



## Assessment of diversity and relative richness of aquatic entomofauna in Jedarpalayam Dam, Namakkal District, Tamil Nadu

Muthulakshmi Murugesan<sup>1</sup>, Jeevitha Chinnappu<sup>2</sup>, Poomani Manoharan<sup>3</sup>, Parameswaran Matheswaran<sup>4</sup>, Latha Raja<sup>5</sup>, Sharmila Banu Gani<sup>6\*</sup>

<sup>1-6</sup> PG and Research Department of Zoology, NKR Government Arts College for Women, Namakkal, Tamil Nadu, India

### Abstract

Insects are exceptional fauna that contributes to maintaining the earth's ecosystem. With the aim of conservation of worldwide insects' strategies, there is an urgent requirement to target species in the regional and local scales. Hence, the present study was designed to assess the diversity and relative richness of insect fauna in Jedarpalayam dam (11°09'50.7"N 77°53'03.0"E), Namakkal district. The field survey was conducted using several indices of species diversity. Sampling was performed biweekly from April 2019 to September 2019 using pitfall and yellow pan traps set. Species abundance and diversity were monitored by Margalef index, Simpson's dominance index, Shannon-Weiner diversity index, Shannon's equitability index, and Menhinick diversity. A total of 3332 individuals were recorded, which comprised 9 orders and 26 families; dominated by order Hemiptera (34%), Diptera (20%) and odanata (19%), and coleoptera (15%). The results from the study showed that percentage composition was highest at station 4 (21.43%), station 1 (20.98%) followed by station 3 (20.53%) while lowest at station 5 (17.7%). Shannon Wiener diversity index shows that the dam has a relative abundance and diverse and well-distributed aquatic insect community. Margalef's Diversity Index and Shannon's equitability exhibit species richness and evenness of the community in the dam.

**Keywords:** diversity, richness, insect species, Jedarpalayam dam, assessment

### 1. Introduction

Insects are exceptional fauna due to their diversity, ecological role, and impact on human health, agriculture, and natural resources. Insects represent 70% of all animal species on the earth that occupy all habitat and play important roles in the structure, function, and stability of aquatic and terrestrial ecosystems [1, 2]. The aquatic insects are economically important, as they are vital roles in the water ecosystem where they constitute as food for fishes and aquatic animals [3, 5]. In addition, aquatic insects serve as bio-indicators of water quality as they have diverse tolerance levels [5, 6]. Nowadays, insects have been used in several innovative studies in biomechanics, climate change, developmental biology, ecology, evolution, genetics, paleolimnology, and physiology [7]. Aquatic insects are classes of arthropods, which live or occupy part of their life cycle in aquatic forms [3]. Normally, aquatic insects are sessile and identify slight relocation. This relocation often occurs due to the input of pesticides in the water or augmented sedimentation in the soil. Individual taxa of the insects have been recognized as complete sets of pollution sensitivity, which are indicators of specific or general types of troubles in the water.

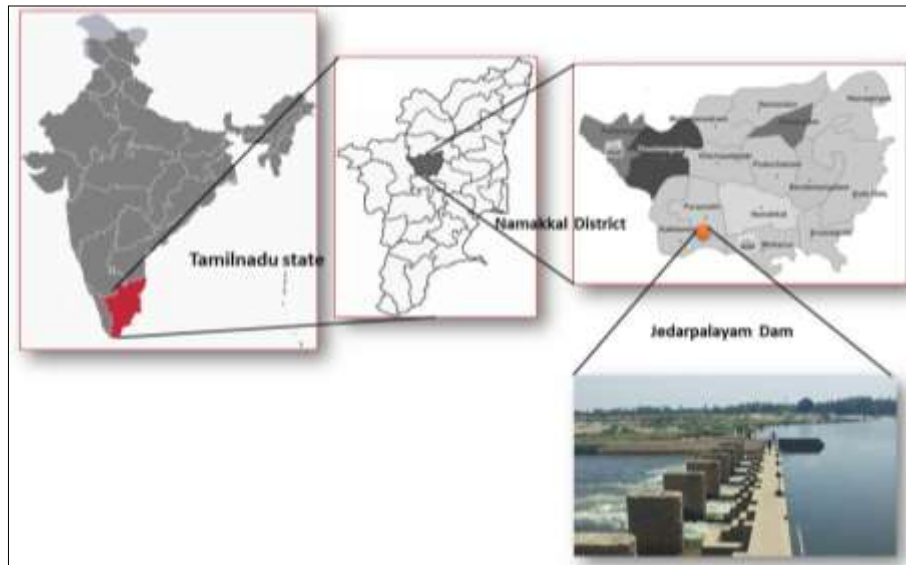
Based on the bio-indicators, the taxonomic identification of the insects is quite easy in the aquatic bodies that can be classified into family and genus [4, 8]. The richness, diversity and species abundance of insects denote the same variety of adaptations to adjustable ecological circumstances. The

biodiversity is the variable among the living things with diverse habitats such as terrestrial, marine, and aquatic ecosystems [9]. Diverse habitats comprise different ecosystems, species, genes, and their relative abundance. Hence, biodiversity refers to the whole body of organisms, their ecological complexity within the environment, and all the environmental processes concerning the systems [10, 11]. Studies on the diversity of Indian aquatic macrofauna including aquatic insects have been described in few works of literature [12, 15]. Our recent study aimed to deal with zooplankton diversity in Kosavampatti Lake, Namakkal district [4] and however, no study has been performed on the biodiversity of aquatic insect fauna in the aquatic regions of Jedarpalayam dam, Namakkal district. Therefore, the study aimed to assess the diversity and abundance of the aquatic insect species in and around the dam.

### 2. Materials and Methods

#### 2.1. Study Area

The study area is Jedarpalayam Dam, situated at Kabilarmalai of Namakkal District, which lies in the range of 11°09'35.66" North Latitude and 77°53'04.54" East Longitude (Figure 1). Namakkal district originates under the Northwestern agro-climatic zone of Tamilnadu. The dam is constructed across the River Cauvery tourist groups often visit during the festival season and on weekends. It lies at an altitude approximately 194 m above sea level.



**Fig 1:** Location map of Jedarpalayam Dam in Namakkal District, Tamil Nadu state, India

## 2.2. Physicochemical water quality assessment

Physicochemical water quality assessment were carried out based on the following parameters including, Air, sediment, water (surface and bottom) temperature, biological oxygen demand (BOD), cadmium, conductivity, copper, dissolved oxygen, faecal coliform, free CO<sub>2</sub>, hardness, iron, lead, manganese, nickel, nitrate, nitrite, pH, phosphate, sulphate, TDS, total alkalinity, total depth, and zinc. All the parameters were analyzed in the following protocol [16, 19].

## 2.3. Samplings of Aquatic insects

The sampling of aquatic insects' was performed in five localities in the stations from April to September 2019 for 6 months. Samplings were usually done between 7.30 am-10.30 pm on a weekly interval. Sweep nets (mesh size of 250mm), dip-net (mesh size of 200mm) and handpicking methods were adopted to collect the insects at random locations within the study sites. Adult insects were collected from the water surface using a dip-net. Adult insects and their nymph were also obtained from the foliage around the stream using a sweep net. The sweep net was passed over the area for at least five minutes. The contents collected were placed in a sorting bucket and the net was accurately checked for insects clinging to the mesh. The hand-picking method was also often used to trap insects, as they are not dangerous to a human while handling with bare hands. The collected insects were then kept in the alcohol-containing container for genera identification. The jar was labelled to display a sample description and collection date.

## 2.4. Identification of Aquatic insects

Insects contained jars were primarily washed using water and remove the sediment or debris that later preserved in a 10% formalin solution. Next, the collected benthic insects were identified with the assistance of a compound microscope. Identified insects were preserved and kept in separate 2cm x 4cm vials containing 10% formalin solution. Labelling of insects was done with date, time of sampling, location, field number and number of samples [20]. The reference of aquatic arthropods classification-based information were used to identify the insects in the taxonomic order and family level [21, 32]. In addition, the identified aquatic insects were confirmed from online

electronic keys present on different web sites.

## 2.5. Various diversity and Statistical analysis

The collected data of mean physicochemical water quality assessment, familywise distribution and sampling percentage of insect orders were subjected to MS Excel 2013 at the level of significance  $p < 0.05$ . The relative abundance of sampled data was calculated. The following diversity tests were carried out to find the outcomes at different levels.

**A. Shannon diversity index (H')** of insect species and this was calculated using equations as shown by Shannon and Weaver [33].

$$\text{Shannon Diversity Index } H' = - \sum P_i \ln P_i (1)$$

Where:  $\sum$  is summation;  $P_i$  is the proportion of individuals found in the  $i$ th species;  $\ln$  is the natural log

The Shannon Weiner index (H') is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types.

**B. Simpson's Dominance Index (D)** as shown by Simpson [34] is a measure of diversity, which takes into accounts both richness (the number of species per sample) and evenness (abundance of the different species making up the richness of an area) as:

$$D = \frac{\sum = n(n-1)}{N(N-1)}$$

Where D = Dominance index

$n$  = number of individuals in the  $i$ th species;  $N$  = total number of entities in the dataset.

**C. Margalef's Species Richness Index (d)** as shown by Clifford and Stephenson [35] and it is the simplest measure of biodiversity and is simply a count of the number of different species in a given area by using the formula:

$$d = \frac{S-1}{\ln N}$$

Where d = Margalef richness index

S = number of species;  $\ln$  = natural log; N = number of individuals in sample

**d. Effective Number of Species (True Diversity):** The diversity indices convert into true diversity values that have given a true picture of the diversity at the selected sites. For the Shannon diversity index, the effective number of species or Shannon effective number of species required to be calculated using the formula by Jost *et al.* [36]

The effective number of species: Shannon equitability (E)

$$= \left( - \sum_{i=1}^S p_i \ln p_i \right)$$

Where S = number of species;  $\sum$  is summation;  $P_i$  is the proportion of individuals found in the  $i$ th species;  $\ln$  is the natural log.

#### e. Measurement of dominance index

The dominance index was calculated using the formula:

$$\text{Relative dominance } R = \frac{n \times 100}{N}$$

Where n: the number of individuals of species; N: the total number of individuals of all species

The total number of species for each sampled station was calculated. The family and species abundance and diversity were calculated for each sampling data and the overall samplings using the Shannon Weiner index (H'). Species richness was determined using Margalef's Diversity Index (d). Evenness of the community was measured using Shannon's equitability (E). Menhinick diversity Index, Simpson's dominance index (D) and Importance value index were also calculated.

### 3. Results and discussion

Physicochemical parameters were analyzed in the water samples collected from the Jedarpalayam dam. Physical parameters such as Air, sediment, water (surface and bottom) temperature, BOD, cadmium, conductivity, copper, dissolved oxygen, faecal coliform, free CO<sub>2</sub>, hardness, iron, lead, manganese, nickel, nitrate, nitrite, pH, phosphate, sulphate, TDS, total alkalinity, total depth, and zinc were analyzed during the study periods and values are given in Table.1. All physicochemical characters present in the water was near the permissible limit. The outcome of the water quality analysis is similar to that of previous literature [37-39]. Aquatic insects often indicate the healthiness of a stream, pond, river, and lake. Aquatic entomofauna are the environment indicators of the quality of water as they are impacted by the various changes as physicochemical and biological alterations in the water [40]. These entomofauna have often influenced by water pollution and display the exact short- and long-term pollution events in the water bodies. They are highly vulnerable to the quality of water parameters especially the amount of dissolved oxygen. The aquatic ecosystems are under increasing pressure from numerous disturbances including pollution and climate conditions [8,41].

From the five sampling stations, 3332 individuals representing 51 genera categorized under 26 families and nine orders were collected from all the sampling sites in the present study (Table 2). The highest percentage composition of insects was recorded at station 4 (21.43%) followed by station 1 (20.98%) and station 3 (20.53%) while lowest at station 5 (17.7%). Among the entomofauna collected, the

order Hemiptera was diverse in several genera comprising 34% of the total insect fauna. It was represented by eight families viz., Belostomatidae (Giant water bugs), Corixidae (Water Boatman), Gerridae (pond skater), Hydrometridae (Pond skater), Mesoveliidae (Water treader), Nepidae (water scorpions), Notonectidae (backswimmer), and Veliidae (riffle bugs). Of these, Nepidae (water scorpions) and Belostomatidae (Giant water bugs) were the most common family among Hemiptera in all Stations. Among the five stations, Libellulidae (skimmer-dragonfly; Order: Odonata), Dytiscidae (Diving Beetle; order: Coleoptera) were the predominant insect families consisted of 7 and 6 species respectively. About 330 mosquito larva (Culicidae) and 320 water scorpions (Nepidae) were largely found in the dam during the study period (Table 2). The species diversity and percentage composition of various insect orders collected from the Jedarpalayam dam are illustrated in Figure 2. The highest family encountered in the five stations was the Hemiptera (34%) followed by Diptera (20%), Odonata (19%), and Coleoptera (15%) and the lowest were the Plecoptera (1%) (Figure 2).

Hemiptera was the most dominant and that of Coleoptera was the least dominant, in this result was similar to the urban Vellayani Lake in Kerala and Amaravathi River water in Tiruppur [37,38]. The species of predatory aquatic bugs of Nepidae (water scorpions) and Belostomatidae (Giant water bugs) have been designated as threatened-vulnerable species in Red Data Book of Japan [42] and are regarded as effective predators of freshwater snails and mosquito larvae [43]. These bugs are utilized in the biological control of mosquito larvae [43, 44]. In many cultures, these insects are edible. For example, Belostomatidae is edible in Thailand used in their stir-fries and salads [45]. The pond skater is a chief source of food for fish and most of the aquatic wildlife. The larvae are the primary food for many aquatic organisms.

In the present study, Odonata contributes 19% of the total fauna. They comprise Lestidae (spread-winged damselfly), Coenagrionidae (Pond Damsels), and Libellulidae (skimmer-dragonfly). Similarly, around 16 genera have been collected in the Western Ghats and Tiruppur by other research teams [38,46]. The richness of the Odonata community can be an indicator of the abundance of various invertebrates and macrophytes in the water bodies [47,48]. Coleoptera in another abundant entomofauna that occupies about 15% of total insect communities in the Jedarpalayam dam. The order, Coleoptera comprises Dytiscidae (Diving Beetle), Elmidae (riffle beetle), Gyrinidae (whirligig beetle), Hydrophilidae (water scavenger beetle), and Lampyridae (dipper firefly). The order of the entomofauna shows the wide range diversity of color, shape and living arrangement [38]. The family of Dytiscidae mostly inhabit leaf of bottom macrophytes of the freshwater and are generally predacious in nature. The entomofauna family of Hydrophilidae is the water scavenger that is generally occurring in shallower regions of the marshland with the richness of macrophytes. The growing young ones often feed detritus, algae and moldy vegetative matter in the water [48].

The order Ephemeroptera is one of the intolerant/sensitive groups that signified in the Jedarpalayam dam. The presence of Baetiscidae (armored mayfly larva) family, which are measured as a water quality indicator [48]. The family Baetidae is added by two genus that was massively present in Station 2 followed by Station 3 and Station 5. The genera Baetis sp. from earlier studies have been reported to be

tolerant of top organic pollution [48,49]. A study piloted by Arimoro and Muller [50] in a stream of Niger Delta disclosed that the overall composition and density of Ephemeroptera fauna varied both spatially and temporally in response to physicochemical and biological factors of the environment. In the present study, the Ephemeroptera taxa richness and diversity remain relatively high in the upper reaches of the Lake at Station 2, 3 and 5 but reduced drastically in lower reaches such as Station 4. Among the Trichoptera taxa occurring in the Jedarpalayam dam, Helicopsychidae (Caddisflies) was common throughout the study sites in all Station. The order Plecoptera is recognized as greatly sensitive to environmental degradation [49-51].

The species diversity indices of entomofauna are presented in Table 3. The highest Shannon diversity index of 3.675 was documented in Station 4 and lowest in Station 3 (2.698), representing the occurrence of a higher diversity of entomofauna in the lentic ecosystems. The diversity of insects in aquatic ecosystems tends to enhance with elevated nutrients and optimum environmental settings favor their richness in the habitat. The distribution of aquatic entomofauna within a habitat is determined by the complex relationship between the substrate, movement of the water, turbulence, and nutrient availability. The high diversity of insect fauna in the Jedarpalayam dam is an indication of larger microhabitat diversity and better water quality conditions prevailing in the lake (Table 3).

In the present study, the evenness value (Shannon's equitability) was noted low in nearly all five Stations, representing relatively even distribution of species in the Jedarpalayam dam. The species diversity and evenness were maximum in nearly all the stations representing good quality of water. In the present investigation, the species diversity index was always greater than one. The dominance documented the lowest value of 0.055 in Station 3 and the highest of 0.088 in Station 1 and 0.076 in station 2. The higher species richness index (Margalef index) of 6.658 was also documented in Station 4, and the nethermost species richness of 5.158 was observed in Station 3. In the present study, selected candidate metrics were carefully chosen, representing individual taxa richness of (Ephemeroptera, Plecoptera, and Trichoptera- EPT), Composition measures (% of EPT) (Table 4). These candidate matrices were followed according to the previous literature [37,52]. The percentage of EPT taxa was formed as 25.53% in Station 5,

21.28% in Station 1 and 3, 18.30% in Station 2, and a lower percentage recorded as 13.62% in Station 4.

In the current study, the family-level biotic index (FBI) of all five stations exhibited a comparative significance about the water quality and aquatic entomofauna diversity. The FBI of Station 2 was kept as a reference site for matching all the other four sites. In the current study, a contrary relationship between EPT and the FBI of the dam was presented in Figure 3. Pollution sensitive groups of EPT taxa were signified in the site by Ephemeroptera and Trichoptera which showed the dam's health, entomofauna ecosystem, and water quality. Higher values of the FBI are often connected with the adverse impressions of organic pollution [37,53]. Lower values of the FBI direct that the macroinvertebrate community is not affected by any organic pollution. This specified higher anthropogenic disruption in Station 4, as this site is very close to more human settlements situated near the dam, and used widely for overall purposes such as the washing of vehicles and removal of solid wastes, etc.

The FBI has often indicated to the alarms in an aquatic ecosystem, using entomofauna as indicators. Hilsenhoff Biotic Index (HBI) value aid to determine the water quality. The value of 4.26-5.0 normally shows good water quality; 5.01-5.75 shows fair quality, 5.76-6.50 specifies fairly poor quality; a value 6.51-7.25 designates poor quality and 7.26-10.0 indicates very poor quality of the water. Bearing in mind, the water quality of station 5 considered as good and 1, 3 measured as fair quality, and that of Station 2 and 4 considered as very poor quality of the water (Table 4, Figure 3). The biodiversity of aquatic insect communities in a given ecosystem often reflects the environmental conditions. The sensitive species inhabiting the habitats due to the impact of the environmental conditions, which are slowly eradicated and the tolerant species may start their colonies and cultivate in abundance [54,55]. The diversity of insect species was found to be moderate in the study stations, which could be attributed to the season of the study. During the rainy season, high flow velocity tends to be major characteristics of water streams and consequently reduces insect abundance. The outcomes of the study publicized a greater diversity of aquatic insects in the Jedarpalayam dam with a chance of pollution can be higher and further suggest that efficient biomonitoring programs are periodically required.

**Table 1:** Mean physicochemical water quality assessment from April 2019 to September 2019 in Jedarpalayam Dam

Parameters	Station1	Station 2	Station 3	Station 4	Station 5
Air Temperature (°C)	33.83	32.08	34.33	33.33	35.08
BOD (mg/L)	2.2	1.8	2.9	2.3	1.9
Cadmium (mg/L)	0.0072	0.0056	0.0069	0.0076	0.0083
Conductivity (µS/cm)	18.49	19.35	15.71	21.59	22.44
Copper (mg/L)	0.0022	0.0026	0.0018	0.0017	0.0033
Dissoved oxygen (mg/L)	8.2	8.9	6.9	7.5	7.6
Fecal Coliform (MPN/100ml)	255	275	305	180	255
Free CO <sub>2</sub> (mg/L)	8.55	7.59	5.48	7.56	6.59
Hardness (mg/L)	33.25	37.89	35.69	39.78	31.24
Iron (mg/L)	0.062	0.076	0.075	0.088	0.093
Lead (mg/L)	0.0018	0.0014	0.0019	0.0011	0.0010
Manganese (mg/L)	0.09	0.12	0.11	0.10	0.13
Nickel (mg/L)	0.055	0.051	0.049	0.049	0.043
Nitrate (µg/ml)	0.55	0.66	0.71	0.84	0.69
Nitrite (µg/ml)	0.35	0.47	0.39	0.46	0.44
pH	6.14	6.98	6.54	6.81	7.15
Phosphate (µg/mL)	1.25	1.36	1.48	1.55	1.29

Sediment temp (°C)	32.5	33.5	34.8	33.8	34.9
Sulfate (µg/ml)	1.55	1.98	1.69	1.79	1.89
TDS (mg/L)	216.98	198.79	188.56	155.69	205.46
Total alkalinity (mg/L)	35.98	32.15	30.28	29.87	36.45
Total depth (cm)	55.69	46.89	41.25	50.28	48.69
Water temperature- Bottom (°C)	29.75	30.67	32.58	31.08	31.67
Water temperature- Surface (°C)	27.89	30.25	29.87	31.27	30.28
Zinc (mg/L)	0.0012	0.0018	0.0016	0.0014	0.0015

**Table 2:** Familywise distribution of aquatic insects showing the number of species of an individual assessment of all five stations from April 2019 to September 2019 in Jedarpalayam dam

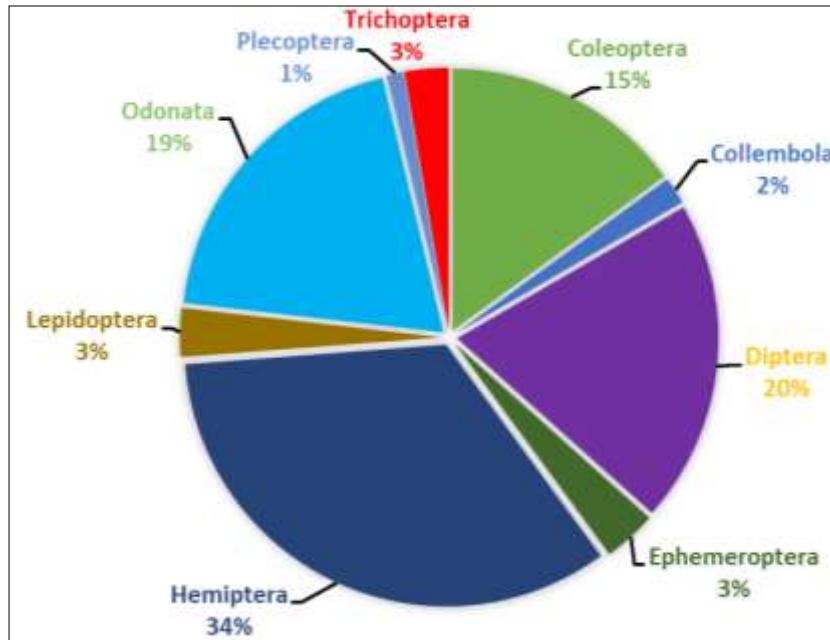
Order	Family (common name)	No. of Species	% of species occurrence	No. of Individuals	% of individual occurrence
Coleoptera	Dytiscidae (Diving Beetle)	6	10.91	155	4.65
	Elmidae (riffle beetle)	1	1.82	79	2.37
	Gyrinidae (whirligig beetle)	1	1.82	56	1.68
	Hydrophilidae (water scavenger beetle)	1	1.82	140	4.20
	Lampyridae (dipper firefly)	1	1.82	69	2.07
Collembola	Brachystomellidae (Springtails)	1	1.82	56	1.68
Diptera	Chironomidae (bloodworms)	1	1.82	175	5.25
	Culicidae (mosquito larva)	1	1.82	330	9.90
	Tabanidae (horsefly larva)	1	1.82	120	3.60
	Tipulidae (Crane fly)	1	1.82	40	1.20
Ephemeroptera	Beatisidae (armoured mayfly larva)	2	3.64	110	3.30
Hemiptera	Belostomatidae (Giant water bugs)	2	3.64	230	6.90
	Corixidae (Water Boatman)	1	1.82	135	4.05
	Gerridae (pond skater)	1	1.82	100	3.00
	Hydrometridae (Pond skater)	1	1.82	64	1.92
	Mesoveliidae (Water treader)	1	1.82	30	0.90
	Nepidae (water scorpions)	3	5.45	320	9.60
	Notonectidae (backswimmer)	1	1.82	40	1.20
	Veliidae (riffle bugs)	2	3.64	210	6.30
Lepidoptera	Pyalidae (stonefly)	1	1.82	79	2.37
	Crambidae (grass moths)	1	1.82	21	0.63
Odonata	Lestidae (spread-winged damselfly)	2	3.64	246	7.38
	Coenagrionidae (Pond Damsels)	6	10.91	155	4.65
	Libellulidae (skimmer-dragonfly)	7	12.73	247	7.41
Plecoptera	Perlidae (stonefly)	3	5.45	35	1.05
Trichoptera	Helicopsychidae (Caddisflies)	2	3.64	90	2.70
Total		51	100	3332	100

**Table 3:** Diversity of aquatic insects in five stations of Jedarpalayam Dam

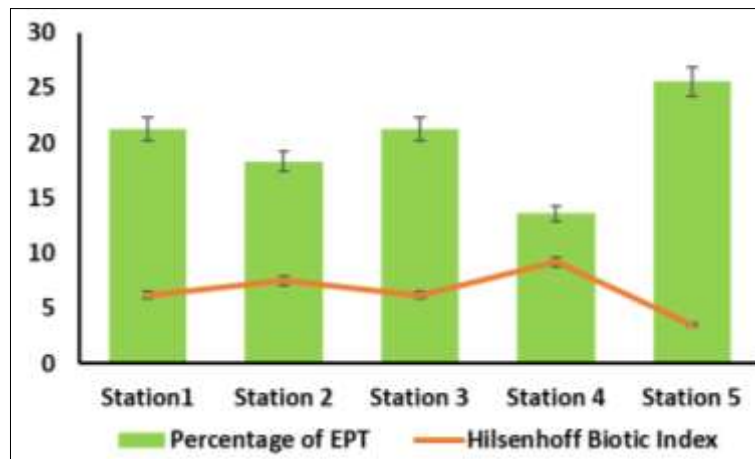
Diversities	Station1	Station 2	Station 3	Station 4	Station 5	Total
No of individuals	699	645	684	714	590	3332
Percentage of individuals	20.98	19.36	20.53	21.43	17.70	100
Dominance Index	0.088	0.076	0.055	0.073	0.056	0.0696
Shannon diversity index	3.258	2.985	2.698	3.675	3.258	3.1748
Simpson Index	0.998	0.896	0.945	0.997	0.932	0.9536
Shannon's equitability	0.589	0.565	0.545	0.598	0.544	0.5682
Margalef index	5.245	6.223	5.158	6.658	6.105	5.8778

**Table 4:** Relationship between the percentage of EPT taxa and Hilsenhoff Biotic Index in Jedarpalayam dam

Diversities	Station1	Station 2	Station 3	Station 4	Station 5	Total
Number of EPT taxa	50	43	50	32	60	235
Ephemeroptera taxa	15	20	22	09	18	84
Plecoptera taxa	15	10	18	11	14	68
Trichoptera taxa	20	13	10	12	28	83
Percentage of EPT	21.28	18.30	21.28	13.62	25.53	100
Hilsenhoff Biotic Index	6.2	7.5	6.2	9.2	3.5	-



**Fig 2:** Sampling percentage of insect orders in all five stations from April 2019 to September 2019 in Jedarpalayam dam



**Fig 3:** Relationship between the percentage of EPT taxa and Hilsenhoff Biotic Index in Jedarpalayam dam

**4. Conclusion**

The present study was carried out the aquatic entomofauna population in the water ecosystem of Jedarpalayam dam between April and September 2019. Insects sampling were collected weekly intervals from the designated five sampling station, identified, and kept in the documentation as taxonomy wise. Physico-chemical analysis of water was carried out and found the permissible quality of the water. In addition, the current study reveals a greater abundance of insects and increasing taxa richness and composition in all five stations in the dam. Results have further discussed the relationship between EPT and HBI and their correlation in aquatic insect diversity and water quality concerning the studies. A total of 3332 individuals were found in which comprised 9 orders and 26 families. Hemiptera (34%) is the predominant order of insects than others. Results show a greater diversity of aquatic insects in the Jedarpalayam dam with a chance of pollution can be higher and suggest that efficient biomonitoring programs are required.

**5. References**

1. Stork NE, McBroom J, Gely C, Hamilton AJ. New approaches narrow global species estimates for beetles,

insects, and terrestrial arthropods. *Proceedings of the National Academy of Sciences*. 2015; 112(24):7519-7523.

2. Stork NE. How many species of insects and other terrestrial arthropods are there on earth? *Annual Reviews of Entomology*. 2018; 63:31-45.

3. Popoola KOK, Otalekor A. Analysis of Aquatic Insects' Communities of Awba Reservoir and its Physico- Chemical Properties. *Research Journal of Environmental and Earth Sciences*. 2011; 3(4):422-428.

4. Vijayapriya S, Latha R, Malathi A, Parameswaran M, Kiruthika P, Banu GS. Assessment of Zooplankton Diversity in Kosavampatti Lake at Namakkal District, Tamil Nadu. *International Journal of Biological and Pharmaceutical Research*. 2019; 10(2):1-5.

5. Siqueira T, Saito VS, Bini LM, Melo AS, Petsch DK, Landeiro VL, *et al*. Community size can affect the signals of ecological drift and niche selection on biodiversity. *Ecology*. 2020; e03014. doi: 10.1002/ecy.3014.

6. Da Rocha JRM, Almeida RJ, Lins GA, Dural A. Insects as indicators of environmental changing and pollution: A review of appropriate species and their monitoring. *A*

- revista* Holos Environment. 2010; 10(2):250-262.
7. Godfray HC. Challenges for taxonomy. *Nature*. 2002; 417:17-19.
  8. Baranov V, Jourdan J, Pilotto F, Wagner R, Haase P. Complex and nonlinear climate-driven changes in freshwater insect communities over 42 years. *Conservation Biology*, 2020. doi: 10.1111/cobi.13477
  9. Balakrishnan S, Srinivasan M, Mohanraj J. Diversity of some insect fauna in different coastal habitats of Tamil Nadu, southeast coast of India. *Journal of Asia-Pacific Biodiversity*. 2014; 7:408-414.
  10. Aslam M. Diversity, Species Richness and Evenness of Moth Fauna of Peshawar. *Pakistan Entomologist*. 2009; 31(2):99-102.
  11. Nazir S, Sharif F, Arshad M, Khan A. Diversity Analysis of Insects of the Thorn Forest Community at Harappa Archaeological Site, Pakistan. *Pakistan Journal of Zoology*. 2014; 46(4):1091-1099.
  12. Victor TJ, Reuben R. Population dynamics of mosquito immatures and the succession in abundance of aquatic insects in rice fields in Madurai, South India. *Indian Journal of Malariology*. 1999; 36(1-2):19-32.
  13. Selvaraj KK, Shanmugam G, Sampath S, Larsson DG, Ramaswamy BR. GC-MS determination of bisphenol A and alkylphenol ethoxylates in river water from India and their ecotoxicological risk assessment. *Ecotoxicology and Environmental Safety*. 2014; 99:13-20.
  14. Sankarappan A, Mani K, Sundaram D, Chelliah B, Muthukalingan K. Hierarchical dynamics influence the distribution of immature black flies (Diptera: Simuliidae). *Acta Tropica*. 2018; 177:105-115.
  15. Wu J, Lu J, Lu H, Lin Y, Wilson PC. Occurrence and ecological risks from fipronil in aquatic environments located within residential landscapes. *Science of the Total Environment*. 2015; 518-519:139-147.
  16. APHA. Standard Methods for the Examination of Water and Wastewater. 22nd Edition. Published by the American Public Health Association, American Water and Water works Association and Water Environment Federation, 2012.
  17. Kumar G, Banu GS, Kannan V. Physico-chemical characteristic of drinking water in selected areas of Tiruchirapalli town. *Journal of Ecobiology*. 2006; 18(3):229-233.
  18. Pandian MR, Banu GS, Kumar G, Maheswaran R, Murugesan AG. Bacterial assessment of Cauvery river water. *Journal of Ecophysiology and Occupational Health*. 2005a; 5:49-51.
  19. Pandian MR, Banu GS, Kumar G, Smila KH. Physico-chemical characteristic of drinking water in selected areas of Namakkal town, (Tamilnadu), India: A Case study. *Indian Journal of Environment and Eco-planning*. 2005b; 10(3):789-792
  20. Inayat TP, Rana SA, Khan HA, Khalil-ur-Rehman. Diversity of insect fauna in croplands of district Faisalabad. *Pakistan Journal of Agricultural Science*. 2010; 47(3):245-250.
  21. Talbot G. The Fauna of British India, including Ceylon and Burma. Butterflies. Today and tomorrow's printers and publishers, New Delhi, India, 1978; 1:660.
  22. Edelman K. Pond and Stream Safari: A Guide to the Ecology of Aquatic Invertebrates. Cornell University Cooperative Extension; 4-H Leader Guide 147L24; Ithaca New York, 1993.
  23. Kellogg L, Kellogg L. Monitor's Guide to Aquatic Macroinvertebrates, Save Our Streams Series, Izaak Walton League of America; Gaithersburg MD 20878-2983, 1994.
  24. Kentucky. Kentucky 4-H Entomology Key to Common Insects' Orders, 2019. Retrieved on 19th June, 2019. <https://entomology.ca.uky.edu/files/deptimages/stfairorder.pdf>
  25. Aspöck H. The Biology of Raphidioptera: A Review of Present Knowledge. *Acta Zoologica Academiae Scientiarum Hungaricae*. 2002; 48(2):35-50.
  26. Borror DJ, DeLong DM. An introduction to the study of insects. 6th Edition, Saunders College Pub., USA. 2005; 3(1):1-659.
  27. Gangwere SK. Entomology. Livonia, Mich.: First Page Publications, 2005.
  28. Triple horn, Johnson, Introduction to the Study of Insects, 7th Edition. In: 4-H Entomology manual. Retrieved on 19th June, 2019. <https://extension.msstate.edu/sites/default/files/publications/publications/p2297.pdf>
  29. Gibb TJ, Oseto CY. Arthropod Collection and Identification: Field and Laboratory Techniques. Academic Press, 2006.
  30. Hickman CP, Roberts LS, Keen SL, Larson A, l'Anson, H, Eisenhour DJ. Integrated Principles of Zoology, McGraw-Hill Companies, New York, 2008, 441.
  31. Capinera JL. Encyclopedia of Entomology. Springer, Atlantic Publisher & Distributor (P) Ltd., New Delhi, India, 2008.
  32. Abowei JFN, Ukoroije BR. The Identification, Types, Taxonomic Orders, Biodiversity and Importance of Aquatic Insects. *British Journal of Pharmacology and Toxicology*. 2012; 3(5):218-229.
  33. Shannon CE, Weaver W. The mathematical theory of communication. *Science*. 1949; 185:27-39
  34. Simpson, EH. Measurement of diversity. *Nature*. 1949; 163:688.
  35. Clifford HT, Stephenson W. An introduction to numerical Classification. Academic Press London, 1975.
  36. Jost, Banos, Tungurahua and Ecuador. Entropy and diversity. *Oikos*. 2006; 113(2):363-375.
  37. Abhijna UG, Ratheesh R, Biju Kumar. Distribution and diversity of aquatic insects of Vellayanilake in Kerala. *Journal of Environmental Biology*. 2013; 34(3):605-611.
  38. Babunath R, Prakash R, Kannadasan N. Diversity of Aquatic Entomofauna in Ecosystem of Amaravathi River Water Nanjaikalipalayam Village, Tiruppur District, Tamil Nadu, India. *Infokara Research*. 2019; 8(12):596-605.
  39. Yang X, Cui H, Liu X, Wu Q, Zhang H. Water pollution characteristics and analysis of Chaohu Lake basin by using different assessment methods. *Journal of Environmental Science and Pollution Research*, 2020. doi: 10.1007/s11356-020-08189-2.
  40. Takaoka H, Sofian-Azirun M, Chen CD, Halim MRA, Lau KW, Low VL, *et al.* A new black fly species of *Simulium* (*Gomphostilbia*) (Diptera: Simuliidae) from Sulawesi, Indonesia. *Zootaxa*. 2019; 4651(2):12.
  41. Hrivniak L, Sroka P, Bojková J, Godunko RJ, Soldán T, Staniczek AH, *et al.* The impact of Miocene orogeny

- for the diversification of Caucasian Epeorus (Caucasiron) mayflies (Ephemeroptera: Heptageniidae). *Molecular Phylogenetics and Evolution*. 2020; 146:106735.
42. IUCN. The 1990 IUCN red list of threatened animals. IUCN, Gland, Switzerland and Cambridge, UK, 1990.
  43. Ohba S, Nakasuji F. Dietary items of predacious aquatic bugs (Nepoidea: Heteroptera) in Japanese wetlands. *Limnology*. 2006; 7:41-43.
  44. Saha N, Aditya G, Bal A, Saha GK. A comparative study of predation of three aquatic Heteropteran bugs on *Culex quinquefasciatus* larvae, *Limnology*. 2007; 8(1):73-80.
  45. Glausiusz. When life was Hell. *Discover*, 2004; 23:10.
  46. Subramanian KA, Sivaramakrishnan KG. Habitat and microhabitat distribution of stream-insects communities of Western Ghats. *Current Science*. 2005; 89(6):976-987.
  47. Bried JT, Ervin GN. Distribution of adult Odonata among localized wetlands in East-Central Mississippi. *Southeastern naturalist*. 2005; 4(4):731-744.
  48. Andrade ICP, Krolow TK, Boldrini R, Pelicice FM. Diversity of EPT (Ephemeroptera, Plecoptera, Trichoptera) Along Streams Fragmented by Waterfalls in the Brazilian Savanna. *Neotropical Entomology*. 2020; 49(2):203-212.
  49. Menetrey N, Oertli B, Sartori M, Wagner A, Lachavanne JB. Eutrophication: Are mayflies (Ephemeroptera) good bioindicators for ponds. *Hydrobiologia*. 2008; 579:125-135.
  50. Arimoro FO, Muller WJ. Mayfly. (Insecta: Ephemeroptera) community structure as an indicator of the ecological status of a stream in the Niger Delta area of Nigeria. *Environmental Monitoring and Assessment*. 2010; 166:581-594.
  51. Fore LS, Karr JR, Wisseman RW. Assessing invertebrate responses to human activities: evaluating alternative approaches. *Journal of North American Benthological Society*. 1996; 15:212-231.
  52. Maxted JR, Barbour MT, Gerritsen J, Poretti V, Primrose N, Silvia A, *et al.* Assessment framework for mid- Atlantic coastal plain streams using benthic macroinvertebrates. *Journal of North American Benthological Society*. 2000; 19:128-144.
  53. Zerlin RA, Henry R. Does water level affect benthic macro-invertebrates of a marginal lake in a tropical river-reservoir transition zone? *Brazilian Journal of Biology*. 2014; 74(2):408-419.
  54. Brasil LS, Luiza-Andrade A, Calvão LB, Dias-Silva K, Faria APJ, Shimano Y, *et al.* Oliveira-Junior JMB, Cardoso MN, Juen L. Aquatic insects and their environmental predictors: a scientometric study focused on environmental monitoring in lotic environmental. *Environmental Monitoring and Assessment*. 2020; 192(3):194.
  55. Jorcin A, Nogueira MG. Benthic macroinvertebrates in the Paranapanema reservoir cascade (southeast Brazil). *Brazilian Journal of Biology*. 2008; 68(4):1013-1024.