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Article

The Effect of the Power Plant on the Biodiversity of Zooplankton

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Abstract: The research was conducted to study the impact of thermal pollution on the Nasseriyah power plant (NPP) on the zooplankton community and the water quality of the Euphrates River. The study area included four stations: the first before the discharge point (control station), the second station, the discharge point of the hot liquid station flows, and the third and fourth stations after the discharge point. Several physical and chemical variables that directly relate to the presence of zooplankton and water quality have been selected, namely water temperature, turbidity, electrical conductivity, salinity, pH, dissolved oxygen, and BOD_5. The study results showed a significant decrease in the quality of river water compared to national and international determinants and a decrease in the number, density, and diversity of zooplankton species. We observed the complete disappearance of the class of Cladocera in the second station in some months of study due to the negative impact of the plant flows.

Keywords: NPP, Zooplankton, Cladocera.

Introduction

In recent years, the freshwater ecosystem has experienced severe threats from human activities such as industrial effluents, agricultural activities, urban waste management issues, and an increase in urbanization. [1,2] Power plants are a significant source of thermal pollution in surface waters, and human demand for energy continues to increase. So will the amount of cooling water that is withdrawn from and subsequently discharged as superheated wastewater back into this aquatic ecosystem. [3] The effects of thermal pollution are diverse, but in short, thermal pollution damages water ecosystems and reduces animal populations.[4]

Zooplankton plays a pivotal role in the food web of aquatic ecosystems by linking the primary producers and high trophic levels [5] Zooplankton is very sensitive and responds more quickly to environmental alteration, nutrient enrichment and different levels of pollution, which leads to change in plankton communities in terms of tolerance, abundance, diversity, and dominance in the habit [6] The dominant zooplankton taxa in freshwater systems are generally rotifers, microcrustaceans (such as cladocerans and copepods), and protozoans [7] Biodiversity is also essential for preserving ecological processes such as fixing and recycling of nutrients soil formation, circulation, and cleansing of air and water, global life support (plants absorb co_2, give out O_2) maintaining the water balance within ecosystems watershed protection maintaining stream and river flows throughout the year erosion control and local flood reduction. [8] The environmental pollution created by the industries has now become a burning issue of the nation [9] as they discharge many kinds of pollution revivers, causing deleterious effects on flora, fauna, and other aquatic organisms. [10] Water quality accompanying anthropogenic favorable arises as a cause of growing concern. It requires surface water monitoring. [11] The condition of the river is typically assessed by regularly monitoring various physical and chemical indicators. [12]

Study Area

The Euphrates River is one of the main rivers in Iraq, with a length of (2775 km) and is classified among the longest rivers in the world. It is considered one of the largest rivers in the Middle East, and its number is (27) in the world [13]. The Euphrates River penetrates the geographical area of the city of Nasiriyah from the northwestern border (Al-Batha) at 911.5 km from the Euphrates River. The Nasiriyah power plant was established at the beginning of the river's entrance to the city, as large quantities of water are used for cooling purposes. Nasiriyah Thermal Power Plant was established in 1978 at the beginning of the river entrance, 7 km from the city center. The study area extends to about 10. The first station is north of the generation station, about 2 km from the hot liquid waste disposal point. It is considered the control point and a reference station for the rest of the study stations, as it is characterized by the presence of agricultural lands on both sides of the river and before the civil facilities of the generation station.

The second station is near the hot liquid waste discharge point for the NPP (Picture No.). The third station is 2 km from the second station, representing the point of merging the station's waste streams with the river water. The presence of orchards and scattered agricultural villages characterize the area. (Picture No.).

The fourth station is 6 km from the third station. On the side of the river, there are drinking water purification stations used by residents. The locations of the stations were determined using a GPS device.

Material and Methods

Sampling methods :

Samples were collected monthly from June 2021 to May 2022. Four sites were chosen, one before NPP S1 as (a control station), another station S2 beside effluent point NPP, and two after NPP as S3 and S4, to collect water samples and zooplankton samples to estimate the effect of effluents of NPP on zooplankton. Samples of water and zooplankton were collected from the study sites every 60 days with three replicates from June 2021 to May o022 to study the status of the Euphrates River. Some properties were conducted concurrently in the study site, such as air and water temperature, electrical conductivity, pH turbidity salinity, BOD_5, dissolved oxygen, and total dissolved solids. All laboratory equipment had been calibrated to conduct direct measurements and had already set the time of collecting samples during daylight hours.

Samples Measurements

All samples were taken near the stream bank about 8-10 m from the shoreline line at a depth of 15-20 cm, never sample stagnant water [14] Kept in a well-stopped polyethylene bottle 1000 ml at 4°C in a refrigerator for the next day for analysis to minimize the changes in the composition due to bacteria. Winkler bottles 250 ml were used to determine dissolved oxygen and allow the formation of bubbles inside the bottle; 1ml of $MnSO_4.H_2O$ (Manganese Sulphate Solution) and 1ml of alkaline iodide-sodium acid solution were mixed with the sample to install the dissolved oxygen. For measuring Biological Oxygen Demand (BOD_5), a dark Winkler bottle of 250 ml was used [14]

The air temperature was measured in the shade, in the same areas where samples were collected by digital air thermometer. In contrast, the water temperature was measured in the same areas where samples were collected by Electrical Conductivity Meter (MARTINI Instruments/Romania), submerging the probe for 3 minutes at 5cm from the water's surface. The results are expressed as Celsius degrees.

After calibration before sample analysis, pH was measured using a Portable Digital pH Meter. Then we dipped the pH meter probe in the sample to obtain a digital readout of the pH [15,16]

Electrical Conductivity (E.C.), Total Dissolved Solids (TDS), and Salinity. These were determined using a portable electrical conductivity meter (MARTINI Instruments/Romania) in situ, the results expressed as micro siemens per centimeter (µS/cm) for electrical conductivity and g/L for measuring TDS [17,18,19]

The electrical conductivity value was then converted to salinity by the following formula

Salinity (‰) = $\mathbf{EC}$ (µ$\mathbf{S/cm}$) × $\mathbf{0.00064}$

Laboratory measurement :

turbidity:

It was measured by using a digital portable turbidity meter (HANNA/HI93703). It was calibrated before being employed by using standard solutions. The instrument uses a light source and one or more detectors to measure the light scatter by particles in water samples. The results were expressed in the Nephelometric Turbidity Unit (NTU).

Biochemical Oxygen Demand Measurement (BOD_5) :

An American-made dissolved oxygen meter was used to measure the dissolved oxygen in mg/L and the oxygen saturation rate in O2%. To calculate the vital oxygen requirement, samples were taken directly from the river water using Winkler bottles and incubated at a temperature of 20 C^0 for some time.

Five days later, a dissolved oxygen meter was used to measure the remaining (final) oxygen, and BOD^5 values were calculated according to [20]

Collection and Identification of Zooplankton Samples :

$$\mathbf{BOD_5\ mg/L = DO\ initially\ mg/L - DO\ mg/L\ (after\ 5\ days\ incubation)}$$

Zooplanktons were collected monthly, from June 2021 to 2022, from 4 different sites between 6 A.M. to 1 P.M., at a depth of 0.5-1 m, with a volume of 40 L to 100 L surface water was collected each time using a graduated bucket. The samples were poured through a 55 µm plankton net. The biological material was preserved in 4% formalin. Following sample condensation, the zooplankton was identified under a compound microscope (Type Kruss MBL 2100) to the lowest possible taxonomic unit in a Sedgewick-Rafter chamber (Adoni, 1985; Baird et al., 2017). (17,16) The number of all taxa in a sample was determined each time. The following references were used for identification: [21,22,23], and the results were defined by the number of individuals in a cubic meter (Ind./m3).

To find the correlation relationship between environmental factors and shifts, a multivariate analysis of environmental data was used using the statistical program [24]

Result

The result of the study showed that the highest value of air temperature was recorded in the fourth station, where it reached 44 C^0 during August, and the lowest temperature was recorded in the first station in December, reaching 8 C^0.

The surface water temperature ranged between the highest temperature recorded in the second station. It reached 43 C^0 in August due to the influence of hot liquid flows from NPP, while the lowest temperature recorded in the first station in December reached 13.8 C^0. (Figures 1 and Figure 2).

Statistical analysis showed a negative correlation coefficient between water temperature, salinity and dissolved oxygen concentration ($r= -0.04$, $r = -0.39$), respectively. At the same time, the correlation coefficient was positive between air and water temperature ($r = 0.41$).

The water temperature is a reflection of the air temperature. We have noticed that the NPP fluxes have added an amount of 5 C^0 to the surface water temperature compared to the temperature of the control station, and since the temperature is the most crucial physical variable affecting the water systems, as the composition of the community and the abundance and food efficiency of the communities.

The results of the study showed that the turbidity in the Euphrates River under the influence of the power station effluents recorded the lowest value of (8.87) NTU in the fourth station in February, and the maximum turbidity value was (118) NTU recorded in the fourth station of August.

The electrical conductivity and salinity content data are represented in Figures (4 and 5). At site 1 before NPP, electrical conductivity and salinity ranged from 2299-3762 µS/cm in August and February, respectively, with salinity units from 1.67- 2.35‰ in October and March, While the highest and lowest readings for electrical conductivity and salinity were recorded in site 2 beside NPP, ranged from 3161- 4120 µS/cm with salinity unite from 2.02 – 2.63 in February and June respectively. As well as, the values ranged from 2301-3995 µS/cm with salinity units from 1.47-2.4‰ in February and October, respectively, at sitting 3 after NPP, whereas, in the last site after NPP at sitting 4, readings for electrical conductivity and salinity ranged from 2286 – 3720µS/cm with salinity unite from 1.46 – 2.38 ‰ in February and October.

The results of the study showed that the electrical conductivity and salinity were at their maximum concentration in the second station, which is the NPP waste discharge point, and the third and fourth stations under its influence.

The statistical analysis results showed that the correlation coefficient was negative between electrical conductivity and salinity and the total average of zooplankton at the probability level ($p \leq 0.05$) $r = -0.41$.

The data of total dissolved solids is represented in Figure (6). At site 1 before NPP, TDS values ranged from 1178 mg/L in August to 1836 mg/L in February. Whereas the minimum and maximum value of TDS ranged from 1215.5 in August and June to 2060 mg/L in site 2 beside NPP. While it ranged from 1150.5 mg/L in October and February to 1997.5 mg/L at sit 3 after NPP, the lowest value of TDS at sit 4 after NPP was 1143 mg/L in October and the highest value to 1860 mg / L in February.

The results of our current study showed that the pH value recorded in the first station before NPP ranged between 7.01 - 8.2 in August of the summer season, respectively, and the pH value next to NPP at the second station ranged between 7.6 - 8.7 in June and August, respectively. The reading of the third and fourth stations after NPP recorded 7.8 - 8.9 in June and August and 7.01 - 8.9 in June and August, respectively. (Figure 7).

The statistical analysis results showed a negative correlation coefficient between pH and water temperature, electrical conductivity, and the total rate of zooplankton, respectively. (r= - 0.4, r= - -0.90 and r= - 0.38) . While the correlation coefficient was positive with dissolved oxygen. (r = 0.055).

The study results showed that the concentration of dissolved oxygen in the waters of the Euphrates River and the study area at site 1 before NPP ranged from 3 to 7 mg/L in August and December, respectively. The beside NPP at sit 2 ranged from 1.6 mg/L in August to 5 mg/L in December. The minimum concentration was 3 mg/L in August, and the maximum was 7 in December in site 3 at immediate NPP. It also ranged from 3.6 to 6.6 mg/L in June and December after NPP at site 4 . (Figure 8).

The results of our current study showed that the BOD_5 value recorded in the first station before NPP ranged between 1.7 – 6 Mg/L in October and August, respectively, and the BOD_5 value next to NPP at the second station ranged between 2.4 – 4.9 Mg/L in April and August, respectively. The reading of the third and fourth stations after NPP recorded 2.2 – 4.4 Mg/L in April and August and 2.1 – 6.6 in October and August, respectively—Figure (9).

The results of the statistical analysis showed that the correlation coefficient between the BOD_5 was positive with the air temperature, the electrical conductivity and the total rate of plankton (r = 0.08, r = 0.06, r = 0.31), respectively, while the correlation coefficient was negative between the $BOD_5$and both water temperature, turbidity, dissolved oxygen and total dissolved salts respectively. (r= - 0.38, r = - 0.03, r = - 0.03, r = - 0.20).

Our current study showed that the density of recorded zooplankton ranged from 260 - 9114 Indi /m^3 and included three classes: Rotifera, cladoceran, and copepods. (Figure 10) .

Zooplankton density at site 1 before NPP ranged from 9114.1 Indi./m^3 to 888 Indi./m^3 in April and December, respectively. The beside NPP at sit 2 ranged from 500 Indi./m^3 in October to 2995 Indi./m^3 in August. The minimum zooplankton density was 440 Indi./m^3 in October, and the maximum was 3910 Indi./m^3 in August in site 3 at immediate NPP. It also ranged from 260 Indi./m^3 to 4176.5 Indi./m^3 in June and February, respectively, after NPP at site 4.

The zooplankton recorded in this study included three main classes: Rotifers, Cladocera, and copepods. The total average of the number of planktons recorded in our current study is 56182.2 Indi./m^3 distributed according to the following ratios. Copepods ranked first with a rate of 50.39% and a total of (28313.8 Ind./m^{3}). Rotifer ranked second with a rate of 45.4% and a total of (25551.2 Indi./m^3), while the cladoceran ranked third with a rate of 4.47% and a total of (2666.2 Indi.m^3). The zooplankton in our study vary in number, density, and diversity depending on the biological characteristics of each species. The copepods occupied the first rank because of their resistance to environmental changes such as heat and salinity, their ability On the merits of various pollutants such as heavy metals and hydrocarbons and their high resistance to synergistic pressures (Figure 13). The Rotifera (Figure 11) came in second place due to its small size and short life cycle; as for the cladoceran (Figure 12), the lowest densities and the lowest species were recorded due to their sensitivity to high temperatures and increased salinity concentration, which are the two factors that determine the presence of cladoceran in the aquatic environment. The biological diversity of plankton and its presence and diversity in the aquatic environment is under multiple pressures, including environmental factors such as temperature, salinity, dissolved oxygen, and nutrients. A significant factor is predation by fish, especially when the environment is poorly nourished and heavily polluted. All of these reasons led to a decrease in the density of plankton and diversity of species and the deterioration of biodiversity.

Parameter	Maximum – Minimum value in the current study	Iraqi Standard No. (417) for the year 2001(31)	(WHO) The standard for the year 2006 (32)
Turbidity (NTU)	8.87 – 118	5	➢ 5
Ec (μ sense/m³)	2286 – 4120	2000	2000
TDS (Mg/L)	1178 – 2060	1000	1000
Salinity %	1.47 – 2.48	-	-
pH	7.2 – 8.9	6.5 – 8.5	6.5 – 8.5
BOD_5 (Mg /L)			
Dissolved Oxygen (mg /L)	1.6 – 6.6		

Table 1. A comparison between the values of physical and chemical variables in the current study with local and international standards.

Discussion

Animal howl is closely related to water temperature and is a direct physiological response [25].

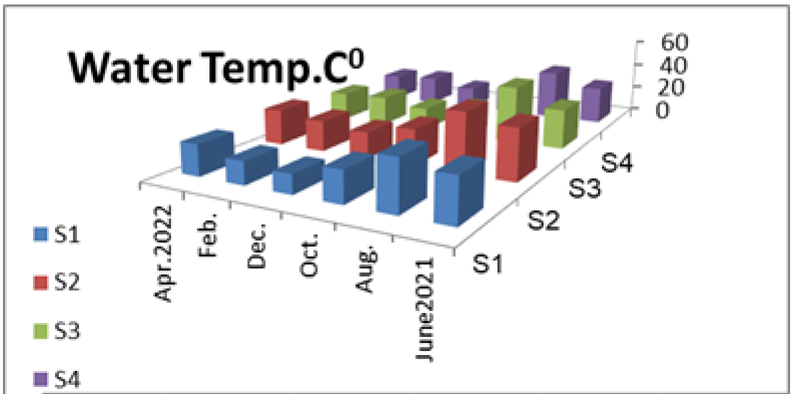
(Figure 3). Statistical analysis proved that the correlation coefficient between turbidity and the total rate of plankton was positive, r = 0.075. That is, the positive relationship is reflected in the increase in the number of plankton because the increase in turbidity reduces the ability of fish to prey on large and active plankton and is limited only to weak and small prey. [26] The high turbidity reduces the visual acuity of fish and feeding by the visual attack method[27]. Our current study showed, through statistical analysis, that the correlation coefficient was positive between salinity, total dissolved solids, and electrical conductivity in all the studied stations, with an alight increase value recorded at station 2, located near NPP's discharge area. This may be due to some ionic strength of the effluents waste or due to an increase in the evaporation rates and increased water temperature in heated effluents area [28]

The results of the study showed that the second station, which is the discharge point of the NPP, recorded the lowest concentration of dissolved oxygen compared to the control station, and this indicates the negative impact of the flows of the hot liquid station, which led to a decrease in the density of zooplankton and the diversity of species because oxygen stress plays an essential role in determining the structure of zooplankton community. [29]

The current study showed fluctuation in the values of the biological oxygen demand, as the summer months of June and August recorded the highest values of (BOD_5), where the fourth station recorded 6.6 Mg/l, the highest value. On the other hand, it increases the surface water temperature and the activity of microorganisms that play a vital role in decomposing organic matter and withdrawing oxygen from the water column. [30]

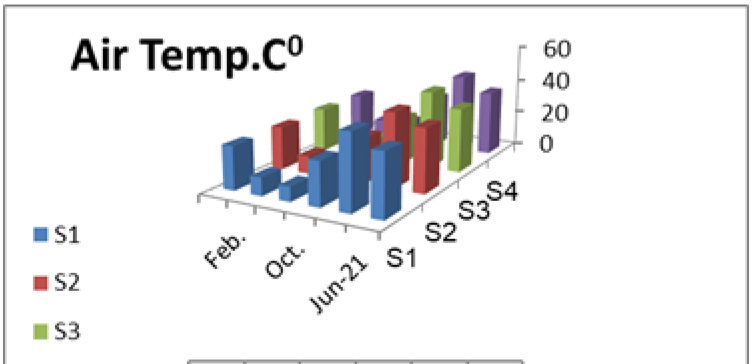
Conclusions

Our current study showed a very significant decrease in the density of zooplankton and in the diversity of species, which led to the deterioration of biodiversity in this part of the Euphrates River, where the water body is subject to multiple synergistic pressures that led to this deterioration in diversity that threatens a fundamental link in the food web and will lead to adverse effects Various environmental and economic reasons, and this may be due to several reasons that have combined and accumulated, knowing that this part of the river has not been subject to previous studies concerning the biodiversity of zooplankton under the influence of the flows of the generation station. The hot liquid flows from the station greatly affected the Euphrates River's physical, chemical, and biological properties, leading to the deterioration of the water quality and its suitability for various purposes.



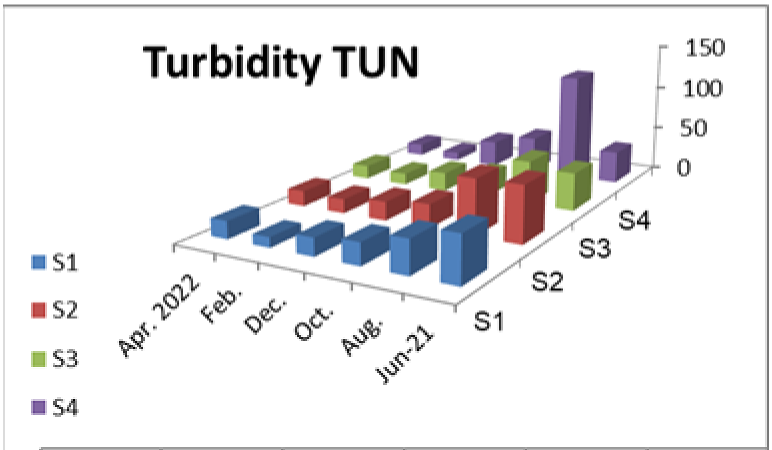
	Apr.2022	Feb.	Dec.	Oct.	Aug.	June2021
S1	22.5	16.4	13.8	22.5	36	31
S2	26	22.3	18.8	26	43	37
S3	21	21.6	17	21	42	29
S4	20	21.4	16	20	37	28

Figure 1. Seasonal variations of the Water temperature in Euphrates during June 2021- April 2022.



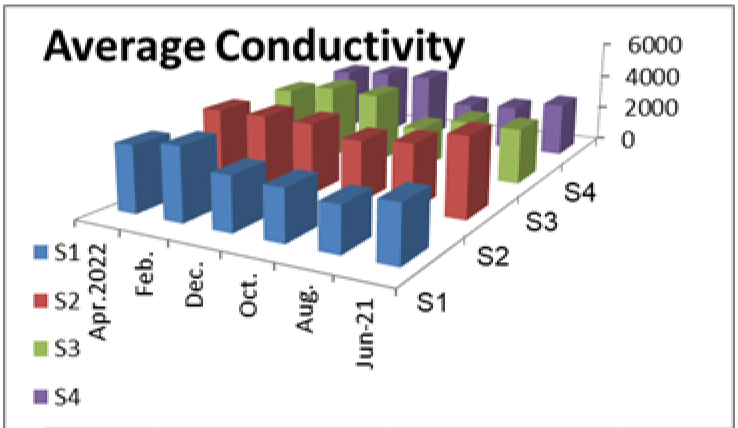
	Apr.2022	Feb.	Dec.	Oct.	Aug	Jun-21
S1	24	10	8	24	41	34
S2	24	10	9	25	41	35
S3	25	11	11	26	43	35.5
S4	25	11	12	29	44	36

Figure 2. Seasonal variations of the Air temperature in Euphrates during June 2021- April 2022.



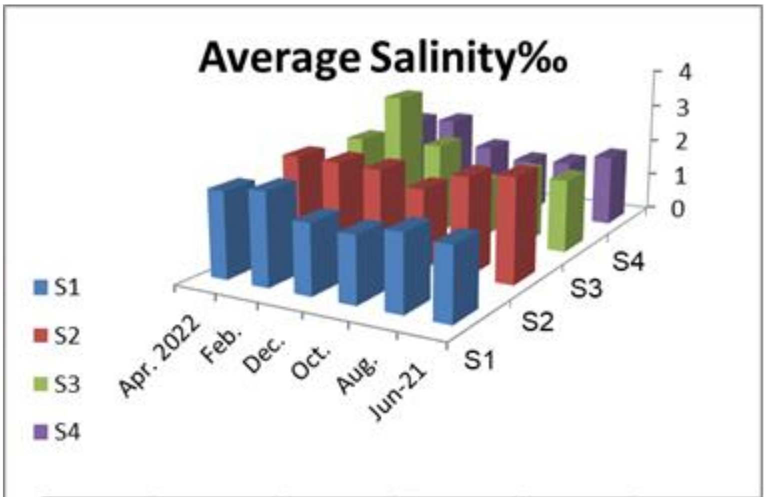
	Apr. 2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	18.91	10.94	19.2	23.53	35.8	49.44
S2	16.74	15.32	20.33	25.55	60	61
S3	14.9	12.51	20.32	24.65	47.2	41.37
S4	13.2	8.87	28.71	39.45	118	35.54

Figure 3. Seasonal variations of the Turbidity in Euphrates during June 2021- April 2022.



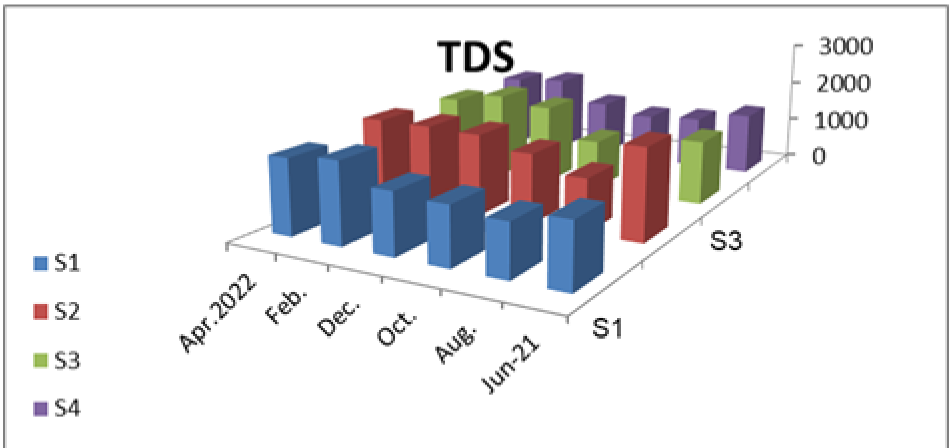
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	3440	3762	2772	2615	2299	2844
S2	3766	3760	3688	3161	3388	4120
S3	3567	3995	3866	2301	2990	2930
S4	3547	3720	3720	2286	2428	2898

Figure 4. Seasonal variations of the Ec in Euphrates during June 2021- April 2022.



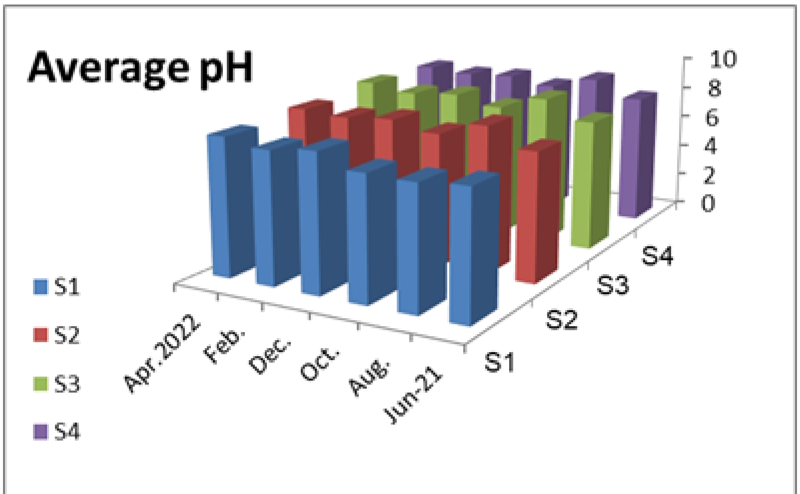
	Apr. 2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	2.2	2.35	1.77	1.67	1.91	1.82
S2	2.41	2.4	2.36	2.02	2.48	2.63
S3	2.29	3.55	2.36	1.47	1.91	1.87
S4	2.27	2.38	1.72	1.46	1.55	1.85

Figure 5. Seasonal variations of the Salinity in Euphrates River during June 2021 – April 2022.



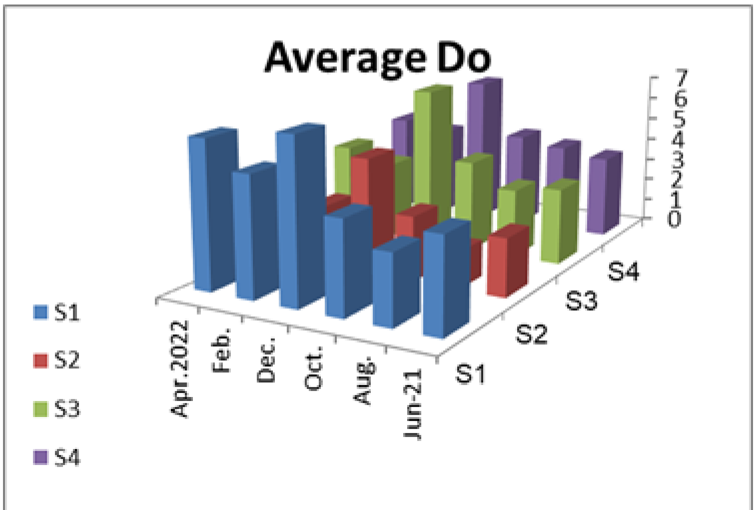
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	1720	1836	1386	1307.5	1178	1422
S2	1883	1880	1844	1580.5	1215.5	2060
S3	1783.5	1997.5	1843	1150.5	1196	1465
S4	1773.5	1860	1346.5	1143	1214	1449

Figure 6. Seasonal variations of the TDS in Euphrates River during June 2021 – April 2022.



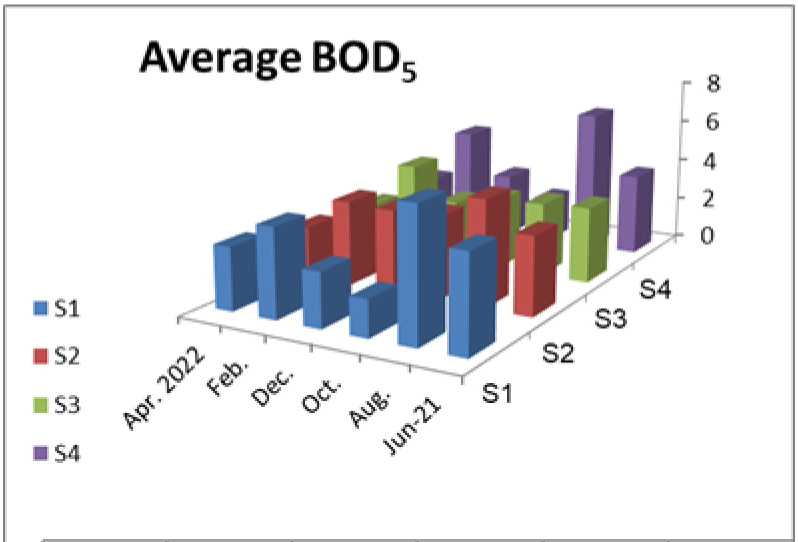
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	8.2	7.8	8.1	7.3	7.2	7.4
S2	8.4	8.2	8.4	7.9	8.7	7.6
S3	8.8	8.4	8.6	8.1	8.9	7.8
S4	8.7	8.5	8.6	8.2	8.9	7.9

Figure 7. Seasonal variations of the Hp in Euphrates River during June 2021 – April 2022.



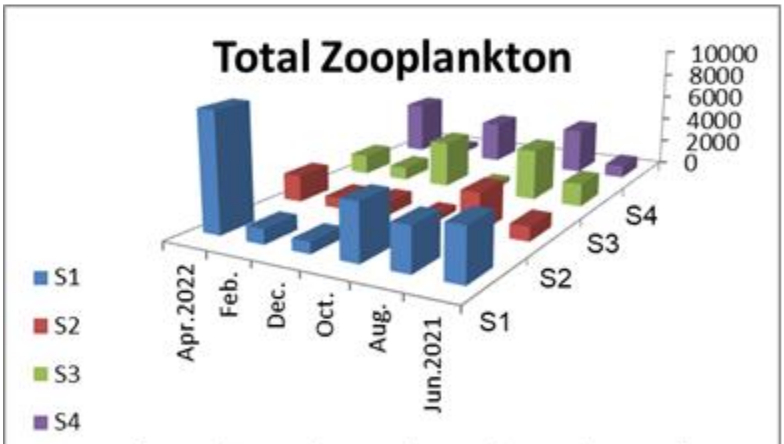
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	6.4	5.2	7	4	3	4
S2	3.7	2.7	5	2.8	1.6	2.5
S3	4	3.4	7	4	3	3.3
S4	4.4	4	6.6	4.2	3.9	3.6

Figure 8. Seasonal variations of the Average DO in Euphrates River during June 2021 – April 2022.



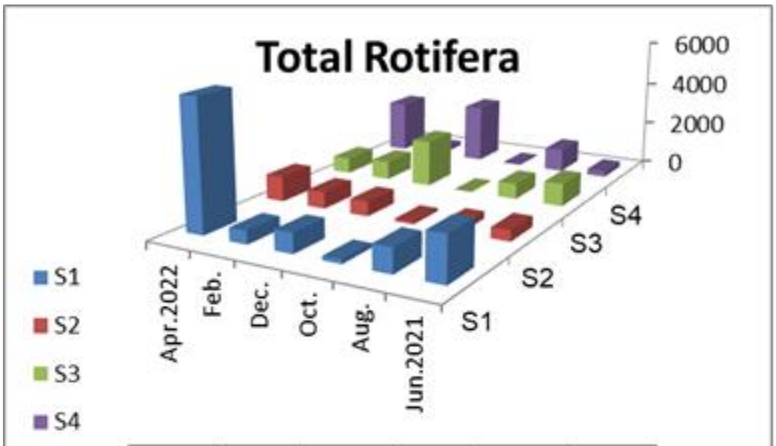
	Apr. 2022	Feb.	Dec.	Oct.	Aug.	Jun-21
S1	2.9	4.1	2.5	1.7	6	4.4
S2	2.4	3.9	3.8	3.8	4.9	3.6
S3	2.2	4.4	2.9	3.3	3.4	3.5
S4	2.3	5	3	2.1	6.6	3.8

Figure 9. Seasonal variations of the BOD $_5$ in Euphrates River during June 2021 – April 2022.



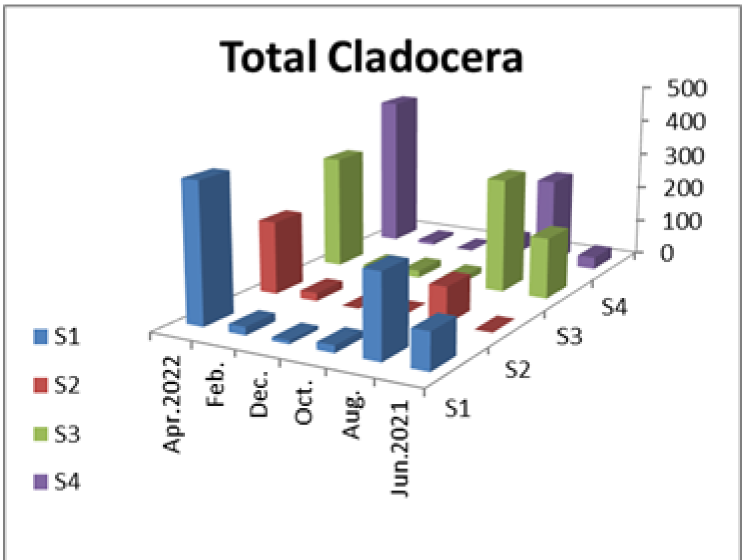
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun.2021
S1	9114.1	1155.1	888	4320	3330	3965.8
S2	2088.1	821.9	1000	500	2995	1099.5
S3	1544.5	999.6	3570	440	3910	1765.8
S4	4176.5	422	3270	260	3580	966.3

Figure 10. Seasonal variations of the Total Zooplankton in Euphrates River during June 2021- April 2022.



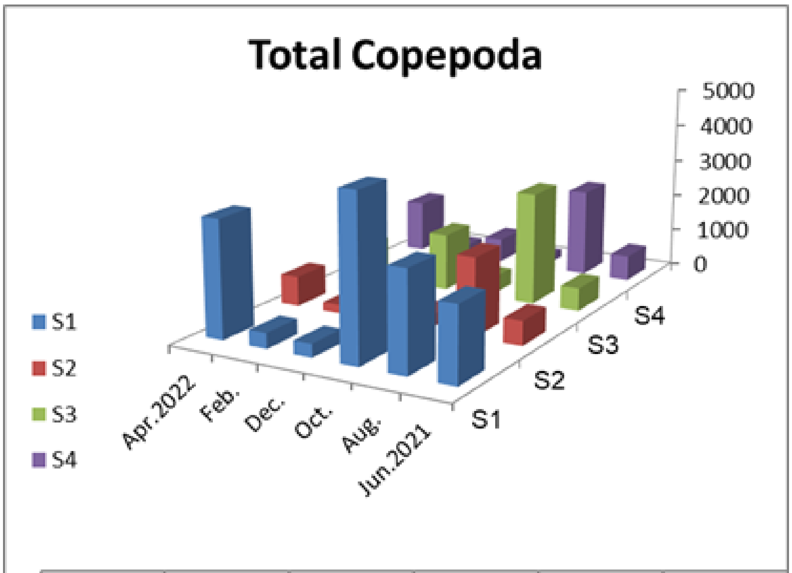
	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun.2021
S1	5688.2	577.5	860	180	1050	1932.9
S2	1110.6	732.9	650	120	330	466.3
S3	710.8	821.9	2060	0	685	999.5
S4	2377.2	222	2640	40	1030	266.4

Figure 11. Seasonal variations of the Total Rotifera in Euphrates River during June 2021- April 2022.



	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun.2021
S1	382.1	22.2	10	20	225	99.9
S2	199.9	22.2	0	0	100	0
S3	311	11	20	18	310	166.6
S4	422	9	0	44	240	33.3

Figure 12. Seasonal variations of the Total Cladocera in Euphrates River during June 2021- April 2022.



	Apr.2022	Feb.	Dec.	Oct.	Aug.	Jun.2021
S1	3043.8	400	350	4200	2565	1933
S2	777.6	222.2	18	320	2025	633.2
S3	799.7	177.7	1490	440	2915	599.7
S4	1377.3	200	630	220	2310	666.6

Figure 13. Seasonal variations of the Total Copepoda in Euphrates River during June 2021- April 2022.

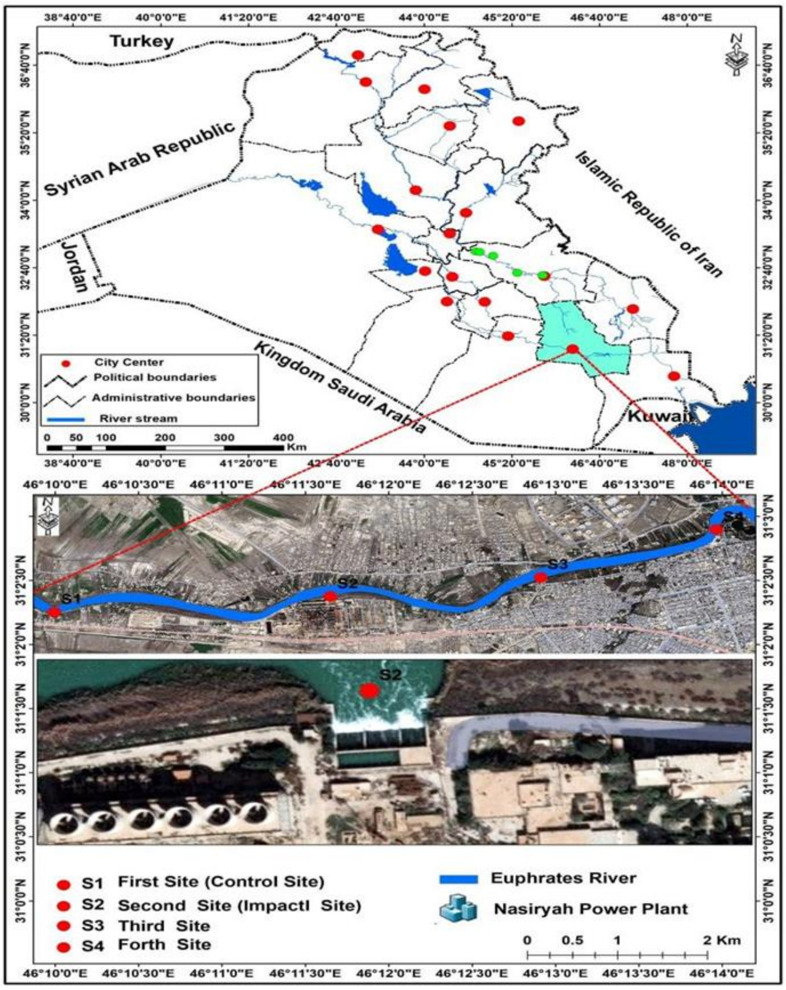


Figure 3.23. Map of Iraq.

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