RESEARCH ARTICLE

Diversity of Aquatic Insects in Relation to Physico Chemical Water Quality in Kallada River, Kollam, India

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ABSTRACT

Insects comprise the most diverse group of organisms that exist on Earth. Aquatic insects are colossally diverse group consisting of thirteen orders having aquatic or semi aquatic stages. The diversity and distribution of aquatic insects and physicochemical water quality variables were studied along three segments of the River Kallada from February 2018 to January 2019. A total of 5,978 individuals belonging to 71 families and 9 orders were identified from River Kallada. Among the aquatic insects collected, order Coleoptera was the most diverse, followed by Odonata, Hemiptera, Diptera, Trichoptera, Ephemeroptera, Lepidoptera, Plecoptera and Megaloptera. However, the most dominant order with the highest numerical abundance was Hemiptera (30.22%). Highest Shannon-Wiener diversity index values were recorded from site S1 (3.523) of upstream segment during premonsoon season and lowest value of 2.76 was noted for site S8 of midstream segment during postmonsoon season. Berger- Parker dominance index was higher in site S8 (0.14) of midstream segment and the lowest value 0.06 was noted for upstream segment during premonsoon season. The physico chemical variations of stream were found to be influencing the distribution of aquatic insects. The high diversity of insects in streams is a sign of large number of microhabitat diversity and good water quality conditions. Deterioration of microhabitat and perturbation in an aquatic ecosystem considerably affects diversity and abundance of entamofauna.

Keywords: Aquatic insects, Ecological indices, Water quality, Richness Index, Diversity Index

INTRODUCTION

Aquatic insects are very diverse groups, including thirteen orders of insects with aquatic or semi aquatic stages. Of these, approximately 76,000 species are accustomed to all sorts of freshwater environments [1]. Moreover, they are most suitable indicators for detecting water purity and they have different levels of tolerance on environmental disturbance. Therefore, studies on the diversity and distribution of these macroinvertebrates play a major role in predicting the health status of a stream. Changes in physicochemical properties may affect water quality and subsequently alter the distribution pattern of aquatic organisms, including insects [2]. Hydro-morphological and physicochemical alteration in a stream drastically reduces the diversity of sensitive insects like mayflies and only few species can cope up with these alteration [3]. Some natural processes such as weathering, evapotranspiration, wind deposition, leaching of soil, hydroelectric flow and biological processes in the aquatic environment also alter the properties of water [4]. Anthropogenic sources such as untreated industrial waste, improperly treated household waste, and agricultural waste are major contributors to surface water pollution and water quality degradation. Abridged level of dissolved oxygen and high biological oxygen demand, accumulation of organic pollutants in rivers invigorates microbial growth, leading to oxygen diminution and uproar of the entire river ecosystem [5]. According to Popoola and Otalekor, dipterans are common in nutrient enriched water and they can tolerate less oxygenated water [6]. Most physicochemical characteristics directly or indirectly affect the diversity of macroinvertebrates, either adversely or positively**.** Habitat degradation along with loss of water quality can lead to diversity drop among aquatic invertebrates because of unavailability of natural resources [7]. The main objective of the present study was to assess seasonal changes of various physico chemical properties of water and its impact on aquatic insects diversity.

MATERIALS AND METHODS

Study area and sampling locations

The study was carried out in Kallada River, Kollam, India, from February 2018 to January 2019 at monthly intervals. The River originates from the Kulathupuzha ranges of Western Ghats, flows towards the west as Kulathupuzha River, near Parappar in Thenmala, joins with Chendurni and Kazhuthurutty rivers and ultimately drains in to the Ashtamudi Lake (Figure 1). To determine the physico chemical water quality and distribution of aquatic insect taxa, six sampling sites were selected from three segments of river namely upstream, midstream and downstream. Stations S1, S3, S5, S7, S9, S11, S13, S15 and S17 represent reference sites and S2, S4, S6, S8, S10, S12, S14, S16 and S18 were test sites (Table 1).

Sample Collection and Analysis

Aquatic insect sampling

Insects were sampled by adopting Large-river Bioassessment Protocol [8]. Aquatic insects were collected from 500 m reach having equally divided 100 m transect for each site. A total of six transects were set. First transect location was selected at the downstream end of the reach with the remaining five transects at 100 m, 200 m, 300 m, 400 m and 500 m, each transects having 10 m sample zone. Sampling gears used were Peterson Grab (25.75 x 13″), Kicknet (600 μm) and D-frame dip net (500 μm). Using D-frame net, a total of 6 sweeps, each of 0.5m in length, were collected within the sample zone on either side of transects. Kick screen net was used at sites where depth of stream was below 1.0 meter and 5 kicks were sampled at various velocities in the water. Grab sampler was used for bottom sampling. Three replicates were taken from each sampling zone. Samples from each transects were preserved in 90% ethyl alcohol for laboratory processing. In the laboratory, all the individuals from each transect sample were sorted, counted, and then preserved in 70% ethyl alcohol for further taxonomic identification.

Sampling of Water

Water samples were collected in polyethylene sampling bottles previously washed with clean distilled water followed by rinsing with water from sampling sites. Temperature and pH were analyzed at the site itself by using thermometer and digital pH meter respectively. For measuring dissolved oxygen, the samples were fixed at the site itself and parameters such as Total Hardness, Dissolved Oxygen, Biological Oxygen Demand, Sulphate, Nitrate and Phosphate were analyzed in the laboratory by using standard methods [9].

Data Analysis

Abundance and taxonomic richness of aquatic insects were estimated for each sample. Ecological indices, including the Shannon-Wiener diversity Index (H'), Berger- Parker Dominance Index (D), Margalef Richness Index were determined for each sampling site. Statistical analysis conducted for physico chemical parameters were Analysis of Variance (between season) and t test (between sites) at 5% level of significance using the software SPSS (SPSS Statistics 21.0). Canonical correspondence analysis (CCA) was performed for finding correlation between insect families and environmental variables using PAST 4.03.

RESULTS AND DISCUSSION

A total of 5,978 individuals belonging to 71 families and 9 orders were identified from River Kallada. Highest diversity was found among insects under order Coleoptera followed by Odonata, Hemiptera, Diptera, Trichoptera, Ephemeroptera, Lepidoptera, Plecoptera and Megaloptera. However, the most dominant order with the maximum numerical abundance was Hemiptera (Figure 2).

Ecological Indices

Table 2, 3 and 4 shows the diversity indices of aquatic insects during premonsoon, monsoon and postmonsoon seasons respectively. Highest Shannon-Wiener diversity index value of 3.52 was recorded from site S1 of upstream segment during premonsoon season and a lowest value of 2.76 was noted for site S8 of midstream segment and site S18 of downstream segment during monsoon and postmonsoon season respectively. The study of Hasmi et al. showed that a positive correlation exists between dissolved oxygen and Shannon-Wiener diversity Index [10]. In the current study, high dissolved oxygen was observed in upstream segment than lower reaches. Current result also shows that Berger- Parker Dominance Index value ranges between 0.06 (reference site) to 0.14 (test site). A polluted aquatic environment can infact sustain certain tolerant organisms to persist and propagate, thus affecting diversity [11]. Hence, higher dominance index is an indication of low water quality in the present study. Richness index measures the number of different taxa in a given area. Here, highest Margalef Richness Index value of 7.03 was observed in Site S1 of upstream segment during postmonsoon season. Margalef Richness Index values were found to be higher in reference sites than test sites. The results of ecological indices revealed that, the diversity and richness of insects at reference sites were high and the dominance index was high at the test sites.

Physicochemical water quality

Physicochemical variables of each sampling station along the stream are shown in table 5. In the present study, the annual mean value of temperature ranged from 26.4 ± 0.33 to 27.2 ± 0.58 in upstream, 27.6 ± 0.36 to 28.6 ± 1.09 in midstream and 27.6 ± 0.4 to 28.6 ± 1.11 in downstream segment. Seasonal mean value of temperature showed significant variation in all the sites during study ($p<0.05$). pH was minimum in site S8 of midstream segment with a value of 6.02 ± 0.27 and maximum at site S18 of downstream segment with a value of 6.89 ± 0.35. In terms of dissolved oxygen, significant seasonal variations were found in sites S3 of upstream segment, S13 of midstream segment and S16 and S17 of downstream segment ($p<0.05$). Annual mean value of dissolved oxygen ranged from 5.96 ± 0.2 at site S18 of downstream segment to 7.33 ± 0.37 at site S1of upstream segment. Biological oxygen demand ranged between 0.74 ± 0.15 and 2.91 ± 0.31.The total dissolved solids varied significantly during seasons in all stations, and showed significant variation between sites too. In the midstream and downstream segments, total dissolved solids became high in monsoon and post-monsoon seasons. Nitrate and sulphate values were observed within the acceptable limit of drinking water quality standards; however nitrate content was high during postmonsoon season. In midstream and downstream segments, phosphate exceeded the standard permissible limit of WHO [12].

According to the analysis of results, most of the physicochemical parameters varied significantly during seasons. In the present study, the temperature showed relatively high values in the midstream and downstream segments, this may be due to the absence of canopy cover and the presence of various pollutants [13]. In the current study, pH values of different stations observed within the permissible limit of Indian water quality standards [14]. The optimum pH for aquatic life is in the range of 6.5 – 8 [15]. Aquatic organisms are hassled as the level of dissolved oxygen drops below 5.0 mg /L [16]. In the present study, dissolved oxygen was comparatively low in midstream and downstream segments. It is obvious from the overall result of physico-chemical analysis that the middle and lower reaches of the stream need more attention to maintain the quality.

Aquatic insect taxa and its correlations with physicochemical parameters

Figure 3 shows the Canonical Correspondence Analysis for correlating distribution of insects with physico chemical variables. Taken together, the first two axes explain 61.26 percentage of variance (Table 6). Axis-1 reveals that the parameters such as Hardness (r = -0.929), Total Dissolved Solids (r = -0.884) and Phosphate (r = -0.773) pose a negative influence on the insect abundance. Axis-2 shows that pH has highest positive effect (r = 0.676) whereas biological oxygen demand (r = -0.561) and temperature (r = -0.527) have highest negative effect on the abundance of aquatic insect. In this study, CCA analysis discloses that, abundance, diversity and distribution of insects are mainly related to dissolve oxygen positively. Ephemeroptera, Plecoptera, and Trichoptera are sensitive groups that require noble water quality conditions [17]. Along with these sensitive taxa, families such as Psephenidae (Coleoptera) and Aphelocheridae (Hemiptera) also showed great affinity towards dissolved oxygen. Elmidae and Gyrinidae also prefers good water quality conditions [18-19]. Intolerant groups of aquatic insects were completely absent in the lower stretches of river with exceptions from among order Ephemeroptera such as Baetidae and Caenidae [20]. Abundance, diversity and distribution of insects were also positively influenced by pH. Decreased temperature, nutrients such as Nitrate, Phosphate and Sulphate and biological oxygen demand positively influenced the diversity of insects. However, families such as Chironomidae, Ceratopogonidae, Tipulidae and Culicidae of Diptera and Coleopterans like Scirtidae, Ptilodactylidae, Chrysomelidae and Carabidae showed tolerance towards low water quality [21-22]. According to Adu et al. [23], Coenagrionidae and Libellulidae in the order Odonata showed adoration towards warmness of water. Mesoveliidae and Leptopodidae showed affinity towards hardness and total dissolved solids. In concordance with the study of Payakka and Prommi, Mesoveliidae showed positive correlation with alkalinity [24]. Previous findings have shown that distribution of aquatic insects like Baetidae, Heptageniidae, Gerridae and Nepidae are interconnected to phosphate concentration and water temperature [25]. Aquatic insects possess different tolerance levels to various contaminants and hence their presence or absence in each site gives an insight to contamination of that aquatic ecosystem.

CONCLUSION

Among the aquatic insects collected, order Coleoptera was the most diverse order whereas, the most dominant order with maximum numerical abundance was Hemiptera. Ecological indices such as Shannon -Weiner Index and Margalef Richness Index showed highest values in reference sites and the Berger- Parker dominance index was high at test sites. In CCA ordination biplot, environmental variables have pronounced influence on numeral abundance and diversity of insect community in all the sites. The distribution pattern of aquatic insects in Kallada River shows that moderate perturbation exists in midstream and downstream segments which needs to be addressed.

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Table 1. Description of the sampling sites of Kallada River

Upstream Sites	S1	S2	S3	S4	S5	S6
Latitude	8.5736	8.958282	8.5745	8.5809	8.982719	8.5922
Longitude	77.0518	77.06347	77.0217	77.0102	76.9904	76.584
Midstream Sites	S7	S8	S9	S10	S11	S12
Latitude	8.998628	9.0054	9.036960	9.04431	9.0455	9.0518
Longitude	76.95996	76.5621	76.91734	76.8966	76.4518	76.452
Downstream Sites	S13	S14	S15	S16	S17	S18
Latitude	9.081353	9.058490,	9.056896	9.026013	9.0134	9.002742
Longitude	76.72517	76.71102	76.68894	76.66482	76.3848	76.62472

Table 2. Ecological Indices of Aquatic Insects During Premonsoon Season in Kallada River

Sites	Number of Family	Number of Individuals	Shannon-Weiner Diversity Index	Berger-Parker Dominance Index	Margalef Richness Index
S1	38	196	3.52	0.06	7.01
S2	18	114	2.84	0.08	3.58
S3	26	114	3.07	0.09	5.28
S4	20	117	2.86	0.09	3.98
S5	25	103	3.08	0.11	5.18
S6	19	105	2.86	0.1	3.87
S7	25	103	3.13	0.09	5.18

S8	18	108	2.76	0.12	3.63
S9	21	102	2.99	0.08	4.32
S10	19	106	2.87	0.12	3.86
S11	23	105	3.04	0.095	4.73
S12	21	108	2.93	0.1	4.27
S13	34	112	3.44	0.06	6.99
S14	28	109	3.24	0.07	5.75
S15	30	126	3.29	0.09	5.99
S16	21	105	2.93	0.1	4.3
S17	25	117	3.09	0.08	5.04
S18	18	105	2.84	0.11	3.9

Table 3. Ecological Indices of Aquatic Insects During Monsoon Season in Kallada River

Sites	Number of Family	Number of Individuals	Shannon-Weiner Diversity Index	Berger-Parker Dominance Index	Margalef Richness Index
S1	25	116	3.05	0.09	5.1
S2	17	108	2.77	0.102	3.41
S3	24	107	2.98	0.09	4.92
S4	19	102	2.79	0.1	3.89
S5	26	104	3.18	0.07	5.38
S6	20	107	2.93	0.8	4.06
S7	23	105	3.02	0.08	4.72
S8	17	102	2.78	0.09	3.45
S9	24	102	3.07	0.09	4.97
S10	23	102	3.04	0.09	4.75
S11	23	102	2.98	0.1	4.75
S12	20	105	2.91	0.1	4.08
S13	34	110	3.39	0.09	7.02
S14	25	108	3.08	0.01	5.12
S15	28	120	3.14	0.1	5.64
S16	19	102	2.8	0.11	3.89
S17	22	103	2.94	0.107	4.53
S18	17	102	2.76	0.108	3.45

Table 4. Ecological Indices of Aquatic Insects during Postmonsoon Season in Kallada River

Sites	Number of Family	Number of Individuals	Shannon-Weiner Diversity Index	Berger-Parker Dominance Index	Margalef Richness Index
S1	37	167	3.5	0.08	7.03
S2	18	110	2.83	0.082	3.61
S3	21	108	2.89	0.1	4.27
S4	20	118	2.82	0.12	3.46
S5	23	101	2.94	0.12	4.76

S6	19	104	2.81	0.13	3.87
S7	24	108	3.09	0.09	4.91
S8	19	111	2.82	0.14	3.82
S9	22	103	3.02	0.09	4.53
S10	22	104	3.03	0.09	4.52
S11	23	105	3.04	0.1	4.72
S12	20	112	2.88	0.11	4.02
S13	35	142	3.46	0.06	6.86
S14	27	127	3.19	0.09	5.36
S15	29	122	3.28	0.07	5.82
S16	21	103	2.97	0.09	4.31
S17	22	106	3.01	0.1	4.5
S18	18	114	2.8	0.11	3.58

Table 5 Annual Average of Physicochemical Water Quality of Kallada River (Mean ± SD)

Sites	Temperature (^{0}C)	TDS (mg/l)	pH	DO (mg/l)	BOD (mg/l)	Hardness (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)
S1	26.4±	15.61±	6.81±	7.33±	0.74±	10.08±	0.05±	0.1±	0.2±
	0.33	1.83	0.1	0.37	0.15	8.75	0.03	0.03	0.17
S2	26.7±	21.7±	6.35±	6.47±	1.54±	14.63±	0.37±	0.34±	0.81±
	0.34	2.58	0.19	0.19	0.28	10.84	0.15	0.08	0.31
S3	26.5±	13.87±	6.76±	7.01±	0.96±	13.35±	0.16±	0.31±	0.3±
	0.37	2.9	0.18	0.41	0.11	11.82	0.04	0.14	0.15
S4	26.7±	24.9±	6.47±	6.73±	1.31±	13.76±	0.22±	0.26±	0.23±
	0.25	7.44	0.18	0.34	0.16	12.11	0.05	0.15	0.09
S5	26.8±	19.64±	6.64±	6.61±	1.08±	14.99±	0.32±	0.32±	0.38±
	0.4	3.33	0.21	0.27	0.18	11.41	0.17	0.19	0.32
S6	27.2±	28.56±	6.61±	6.33±	1.85±	21.33±	0.73±	0.44±	0.8±
	0.58	3.46	0.29	0.4	0.22	13.22	0.27	0.22	0.27
S7	28.1±	18.5±	6.62±	6.54±	1.85±	16.87±	0.15±	0.23±	0.56±
	1.05	2.51	0.13	0.52	0.29	13.6	0.06	0.13	0.31
S8	28.6±	24.07±	6.02±	6.03±	2.48±	23.05±	0.33±	0.52±	1.33±
	1.09	3.49	0.27	0.25	0.33	15	0.12	0.1	0.95
S9	27.9±	18.17±	6.51±	7.09±	1.7±	16.64±	0.22±	0.48±	0.34±
	0.41	2.16	0.31	0.17	0.13	11.99	0.09	0.17	0.15
S10	27.6±	27.49±	6.41±	6.31±	1.77±	19.79±	0.27±	0.69±	0.26±
	0.36	8.4	0.24	0.22	0.18	13.11	0.11	0.21	0.15
S11	27.8±	23.5±	6.64±	6.75±	2.08±	18.6±	0.31±	0.56±	0.52±
	0.57	2.62	0.13	0.37	0.84	12.72	0.07	0.11	0.43
S12	27.6±	30±	6.48±	5.98±	2.91±	26.21±	0.38±	0.74±	1.35±

	0.44	3	0.18	0.27	0.31	16.78	0.24	0.19	0.82
S13	28±	27.75±	6.61±	6.61±	2.05±	21.77±	0.34±	0.25±	0.46±
	1.08	3.7	0.16	0.23	0.22	16.01	0.15	0.08	0.1
S14	28.6±	29.25±	6.49±	6.33±	2.86±	27.85±	0.39±	0.49±	0.75±
	1.11	2.73	0.27	0.18	0.47	20.3	0.19	0.16	0.16
S15	27.9±	30.47±	6.61±	6.82±	2.62±	30.85±	0.25±	0.42±	0.49±
	0.54	4.84	0.25	0.42	0.33	21.83	0.16	0.17	0.16
S16	27.6±	52.14±	6.59±	6.2±	2.8±	39.54±	0.49±	0.54±	0.65±
	0.4	7.12	0.14	0.52	0.55	28.78	0.23	0.22	0.24
S17	27.7±	91.51±	6.68±	6.31±	2.13±	50.81±	0.45±	0.5±	0.38±
	0.67	26.52	0.19	0.26	0.4	38.83	0.18	0.12	0.23
S18	27.6±	1217.76±	6.89±	5.96±	2.34±	93.26±	0.6±	0.91±	0.53±
	0.44	634.9	0.35	0.2	0.26	73.25	0.25	0.34	0.13

Table 6. Summary Statistics of CCA between Aquatic Insect Abundance and Environmental Variables for First Two Axes in Kallada River

Environmental Parameters	Axis 1	Axis 2
Temperature	-0.338	-0.527
pH	-0.143	0.676
Total Dissolved Solids	-0.884	0.492
Dissolved oxygen	0.681	0.382
Biological oxygen demand	-0.529	-0.561
Hardness	-0.929	0.250
Nitrate	-0.651	-0.260
Phosphate	-0.773	-0.125
Sulphate	-0.221	-0.452
Eigenvalue	0.263	1.181
% of variance explained	36.35	24.91
Total % explained	61.26	

Source: E sri, M axar, GeoEye, Earthstar Geographics, CNE S/Airbus D s, SDA, USGS, AeroGRID, IGN and the GIS User Community

Figure 1. Location Map of Study Area with Sampling Sites at Different Segments

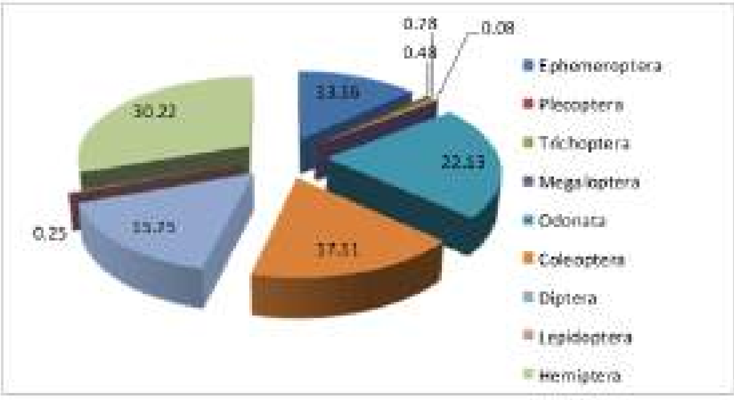

Figure 2. Composition of Aquatic Insect Orders Collected from Kallada River

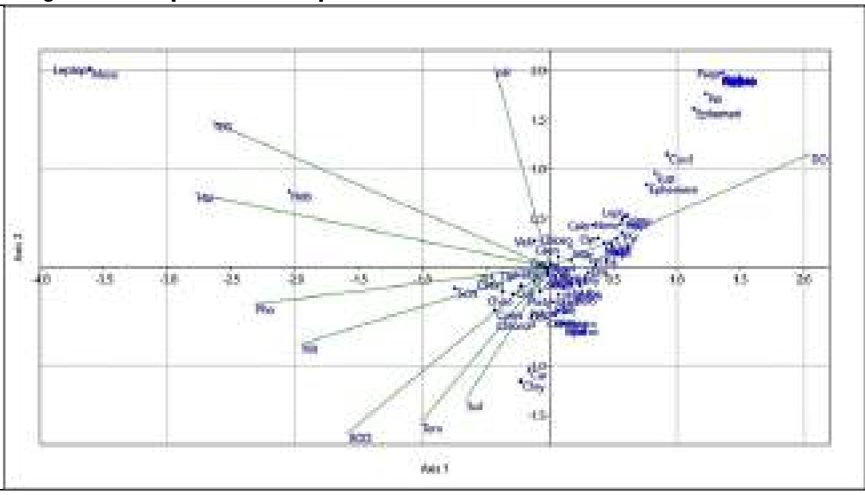

Figure 3 CCA Ordination Biplot Diagram for the Data set Between Aquatic Insect Taxa and Environmental Variables in Kallada River.

Note: Abbreviations of taxa (Baet (Baetidae), Caen (Caenidae), Ephemere (Ephemerellidae), Ephemeri (Ephemeridae), Hept, (Heptageniidae), Iso (Isonychidae), Lept (Leptophlebiidae), Tric (Tricorythidae), Per (Perlidae), Cala (Calamoceratidae), Hydrob (Hydrobiosidae), Hydrop (Hydropsychidae), Lepido (Lepidostomatidae), Lepto (Leptoceridae), Philo (Philopotamidae), Poly (Polycentropodidae), Sten (Stenosychidae), Cory (Corydalidae), Chlorol (Chlorolestidae), Chloro (Chlorocyphidae), Prot (Protoneuridae), Platy (Platystictidae), Gom (Gomphidae), Libe (Libellulidae), Eup (Euphaeidae), Cord (Corduliidae), Platyc Platycnemididae), Coen Coenagrionidae), Calo (Calopterygidae), Mac (Macromidae), Car Carabidae), Chry (Chrysomelidae), Cur (Curculionidae), Dry (Dryopidae), Dyt (Dytiscidae), Elm (Elmidae), Gyr (Gyrinidae), Hydrae (Hydraenidae), Hydroc (Hydrochidae), Hydroph (Hydrophilidae), Hygro (Hygrobiidae), Lam (Lampyridae), Not (Noteridae), Psep (Psephenidae), Ptilo (Ptilodactylidae), Scirt (Scirtidae), Stap (Staphylinidae), Tene (Tenebrionidae), Athe (Athericidae), Cerat (Ceratopogonidae), Chiro (Chironomidae), Culi (Culicidae), Empi (Empididae), Simu (Simulidae), Tab (Tabanidae), Tha (Thaumalidae), Tip (Tipulidae), Cra (Crambidae), Pyr (Pyralidae), Aph (Aphelocheiridae), Belo (Belostomatidae), Cori (Corixidae), Ger (Gerridae), Heb (Hebridae), Hydrom (Hydrometridae), Leptop (Leptopodidae), Meso (Mesoveliidae), Nau (Naucoridae), Nep (Nepidae) and Noto (Notonectidae)