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Spatial distribution and population density of submerged aquatic vegetation in Shatt Al-Arab River

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Abstract

Submerged aquatic vegetation (SAV) is an integral component of aquatic ecosystems and provides essential habitats and ecosystem services. This study investigated the distribution and abundance of SAV in the Shatt Al-Arab River, located in Southern Iraq, and examined its relationship with changing environmental factors. Monthly surveys were conducted at three stations from October 2015 to September 2016 to assess the percentage cover of vegetation, biomass, and the physicochemical properties of water and sediment. Three SAV species belonging to the Potamogetonaceae family have been recorded. Canonical correspondence analysis showed a negative relationship between *Potamogeton perfoliatus* and depth/reactive phosphorus. The abundance of plants in this area was significantly lower than that reported in previous studies. Species richness and abundance were analyzed at all stations during the same period using biodiversity indices. The analysis revealed differences in species richness between the stations. This decline in abundance was likely due to increased salinity, nutrients, and anthropogenic pressures. This study demonstrates the impact of environmental changes on ecologically important SAV and emphasizes the necessity of implementing conservation and management strategies.

Keywords: Submerged aquatic plants; Distribution; Shatt Al-Arab River; Iraq

1. Introduction

Aquatic ecosystems are intricate networks of biotic and abiotic components that feature a rich diversity of plants and animals. Submerged aquatic plants constitute critical components of these systems and play both structural and functional roles. They act as foundational species, creating habitats that are essential for the sustenance of myriad aquatic organisms, including fishes, invertebrates, and birds. Beyond offering shelter and food resources, these plants are integral to maintaining ecological balance through processes such as nutrient cycling and sediment stabilization. They also serve as substrates for plankton, thereby playing a vital role in the primary productivity and food web dynamics [1] [2].

The role of submerged aquatic plants extends beyond habitat provision. Recent studies have highlighted the potential for phytoremediation. For instance, certain species have shown wastewater pretreatment capabilities, and their metabolic activities contribute to the reduction of pollutants in aquatic systems, while several studies focused on some algae as phytoremediator [3]. This adds an extra dimension to their ecological significance as they can be leveraged for environmental restoration projects aimed at mitigating pollution.

Despite their ecological importance, aquatic ecosystems are facing mounting threats that are largely attributable to human activities. The encroachment of human development into natural habitats and increased agriculture have led to a surge in nutrient loading and sedimentation. Anthropogenic changes in water chemistry, particularly elevated salinity,

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pose challenges for the long-term sustainability of these systems. These stressors have a cascading effect that disrupts the intricate equilibrium of aquatic ecosystems and threatens their biodiversity and functional integrity [4].

The spatial distribution and overall health of SAV are influenced by the complex interplay between environmental factors. These range from physical factors, such as temperature regimes, light availability, and water movement patterns to chemical factors, such as nutrient concentrations, salinity levels, and pH values. Biological factors, including grazing pressure, interspecies competition, and human intervention also play pivotal roles. One study emphasized the competition between submerged plants and algae, particularly in light-limited environments, and showed that biotic interactions can significantly affect plant distribution and abundance [5].

In the wake of these ecological challenges and complexities, this study aimed to investigate the impact of environmental variables on submerged aquatic plants in selected locations along the Shatt Al-Arab River. By examining how these myriad factors collectively shape the spatial distribution and health of these plants, we aimed to provide valuable insights that could guide future conservation and management strategies for aquatic ecosystems.

2. Material and methods

2.1. The study area

The Shatt Al-Arab River consists of the confluence of the Tigris and Euphrates Rivers in Qurna, north of Basra city, and then flows in a southeastern direction to pour into the Arabian Gulf. Today, it is an extension of the Tigris River after the Euphrates are closed. The Shatt Al-Arab River is 200 km long with an average depth of 3-15 m. The Shatt Al-Arab River is characterized by the presence of tides that occur twice a day and whose source is the Arabian Gulf.

Three stations in the Shatt Al-Arab River were selected from November 2015 to September 2016 (Fig.1): the first station (30.345350 N, 47.461260 E) is called Al-Jazeera Al-Muhammadiyah, the second (N30.502609, 47.861353 E) is called Al-Salihiya, and the third (30.466939 N, 47.925735 E).

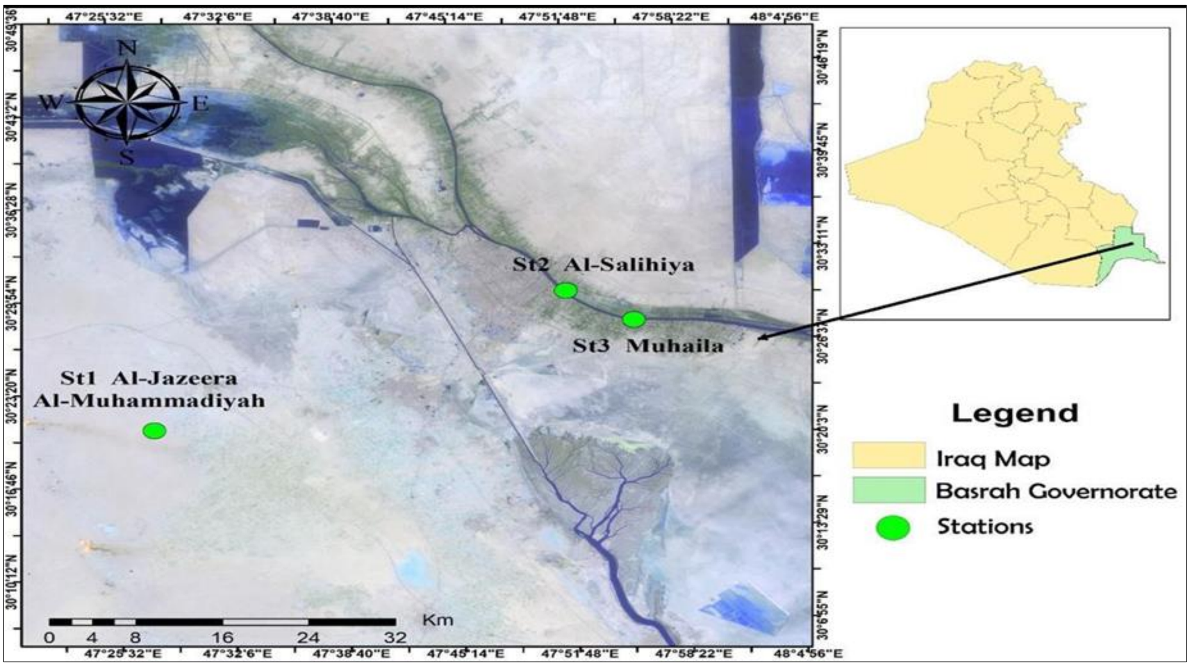

Figure 1 Map of study station in Shatt Al-Arab

2.2. Environmental variables

A simple thermometer was used to measure the air and water temperatures, and the water pH was measured using a Wissenschaftlich Technische Werkstatten (WTW) model 3110. Electrical conductivity was measured using a Wissenschaftlich Technische Werkstatten (WTW) 3310. Dissolved oxygen was measured using Wissenschaftlich Technische Werkstatten (WTW) model 3205.

A Turbi direct meter was used to measure turbidity and a Secchi disk with a diameter of (30 cm) was used to measure light penetration. The water depth was measured using a long stick and measuring tape. Reactive phosphorus was measured using a Spectrophotometer type UV-VIS / T80 at a wavelength of 885 nm [6]. Nitrate was measured using a UV-VIS/T 80 spectrophotometer at 220 and 275 nm [7].

The sediment samples were analyzed for pH, electrical conductivity (EC), phosphorus content, and organic matter content.

Plant samples were measured for their presence, biomass, vegetation cover, and biodiversity indices (Simpson's diversity index, Shannon's diversity index, Jaccard coefficient, and Berger-Burker index).

- Simpsons diversity Index (D) = $\sum ni(ni-1)/N\ (N-1)$
  - ni: Number of individuals of each plant species
  - N: The total number of individuals counted
- Shannon's diversity Index (H) = $-\sum pi\ \ln pi$
  - Pi: The ratio of the number of individuals of a plant species to the number of all species
  - Ln: Natural logarithm
- $J= (a/a+b+c)*100$
  - J: Jaccard coefficient
  - a: Number of species present in both communities studied.
  - bNumber of species present in the first community but not in the second community.
  - c: The number of species present in the second community that are not present in the first community.
- Berger-Parker = n/N
  - n: Number of individuals of the dominant species
  - N: The total number of individuals in the sample

2.3. Statistical Analysis

Descriptive statistics provided insights into environmental variables, while correlation and ANOVA analyses identified significant relationships and station-specific variations using the SPSS software. Canonical Correspondence Analysis (CCA) was used to assess the connection between environmental factors and plant species. Biodiversity indices were statistically analyzed to detect differences in species diversity.

3. Results

Table 1 shows the seasonal changes in the water temperature, which ranged from 15.2-31.2 °C. The highest EC value of 8.3 mS/cm was recorded during autumn at the third station, whereas the lowest value of 4 mS/cm was recorded at the first and second stations. The pH ranged from 7.7. - 8.3, The value of dissolved oxygen was 4.5 mg/L in the summer in the third station while the highest value was 8.6 mg/L in the winter in the second and third stations. The water ranged from 73.3-166 cm. The seasonal turbidity and transparency were also measured, with the lowest value of 17.9 NTU and 27.7 cm respectively, while the highest values were recorded at 51.9 NTU and 70 cm in winter and summer, respectively.

Seasonal changes in nutrient concentrations NO3- and $PO4^{-3}$ have recorded low values of 117.9 ug/l and 5.5 ug/l in the winter and spring respectively, while their highest value of 430 ug/l and 7.8 ug/l in the autumn.

Table 2 shows the seasonal changes in pH of sediment ranging from 7.8-8.1 and EC of sediment ranged from 1.1-1.8 mS/cm, Seasonal changes in reactive phosphorus were recorded ranging from 8.8-39.1 ug/L, changes in organic matter ranged between 6.4-13.4%.

Table 1 Seasonal variation of water parameter in the Shatt Al-Arab stations during study period

Measurement	Unit	Season	1	2	3
WT	C	Winter	15.2	18.2	18.6
		Spring	23.7	25	25.4
		Summer	30	31	31.2
		Autumn	24	27.6	28.6
DO	mg/L	Winter	7.8	8.6	8.6
		Spring	5.2	6.6	5.6
		Summer	5	5.1	4.5
		Autumn	7.6	7.7	8
EC	mS/cm	Winter	7.9	6.2	6.7
		Spring	5	4	4.1
		Summer	4	4.7	4.6
		Autumn	8	7.9	8.3
pH	_	Winter	7.9	8.2	8.3
		Spring	8	8.1	8
		Summer	7.7	8	8
		Autumn	8	7.8	8.2
$PO4^{-3}$	µg/l	Winter	6	6.8	7
		Spring	5.5	6.4	6.7
		Summer	6.8	7.1	7.8
		Autumn	6.7	7.4	7.8
NO_3	µg/l	Winter	119	117.9	119.4
		Spring	124	128.5	128.4
		Summer	151.6	151	151.5
		Autumn	430	335.2	361.9
Depth	cm	Winter	73.3	83.3	56.6
		Spring	86.6	103.3	47.6
		Summer	113	136.6	63.3
		Autumn	113.3	166	53.3
Transparency	cm	Winter	48.3	50	47.5
		Spring	46.6	58.3	27.7
		Summer	63.3	70	36.8
		Autumn	58.3	50	42.7
Turbidity	NTU	Winter	42	51.9	120
		Spring	23.5	17.9	123.3

		Summer	27.9	21.3	128.3
		Autumn	29.4	22.3	140

Table 2 Spatial and temporal variation of sediment parameter in Shatt Al-Arab River during the study period

Measurement	Season	1	2	3	Average
EC	Winter	1.6	1.5	1.5	1.5
	Spring	1.4	1.6	2	1.6
	Summer	1.1	1.6	1.4	1.3
	Autumn	1.7	1.8	1.6	1.7
pH	Winter	8	7.8	7.9	7.9
	Spring	7.8	8	8	7.9
	Summer	8.1	7.9	8	8
	Autumn	8	8.1	7.9	8
TOC	Winter	13.3	13.4	10.3	12.3
	Spring	9	9.5	9.1	9.2
	Summer	6.4	10.4	11.1	9.3
	Autumn	10.5	10.5	10.6	10.5
$PO4^{-3}$	Winter	14.4	12.1	10.6	12.3
	Spring	34	32.2	33.4	33.2
	Summer	31	28.4	39.1	32.8
	Autumn	9.9	8.8	18.1	12.2

Table 3 Comparison of some physical and chemical properties of water in the study stations with previous studies

Temperature (°C)	Depth (cm)	Light penetration (cm)	Turbidity NTU	EC (mS/cm)	pH	DO (Mg/l)	Nitrates (µg/l)	$PO4^{-3}$ (µg/l)	Previous studies
—	—	—	39.3-9.8	18.45-1.46	8.57-7.26	11.5-5.8	88.50-7.90	2.12-0.01	[8]
31-15	254-150	—	—	3.7-2.8		10.3-7	13.5-0.3	0.1-0.03	[9]
28.5	—	—	—	4.1	7.3	5.8	620	0.35	[10]
—	—	—	97-2	2.85-1.33	8.65-7.10	—	110.12-3.54	5.78-0.43	[11]
29-14	—	140-68	30-10	10.5-3.2	8.3-7.4	9.3-3.8	3871-550	6.9-2	[12]
33.6-10.2	—	—	—	6.1-2.9	8.2-7.6	11.5-5.9	0.86-0.26	2.91-0.24	[13]
32.3-14.2	200-60	90-23	68.3-12.8	12.4-2.8	8.51-7.5	9.7-4.5	569.42-106.17	9.13-4.93	current study

Three plant species of submerged aquatic species were recorded (*Potamogeton crispus*, *Potamogeton pectinatus*, and *Potamogeton perfoliatus*) in some seasons belonging to one family, and the percentage of their vegetation cover was calculated as the highest proportion of *P. perfoliatus* (38%), followed by *P. crispus* (35%), while *P. pectinatus* had the lowest ratio (27%) (Fig. 2). The highest biomass of *P. crispus* was recorded at the second station, whereas the lowest biomass of *P. perfoliatus* was recorded at the same station (Fig. 3).

The relationships between environmental variables and species were statistically calculated using CCA. A negative relationship was observed between *P. perfoliatus* and the water depth. A negative relationship was also observed between *P. perfoliatus* and reactive phosphorus, a negative relationship between dissolved oxygen and temperature, and a positive relationship between NO_3 and EC (Fig. 4).

Table 4 shows the values of biodiversity indices at the study stations. The third station was the least diverse, while it was the most equal to the first and second stations, and the second station was the most dominant. The number of recorded species was lower than that recorded in historical data (Table 5).

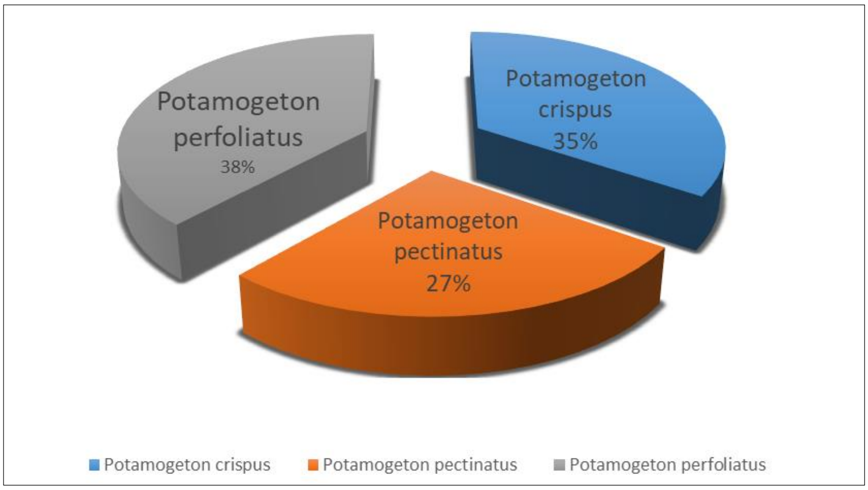

Figure 2 Percentage of vegetation cover of Aquatic plants in Shatt Al-Arab River

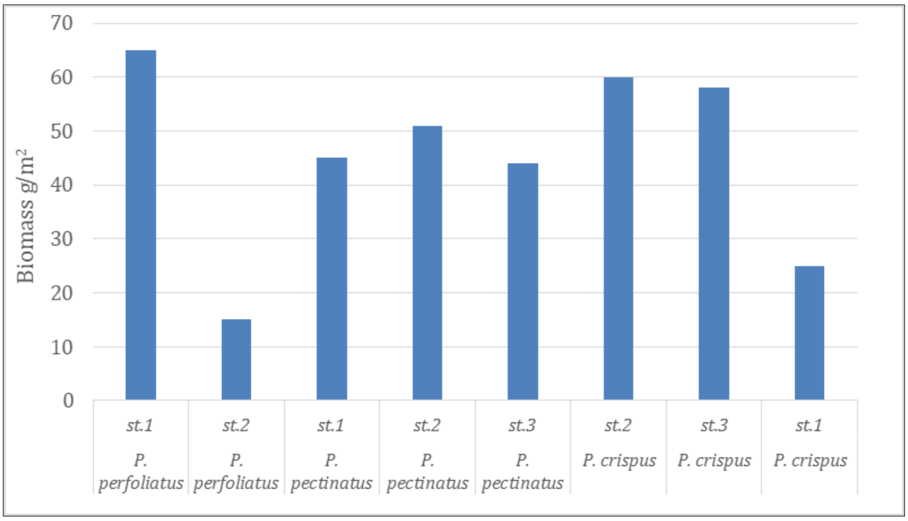

Figure 3 Biomass of Aquatic plants in Shatt Al-Arab River

Table 4 Values of biodiversity indices of Submerged plants in Shatt Al-Arab River

biodiversity indices	**Stations**		
Index	St.1	St.2	St.3
Shannon H'	0.885	0.803	0.678
Shannon E	0.806	0.731	0.978
Simpson 1/D	2.097	1.952	1.966
Berger-Parker 1/*d*	7.1	1.517	1.708

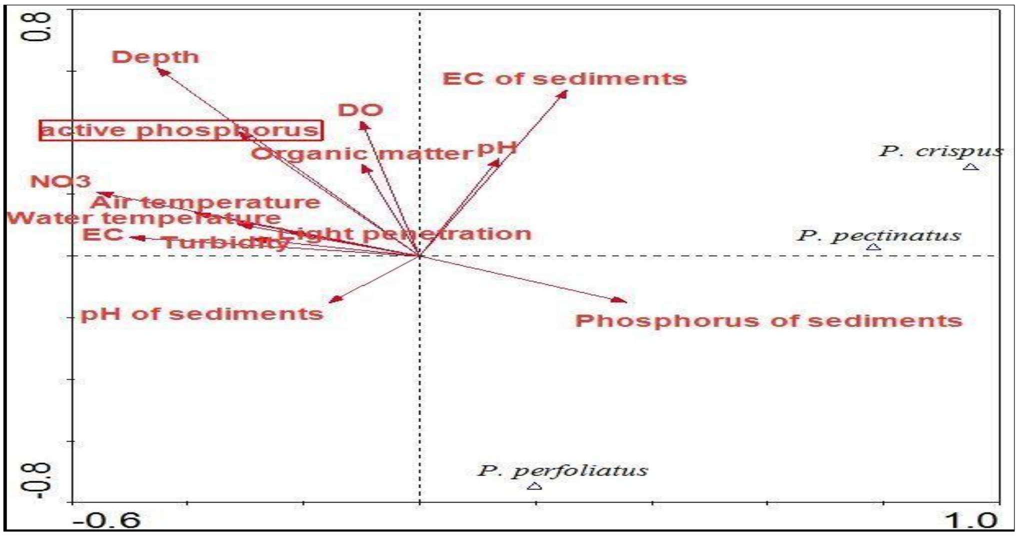

Figure 4 Relationship between aquatic plant species and biological environmental characteristics determined using CCA

Table 5 Comparison of the presence of submersed aquatic plants in the study stations with previous studies

Plant species	**[14]**	**[15]**	**[16]**	**[9]**	**present study**
Ceratophyllum demersum	+	+	+	+	
Chara vulgaris					
Hydrilla verticillata			+	+	
Myriophyllun spicatum					
Najas marina					
Najas minor					
Potamogeton crispus	+	+	+	+	+
Potamogeton pectinatus	+	+	+		+
Potamogeton perfoliatus		+	+	+	+
Vallisneria spiralis	+	+	+	+	
Number of species	4	5	6	5	3

+ mean presence

4. Discussion

The change in the Iraqi aquatic environment is evident through the variation in water quality from one period to another, which is reflected in the presence, vegetation coverage, and biomass of submerged aquatic plants as well as the role of biological and human activities that may affect the presence and distribution of submerged aquatic plants.

Temperature is an important environmental factor that plays a role in the distribution of submerged aquatic plants and affects the chemical and physical properties of water [17]. The results of this study showed that there were differences in temperature values due to the different seasons during the year and the length of the day as well as the difference in water movement in the tides and ebbs.

The pH values showed an alkaline trend owing to the alkaline nature of Iraqi water, which is a distinctive characteristic of Iraqi water owing to the nature of the land in Mesopotamia [18]. The slight variation in pH values is due to the buffering of water resulting from its high carbonate and bicarbonate content [19].

The values of electrical conductivity led to a decrease in the growth and diversity of aquatic plants in freshwater [20], and the seasonal difference in the values of conductivity was due to the arrival of the Karun River to the Shatt Al-Arab River, which drains agricultural land from the Iranian side. The difference between precipitation and evaporation leads to an increase or decrease in salinity [21] [22].

Seasonal differences in depth values were a result of low discharge from the Tigris River and semi-closure of the Karun River.

Light penetration is an important characteristic of the water surface as it directly affects the growth and distribution of submerged aquatic plants [23]. The variation in light pentation values during the seasons was due to the variations in turbidity and increase in pollutants which in turn helps the growth of plankton and thus reduces light pentation, in addition to the Shatt Al-Arab containing large amounts of sediment [24] [25]

Turbidity is affected by the number of suspended and dissolved particles, light intensity, water movement, and prevailing weather conditions [26]. The variation in turbidity values during the seasons was due to the lack of SAV, movement of boats, and rainfall.

This difference in dissolved oxygen concentration may be due to changes in the water level and other environmental factors, as well as vital processes such as photosynthesis and respiration, along with the presence of sufficient concentrations of dissolved oxygen due to tidal movement, which allows the oxygen present in the atmosphere to dissolve during gas exchange [27].

Nitrates are present in large quantities in nitrogen fertilizers and introduced into the water surface through animal and human waste [28]. The variation in nitrate values is due to several factors, including rainfall and its consumption by aquatic plants and phytoplankton [29].

The concentration of active phosphorus in a water body depends on the nature of the land surrounding the water body, population density, and agricultural waste [30]. The seasonal variation in the values of active phosphorus is due to water-draining agricultural lands laden with phosphate fertilizers, as well as rainfall.

Three species of submerged aquatic plants have been recorded in the study area. The reason for the small number of recorded plant species may be the continuous changes that occur in aquatic environments, such as sudden increases in salinity and nutrient levels. The diversity among the Shatt Al-Arab River stations was higher at station one, which explains why it was less affected by changes in water quality in addition to human activities.

The salts found in sediments affect the osmotic efficiency of plants, which plays a role in nutrient uptake, and thus affects their presence and distribution [31]. The difference in the electrical conductivity values of the sediments was due to the difference in the water discharge.

The pH of the sediment was within the alkaline range during the study period because of the nature of Mesopotamia [18]. The difference in the values of active phosphorus in the sediments may be due to the presence of a population around the study area and the increase in human waste, or it may be due to the discharge of water from the agricultural lands surrounding the area, which is loaded with phosphate fertilizers.

Organic matter (OM) is an important source of nutrients for plants and plays an important role in improving the physical, chemical, and biological properties of the soil. It is also considered a major factor in soil productivity and fertility by providing nutrients to the soil and increasing its ability to retain water [32]. The results of this study showed variations in organic matter values, which may be due to the difference in temperature during the seasons and their relationship with the activity of microorganisms.

Comparing the results of this study with those of previous studies, there were some compatible results, such as temperature, pH, and dissolved oxygen, although the study recorded high values for electrical conductivity and nutrients. (Table 3).

The lack of species recorded during the study period might have been due to continuous changes in the aquatic environment, such as a sudden rise in salinity values and nutrients.

This study showed that the percentage of vegetation cover for *P. crispus* and *P. pectinatus* was higher than that recorded in previous studies, which may be attributed to the recent improvement in salinity of the Shatt Al-Arab River.

This study showed a difference in the biomass values of plant species, which may be due to high salinity, sediment conditions, and lighting, which are important factors affecting the biomass of submersible aquatic plants [33] [34].

5. Conclusion

In conclusion, our study on submerged aquatic vegetation (SAV) in the Shatt Al-Arab River revealed significant fluctuations in environmental variables and highlighted the influence of high salinity levels on SAV distribution. Despite recording only three SAV species, our findings align with the historical data for some variables. However, increased electrical conductivity and nutrient levels indicate ongoing environmental changes. This study underscores the urgency of implementing conservation measures to protect these vital aquatic plants and maintain the ecological equilibrium of the Shatt Al-Arab River ecosystem.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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