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# Benthic invertebrate at three sites on the Tigris River, Iraq

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**ABSTRACT:** The study was conducted from November 2021 to May 2022 at the three study sites within the Baghdad governorate. The study aims to identify the impact of human activities on the Tigris River, so an area free of human activities was chosen and represented the first site. A total of 48 types were diagnosed, 6204 ind/m$^3$ spread over three sites. The following environmental indicators were evaluated: Constancy Index (S), Relative abundance index (Ra), Richness Index (between 17.995 and 23.251), Shannon Weiner Index (0.48-1.25 bit/ind.), Uniformity Index (0.124 -0.323). The study showed that the highest percentage recorded was for the phylum Annileda 34%; and the stability index shows that taxes (*Stylaria* sp., *Aoelosoma* sp., *Branchinra sowerby*, *Chrironomidae* sp.) found by 100%, the relative abundance index show that taxes: *Seinura* sp. 46% in site 2; other nematodes - 43% in site 3 and 42% in site 1; and *Physa* sp. 41% in site 1). The physical and chemical factors were measured BOD between (4.4- 1 mg L$^{-1}$), DO (10.3-8.3 mg L$^{-1}$), E.C (893-532 ‰), $NO_3$ (3.12-1 mg L$^{-1}$), O.M (4.76-1 %), pH (6.8-7.5), $PO_4$ (0.39-0.1 mg L$^{-1}$), S (0.340-0.571 %), T.H. (321-489 mg L$^{-1}$), TDS (450-276 mg L$^{-1}$), Turb (6.3-3.4 mg L$^{-1}$), C.W. (0.97-0.51 m sec$^{-1}$), W.T. (13-7 D°).
**Keywords:** environmental monitoring; water quality; aquatic macroinvertebrates.

# Invertebrados bentônicos em três locais do Rio Tigres, Bagdá, Iraque

**RESUMO:** O estudo foi realizado de novembro de 2021 a maio de 2022, em três locais na província de Bagdá, objetivando identificar o impacto das atividades humanas no Rio Tigre; nesse caso, foi escolhida uma área livre de atividades humanas – representando o ponto de coleta 1. Foram diagnosticados 48 tipos, 6.204 ind/m$^3$ distribuídos em três locais. Foram avaliados os seguintes indicadores ambientais: índice de constância (S), Índice de Abundância Relativa (Ra), Índice de Riqueza entre (17.995-23.251), Shannon Weiner Índice (0,48-1,25 bit/ind.), índice de uniformidade (0,124 -0,323) e índice de estabilidade. O estudo mostrou que o maior percentual registrado foi para o filo Annileda 34%; e o índice de estabilidade mostra que os macroinvertebrados (*Stylaria* sp., *Aoelosoma* sp., *Branchinra sowerby*, *Chrironomidae* sp.) encontrados em 100%, o índice de abundância relativa mostra que os impostos (*Seinura* sp. 46%, no local 2) (Outros nematóides - 43 % no local 3; e 42% no local 1),(*Physa* sp. 41% no local 1). Os fatores físicos e químicos medidos apresentaram os seguintes resultados: BOD entre (4.4- 1 mg L$^{-1}$), DO (10.3-8.3 mg L$^{-1}$), E.C (893-532 ‰), $NO_3$ (3.12-1 mg L$^{-1}$), O.M (4.76-1 %), pH (6.8-7.5), $PO_4$ (0.39-0.1 mg L$^{-1}$), S (0.340-0.571 %), T.H. (321-489 mg L$^{-1}$), TDS (450-276 mg L$^{-1}$), Turb (6.3-3.4 mg L$^{-1}$), C.W. (0.97-0.51 m sec$^{-1}$), W.T. (13-7 D°).
**Palavras-chave:** monitoramento ambiental; qualidade da água; macroinvertebrados aquáticos.

## 1. INTRODUCTION

One of the most important resources and the wellspring of all life is water (Erden, 2023); fresh water is essential for the survival of humans and other environmental species and the preservation of the natural order. Humans use water resources for various things, including agriculture, industry, hydropower, fishing, and enjoyment (HASHIM, 2023). Rivers are ecosystems with complex societies and a life value represented by plant and animal communities. These neighborhoods have a pattern that makes them vulnerable to environmental changes, especially changes resulting from human activities (EL-SEBAEI et al., 2021). Benthic invertebrates have been used as biomarkers in determining water quality. One of the recent trends in environmental studies is to give more importance to biological factors in describing the state of the ecosystem. The physical and chemical factors do not reflect the state of the ecosystem, because of the great overlap between them, which makes it difficult to distinguish the most influential factor in the life of the organisms that live in those systems, as well as the complexity and diversity of ecosystem response to these indicators, that monitoring ecosystems requires more accurate measurements that support and describe these systems (HASHIM, 2022). Also, biological communities are usually fixed, stable, and in constant contact with the properties of water, so they are considered to be continuous monitors of the condition of this water. In addition, direct measurement of the state of the organism subject to influence prepares sufficient information to assess the characteristics of water. In addition, these communities respond to a wide range of biological, physical, and chemical factors in the environment (HANNA; SHEKHA, 2024). The largest river in Iraq, the Tigris, serves as Baghdad's primary water supply (HASHIM, 2022).

Tigris River, many studies include environmental studies and physical and chemical properties. Aljanabi et al. (2022)

conducted a study to assess the Tigris River waters within Baghdad until the indicated concentrations. The hardness, electrical conductivity, and suspended solids were high (AL-OBAIDY et al., 2016). A study was conducted on the effect of the expenditures of the Medical City and Al-Rasheed Station on the waters of the Tigris River, and the water was classified as very inappropriate.

## 2. MATERIAL AND METHODS

### 2.1. Study area

Three sites within the province of Baghdad were chosen (Figure 1). The first site represented an agricultural area north of Baghdad, and it is 5.66 Km away from the center of Baghdad and that the coordinates of the area are 44º 20.18'N and 43º 24.33' E; the second site was chosen near the medical complex in the Bab Al-Moadham area and is located 3.59 Km from the center of Baghdad, with that the coordinates of the area are 44 º 22.27' N and 46º 20.33' E; as for the third site, it was chosen in the south of Baghdad in the Al-Dora area, which represents an area free of human activities and is 23.54 km away from the center of Baghdad, and the coordinates of the area are 44° 23.18'N, 51º 15.33'E.

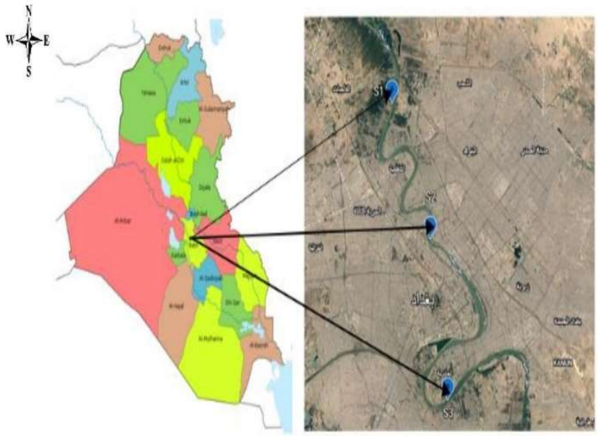

Figure 1. The study areas within the Baghdad governorate.
Figura 1. As áreas de estudo na província de Bagdá.

### 2.2. Sampling method

Samples were collected within an area of 1 square meter, and the sediment, filamentous algae, and the remains of dead plants attached to the river bed were collected from the studied sites using a shovel and with three replications, knowing that the samples were collected at a distance of 0.5-0.8 m from the bank and a depth of 0.5-1.0 m, in all locations.

Macro-benthic invertebrates attached to the sediments were isolated by forceps and kept in sealed polyethylene containers, then alcohol was added to them, and the site name, number, and date of sample collection were marked; as for plants and algae, they were placed in plastic containers with a little river water, and the site name, number, and date of sample collection are indicated. Then they are transferred to the laboratory, and appropriate ventilation is provided by special air pumps in the laboratory to isolate small and medium-sized invertebrates; as for the bottom sediment samples, they are placed in a manual sieve with a capacity of (0.2) mm, and the sediment is washed with river water. After the sieving process, the sediment is placed in a plastic container with a quantity of river water. The worms were taken with low cilia and placed in a plate containing 30% ethyl alcohol, left for 10 minutes, then washed with distilled water, placed on glass slides, and immersed in a solution consisting of a drop of glycerin and 1 mL of lactophenol solution, then covered with the slide cover slides are left for five days, and then examined under the microscope. A compound microscope has been used to identify some phenotypic characteristics and minute parts of organisms (AL-HASSANY et al., 2021). Benthic invertebrates were diagnosed using the sources Molluscs (Dobson et al., 2012), Crustacea (Merritt et al., 2005), Nematoda (Grey, 2004), other groups (Badawy et al., 2013).

### 2.3. Measurement of environmental factors

Both were measured BOD and DO as described by Hanna; Shekha (2024). Nihal; Yahya (2023), E.C.S. (Shareef; Aziz, 2023), $NO_3$ (Shekha, 2008), O.M. (Al-Hadethi et al., 2019), pH by Portable Digital PH meter from Hanna Company, $PO_4$ (Krishnanandan; Srikantaswamy, 2013), TH, TDS (Ibrahim et al., 2020), Turb (Otieno; Atem, 2016), W.C. The velocity of water flow was calculated by throwing a water bottle. After a distance of 10 m was determined, the time required to travel this distance was calculated, and then the flow velocity was extracted. The unit of measurement was cm/sec, W.T. by HACH *Multimeter* (HQ 40).

### 2.4. The Ecological Index and Data Analysis

The environmental indicators, which include the Constancy index (S) and the Stability index (Serafim et al., 2003), Relative abundance index (Ra) (Forro et al., 2008), Richness index (D) (Jaffer et al., 2023), Shannon Weiner index (Al-Fanharawi, 2010) and Uniformity index (Neves et al., 2003), were utilized.

$$S = n / N * 100 \quad (01)$$

where: N is the overall sample count: n + the number of samples where the species is present.

$$(Ra) = (N / Ns) * 100 \quad (02)$$

where: N = The sample's total number of members from each taxonomic group; Ns = The sample's overall organism count.

$$D = \frac{(S - 1)}{\text{Logarithm of the species richness index}} \quad (03)$$

where: N = The whole population at the location; S = Stands for species.

$$ni * N = Ln\ (ni / N) \quad (04)$$

This is the site's user count broken down by user type:

$$E = H / Ln\ (N) \quad (05)$$

E = The species uniformity index; H = equal to the Shanon-Weiner Diversity Index number; S = the number of species at the location statistical analysis is performed using R. statistical programming packages (ALMUSLAMAWY et al., 2023)

## 3. RESULTS

48 benthic invertebrate taxa were observed in three sites on the Tigris River, the total count of benthic invertebrates was 6204 ind $m^{-3}$; 3425 ind $m^{-3}$ of benthic organisms were diagnosed in the first site, and 1699 ind $m^{-3}$ in the second site, while 1080 ind $m^{-3}$ were diagnosed in the third site as shown in Table 1.

Table 1. The benthic invertebrates were diagnosed for the period November 2021 to May 2022.
Tabela 1. Invertebrados bentônicos diagnosticados no período de novembro de 2021 a maio de 2022.

| Taxa | S1 | S2 | S3 | Total |
|---|---|---|---|---|
| Cnidarian | 12 | 30 | 3 | 45 |
| Turbellaria | | | | |
| *Macrostomium* sp. | 45 | 23 | 67 | 135 |
| *Microstomium* sp. | 32 | 12 | 45 | 89 |
| *Stenostomium* sp. | 23 | 16 | 41 | 80 |
| Other turbellaria | 8 | 4 | 12 | 24 |
| Nemtoda | | | | |
| *Seinura* sp. | 15 | 46 | 10 | 71 |
| *Dorylaimus* sp. | 8 | 15 | 5 | 28 |
| *Trilobus longus* | 3 | 8 | 1 | 12 |
| Other nematode | 19 | 32 | 12 | 63 |
| Annileda | | | | |
| *Stylaria* sp. | 121 | 234 | 86 | 441 |
| *Pristina* sp. | 32 | 78 | 12 | 122 |
| *Ophidonais* sp. | 9 | 15 | 3 | 27 |
| *Cheatogaster* sp. | 64 | 89 | 32 | 185 |
| *Aoelosoma* sp. | 113 | 148 | 67 | 328 |
| *Dero* sp. | 5 | 11 | 2 | 18 |
| *Nais* sp. | 9 | 17 | 1 | 27 |
| *Branchinra sowerby* | 53 | 97 | 32 | 182 |
| *Limnodrilus* sp. | 46 | 67 | 20 | 133 |
| *Glossiphonia* sp. | 21 | 35 | 15 | 71 |
| *Helobdella* sp. | 12 | 19 | 8 | 39 |
| Other Annelida | 11 | 17 | 5 | 33 |
| Crustaceans | | | | |
| *Ostracoda* sp. | 27 | 15 | 38 | 80 |
| *Camaras* sp. | 36 | 12 | 26 | 74 |
| *Daphinia* sp. | 79 | 36 | 91 | 206 |
| *Cyclopodia* sp. | 68 | 15 | 68 | 151 |
| *Macrobrachium* sp. | 24 | 7 | 45 | 76 |
| Decapoda (Crab) | 0 | 1 | 2 | 3 |
| *Naplus larvae* | 15 | 9 | 39 | 63 |
| Insecta | | | | |
| Anisoptera | 48 | 69 | 21 | 138 |
| Zygoptera | 22 | 55 | 18 | 95 |
| Trichoptera | 2 | 7 | 0 | 9 |
| Corixidae | 5 | 16 | 2 | 23 |
| *Plea leachi* | 18 | 27 | 10 | 55 |
| Dytiscidae | 4 | 9 | 3 | 16 |
| Hydrophilidae | 32 | 45 | 12 | 89 |
| *Coleoptera larvae* | 1 | 4 | 2 | 7 |
| *Diptera pupae* | 22 | 35 | 20 | 77 |
| Culicidae | 84 | 102 | 36 | 222 |
| *Chrironomidae* sp. | 112 | 159 | 67 | 338 |
| Mollusca | | | | |
| *Acroloxus* sp. | 321 | 23 | 35 | 379 |
| *Physa* sp. | 439 | 17 | 20 | 476 |
| *Lymnea* sp. | 52 | 8 | 10 | 70 |
| Melonoides | 57 | 4 | 7 | 68 |
| Tuberculate | | | | |
| *Melnopsis nodosa* | 21 | 3 | 6 | 30 |
| *Melanopsis costata* | 9 | 0 | 1 | 10 |
| *Bellamya bengalensis* | 41 | 3 | 9 | 53 |
| Pseudontopsis | 7 | 0 | 6 | 13 |
| Euphraticus | | | | |
| *Unio tigrids* | 25 | 1 | 1 | 27 |
| *Corbicula* sp. | 98 | 4 | 6 | 108 |
| Total | 3425 | 1699 | 1080 | 6204 |

The percentages of benthic invertebrates were 1, 6, 34, 12, 20 and 23% for Cnidarian, Turbellaria, Nematoda, Annileda, Crustacea, Insecta and Mollusca, respectively (Figure 2).

Constancy Index (S) of benthic invertebrates in Table 2, noting that the taxes other turbellaria in site 3 represent accessory species, *Trilobus longus*, other nematode, *Ophidonais* sp, represent accessory species in all sites. The rest of the species are distributed among the sites: constant species, accessory species, or accidental species. The relative abundance index (Ra) is shown in Table 3. Noting the lack of dominance of any of the species at the expense of the rest indicates that there are no environmental pressures in the studied areas in a way that allows the dominance of a particular species or group of species. We note that all diagnosed types are either abundant species or less abundant species or rare species.

Diversity was measured, such as the species index, Richness Index, Shannon Weiner Index, uniformity index, and the species index, and the results were shown by calculating the monthly changes for each index (Figure 3).

Tables 4, 5 and 6 represent descriptive statistics, measuring mean, standard deviation, variance minimum and maximum for each index in all sites. This was represented by boxplots (Figures 4, 5 and 6).

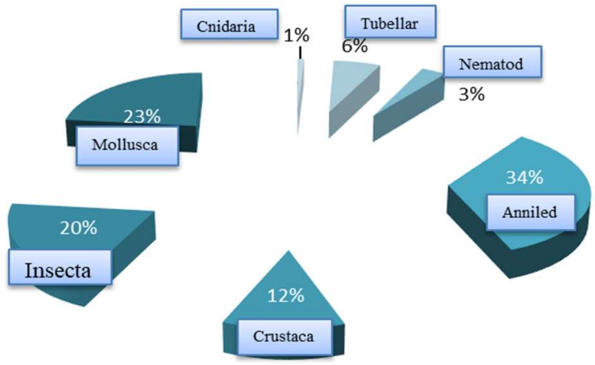


Figure 2. Percentages of Benthic Invertebrates in three sites on the Tigris River.
Figura 2. Porcentagens de Invertebrados Bentônicos em três locais do Rio Tigre.

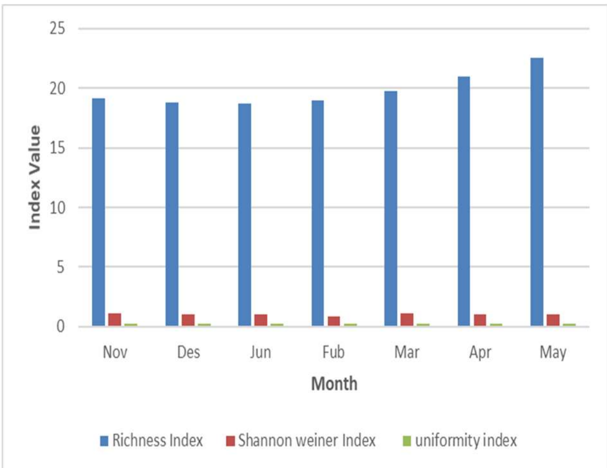


Figure 3. The monthly changes of the diversity index (Richness Index, Shannon Weiner Index, uniformity index).
Figura 3. Variações mensais do índice de diversidade (Índice de Riqueza, Índice de Shannon Weiner, índice de uniformidade)

Table 2. The stability index of benthic invertebrates (S%).
Tabela 2. Índice de estabilidade (S%) de invertebrados bentônicos.

| Taxa | S1 | S2 | S3 | Taxa | S1 | S2 | S3 |
|---|---|---|---|---|---|---|---|
| Cnidarian | 71 | 57 | 43 | | | | |
| Turbellaria | | | | Turbellaria | | | |
| *Macrostomium* sp. | 71 | 71 | 100 | *Macrostomium* sp. | 42 | 42 | 41 |
| *Microstomium* sp. | 71 | 57 | 100 | *Microstomium* sp. | 30 | 22 | 27 |
| *Stenostomium* sp. | 57 | 57 | 71 | *Stenostomium* sp. | 21 | 29 | 25 |
| Other turbellaria | 71 | 57 | 43 | Other turbellaria | 7 | 7 | 7 |
| Nemtoda | | | | Nemtoda | | | |
| *Seinura* sp | 71 | 71 | 71 | *Seinura* sp | 33 | 46 | 36 |
| *Dorylaimus* sp. | 43 | 57 | 57 | *Dorylaimus* sp. | 18 | 15 | 18 |
| *Trilobus longus* | 29 | 43 | 14 | *Trilobus longus* | 7 | 8 | 4 |
| Other nematode | 43 | 71 | 43 | Other nematode | 42 | 32 | 43 |
| Annileda | | | | Annileda | | | |
| *Stylaria* s p | 100 | 100 | 100 | *Stylaria* s p | 24 | 28 | 30 |
| *Pristina* sp | 71 | 100 | 71 | *Pristina* sp | 6 | 9 | 4 |
| *Ophidonais* sp | 43 | 43 | 29 | *Ophidonais* sp | 2 | 2 | 1 |
| *Cheatogaster* sp | 86 | 71 | 71 | *Cheatogaster* sp | 13 | 11 | 11 |
| *Aoelosoma* sp | 100 | 100 | 100 | *Aoelosoma* sp | 23 | 18 | 24 |
| *Dero* sp | 43 | 71 | 14 | *Dero* sp | 1 | 1 | 1 |
| *Nais* sp | 71 | 71 | 14 | *Nais* sp | 2 | 2 | 0 |
| *Branchinra sowerby* | 100 | 100 | 100 | *Branchinra sowerby* | 11 | 12 | 11 |
| *Limnodrilus* sp | 71 | 100 | 71 | *Limnodrilus* sp | 9 | 8 | 7 |
| *Glossiphonia* sp | 43 | 71 | 57 | *Glossiphonia* sp | 4 | 4 | 5 |
| *Helobdella* sp | 57 | 71 | 57 | *Helobdella* sp | 2 | 2 | 3 |
| Other annelida | 57 | 71 | 43 | Other annelida | 2 | 2 | 2 |
| (Crustacea) | | | | (Crustacea) | | | |
| *Ostracoda* sp | 71 | 57 | 100 | *Ostracoda* sp | 11 | 16 | 12 |
| *Cameras* sp | 71 | 86 | 71 | *Cameras* sp | 14 | 13 | 8 |
| *Daphinia* sp. | 100 | 57 | 100 | *Daphinia* sp. | 32 | 38 | 29 |
| *Cyclopodia* sp. | 100 | 57 | 100 | *Cyclopodia* sp. | 27 | 16 | 22 |
| *Macrobrachium* sp | 71 | 71 | 100 | *Macrobrachium* sp | 10 | 7 | 15 |
| Decapoda (Crab) | 0 | 14 | 29 | Decapoda (Crab) | 0 | 1 | 1 |
| *Naplus larvae* | 57 | 86 | 100 | *Naplus larvae* | 6 | 9 | 13 |
| Insecta | | | | Insecta | | | |
| Anisoptera | 86 | 100 | 86 | Anisoptera | 14 | 13 | 11 |
| Zygoptera | 71 | 100 | 100 | Zygoptera | 6 | 10 | 9 |
| Trichoptera | 29 | 57 | 0 | Trichoptera | 1 | 1 | 0 |
| Corixidae | 57 | 57 | 29 | Corixidae | 1 | 3 | 1 |
| *Plea leachi* | 71 | 57 | 86 | *Plea leachi* | 5 | 5 | 5 |
| Dytiscidae | 43 | 57 | 43 | Dytiscidae | 1 | 2 | 2 |
| Hydrophilidae | 71 | 71 | 71 | Hydrophilidae | 9 | 9 | 6 |
| *Coleoptera larvae* | 14 | 43 | 29 | *Coleoptera larvae* | 0 | 1 | 1 |
| *Diptera pupae* | 86 | 71 | 57 | *Diptera pupae* | 6 | 7 | 10 |
| Culicidae | 100 | 100 | 71 | Culicidae | 24 | 19 | 19 |
| *Chrironomidae* sp. | 100 | 100 | 100 | *Chrironomidae* sp. | 32 | 30 | 35 |
| Mollusca | | | | Mollusca | | | |
| *Acroloxus* sp. | 100 | 71 | 100 | *Acroloxus* sp. | 30 | 37 | 35 |
| *Physa* sp | 100 | 57 | 86 | *Physa* sp | 41 | 27 | 20 |
| *Lymnea* sp. | 100 | 43 | 57 | *Lymnea* sp. | 5 | 13 | 10 |
| *Melonoides tuberculate* | 100 | 43 | 57 | *Melonoides tuberculate* | 5 | 6 | 7 |
| *Melnopsis nodosa* | 57 | 43 | 57 | *Melnopsis nodosa* | 2 | 5 | 6 |
| *Melanopsis costata* | 71 | 0 | 14 | *Melanopsis costata* | 1 | 0 | 1 |
| *Bellamya bengalensis* | 86 | 43 | 71 | *Bellamya bengalensis* | 4 | 5 | 9 |
| *Pseudontopsis euphraticus* | 57 | 0 | 57 | *Pseudontopsis euphraticus* | 1 | 0 | 6 |
| *Unio tigrids* | 57 | 14 | 14 | *Unio tigrids* | 2 | 2 | 1 |
| *Corbicula* sp. | 100 | 43 | 57 | *Corbicula* sp. | 9 | 6 | 6 |

Note: Constant species - > 50%; Accessory species - 25-50%; Accidental species - 1-25%.

Table 3. The relative abundance index (Ra%)
Tabela 3. Índice de abundância relativa.

| Taxa | S1 | S2 | S3 | Taxa | S1 | S2 | S3 |
|---|---|---|---|---|---|---|---|
| Turbellaria | | | | Insecta | | | |
| *Macrostomium* sp. | 42 | 42 | 41 | | | | |
| *Microstomium* sp. | 30 | 22 | 27 | Anisoptera | 14 | 13 | 11 |
| *Stenostomium* sp. | 21 | 29 | 25 | Zygoptera | 6 | 10 | 9 |
| Other turbellaria | 7 | 7 | 7 | Trichoptera | 1 | 1 | 0 |
| Nemtoda | | | | Corixidae | 1 | 3 | 1 |
| *Seinura* sp. | 33 | 46 | 36 | *Plea leachi* | 5 | 5 | 5 |
| *Dorylaimus* sp. | 18 | 15 | 18 | Dytiscidae | 1 | 2 | 2 |
| *Trilobus longus* | 7 | 8 | 4 | Hydrophilidae | 9 | 9 | 6 |
| Other nematode | 42 | 32 | 43 | *Coleoptera larvae* | 0 | 1 | 1 |
| Annileda | | | | *Diptera pupae* | 6 | 7 | 10 |
| *Stylaria* s p. | 24 | 28 | 30 | Culicidae | 24 | 19 | 19 |
| *Pristina* sp. | 6 | 9 | 4 | *Chrironomidae* sp. | 32 | 30 | 35 |
| *Ophidonais* sp. | 2 | 2 | 1 | Mollusca | | | |
| *Cheatogaster* sp. | 13 | 11 | 11 | *Acroloxus* sp. | 30 | 37 | 35 |
| *Aoelosoma* sp. | 23 | 18 | 24 | *Physa* sp | 41 | 27 | 20 |
| *Dero* sp. | 1 | 1 | 1 | *Lymnea* sp. | 5 | 13 | 10 |
| *Nais* sp. | 2 | 2 | 0 | *Melonoides tuberculate* | 5 | 6 | 7 |
| *Branchinra sowerby* | 11 | 12 | 11 | *Melnopsis nodosa* | 2 | 5 | 6 |
| *Limnodrilus* sp. | 9 | 8 | 7 | | | | |
| *Glossiphonia* sp. | 4 | 4 | 5 | *Melanopsis crostata* | 1 | 0 | 1 |
| *Helobdella* sp. | 2 | 2 | 3 | *Bellamya bengalensis* | 4 | 5 | 9 |
| Other annelida | 2 | 2 | 2 | *Pseudontopsis euphraticus* | 1 | 0 | 6 |
| (Crustacea) | | | | *Unio tigrids* | 2 | 2 | 1 |
| *Ostracoda* sp. | 11 | 16 | 12 | Corbicula | 9 | 6 | 6 |
| *Cameras* sp. | 14 | 13 | 8 | *Acroloxus* sp. | 30 | 37 | 35 |
| *Daphinia* sp. | 32 | 38 | 29 | | | | |
| *Cyclopodia* sp. | 27 | 16 | 22 | | | | |
| *Macrobrachium* sp. | 10 | 7 | 15 | | | | |
| Decapoda | 0 | 1 | 1 | | | | |
| *Naplus larvae* | 6 | 9 | 13 | | | | |

Note: Dominant species - > 70%; Abundant species - 40-70%; Less abundant species - 10-40%; Rare species - <10%.



Table 4. Descriptive Statistics Richness Index.
Tabela 4. Índice de Riqueza Estatística Descritiva.

| | Site1 | Site2 | Site3 |
|---|---|---|---|
| Mean | 19.143 | 20.199 | 20.199 |
| Std. Deviation | 1.281 | 1.516 | 1.516 |
| Variance | 1.642 | 2.299 | 2.299 |
| Minimum | 17.995 | 19.130 | 19.130 |
| Maximum | 21.150 | 23.251 | 23.251 |

Table 5. Descriptive Statistics Shannon Weiner.
Tabela 5. Estatística Descritiva Shannon Weiner.

| | Site1 | Site2 | Site3 |
|---|---|---|---|
| Mean | 1.056 | 0.894 | 1.141 |
| Std. Deviation | 0.273 | 0.099 | 0.036 |
| Variance | 0.075 | 0.010 | 0.001 |
| Minimum | 0.481 | 0.695 | 1.084 |
| Maximum | 1.257 | 0.981 | 1.182 |

Table 6. Descriptive Statistics uniformity index.
Tabela 6. Índice de uniformidade da Estatística Descritiva.

| | Site1 | Site2 | Site3 |
|---|---|---|---|
| Mean | 0.271 | 0.230 | 0.293 |
| Std. Deviation | 0.070 | 0.026 | 0.009 |
| Variance | 0.005 | 6.514e-4 | 8.725e-5 |
| Minimum | 0.124 | 0.179 | 0.278 |
| Maximum | 0.323 | 0.252 | 0.304 |

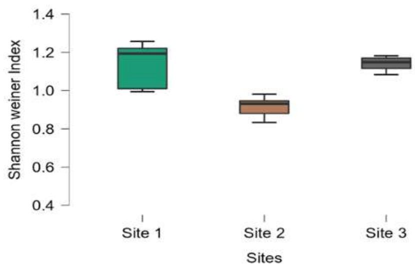


Figure 4. Boxplots Richness Index.
Figura 4. Boxplots do índice de riqueza

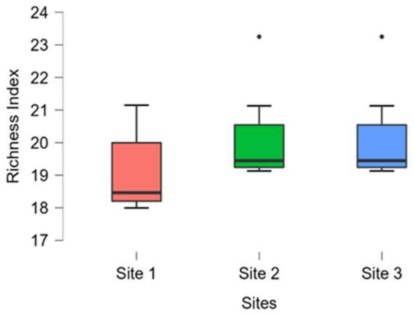


Figure 5. Boxplots Shannon Weiner Index.
Figura 5. Boxplots do índice de Shannon Weiner.

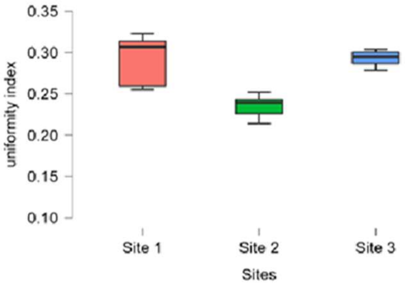


Figure 6. Boxplot uniformity index.
Figura 6. Boxplots do índice de uniformidade.

Table 7 shows the averages, standard deviations, and range of environmental indexes. The table below shows no significant differences for each evidence in the different regions.

Table 8, Post Hoc Comparisons – Index Big emotional differences were found between the Richness Index and all of the Shannon Weiner Index and uniformity index. At the same time, there were few significant differences between the Shannon-Weiner Index and uniformity index (where *p < 0.05; **p < 0.01; and ***p < 0.001.

Figure 7 shows the presence of Benthic invertebrates during the study period. Through the diagnosis, it was found that Cnidarian, Annileda, and Mollusca were present in April and May, while he was Turbellaria, Crustaceans, and Insecta in November and December.

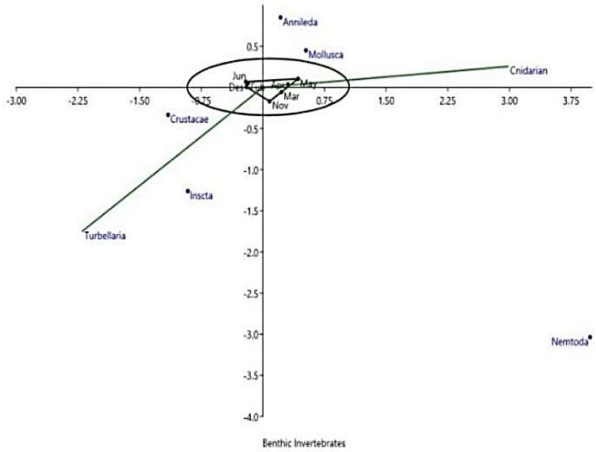


Figure 7. The presence of Benthic invertebrates during the study period November 2021-May 2022.
Figura 7. Presença de invertebrados bentônicos durante o período de estudo de novembro de 2021 a maio de 2022.

### 3.1. The results of physical and chemical factors

The study showed that Table 9, ANOVA - Parameter Value, shows us significant differences between the sites, as it shows a significant difference between the physical and chemical factors that were measured. It also shows significant differences between the sites and the measured factors. Table 10 shows the mean and standard deviation for each site and the mean average and standard deviation for all sites.

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Table 7. Means, standard deviations, and range of environmental index in the Tigris River study sites from November 2021 to May 2022.
Tabela 7. Médias, desvios padrão e variação do índice ambiental nos locais de estudo, no Rio Tigre durante o período de novembro de 2021 a maio de 2022.

| Index | Station Work | | | LSD |
|---|---|---|---|---|
| | S1 | S2 | S3 | |
| Shanon -Weiner | 1.056±0.273[a] (0.481-1.257) | 0.894±0.099[a] (0.695-0.981) | 1.141±0.036[a] (1.082-1.184) | 1.00 (NS) |
| uniformity | 0.271±0.070[b] (0.124-0.323) | 0.230±0.026[b] (0.179-0.252) | 0.293±0.009[b] (0.278-0.304) | 1.00 (NS) |
| Richness | 19.143±1.281[c] (17.995-21.150) | 20.199-1.516[c] (19.130-23.251) | 20.199±1.516[c] (19.130-23.251) | 0.329 (NS) |
| LSD | | 4.373e-13*** | S | |

Table 8. Post Hoc Comparisons – index.
Tabela 8. Comparações Post Hoc índice.

| | | Mean Difference | SE | t | $p_{tukey}$ | |
|---|---|---|---|---|---|---|
| Richness Index | Shannon Weiner Index | 18.817 | 0.263 | 71.672 | 1.989e-11 | *** |
| | uniformity index | 19.583 | 0.263 | 74.588 | 1.989e-11 | *** |
| Shannon Weiner Index | uniformity index | 0.766 | 0.263 | 2.916 | 0.014 | * |

Table 9. ANOVA - Parameters Values.
Tabela 9. ANOVA – Valores dos Parâmetros.

| Cases | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|
| Sites | 59021.585 | 2 | 29510.792 | 82.866 | 6.184e-28 |
| Parameters | 1.163e+7 | 12 | 968919.127 | 2720.713 | 1.034e-243 |
| Sites ✻ Parameters | 225534.221 | 24 | 9397.259 | 26.387 | 2.147e-53 |
| Residuals | 83333.684 | | 234 | 356.127 | |

Note. Type III Sum of Squares.

| | | | Mean Difference | SE | t | $p_{tukey}$ |
|---|---|---|---|---|---|---|
| Site 1 | Site 2 | -28.827 | 2.798 | -10.304 | 0.000 | *** |
| | Site 3 | 4.286 | 2.798 | 1.532 | 0.278 | |
| Site 2 | Site 3 | 33.112 | 2.798 | 11.836 | 0.000 | *** |

Table 10. The Range of the mean values and SD (standard deviation) of the evaluated variables.
Tabela 10. Variações das médias e desvio padrão das variáveis avaliadas.

| Parameters | Range | Descriptive - Parameter Value | S1 | S2 | S3 |
|---|---|---|---|---|---|
| BOD | 4.4- 1 | 1.985667 | 1.629 | 3.071 | 1.257 |
| | | -+0.578 | 0.642 | 0.862 | 0.23 |
| DO | 10.3-8.3 | 9.828333 | 10.071 | 9.343 | 10.071 |
| | | -+0.412333 | 0.214 | 0.802 | 0.221 |
| E.C | 893-532 | 669.4287 | 623.714 | 802.286 | 582.286 |
| | | -+56.50067 | 73.389 | 53.172 | 42.941 |
| NO3 | 3.12-1 | 1.574333 | 1.333 | 2.006 | 1.384 |
| | | -+0.467333 | 0.291 | 0.794 | 0.317 |
| O.M | 4.76-1 | 2.231667 | 1.669 | 3.837 | 1.189 |
| | | -+0.458333 | 0.571 | 0.675 | 0.129 |
| pH | 6.8-7.5 | 7.161667 | 7.157 | 6.957 | 7.371 |
| | | -+0.094 | 0.079 | 0.127 | 0.076 |
| PO4 | 0.39-0.1 | 0.406667 | 0.75 | 0.346 | 0.124 |
| | | -+0.360667 | 1.029 | 0.036 | 0.017 |
| S | 0.340-0.571 | 0.428333 | 0.399 | 0.513 | 0.373 |
| | | -+0.036 | 0.047 | 0.034 | 0.027 |
| T.H | 321-489 | 383.6667 | 347.857 | 448.143 | 355 |
| | | -+19.597 | 7.712 | 32.308 | 18.771 |
| TDS | 450-276 | 340.4283 | 316.571 | 408 | 296.714 |
| | | -+27.55967 | 34.476 | 26.16 | 22.043 |
| Turb. | 450-276 | 4.909333 | 4.871 | 5.886 | 3.971 |
| | | -+0.421 | 0.359 | 0.313 | 0.591 |
| C.W | 0.97-0.51 | 0.717 | 0.781 | 0.734 | 0.636 |
| | | -+0.13 | 0.163 | 0.136 | 0.091 |
| W.T | 13-7 | 9.666667 | 9.286 | 9.714 | 10 |
| | | -+2.001 | 1.799 | 2.289 | 1.915 |

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The results were represented as Raincloud plots (Figure 11) in Table 11 Post Hoc Comparisons – Sites. The results showed significant differences in the measured physical and chemical factors between the first and second sites and significant differences between the second and third sites. There are no significant differences between the first and third positions.

Table 11. Post Hoc Comparisons – Sites.
Tabela 11. Comparações Post Hoc – Locais.

| | | | Mean Difference | SE | t | $p_{tukey}$ |
|---|---|---|---|---|---|---|
| Site 1 | Site 2 | -28.827 | 2.798 | -10.304 | 0.000 | *** |
| | Site 3 | 4.286 | 2.798 | 1.532 | 0.278 | |
| Site 2 | Site 3 | 33.112 | 2.798 | 11.836 | 0.000 | *** |

*** $p < .001$
Note. P-value adjusted for comparing a family of 3.
Note. Results are averaged over the levels of Parameters.

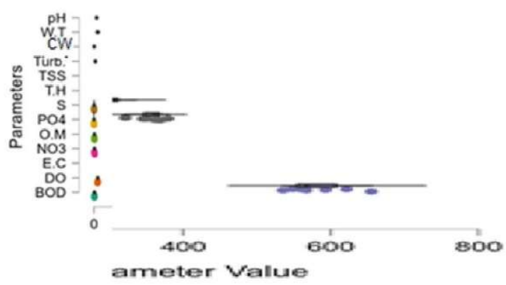


Figure 8. Raincloud plots showing Parameter Value: Sites.
Figura 8. Gráficos Raincloud mostrando o valor do parâmetro: Sites.

### 3.2. Post Hoc Comparisons - Sites ✻ Parameters

In Table 12, the factors whose results showed significant differences in the different sites were mentioned, while the factors that were not addressed did not show significant differences in the results.

Figure 12 shows the positive and negative correlations between the factors (-Indicates a negative or inverse relationship and positive numbers indicate a positive relationship. The dark blue color indicates that the correlation is strongly positive, while the dark walnut color indicates that the correlation is significantly negative.

Table 12. Post Hoc Comparisons - Sites ✻ Parameters.
Tabela 12. Comparações Post Hoc - Locais ✻ Parâmetros.

| | Mean Difference | SE | t | $p_{tukey}$ |
|---|---|---|---|---|
| Site 1 E.C | -622.086 | 10.087 | -61.671 | 0.000 |
| Site 2 E.C | -800.657 | 10.087 | -79.374 | 0.000 |
| Site 3 E.C | -580.657 | 10.087 | -57.564 | 0.000 |
| Site 1 T.H | -346.229 | 10.087 | -34.324 | 0.000 |
| Site 2 T.H | -446.514 | 10.087 | -44.266 | 0.000 |
| Site 3 T.H | -353.371 | 10.087 | -35.032 | 0.000 |
| Site1 TDS | -314.943 | 10.087 | -31.222 | 0.000 |
| Site2 TDS | -406.371 | 10.087 | -40.286 | 0.000 |
| Site3 TDS | -295.086 | 10.087 | -29.254 | 0.000 |

p < .05, *** p < .001
Note. P-value adjusted for comparing a family of 13
Note. Results are averaged over the levels of the Month.

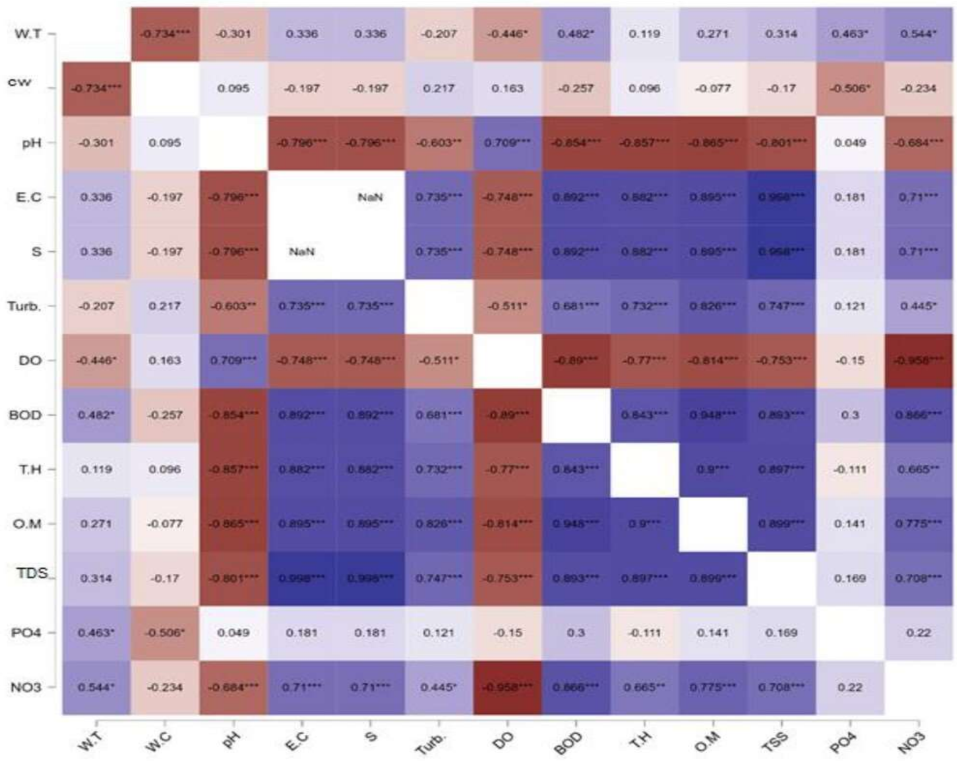


Figure 9. The correlations between the factors.
Figura 9. Correlações entre os fatores.

## 4. DISCUSSION

The Tigris River is known to pass through Baghdad, extending from its north to its south. The results at the first site showed a high density of benthic invertebrates, 3425 ind m$^{-3}$; this is due to the nature of the agricultural area and the presence of different aquatic, which provides a suitable environment for types of invertebrate organisms; this result is identical to the result (AL-OBAIDY, 2016). The second site showed less density of benthic invertebrates 1699 ind m$^{-3}$. This may be due to the nature of the area and the diverse population activities, in addition to the fact that most of the pollutants are thrown into the river; the results were consistent (SHEKHA, 2008).

The third site lacks population activities, decreasing the density of invertebrate organisms 1080 and m$^{-3}$ (HASHIM, 2022). On the other hand, the results show high environmental evidence values in the third site. So they were the values, Shanon-Weiner (1.082-1.184) bit/ind, uniformity (0.278-0.304) and Richness (19.130-23.251). The percentage of annelid worms was 34%, and this is due to the availability of food represented by organic materials (HASHIM, 2022). As for the environmental factors of water that affect invertebrate organisms, most values appear to be higher in the second site; on the contrary, oxygen in the water appears to be lower than in the rest of the sites. The area has a large population activity (AL-OBAIDY, 2016).

## 5. CONCLUSIONS

Through the results and the diagnosed invertebrates, Annileda recorded the highest percentage in the current study, indicating the presence of organic materials in the study sites (Swayne et al., 2004); its presence was concentrated in April and May. The environmental Index, Shanon-Weiner, uniformity and richness, did not show significant differences between the study sites, and the study results did not show environmental pressures on one or more sites. The study showed electrical conductivity, dissolved solids, and total hardness between the study sites. The low presence of Turbellaria in the second site and its high presence in the third site, which is free from human activities, because Turbellaria prefer to live in clean areas, i.e., low pollution (MOODLEY et al., 2005).

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**Data availability:** Study data can be obtained by request of the corresponding author or the second author via e-mail. It is not available on the website as the research project is still under development.

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