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Bio-monitoring of Western Ghats Stream using Aquatic insects

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Abstract: In this study health of the Kallar stream and its tributaries originating from Western Ghats in Kerala using aquatic insects as indicators was assessed. Two-year sampling of aquatic insects was done on a monthly basis from five different sites. Insects were collected and identified using the methodology of Rapid Bio-assessment Protocol. A total of 29372 individuals belonging to 9 orders and 61 families of aquatic insects were collected and identified from the selected study sites. Highest number of aquatic insect was obtained in the site 5 (7531) and the lowest number was observed in site 3 (4571). All richness measures were maximum in site 5 and the minimum in site 3. In addition to that the biotic indices like Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP) Score and Average Score per Taxon (ASPT) also show that water quality of site 5 is free from organic pollution compared to the other sites.

Keywords: Aquatic insects, Biomonitoring, Family Biotic Index, Indicators, Kallar stream

Aquatic insects have been used as bio-indicators and are amongst the most frequently used groups in biological assessment of water quality worldwide (Bunn et al 2010, Chon et al 2013, Kamal and Kumar 2021). They play important ecological roles in keeping freshwater ecosystems functioning properly (Choudhary and Janak 2015). Aquatic insects may have considered model organisms in analyzing the structure and function of the freshwater ecosystem because of their high abundance, high birth rate with short generation time, large biomass and rapid colonization of freshwater habitats (Solanki and Shukla 2015, Pandian et al 2019). Rapid bio-assessment approaches are meant to provide an initial screening of water bodies for further investigations (Mandaville 2002). Family level identification is useful for one-time assessment of water quality in a specific area, or in the ranking of sites for additional study. Variations in the diversity of aquatic insects may be attributed to the degree of anthropogenic interference in the ecological balance of fresh water bodies, where anthropogenic activities of humans associated with a reduction in diversity of aquatic insect communities (Popoola and Otalekor 2011, Wahizatul et al 2011, Abhijna et al 2012, Adu and Oyeniyi 2019). The present study is an attempt to evaluate the water quality of Kallar stream and its tributaries using aquatic insects. This data will be helpful as a yardstick to assess the water quality in the years to come.

MATERIAL AND METHODS

Study area: The study stream Kallar is a perennial river located near Ponmudi in Thiruvananthapuram district, Kerala, part of the Southern tip of Western Ghats. 'Kallar' literally means stony river. It forms the upper course of Vamanapuram River, part of Neyyar Wildlife Sanctuary. It originates from Chemmunji Mottai, a mountain peak in the Western Ghats at an elevation of 1860 m above MSL. In this study five collection sites were selected were- Darpha-Kalungu (S1- 8˚40'42se N, 77˚04'02se E), Pottanchira (S2- 8˚41'31se N, 77˚03'09se E), Kaliyikkal (S3- 8˚40'16se N, 77˚06'04se E), Meenmutti (S4- 8˚42'36se N, 77˚07'41se E) and main Kallar (S5- 8˚43'42se N, 77˚07'37se E) (Table 1, Fig. 1). From these the first four sites are the tributaries of Kallar stream and the fifth one is the main stream. The sites are chosen based on their location relative to habitat availability, land use pattern and human intervention. At each sampling locality, a stretch of 100 m area was chosen for collection of samples.

The aquatic insect sampling was done for two years (January 2012- December 2013) based on the methodology of Rapid Bio-assessment Protocol (Barbour et al 1999). Aquatic insects were collected by using kick net (1m² area, mesh size 200 µm) and D-frame net (mesh size 50 µm). The organisms trapped within the net were collected without any damage using fine forceps and brush and preserved in 70% alcohol. In the laboratory, the immature insects were sorted, identified and counted. Family level identifications were made by using available references (Mc Cafferty and Provonsha 1981, Morse et al 1984, Yule and Sen 2004, Subramanian and Sivaramakrishnan 2007). All the taxa encountered during the study were assigned a habit (mode of existence) and functional feeding categories with the help of published references (Resh and Rosenberg 1984, Pringle et al 1988, Merrit and Cummins 1996). Benthic metrics like richness measures (taxa), composition measures (%), feeding measures (%) and habit measures were calculated for each site (Barbour et al 1999). In addition to that the biotic indices like Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP) Score and Average Score Per Taxon (ASPT) values were also measured.

Family biotic index (FBI): The biotic index was originally developed by Hilsenhoff (1982) to provide a single 'tolerance value' which is the average of the tolerance values of all species within the benthic arthropod community. The biotic index was subsequently modified to the family-level with tolerance values ranging from 0 (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution, creating the Family Biotic Index (FBI) (Hilsenhoff 1988). FBI was further developed by the State of New York to include other macroinvertebrates for the use of the U.S. EPA Rapid Bio-assessment Protocol II (Plafkin et al 1989, Bode 1991). FBI was calculated as:

$$FBI = \frac{n_i t_i}{N}$$

Where, n_i = number of organisms in each family

t_i = tolerance value of that family

N = total number of insects

Biological monitoring working party score (BMWP): The biological monitoring working party score (BMWP) provides single values, at the family level, representative of the organisms' tolerance to pollution. The greater their tolerances towards pollution, the lower the BMWP score. To reflect conditions within North America, Mackie (2001) has modified this index. BMWP was calculated by adding the

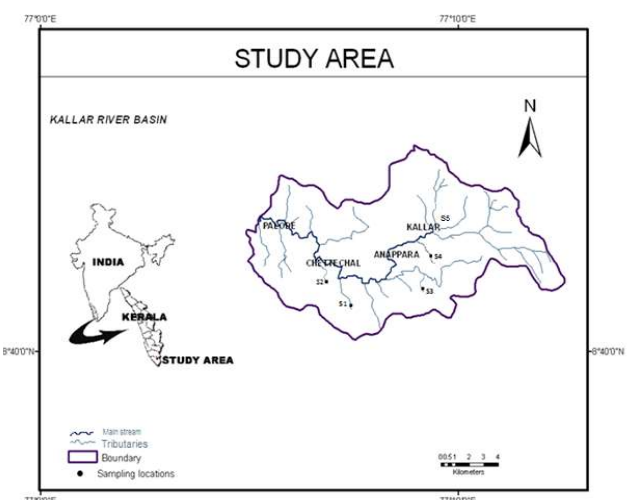

Fig. 1. Location site

Table 2. Evaluation of water quality using the family-level biotic index

FBI	Water quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 3. Evaluation of water quality using the average score per taxon (ASPT)

ASPT value	Water quality assessment
>6	Clean water
5-6	Doubtful quality
4-5	Probable moderate pollution
<4	Probable severe pollution

Table 1. Characteristics of Kallar stream and its tributaries

Characteristics	Site 1	Site 2	Site 3	Site 4	Site 5
Name of site	Darpha-Kalungu	Pottanchira	Kaliyikkal	Meenmutty	Main Kallar
Latitude	8˚40'42se N	8˚41'31se N	8˚40'16se N	8˚42'36se N	8˚43'42se N
Longitude	77˚04'02se E	77˚03'09se E	77˚06'04se E	77˚07'41se E	77˚07'37se E
Altitude(m)	111	105	116	156	227
Subsystem	Perennial	Perennial	Perennial	Perennial	Perennial
Vegetation	Trees and grass	Trees and grass	Trees and grass	Trees and grass	Trees and grass
Land use	Plantations	Plantations	Residential	Forest	Forest
Canopy	Open	Open	Open	Shaded	Shaded
Turbidity	Clear	Clear	Clear	Clear	Clear
Human settlement	Present	Present	Present	Present	Absent

Table 4. Aquatic insects collected from the study sites

Family	Site 1	Site 2	Site 3	Site 4	Site 5	Tolerance values	BMWP score value
Ephemeroptera							
Leptophlebiidae	932	1028	380	631	461	2	10
Ephemeridae	24	24	17	14	29	4	10
Potamanthidae	9	0	0	0	8	4	10
Ephemerellidae	2	4	0	4	8	1	10
Tricorythidae	0	0	0	0	2	4	
Caenidae	286	207	138	37	36	7	7
Heptageniidae	25	17	7	717	1230	4	10
Baetidae	300	245	177	184	129	4	4
Plecoptera							
Perlidae	216	297	49	695	1046	1	10
TRICHOPTERA							
Hydropsychidae	850	1312	845	1360	1890	4	5
Polycentropodidae	6	21	5	97	130	6	7
Psychomyeidae	0	3	0	0	4	2	8
Xiphocentropodidae	0	2	0	0	4		
Calamoceratidae	4	2	2	1	7	3	
Odontoceridae	2	2	2	4	8	0	10
Philopotamidae	0	2	5	150	189	3	8
Stenopsychidae	0	0	0	30	58		
Brachycenridae	4	4	4	18	17	1	10
Lepidostomatidae	2	0	0	9	50	1	10
Odonata							
Gomphidae	426	1044	374	320	683	1	8
Cordullidae	70	17	137	79	8	5	8
Libellulidae	240	31	259	42	12	9	8
Macromidae	7	20	37	10	4	3	
Coenagrionidae	14	18	24	13	15	9	6
Platycnemididae	51	3	94	11	24		6
Platystictidae	14	18	24	13	42		
Protoneuridae	86	14	75	9	7		
Lestidae	13	7	14	4	12	9	8
Chlorolestidae	70	79	156	95	123		
Calopterygidae	207	110	76	84	18	5	8
Chlorocyphidae	8	7	14	9	18		
Euphaidae	99	164	180	80	234	4	
Hemiptera							
Aphelocheridae	11	8	9	73	12		10
Nepidae	34	16	11	8	0	7	5
Belostomatidae	178	4	27	0	5	9	5
Naucoridae	624	166	932	330	215	5	5
Notonectidia	3	2	0	0	0	6	5

Cont...

Table 4. Aquatic insects collected from the study sites

Family	Site 1	Site 2	Site 3	Site 4	Site 5	Tolerance values	BMWP score value
Pleidae	2	3	1	4	7	1	5
Vellidae	80	103	21	92	2	6	5
Gerridae	71	76	83	82	26	5	5
Hydrometridae	10	0	0	0	0		
Coleoptera							
Hydroscaphidae	13	5	8	5	0	7	
Dytiscidae	313	130	100	59	17	5	5
Gyrinidae	9	35	6	14	5	4	5
Amphizoidae	0	9	4	3	14	1	
Hydraenidae	75	104	37	46	11	5	
Elmidae	9	51	12	64	80	4	5
Dryopidae	2	5	8	28	45	5	5
Hydrophilidae	21	15	45	46	13	5	5
Psephinidae	7	6	21	163	281	4	
Sperchidae	2	0	5	0	0		
Scritidae	0	0	6	0	0	5	5
Megaloptera							
Corydalidae	4	2	7	87	105	0	6
Lepidoptera							
Pyralidae	4	2	2	16	20	5	
Diptera							
Tipulidae	51	64	14	78	90	3	5
Ceratopogonidae	12	38	19	26	23	6	4
Chironomidae	4	6	17	5	6	6	2
Simulidae	8	12	35	19	10	6	5
Tabanidae	17	3	30	12	4	6	3
Athericidae	13	7	14	159	24	2	6
Ephydridae	5	4	2	4	10	6	4
Total	5549	5578	4571	6143	7531		

individual scores of all families, and order Oligochaeta (Friedrich et al 1996), represented within the community.

Average score per taxon (ASPT): The average score per taxon (ASPT) represents the average tolerance score of all taxa within the community, and was calculated by dividing the BMWP by the number of families represented in the sample (Friedrich et al 1996). From this value, the water quality of each lake was assessed.

RESULTS AND DISCUSSION

Overall 29372 individuals belonging to 9 orders and 61 families of aquatic insects were collected and identified. From this, a total of 5549 individuals belonging to 54 families were collected from site 1, 5578 individuals of 54 families from site 2, 4571 individuals of 53 families from site 3, 6143 individuals of 52 families from site 4 and 7531 individuals of 61 families from site 5 (Table 4). Aquatic insects were mostly contributed by the immature stages. They were represented by the orders of Ephemeroptera, Plecoptera, Trichoptera, Odonata, Hemiptera, Coleoptera, Megaloptera, Lepidoptera and Diptera. Ephemeroptera was the most dominant order with the highest number of individuals (24.89%) followed by Trichoptera, Odonata , Hemiptera and Plecoptera.

Highest number of aquatic insects was obtained in the site 5 (7531) and the lowest number was observed in site 3 (4571) (Table 4). The aquatic insects like Ephemeroptera, Plecoptera and Trichoptera are sensitive to environmental perturbations and occur in clean and well oxygenated waters

Table 5. Benthic metrics of the aquatic insects from selected sites

Category	Metrics (Taxa)	Site 1	Site 2	Site 3	Site 4	Site 5
Richness measures	Total number	5549	5578	4571	6143	7531
	EPT	2662	3170	1631	3951	5306
	Ephemeroptera	1578	1525	719	1587	1903
	Plecoptera	216	297	49	695	1046
	Trichoptera	868	1348	863	1669	2357
Composition measures (%)	EPT	47.97	56.83	35.68	64.32	70.46
	Ephemeroptera	28.44	27.34	15.73	25.83	25.27
	Trichoptera	15.64	24.17	18.88	27.17	31.30
	Diptera	1.98	2.40	2.87	4.93	2.22
	Chironomidae	0.07	0.11	0.37	0.08	0.08
Feeding measures (%)	Collector Filters	11.84	19.36	14.87	20.63	23.56
	Scrapers	18.89	18.27	12.16	20.50	22.29
	Collector-gatherers	24.22	23.98	14.83	23.09	21.52
	Predators	44.52	37.72	57.59	34.10	30.18
	Shredders	0.53	0.67	0.55	1.68	2.44
Habit measures	Number of clingers	3133	3353	2551	4717	6069
	Clingers (%)	35.70	41.10	38.10	53.10	64.60
FBI		4.2	3.22	4.42	3.4	3.16
BMWP		255	246	238	233	261
ASPT		6.38	6.31	6.26	6.47	6.53

only. Among EPT taxa, Oder Plecoptera have long been as the most pollution intolerant of the aquatic insect orders compared to the other two groups in this category such as Ephemeroptera and Trichoptera (Ab - Hamid 2017). In our study the number of Plecoptera was found to be maximum site 5 and the minimum value was observed in site 3. The Diptera was maximum in site 4 and the minimum in site 1. Diptera can be found in a clean stream to polluted streams (Abbasi et al 2020). The Chironomidae measures indicates that highest value was in site 3 and the lowest value in site 1. Family Chironomidae belongs to order Diptera is considered to be a pollution tolerant group may be due to the presence of hemoglobin pigment that helps them to collect oxygen directly from the atmosphere (Davason and Henry 2007).

The feeding measures like collector- filterers and shredders were highest in site 5 and the lowest in site 1. The percent scrapers were maximum in site 5 and minimum in site 3. The highest value of collector- gatherers was observed in site 1 and lowest in site 3. The maximum predators were obtained in site 3 and the minimum in site 5. The clingers were found to be maximum in site 5 and minimum in site 1. Collector gatherers are more tolerant to disturbances because they exhibit generalist feeding habits, whereas shredders and scrapers are exhibited the highest level of feeding specialization because of that they are considered to be more sensitive to environmental disturbances (Min et al 2019).

Comparison of FBI throughout the study showed that the higher FBI value was at site 3 (4.54) indicating greater pollution due to the presence of highly tolerant taxa such as Libellulidae, Coenagrionidae, Lestidae and Chironomidae compared to other sites which shows less pollution. Lower FBI value was found in site 5 (3.14) and it is due to the large number of pollution intolerant taxa like Ephemerellidae, Perlidae, Odontoceridae, Brachycentridae, Lepidostomatidae and Corydalidae. In our study the value of FBI ranged between 3.16 to 4.42 that is excellent to good water quality conditions. Similar results were also observed by Marwein and Gupta (2018) in a small stream of Shillong, Meghalaya. The maximum BMWP score was reported from site 5 and minimum in Site 3. This is because in site 5 the number of pollution intolerant families was high, while in site 3 pollution tolerant families are dominant. Low index value indicates the study area was physically disturbed and which results from the low abundance of aquatic organisms (Bhandarkar and Bhandarkar 2013). In study the highest ASPT score was reported in site 5 and lowest values observed in site 3.

CONCLUSION

The biomonitoring based on aquatic insects played a significant role in assessing the environmental status of Kallar stream and its tributaries. The biotic index value of site 3 comes in the range of 4.26-5.00, water quality is good but some organic pollution is possible here. The small scale human activities in site 3 are sufficient to produce some kind of organic pollution and to change the composition of aquatic insects during the period of observation. Rare specimens of habitat sensitive organisms such as Ephemeroptera, Plecoptera and Trichoptera still minimum in site 3 and maximum numbers were present in site 5. In addition to that all the calculated benthic metrics revealed that the water quality of site 5 was good compared to the other four sites, i.e. tributaries. Routine monitoring and continuous investigations are required to keep the stream healthy in the future also. The rapid bio-assessment protocols are being applied in many countries with success and optimizing time and resources in sample methodologies. But there is lack thorough knowledge on the taxonomy and ecology of regional aquatic insects. Hence, more comprehensive investigations are needed to expand our knowledge on aquatic insect diversity, and then only and can assign tolerance value to the regional biota and to develop our own biotic index and metrics to evaluate water quality.

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REFERENCES

Abbasi M, Doosti S, Vatandoost H and Hosseini-Vasoukolaei N 2020. Study on the fauna of aquatic insects in northwestern Iran. *Journal of Arthropod-Borne Diseases* **14** (1): 1.

Ab-Hamid S and Rawi CSM 2017. Application of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) in water quality assessment of Malaysian headwater. *Tropical Life Sciences Research* **28**(2): 143.

Abhijna UG, Ratheesh R and Biju Kumar A 2013. Distribution and diversity of aquatic insects of Vellayani lake in Kerala. *Journal of Environmental Biology* **34**(3): 605-611.

Adu BW and Oyeniyi EA 2019. Water quality parameters and aquatic insect diversity in Aahoo stream, southwestern Nigeria. *The Journal of Basic and Applied Zoology* **80**(1): 15.

Barbour MT, Gerritsen J, Snyder BD and Stribling JB 1999. Rapid bioassessment protocols for use in streams and Wadeable rivers: Periphyton, benthic macroinvertebrates and fish. *EPA841-B-99-002, US Environmental Protection Agency: Office of Water*; Washington DC, second edition, p 299.

Bhandarkar SV and Bhandarkar WR 2013. A study on species diversity of benthic macro invertebrates in freshwater lotic ecosystems in Gadchiroli district Maharashtra. *International Journal of Life Sciences* **1:** 22-31.

Bode RW 1991. *Quality assurance work plan for biological stream monitoring in New York State.* New York Department of Environmental Conservation Technical Report, p 79.

Bunn SE, Abal EG, Smith MJ, Choy SC, Fellows CS, Harch BD, Kennard MJ and Sheldon F 2010. Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation. *Freshwater Biology* **55**: 223-240.

Chon TS, Qu X, Cho WS, Hwang HJ, Tang H, Liu Y and Choi JH 2013. Evaluation of stream ecosystem health and species association based on multi-taxa (benthic macro invertebrates, algae, and microorganism) patterning with different levels of pollution. *Ecological Informatics* **17**: 58-72.

Choudhary A and Janakahi 2015. Diversity and distribution of aquatic insect population in Lakha banjara Lake, Sagar (MP), India. *Journal of International Academic Research for Multidisciplinary* **3**(5): 367.

Davanson RCS and Henry R 2007. Composition and abundance of Chironomidae and Ephemeroptera in a lateral lake in the mouth zone of Paranapanema River in to Jurumirin Reservoir (State of Sao Paulo). *Acia Limnologica Brasiliensia* **19**: 131-142.

Friedrich G, Chapman D and Beim A 1996. The Use of Biological Material in Water Quality Assessments: A Guide to the Use of Biota. *Sediments and Water in Environmental Monitoring*, 2nd ed. Chapman D (ed.). E. & F.N. Spon, New York.

Hilsenhoff WL 1982. Using a biotic index to evaluate water quality in streams. *Wisconsin Department of Natural Resources Technical Bulletin,* 132, p 22.

Hilsenhoff WL 1988. Rapid field assessment of organic pollution with a family level biotic index. *Journal of the North American Benthological Society* **7:** 66-68.

Kamal S and Kumar RS 2021. Assessment of biological water quality based on functional feeding groups of benthic Macroinvertebrates: A case study of Pampa River. *Indian Journal of Ecology* **48**(3): 837-841.

Mackie GL 2001. *Applied Aquatic Ecosystem Concepts*. Kendall/Hunt Publishing Company, 26, p 744.

Mandaville SM 2002. Benthic macroinvertebrates in freshwaters-Taxa, tolerance values, metrics and protocols. *(Project H-1) Soil and Water Conservation Society of Metro Halifax*, pp 1-47.

Marwein I and Gupta S 2018. Aquatic insects as indicator of water quality: A study on a small stream of Shillong, Meghalaya, North-east India. *Indian Journal of Ecology* **45**(3): 511-517.

Mc. Cafferty PW and Provonsha VA 1981. *Aquatic Entomology*. Jones and Bartlett Publishers, London, p 396.

Merritt RW and Cummins KW 1996. *An introduction to the aquatic insects of North America*. Dubuque, Kendall-Hunt, 3, p 862.

Min JK, Kim YJ and Kong DS 2019. Spatial distribution patterns of benthic macroinvertebrate functional feeding groups by stream size and gradient in Republic of Korea. *Journal of Freshwater Ecology* **34**(1): 715-738.

Morse JC, Yang L and Tian L 1984. *Aquatic insects of China useful for Monitoring Water quality*. Hohai University Press, Nanjing, 570.

Pandiarajan S, Thambiratnam S, Rajasekaran I and Sivaruban B 2019. Bio-monitoring and detection of water quality using Ephemeroptera, Plecoptera and Trichoptera (EPT) complex in Karanthamalai stream of Eastern Ghats. *Indian Journal of Ecology* **46**(4): 818-822.

Plafkin JL, Babour MT, Porter JG, Gross SK and Hughes RM 1989. *Rapid bioasseement protocols for use in Streams and Rivers, Benthic Macroinvertebrates and Fish.* EPA/444/4-89/001, Office of Water Regulations and Standards, U. S. Environmental Protection Agency, Washington, DC, p 411 .

Popoola KOK, Otalekor A 2011. Analysis of aquatic insects' communities of Awba Reservoir and its physico-chemical properties. *Research Journal of Environmental and Earth Sciences* **3**(4): 422-428.

Pringle CM, Naiman RJ, Bretschko G, Karr JR, Oswood MW, Webster JR, Welcomme RL and Wintervourn MJ 1988. Patch dynamics in lotic system: The stream as a mosaic. *Journal of the North American Benthological Society* **7**: 503-524.

Resh VH and Rosenberg DM 1984. *The ecology of aquatic insects*. Praeger Publishers, New York, pp 625.

Solanki R and Shukla A 2015. Aquatic insect for biomonitoring freshwater ecosystem: A report. *International Journal of Science and Research* **6**: 2056-2058.

Subramanian KA and Sivaramakrishnan KG 2007. *Aquatic insects for biomonitoring freshwater ecosystems: A methodology manual.* Asoka Trust for Research in Ecology and Environment (ATREE), Bangalore, India, p 31.

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Wahizatul AA, Long SH and Ahmad A 2011. Composition and distribution of aquatic insect communities in relation to water quality in two fresh water streams of Hulu Terengganu, Terengganu. *Journal of Sustainability Science and Management* **6**(1): 148-155.

Yule MC and Sen HY 2004. *Freshwater Invertebrates of the Malaysian Region*. Akademi Sains, Malaysia.