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INFLUENCE OF SUBMERGED MACROPHYTES ON ZOOPLANKTON BIOMASS IN SOME WATER BODIES SOUTHERN IRAQ

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Abstract

This study aimed to show how submerged macrophytes affect zooplankton biomass. From November 2020 to October 2021, samples of water, plants, and zooplankton were collected monthly from six stations in the Al-Hammar, Al-Chebiyesh Marshes, and Euphrates River. Physical, chemical, and biological water parameters were analysed including water temperature, water current, light penetration, NO_3, PO_4, Chlorophyll-*a*, and plant biomass. Zooplankton biomass was estimated as wet weight, dry weight, and displacement volume. Water temperature ranged from 13 °C to 33 °C in February and August; water's current ranged from 0.02 to 0.52 m/sec in November and February. Light penetration ranged from 7 to 218 cm in November and February, NO_3 ranged from 2.3 to 6.4 mg/L in August and February, PO_4 ranged from 0.24 to 0.76 mg/L in August and February, Chlorophyll-*a* ranged from 5.01 to 19.13 µg/L in February and September. Plant biomass ranged from 40.89 to 1120.6 gm DW/m^2. In stations with submerged macrophytes, zooplankton biomass as dry weight ranged from 4.1 to 100.7 gm/m^3. Wet weight ranged from 3.4 to 128.31 gm/m^3 in February and October respectively. The biomass ranged from 1.2 to 7.6 gm/m^3 DW and 1.75 to 9.3 gm DW/m^3 in February and October respectively. In contrast, in stations with submerged macrophytes and those without, the displacement volume ranged from 0.08 to 0.92 mL/m^3 and 0.11 to 1.01 mL/m^3 in February and October.

Keywords: Submerged Macrophytes, Zooplankton, Biomass, Water Bodies

Introduction

Water bodies are not devoid of large and small assemblies of organisms living within the ecosystem. Such organisms are linked with one another, and their environment by relationships and are thus subject to the negative or positive influence of physical, chemical, and biological factors on them (Salman *et al*., 2003). Zooplankton has a pivotal role in the food chain by controlling the production of phytoplankton Malfunctions of each trophic level affect even the predator–prey interaction, leading a severe degradation of the ecosystem, as zooplankton was the major link between low and high trophic levels and thus supports its biodiversity (Lomartire *et al*., 2021). The study of changes in the zooplankton community was necessary to know the population dynamics and thus the structure of aquatic ecosystems (Havens, 1998). Zooplankton biomass was measured directly as wet or dry weight or it is estimated indirectly from other measurements, one of the most commonly used indirect methods was the displacement size (Bode *et al*., 1998).

Locally, studies lacked a link between zooplankton and other living components of aquatic ecosystems, such as submerged aquatic plants, which were not studied. Some studies were limited to plant-attached plankton, including the study of Laghiwi (2019), found a wide difference in zooplankton groups in terms of types and densities. Al-Amiri (2021) assessed water quality of Shatt Al-Arab River. The author concluded that the water quality is worsening in the southern portion of the river because of the dramatically increased salty concentrations and total hardness, including the association between zooplankton kinds and densities and the Canadian Water Quality Index.

Several researchers examining the importance of aquatic plants for zooplankton reached a consensus (Arora and Mehra, 2003; Lauridsen *et al*., 2001). They showed that aquatic plants could provide food and a safe refuge for zooplankton from predators. They support zooplankton diversity in shallow water bodies. Some studies revealed that its importance changes with the lake's trophic status, as it is higher in hypertrophic lakes than in oligotrophic (Nurminen, 2003). However, according to Thomaz and Cunha (2010), Aquatic macrophytes have been important habitat structurers, are highly influential on the composition of the associated fauna and influence interspecific relationships. Increases in animal abundance, richness and diversity due to macrophyte habitat complexity may be explained by simple mechanisms that involve the availability of habitat, which increases the possibility of available food and consequently attracts other organisms. The open water zone was characterised by the lowest values of biocoenotic parameters, while more heterogenic vegetated zones usually possessed more abundant zooplankton communities. (Kuczyska-kippen and Joniak, 2010). According to Kuczyn ska-Kippen (2005) and Meerhoff *et al*. (2007) the availability of large plants as food sources and refuges for zooplankton depends on various factors, including plant structure, size, and vegetation density, and the predators that these plants host.

The variety of environmental factors, including biological parameters, such as predation or competition, as well as by physical-chemical factors, among which the kind of macrophyte substratum and parameters relating to the trophic state of the water body may be shape the structure the community of zooplankton (Basi'nska and Kuczy'nska-Kippen, 2009). Aquatic plants change the chemistry of water as they improve its quality and consequently maintain the great diversity of aquatic organisms, including zooplankton, in addition to the spatial structure of the habitats of these organisms (Kurbatova *et al*., 2016; Celewicz-Goodyn and Kuczynska-Kippen, 2017; Sipauba-Tavares and Dias, 2014).

Lei *et al*. (2018) linked the size-biomass dependent responses of zooplankton to submerged macrophytes restoration. Hence, the number of Crustaceans and the ratio of Crustaceans to Rotifera in large size may flourish when increasing the biomass of aquatic plants. By contrast, the density of sizes decreases significantly by less than 400 µ. According to Stahr and Kaemingk (2017), zooplankton biomass patterns in main aquatic plants and open-water habitats were inconsistent over the months because some zooplankton taxa were more abundant in vegetation compared to open water habitats. Moreover, others used open water habitats during the day as a refuge from predators when predation risk rose.

In contrast to the above findings, Nakamura *et al*. (2008) indicated that zooplankton is less abundant in ponds with submerged aquatic plants than those without, in conditions without fish, to reduce the effect of zooplankton grazing. This result supports the conclusion of They and Marques (2019) that aquatic plants are a structuring driver of the plankton community. The reason is that most groups of bacteria, plant and zooplankton density was recorded due to the decrease in the concentration of nutrients, mainly PO_4 and Chlorophyll-*a,* in shallow lakes.

Materials and Methods

1.1. Description of the study area

AL-Hammar Marshes is located south of the Euphrates River. It is a water body shared between the Provinces of Basra and Thi-Qar, with an estimated area of approximately 2,800 km^2 as marshes or permanent ponds that can accommodate up to 4,500 km^2 in times of water flooding. Its length is 120 km, and its width is 25 km (Al-Saadi, 2009). The Euphrates River and its various tributaries supply the western part, whereas the eastern part mainly supplies the Shatt al-Arab because of the low water levels. Currently, the eastern part of the marsh deliberately feeds it on the waters of the Shatt al-Arab through the tide. Two sites were selected: S1, Mniassfa, characterized by the presence of submerged macrophytes, and S2 Al Burka, located in the south of S1 Mniassfa, characterized by the absence of submerged macrophytes. The average distance between them is 4 km, and the depth ranges from 32 to 243 cm.

Al-Chebiyesh marshes before desiccation were among the parts of the central marshes, which are located to the west of Tigris and north of the Euphrates, delimited by the triangle among the towns of Al-Nasiriyah, AlAmarah, and Al-Qurnah (Al-Abbawy, 2010), which is a large area from the permanent and temporary marshes. Two sites were selected. The Abu-Alsabaa represents S3; the water depth ranges from 0.65 to 1.75 m. The presence of submerged macrophytes characterizes them. Inhabitants of a few population centers practice the professions of fishing operations and herding animal. We selected S4, approximately 1 km away from S3. The absence of submerged macrophytes is compared with S3.

Two stations were selected in the southern part of the Euphrates River. S3 Salih River has located approximately 11 km from the Almduaina center in the northwest of Basra Province after the Euphrates concrete barrier near the village of Shutayt. The water depth ranges from 2 to 3 m. The average width is 500 m. S6 is located 8 km north of S5. Both stations are characterized by high water transparency.

Table 1. Location of the sampling area.

Position	Station name	Latitudes (North)	Longitudes (East)
AL-Hammar marshes	S1	N: 30° 41′ 45.87″	E: 47° 32′ 59.56″

	S2	N: 30° 41′ 22.16″	E: 47° 37′ 4.78″
Al-Chebiyesh marshes	S3	N: 30° 59′ 3.45″	E: 47° 8′ 39.80″
	S4	N: 30° 58′ 51.04″	E: 47° 10′ 47.90″
Euphrates River	S5	N: 30° 57′ 7.18″	E: 47° 9′ 2.74″
	S6	N: 30° 57′ 8.88″	E: 47° 7′ 42.81″

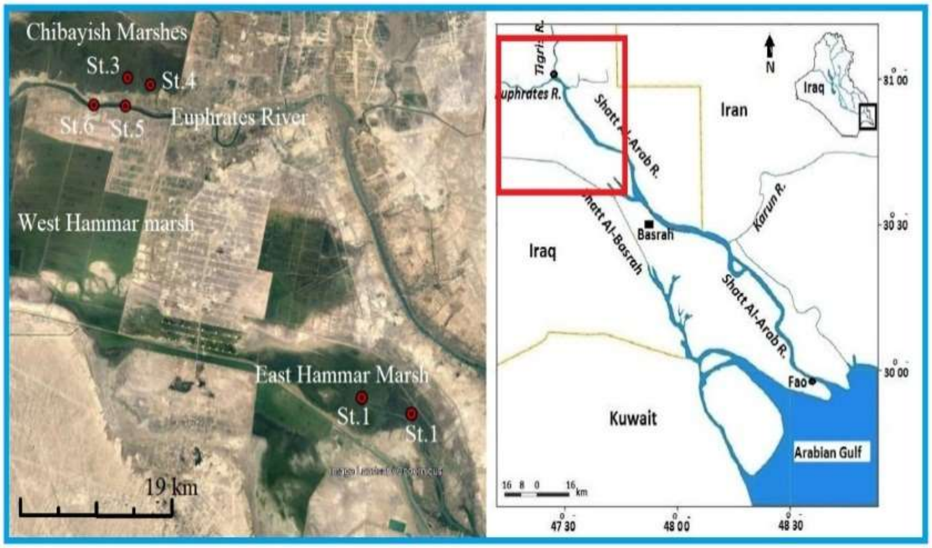


Figure 1. Showing Sampling Stations

1.2. Water Sample Collection

Zooplankton samples were collected in three replicates monthly from six stations (three containing submerged macrophytes and three absences them) from November 2020 to October 2021. The temperature (°C), water current (m/sec), and light penetration (cm) were measured as Secchi Depth. These variables were measured in the field immediately during sampling.

Polyethylene containers were used to collect water samples which stored in ice box until further analysis. NO_3 and PO_4 were determined according to APHA (2005), and Chlorophyll-*a* was determined following Lind (1979). To estimate submerged macrophytes, biomass as dry weight g/m^2 was performed using a quadrate (1m*1m) described by Lind (1979).

Zooplankton Biomass

For quantitative analysis of zooplankton, a 10-L plastic container was used to pass 100 L of station water through plankton net (40 µ mesh-size and 30 cm mouth aperture). They were rinsed several times. Specimens were kept in a 500-mL labeled plastic containers and preserved with 4% formalin immediately after towing**.**

Wet and Dry Weight of the Zooplankton

The wet and dry weights of samples were calculated according to Al-Sakini (1990). Dry and wet weights of an empty Millipore filter paper of 0.45 μ were recorded using Sartory balance. The wet weight was calculated in terms of mg/m^3, filters were dried at 60 °C for 24 hours, dry weight of filters were recorded, according to the wet weight and the dry weight in terms of mg/m^3.

Displacement Volume of the Zooplankton

The zooplankton displacement volume was measured in the laboratory for each sample by placing the sample into a 500-mL volumetric flask and the volume was raised to the final mark by adding water. The sample was filtered into another volumetric flask of similar capacity through a net of a mesh size less than that used for sample collection. The volume was completed to the mark using a 1-mL cylinder. Added volume of water is equal to the displacement volume of the zooplankton (Ajeel *et al*., 2008), and the displacement was measured in mL/m^3.

Results

1.3. Water Temperature

Monthly water temperature variations varied in the stations with time; they ranged from 3 °C to 33 °C in February and August (Fig. 2).

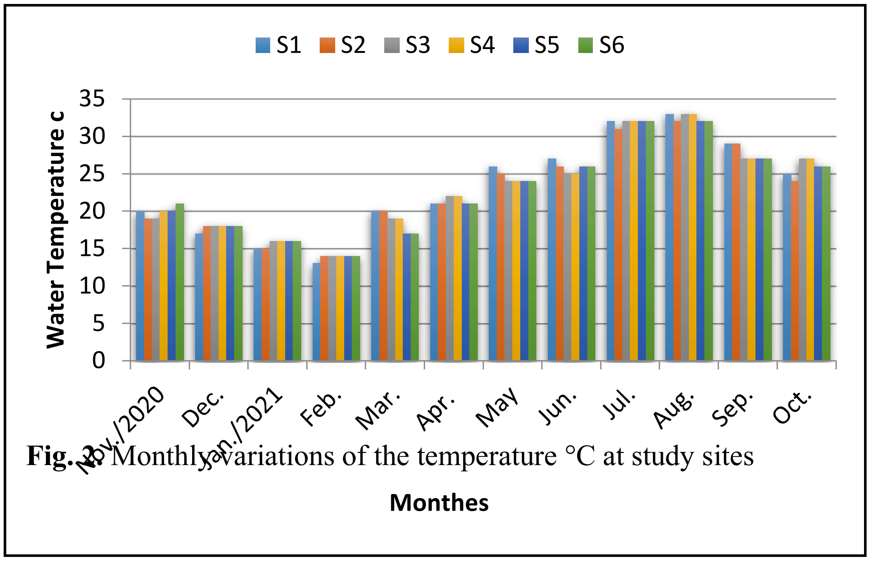
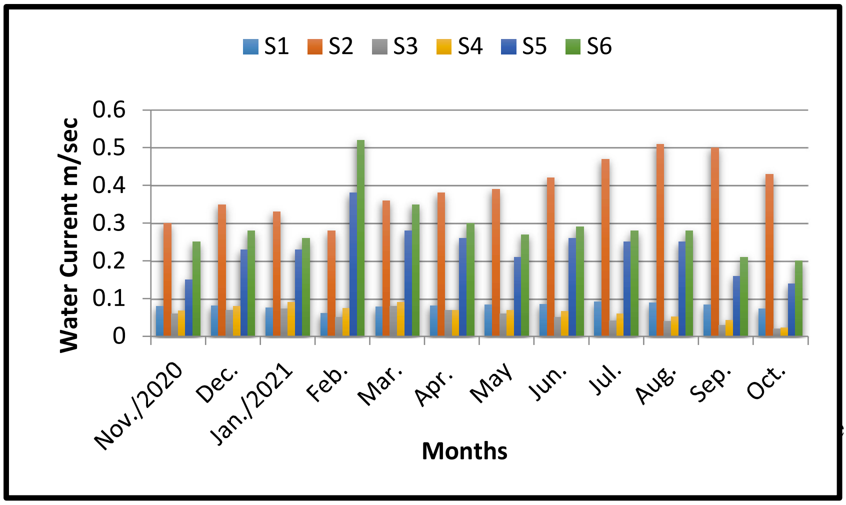


Fig. 2: Monthly variations of the temperature °C at study sites

1.4. Speed of Water Current m/sec

Water current speed varied monthly 0.5 to 0.09 and 0.52 m/sec as maximum value in August, March and February, respectively, while they were 0.061 to 0.02 and 0.14 m/sec minimum value in February and October. The current water speed has an average value of 0.236, 0.059, and 0.262

m/sec in AL-Hammar, Al- Chebiyesh, and the Euphrates, respectively (Fig. 3). Statistical analysis showed a significant difference (*p* ≤ *0.05*).



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1.5. Light Penetration

Fig. 4 illustrates the monthly changes in light penetration. The highest values were 49, 38, and 218 cm in June, February and February, while the lowest were 10, 7, and 97 cm in October, November and October respectively.

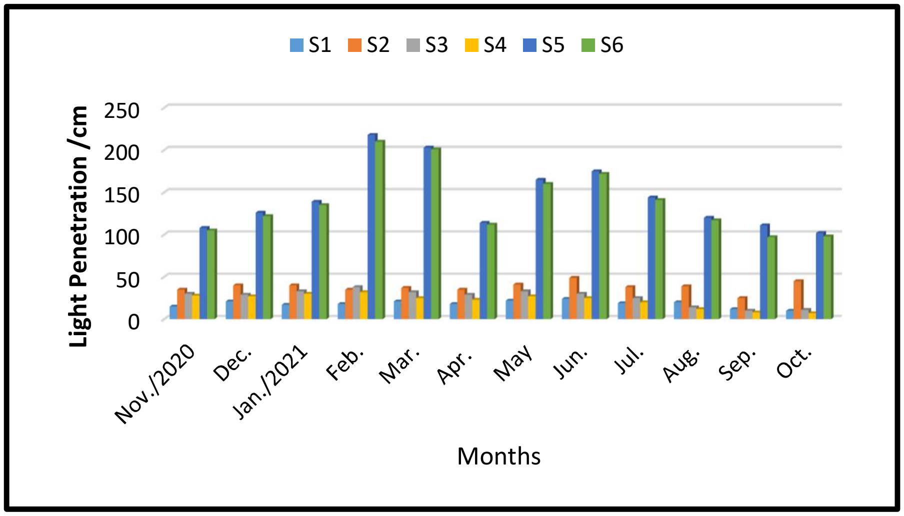


Fig. 4. Monthly light penetration/cm variations at study sites .**Figure 4.**

1.6. Nitrate (NO_3^-)

NO_3 concentrations in AL-Hammar ranged from 6.4 to 3.33 mg/L in February and August, with an average value of 5 mg/L. In Al-Chebiyesh, the values went between 5.54 mg/L in February and 3.21 mg/L in February and August, with an average value of 4.3 mg/L. In the Euphrates, the values ranged between 4.82 and 2.3 mg/L in February and August respectively, with an average of 3.32 mg/L (Fig. 5). Statistical analysis showed a significant difference *($p \leq 0.05$)*.

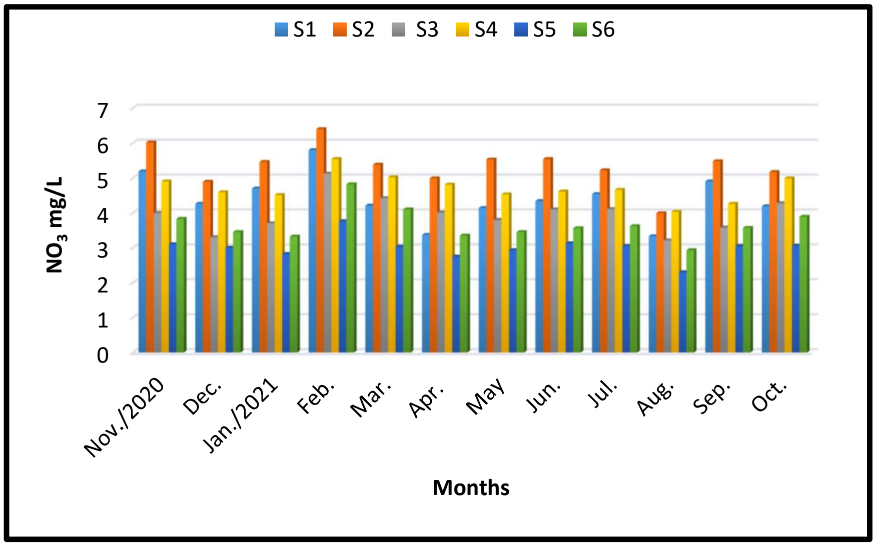
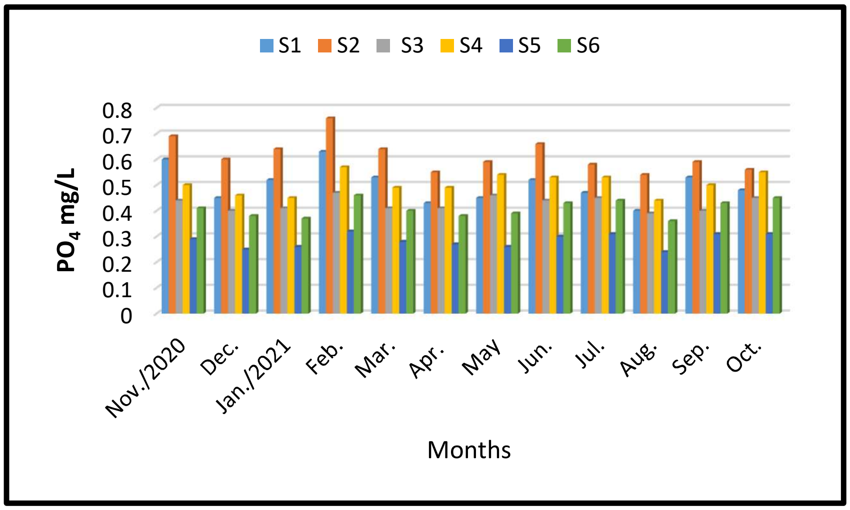


Fig. 5. Monthly variations of the Nitrate NO_3 at study sites

1.7. Orthophosphates (PO_4^{-3})

The highest and lowest concentrations ranged between 0.76 and 0.4 mg/L in February and August in AL-Hammar and 0.57 and 0.39 mg/L during February and August in Al- Chebiyesh, whereas 0.46 and 0.24 mg/L in Euphrates in February and August. The general average was 0.56, 0.46, and 0.34, respectively (Fig. 6). Statistical analyses showed that a difference ($p \leq 0.05$) between stations was insignificant.



1.8. **Chlorophyll-*a***

Fig. 7 shows that the highest values of Chl-*a* (19.13, 16.01, and 15.06 µg/L) were recorded in September, and the lowest values (6.2, 5.2, and 5.01 µg/L) were recorded in February. The general average was 11.16, 9.34, and 5.55 µg/L in AL-Hammar, Al-Chebiyesh, and Euphrates respectively. Significant differences ($p \leq 0.05$) were found among months.

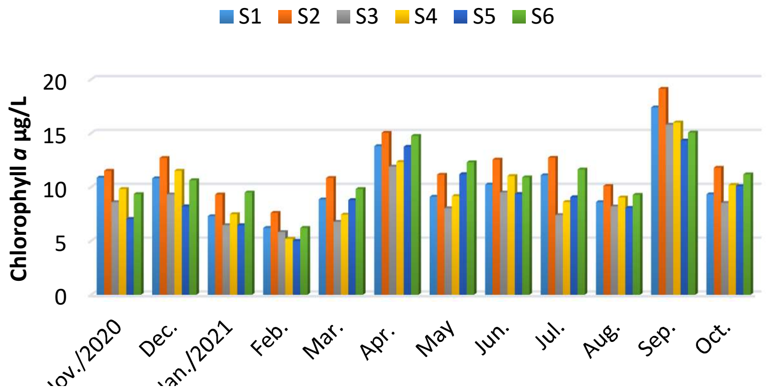


Fig. 7. Monthly variations of Chlorophyll-*a* at study sites

1.9. Plant Biomass

Fig. 8 shows monthly changes in submerged plant biomass in stations containing it (S_1, S_3, and S_5). The highest values (230.5, 381.4, and 1120.6 gm/m^2) were in April, April, and August, respectively. The lowest values (40.89, 82.7, and 795 gm/m^2) were in October, October, and February. The average is 206.18, 553.95, and 1001.85 gm/m^2 in AL-Hammar, Al-Chebiyesh, and Euphrates, respectively. Significant differences ($p \leq 0.05$) were found among months.

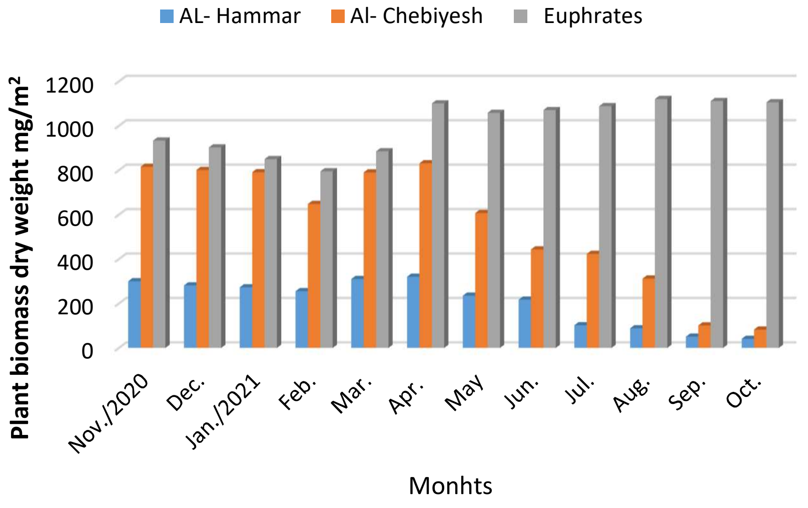


Fig. 8: Monthly variation of submerged plant biomass in S1, S3, and S5

1.10. Zooplankton Biomass Wet Weight

The highest values of zooplankton Biomass were (100.7, 60.95, and 42.9) mg WW m^{-3} in stations containing plants, whereas (128.31, 73.8, and 53.41) mg WW m^{-3} in those without plants in November. While lowest values were (4.61, 10.8, and 4.12) mg WW m^{-3} in stations that contain plants and (3.4, 11.4, and 9.3) mg WW m^{-3} in stations without plants in February in AL-Hammar, Al-Chebiyesh, and the Euphrates, respectively (Fig. 9). Significant differences ($p \leq 0.05$) were found among months

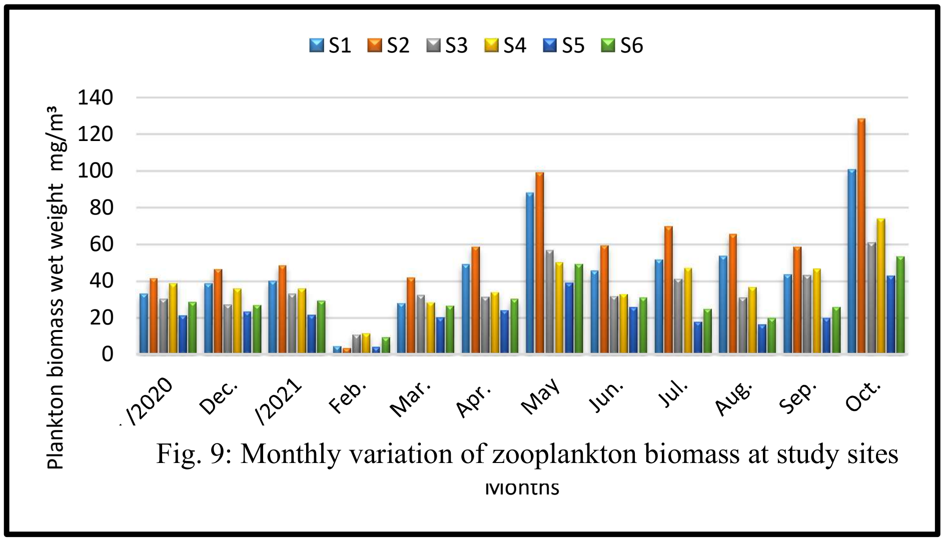


Fig. 9: Monthly variation of zooplankton biomass at study sites

1.11. Zooplankton Biomass Dry Weight

Zooplankton biomass at the highest values ranged from 7.61, 6.2, and 3.38 mg DW m^{-3} to 9.3, 7.7, and 3.93 mg DW m^{-3} in October in stations with and without plants, respectively. The lowest values ranged from 2.61, 1.2, and 1.3 38 mg DW m^{-3} to 2.8, 1.9, and 1.75 38 mg DW m^{-3} in February in stations with and without plants in AL-Hammar, Al-Chebiyesh, and the Euphrates, respectively (Fig. 10). Significant differences ($p \leq 0.05$) were found among months.

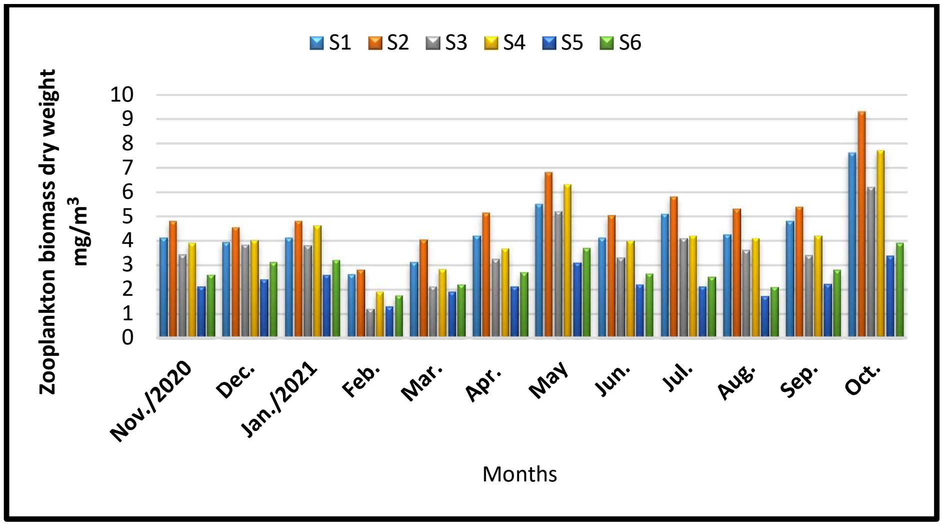


Fig. 10: Monthly variation of zooplankton biomass at study sites

1.12. Zooplankton Biomass Displacement Volume

Zooplankton biomass as displacement volume ranged from 0.92, 0.53, and 0.4 mL/m^3 to 1.01, 0.61, and 0.43 mL/m^3, with the highest value in October in stations with and without plants respectively. The lowest value ranged from 0.21, 0.15, and 0.08 mL/m^3 to 0.25, 0.2, and 0.11 mL/m^3 in February in stations with and without plants, respectively (Fig. 11). Significant differences ($p \leq 0.05$) were found among months.

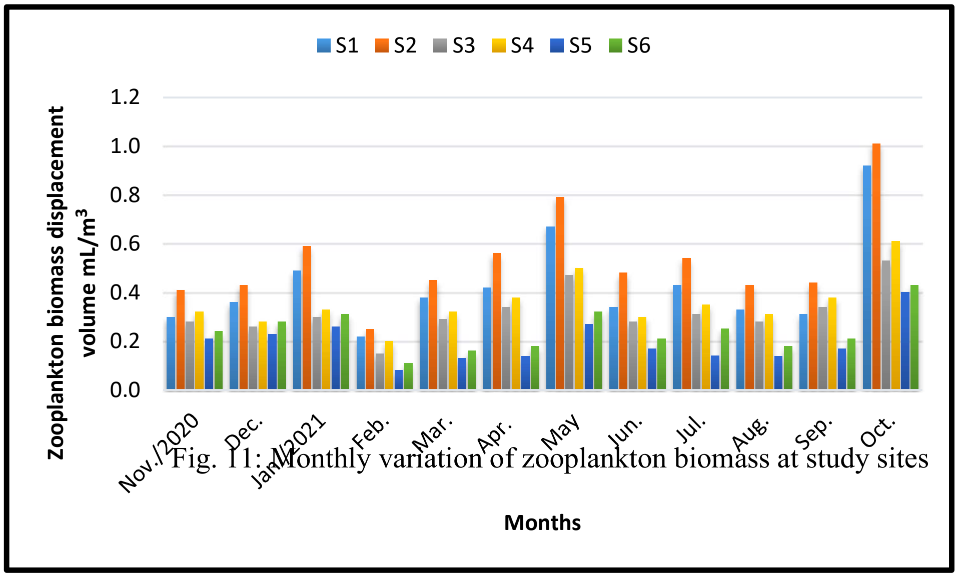


Fig. 11: Monthly variation of zooplankton biomass at study sites

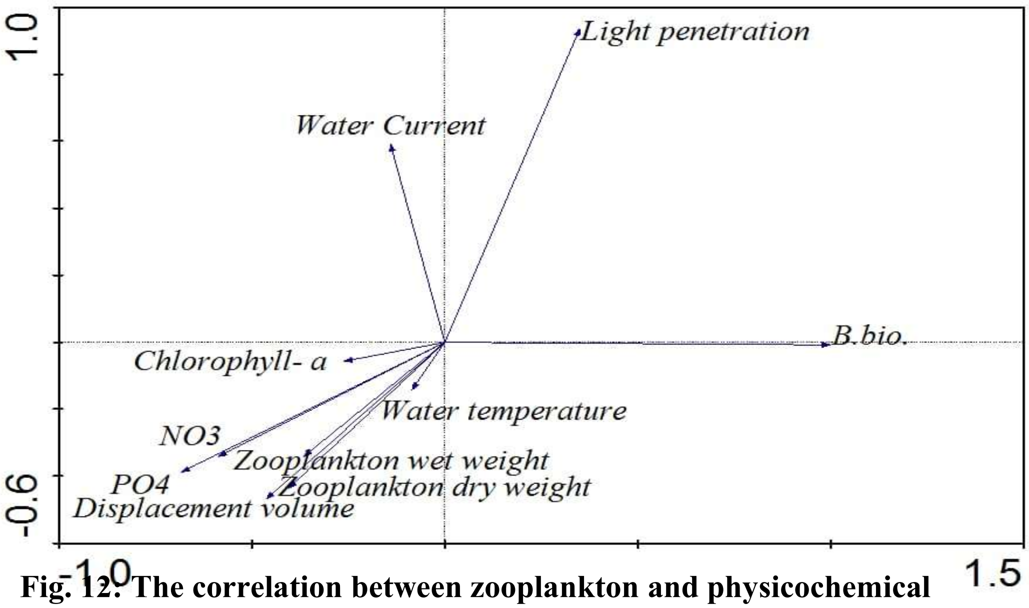


Fig. 12: The correlation between zooplankton and physicochemical variables by using PCA analysis .

Discussion

The zooplankton community is an essential component of aquatic ecosystems that are affected by biotic interactions, predation, and competition for food resources (Neves *et al*., 2003). Its presence influences ecosystem dynamics (Bruce *et al*., 2006) as a major component of the food web as it plays a significant role in the chemical and biological cycles transporting energy and materials from primary producers to higher trophic levels (Karpowicz *et al*., 2021). The roles of microorganisms and aquatic plants in wetland ecosystems are closely related. They must be studied simultaneously rather than isolated (Rejmankova, 2011) to understand the nature of the work of that system.

It is difficult to determine the direct mechanism by which submerged macrophytes affect zooplankton biomass subject to several other environmental factors and their overlapping influences within water bodies. Aquatic plants influence the aquatic environment's abiotic parameters and impact relationships between organisms in the aquatic food web (Goldyn *et al*., 2015; Spoljar *et al*., 2012). The current study showed that plants could affect zooplankton directly and indirectly.

The study revealed that the presence of submerged macrophytes in some stations had a negative impact on zooplankton biomass in it. As a result, their average was higher in open water than inside the plant beds, which may serve as a haven for a variety of living organisms, whether invertebrates or vertebrates, feeding on zooplankton. Sukatar *et al*., (2020) stated that many aquatic organisms feed on zooplankton at least for a certain period of their lives. That submerged vegetation serves as a shelter for feeding, spawning, and breeding for fish (Persson and Eklov, 1995 Lammens, 1989). Katende (2004) mentioned that it is a refuge for small fish and thus is one of the main factors in structuring the fish community in shallow water bodies, as fish predation is among the main factors affecting zooplankton community in shallow lakes (Havens *et al*., 2015). Because predators affect the behavior of zooplankton (Tessier and Welser, 1991). Schriver *et al*. (1995) revealed that fish predation has less impact on the zooplankton community in the more structured environment of macrophyte beds,even small improvements in submerged macrophyte abundance may have a substantial positive impact on the zooplankton. Therefore, zooplankton may avoid the plant layer to avoid predation. Predators are essential in limiting zooplankton's spread (Kurbatova and Yershov, 2020). As Burks *et al*. (2002) indicated, some zooplankton may use open-water habitats during daylight hours and may be more abundant in these habitats. Compared with more habitat complexity, in addition to the direct influence through the impact on their food represented by phytoplankton, measured by Chlorophyll-*a*, which expresses phytoplankton biomass with its concentrations fluctuating depending on different species, an indirect effect also exists through the impact on their food (Yoder and Kennelly, 2003). Most researchers concurred that surface water communities' structure is organized from the bottom up, starting with nutrients and light that control phytoplankton. This is the first link in the aquatic food chain through the process of photosynthesis, which is controlled by zooplankton as one influences the other (Nwankwo, 2004; Jeppesen *et al*., 2003). Both are affected by environmental parameters (Chou *et al*., 2012).

Zooplankton indicators were directly related to the concentrations of each nutrient (NO_3 and PO_4) and Chl α. Their concentrations were lower in stations with submerged macrophytes than in other stations. Plants convert inorganic materials with water into organic through photosynthesis (Xun, 2020). Aquatic plants affect the nutritional resources of zooplankton through their effect on the nutrient balance (Kurbatova *et al*., 2018). The competitive advantage of plants depends on their ability to influence the cycle of nutrients in two ways. The first is to withdraw nutrients through their roots and leaves. The second is to reduce the ratio of nutrients emitted from sediments by reducing the current water speed, thereby reducing the available ones for other organisms (Madsen *et al*., 2001; Meerhoff *et al*., 2003; Szabo *et al.*, 2010).

Consequently, the rate of recycling nutrients from sediments is better in the absence of the plant (Horppila and Nurminen, 2003). It is a strong rival for nutrients and light with the phytoplankton community, which is the first biological community to react to differences in nutrient concentrations and is consequently inversely correlated with them (Mulderij *et al*., 2007; Swe *et al*., 2021). Plant shading may also explain the reduced abundance of phytoplankton in vegetation areas, at least in part (Ozimek *et al*., 1990).

Alternatively, some plant species, through a biological phenomenon known as Allopathy, may secrete many organic compounds as secondary metabolic compounds known as allelochemicals to the surrounding environment as an effective defense strategy against other photosynthetic organisms that compete for light and nutrients. Their release is strongly associated with competition for resources as environmental pressures often increase their production and affect the growth or functional aspects of the receiving species, among which are types of algae and thus inhibit its growth (Einhellig, 1995; Van donk and Van de bund, 2002; Cheng and Cheng, 2016). This phenomenon is important in the formation of communities in aquatic ecosystems (Addisie and Medellin, 2012) by targeting multiple physiological processes of metabolizing allelochemicals such as cell division and differentiation, respiration or binding to enzymes, thus disrupting their function as well as photosynthesis (Gross *et al*., 1996: Inderjit, 2003 and Belz and Hurle, 2004). Inhibiting or decreasing the rate of photosynthesis, which is the central physiological process of primary producers, causes a slower growth of competing plankton (Addisie and Medellin, 2012). In laboratory experiments, it has been shown that inhibiting phytoplankton growth from Before some species of aquatic plants has a relatively strong allelopathic capacity ranging from 80-50% (Mulderij *et al*., 2007). Some studies have explained the negative influence of submerged macrophytes on generic richness of phytoplankton may be mediated by herbivory in the presence of macrophytes. The negative effect of macrophytes on phytoplankton contrasts with the positive effect of macrophytes onother organisms (Declerck *et al*., 2005). Therefore, species of zooplankton that feed on algae and have a high selectivity of food items may not find enough food among plants (Kurbatova and Yershov, 2020). Hence, this study did not agreement with many global studies showing that zooplankton is more abundant within the aquatic plant community, except for Nakamura *et al*. (2008) and They and Marques (2019).

Monthly changes in zooplankton indicators values also confirmed that they are positively affected by phytoplankton and it negatively impact on the values of Chlorophyll-a, as zooplankton biomass is positively correlated with Chlorophyll-*a* (Terbiyik Kurt and Polat, 2013). Two peaks were recorded for zooplankton that followed the two peaks of Chlorophyll-*a*, where the lowest peak was during May, and the highest peak was during October.

Zooplankton indicators decreased to lowest values during February despite the increase in nutrient values during this month, which may be attributed to the decrease in temperature. This directly affects zooplankton growth and thus becomes unsuitable for their presence (Ranta *et al*., 1993). This was in line with the finding of Ajeel and Abbas (2013) and Shil *et al*. (2013). They indicated that the density of zooplankton is directly related to the water temperature or indirectly by altering the quantity and quality of their food, competition, and predation patterns (Abrusan, 2004; Jeppesen *et al*., 2014).

The values of zooplankton indicators differed in different environments as a result of the different environmental factors in them. They were higher in AL-Hammar and Al-Jabayish marshes than in the Euphrates River. The Marshes usually rich in nutrients height generally increases abundance and biomass through changes in lower trophic levels (Auer *et al*., 2004; Ahangar *et al*., 2012; Neves *et al*., 2015). In addition to the fact that the Euphrates water has the highest current speed compared with other environments, Redden *et al*. (2009) reported that the flowing waterbodies are generally unsuitable habitats for plankton. The reason is that the floating organisms are continually washed downstream.

Conclusions

This study showed that the presence of submerged macrophytes significantly impacts the variance of zooplankton biomass. In general, the zooplankton community was negatively impacted by the presence of submerged macrophytes. As a result, it is lower in stations with submerged macrophytes than in stations without them. The main reason is the changes in the water chemistry, particularly nutritional changes that impacted the primary product (phytoplankton), which in turn impacted zooplankton.

Acknowledgment

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