0.3	0.6	0.8	0.6	0.8	0.5	0.6	0.8	0.5	0.6
Dissolved oxygen (mg/L)	7.64	7.79	8.5	8.2	8	9.07	8.2	8.5	6.2	8
Free CO_2	1.1	1	1	1	1	1	1	1	1	1.3
pH	7.63	7.8	7.30.12	7.8	7.2	7.93	7.8	7.8	7.4	7.5
Total Solids	0.4	0.55	0.6	0.5	0.09	0.56	0.5	0.6	0.56	0.5
Dissolved Solids	0.04	0.05	0.04	0.02	0.01	0.1	0.02	0.04	0.02	0.02
Suspended Solids	0.36	0.45	0.56	0.06	0.08	0.46	0.06	0.56	0.06	0.04
Substrate Index	5.8	5.6	5.8	5.6	5.7	5.8	5.5	5.9	5.3	5.7

Table.6 Taxa richness, individuals, Simpson index, Shannon index and evenness values for the sites studied in the southern Western Ghats

	A	B	C	D	E	F	G	H	I	J
Taxa richness	14	13	14	14	14	16	15	16	5	5
Individuals	135	86	118	79	276	274	92	190	57	52
Simpson	0.8679	0.8913	0.8951	0.8598	0.8721	0.9061	0.8795	0.9044	0.6568	0.5814
Shannon	2.222	2.346	2.429	2.254	2.238	2.501	2.369	2.496	1.303	1.184
Evenness	0.6591	0.8031	0.8107	0.6803	0.6699	0.7622	0.7122	0.7581	0.7361	0.6533

A- Panathertham; B- Kallar; C- Sorimuthu Ayyanar river; D- Agasthiar falls; E- Thalaianai; F- Kurangani; G- Suruli falls; H- Valiparai; I- Thiruvedagam and J- Peranai

Table.7 Summary of the preferred substrate, morphologic adaptations and tolerance to the measured stress of the sixteen Baetidae species analyzed in southern Western Ghats

S.No	Name of the species	Preferred substrate	Habit and morphologic adaptation to live in the substrate	Tolerance to the measured stress
1	***Baetis acceptus***	Grasses	Small body, Clingers, Swimmers	Somewhat sensitive
2	***Baetis conservatus***	Pebbles	Small body, live between pebbles attaché algae and pebbles	Somewhat sensitive
3	***Baetis* sp.**	Pebbles	Small body, live between *Stenopsyche* nest and Rock	Very sensitive
4	***Baetis frequentus***	Pebbles and grasses	Small body, Swimmers	Somewhat sensitive
5	***Cloeon bimaculatum***	Pool and Grasses	Small to medium body, Swimmers, long and setae caudal filament, live between grass and algae	Tolerant
6	***Chopralla ceylonensis***	Rock and Pebbles	Small body, long claw dentecles	Somewhat sensitive
7	***Chopralla similis***	Rock and Pebbles	Small body, long claw dentecles	Somewhat sensitive
8	***IndoBaetis michaelohubbardi***	Pebbles and Wood debris	Small body	Very sensitive
9	***LabioBaetis geminatus***	Grasses	Small body, Swimmers	Somewhat sensitive
10	***LabioBaetis pulchellum***	pebbles	Small body, live between pebbles attach algae and pebbles	Somewhat sensitive
11	***LabioBaetis* sp.**	Grasses and Pebbles	Small body, Swimmers	Very sensitive
12	***LabioBaetis soldani***	Grasses and Pebbles	Small body, Swimmers	Very sensitive
13	***Liebebiella vera***	Pebbles	Small body	Somewhat sensitive
14	***NigroBaetis* sp.**	Grasses and Pebbles	Small body, Swimmers, long caudal filaments	Very sensitive
15	***Cloeon* sp.**	Pebbles and Grasses	Small body, reduced caudal filament	Very sensitive
16	***Procloeon regularum***	Pool and Grasses	Small to medium body, Swimmers, long and pointed claw, live between grass and algae	Tolerant

Substrate preference

Baetid species of *L. pulchellum* (100%) followed by *Baetis* sp. (89.28%), *C. ceylonensis* (58.25%), and *I. michaelohubbardi* (53.84%) occurred preferentially in pebbles substrates and exhibit morphologic adaptations to resist hydraulic stress such as the presence of long caudal filament in the tail of Nigro *Baetis* sp. Salles *et al.*, (2003) found one of *C. dasilvai* (as *Cryptonympha* sp.) in riffle areas, corroborating that this species probably occurs preferentially in this habitat. The species *L. geminatus* was found associated to grass substrate (78.28%), and to a lesser in pebbles areas (21.73%). The species *C. ceylonensis* and *C. similis*, in contrast to the other species that occupied rocky substrate, do not show morphologic characteristics to resist fast water current (on the contrary, larvae have narrow legs and claws without denticules). In field observations suggest that *C. bimaculatum*, when associated to pool areas, live in areas less exposed to the water flow.

The field observations suggest that *C. bimaculatum*, when associated to pool areas, live in areas less exposed to the water flow. But, the species *I. michaelohubbardi* was found predominantly on the wood debris and leaf litter. These findings are in accordance with Francischetti *et al.*, (2004).The species *I. michaelohubbardi* was found predominantly in wood debris and leaf litter substrate. These findings are in accordance with Francischetti *et al.*, (2004), *I. michaelohubbardi* was associated to areas with slow water flow, frequently living beneath litter, while the robust species *L. soldani* is more often found associated to pebbles substrate influenced by faster water current. *C. bimaculatum* (32.25%) and *P. regularum* (29.42%) were often occurred on pool substrates, but they were also found in rocky areas. Little is known about the biology of both species, but the field observations indicate that species of *C. bimaculatum* seems to be more often associated to pool areas.

Site preference of Baetidae species

The higher abundance of baetids in intermediately impaired areas corroborate the classification of the family Baetidae as ‘somewhat sensitive’ in biotic indices worldwide (Armitage *et al.*, 1983; Hilsenhoff, 1988; Buss and Salles, 2007). However, considering the taxa richness, all sixteen species occurred in sites of classes 1 and 3, while richness in the most impaired site was low (and often with low abundance). Therefore, taxa richness of Baetidae, in spite of being a simple parameter, was a valid indicator of water quality. In this study it was possible to verify that not all species have the same response to impacts, and it was possible to identify which species were associated to unimpaired and impaired areas.

Based on the distributional pattern of baetid species and as verified in the CCA ordination, species could be assigned to one of the five tolerance classes: ‘Very sensitive’ for those restricted to unimpaired sites; ‘sensitive’ for those predominantly associated to areas of classes 1 and 3 (high CCA values and dissolved oxygen concentration); ‘somewhat sensitive’ for those well represented in classes 2 site; ‘tolerant’ for those found with high abundance in sites of class 4 and the most impaired sites (I and J); and ‘very tolerant’ for those restricted to impaired sites (Fig. 1).

Members of the baetids observed in this study assigned to the not ‘very tolerant’ class. Since these species are frequently associated with pebbles substrates, in this study one of the main factors restricting baetid distribution was the high sedimentation observed in sites of classes 4. Tolerance classification, together with information on the preferred substrate of each species, is a first approach towards a biological monitoring program considering species-level in tropical region.

In a time where rapid bioassessment tools are growing in importance, analyses at family or order level are often preferred, because of difficulties on taxonomy and better cost-effectiveness ratio (Resh, 1995; Barbour *et al.,* 1999). However, information on lower taxonomic levels allows complementary refined results for specific responses, especially in the chronically misleading 'intermediately impaired sites'. The advantages of using a species-level approach were clear with the two species of *Labiobaetis*. (For instance, *Labiobaetis* sp. occurred in pebbles substrates, while *L. soldani* occurred in grasses areas), and have different tolerance to the measured stress (90% of individuals of *Labiobaetis* sp. occurred in the two least impaired sites, while *L. soldani* occurred with higher abundance at intermediately impaired sites and seem to be the only baetid species able/88 to live in the most impaired site in this study.

In conclusion, the present study corroborates wit earlier report that the members of the family Baetidae are the bio-indicators indicator of water quality and ecosystem health primarily because of presence in both the polluted and unpolluted reaches of the two River basins. However, they are sensitive to pollution as species richness and numbers are significantly reduced at downstream sites. The genus *C. bimaculatum* and *P. regularum* are tolerant to organic pollution. This study reveals that assemblages of species of Baetidae, responded to changes in substrate composition, habitat and water quality. The results of this study highlight the regional diversity and distribution of Baetidae in the Western Ghats streams and rivers. However, research involving the entire benthic macroinvertebrates will be better to understand overall structure and function of streams and rivers of the Western Ghats with special reference to bio-assessment aspects.

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