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FINAL REPORT: APPENDIX C
MARSHLANDS MONITORING ACTIVITIES

AGRICULTURE RECONSTRUCTION AND DEVELOPMENT PROGRAM FOR IRAQ
ARDI

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1.0 Introduction & Background

Iraq's Mesopotamian marshes are considered by many to be the "cradle of western civilization" and have often been referred to as the Garden of Eden. The word Mesopotamia means "between rivers" and refers to the location between the Tigris and the Euphrates. The marshes were once the largest wetlands in southwest Asia and covered more than 15,000 square kilometers (km^2), an area nearly twice the size of the original Everglades. However, by the year 2000 less than 10% of the area remained as functioning marshes due to a systematic plan by the Iraqi government to ditch, dike, and drain the marshes (Richardson and Hussain 2006).

The marshes were also once famous for their biodiversity and cultural richness. They were the permanent habitat for millions of birds and a flyway for millions more migrating between Siberia and Africa. More than 80 bird species were found in the marshes in the last complete census in the 1970s. Populations of rare species like the marbled duck (*Marmaronetta marmarometta*, 40%-60% of the world population) and the Basrah reed warbler (*Acrocephalus griseldis*, more than 90% of the world population) were thought to be close to extinction but have recently been seen in a winter bird survey. Coastal fish populations in the Persian Gulf used the marshlands for spawning migrations, and the marshes also served as nursery grounds for penaeid shrimp (*Metapenaeus affinis*) and numerous marine fish species. The marshlands also once served as a natural filter for waste and other pollutants in the Tigris and Euphrates Rivers, protecting the Persian Gulf, which has now become noticeably degraded along the coast of Kuwait (Richardson et al. 2005).

The Iraqi marshlands, once one of the world's largest wetlands ecosystems, have been undergoing extensive restoration. This process was implemented to remedy the damage done between 1991 and 2003, when the marshes were drained and reduced to a tenth of their original size. Reflooding efforts after 2003 have now restored the marshlands to one-third their original size, making them now the largest wetland area in the Middle East, covering 8000 square kilometers (UNEP 2005).

These marshlands are both regionally and globally significant as cultural, political, and economic resources. Through restoration activities, they are, once again, rich in aquatic productivity and provide a natural refuge for aquatic organisms, especially fish and birds. They play a vital role in the maintenance of biodiversity in the Middle East, due to their unique ecosystem characteristics and isolation from other comparable systems. Additionally, many refugee and internally displaced families of Marsh Dwellers are returning to their homes in response to increased economic opportunities.

1.1 Goals of the Project

In support of the marshlands restoration, the Agriculture Reconstruction and Development Program for Iraq (ARDI) established monitoring teams to assess the success of wetlands restoration efforts and to collect data that will guide the Iraqi government's policies and decisions regarding the area. ARDI's monitoring activities provided an assessment of where the inundation occurred, how it shifted over time, and what responses occurred in the ecology of water, soil, vegetation, and wildlife—and in the society and economy of the region—as a result of the newly increased flows. USAID, through ARDI’s marshlands component, assisted the restoration process.

1.2 The key objectives of the monitoring program were to:

- Gain an accurate understanding of the present restoration status of the marshlands;
- Develop protocols for monitoring marsh restoration that can be institutionalized by the Ministry of Water Resources, Ministry of Environment, and Ministry of Agriculture;

- Assist the Ministry of Water Resources and Ministry of Environment in determining the best areas for inundating and restoration in the future;
- Establish baseline information about the reflooded marshes;
- Characterize the immediate and long-term effects of inundation on water, soil, and biotic resources through:
  - Assessment of the changes in biodiversity, ecosystem structure, functioning, and human use;
  - Quantification, to the extent possible, of long-term restoration sustainability;
  - Development of a long-term database;
  - Characterization and definition of the properties of a sustainable marshland ecosystem;
  - Provision of future working protocols for the local and scientific media;
  - Preparation of guidelines for future restoration efforts and suggestions for future plans concerning the development of agriculture and fisheries;
  - Recognition of the effect of restoration on the livelihoods of Marsh Dwellers.

Another goal of the monitoring program was to measure the marshland ecosystem functions, according to guidelines by Richardson and Nunnery (1998). These can be summarized as: hydrological flux and water storage, plant productivity, biogeochemical cycles and nutrient storage, organic matter decomposition, and community biodiversity. Other program goals were to examine species community structure (species composition), to recognize monthly changes in essential ecological indices (diversity, richness; evenness), and to develop a similarity index between restored wetlands and the remaining natural parts of the Al-Hawizeh marsh.

Specifically, this report includes comparison of data collected in 2005 and 2006 and an analysis of:

- Water quality characteristics;
- Phytoplankton productivity as indexed by chlorophyll-a concentration and species identification;
- Zooplankton biomass and species identification;
- Aquatic macrophyte densities, cover percentage, frequency, seasonal and annual biomass harvest yield;
- Macroinvertebrates densities, either on aquatic plants or the substratum, seasonal changes in ecological indices, and species identification;
- Fish abundance, species composition, and other ecological indices, as well as fishing catch rate;
- Spawning activities of fish and identification of species; and
- Water birds species identification, frequency, and related ecological information.

1.3 Methods and Sampling Locations

1.3.1 Monitoring Plan

The main monitoring plan was formulated in numerous meetings between DAI experts and Iraqi scientists in Basrah, after field visits to the marshes in 2003 and 2004. The plan's final version was developed by Professor Curtis Richardson (scientific consultant of the project), and consisted primarily of monthly and seasonal field sampling of key water quality parameters and biological indicators, as well as essential biannual and annual measurements of plant and algal productivity and soils. In addition, lab work was done at the University of Basrah’s labratories, newly refurbished and equipped by USAID. Key components measured were:

- Primary production and community structure via chlorophyll-a concentrations in phytoplankton, annual plant harvest yield, density and cover of aquatic plants, density of macroinvertebrates on bottom sediments and aquatic plants.

- Identification of the structure of the marsh ecosystem through species composition of the restored marshes, and comparison of those results with historical records before desiccation.
- Recognition of the monthly and seasonal changes in marsh ecosystem diversity.
- Marsh water resources quality each month.
- Annual marsh soil quality measurements.
- Estimation of decomposition rates of organic material in the marshes.
- Evaluation of the fish catches in the marshes.

Six stations were selected at different locations in the marshes. The monitoring team decided that those locations reasonably represent the ecological and environmental changes over time in the restored marshes. The site information is given in Table 1.1. To undertake the full task as designed, the following methodology was adopted. (See Appendix 6 for methods and supporting references):

- Monthly water quality included measurements of temperature (air & water) conductivity, salinity, TDS, pH, dissolved oxygen, nutrients (Total N, Total P, NO_3-N & NH_4-N), Na, SO_4-S, and HCO_3. We measured air and water temperature, DO, conductivity, salinity, pH, and TDS by using a YSI portable instrument (YSI 556MPS). Water flow and depth were measured using a Sontek instrument.
- Seasonal water quality samples were collected from the water sources of the monitored marshes and from the outlet. Water parameters measured were the same as in the monthly samples.
- Phytoplankton was gathered, using a 25 μm mesh size net, to determine the concentration of chlorophyll-a, total number of cells, and species.

- Zooplankton was collected, using a plankton net of 60 μm mesh size, to determine the major orders and number of individuals.
- Submerged and emergent aquatic plants were collected, using a 25 cm quadrat, to determine the species frequency, percentage of cover, and density.
- Macroinvertebrate samples were assessed on aquatic plants, utilizing a 25 cm quadrat. Benthos sampling was done using a grab sampler of 25 cm width.
- Fish were collected to identify species, abundance, diversity, evenness, and similarity among different marshes using several methods: (1) hiring a local fisherman with his tools (electrical device, cast net; fixed gill net), (2) using hand nets for the small specimens, and (3) purchasing supplementary samples from local fish markets.
- The numbers of bird species and individuals were counted by most of the team. Local markets were visited to monitor numbers of ducks for sale. Since the number of mammals was limited, no formal counts were done; however, the presence of species in each marsh was noted.
- A database was established to record all the data collected by different groups (tasks), and to make these data accessible and easy to utilize in future analysis.
- General observations of the prevailing ecological parameters, weather conditions, wind, numbers of fishermen, and new settlers were recorded on each sampling trip.

1.3.2 Monitored Marshes (Stations)

A total of six stations (2 in each marsh) were established at appropriate locations to provide a basis for the monthly sampling (Table 1.1). GPS readings and other details of those locations are shown in Table 1.1 and Figure 1.1.

Table 1.1. Marsh sampling locations in two restored and the natural Al-Hawizeh marsh.

Marsh	Station	GPS	Environment	Status
Al-Hawizeh	Um Alnaaj	N 31 38 30 E 47 35 21	Open Water	Natural station
Al-Hawizeh	Taraba	N 31 29 48 E 47 31 48	Dense Vegetation	Desiccated station
Suq Al-Shuyukh	Amia	N 30 51 41 E 46 38 13	Channel Water	Desiccated station
Suq Al-Shuyukh	Al-Wineas	N 39 51 50 E 46 40 42	Dense Vegetation	Desiccated station
East Hammar	Saddah	N 30 40 04 E 47 38 06	Tidal Sparse Vegetation	Natural station
East Hammar	Burkah	N 30 40 22 E 47 33 03	Tidal Open Water	Desiccated station

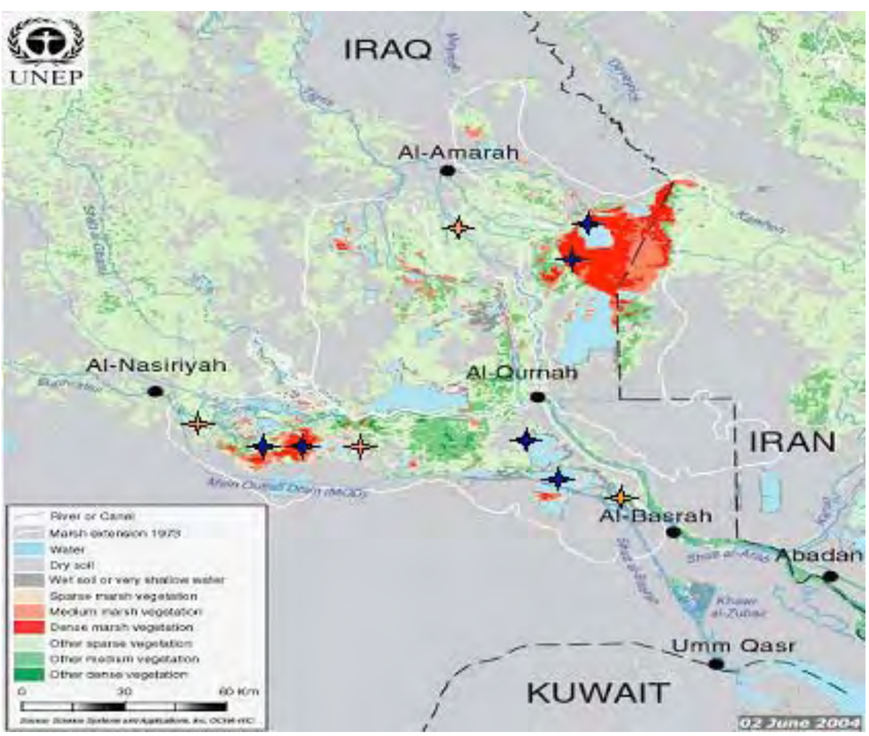


Figure 1.1. Map showing (solid black crosses) the general location of the pairs of sampling stations in Hammar marsh (East Hammar and Suq Al-Shuyukh) and the natural Al-Hawizeh marsh, and the input and output water stations (gold crosses).

Al-Hawizeh marsh: This marsh extends over the Iranian border on the west, but the major part lies in Iraq, where it is bordered on the east by the Tigris River and it's outflow waters. It was the only part of marshes to be left partly natural (undesiccated), leaving only about 10% of the total original marsh area intact. Two stations were selected for field studies and monitoring. The first was Um Alnaaj, which represents the natural environment, with open water extended to the Iranian side and several stands of *Phragmites australis* appearing like islands. Our station of record, according to GPS readings, was located at (N 31 38 30, E 47 35 21). The actual field sampling sites were further away in the marsh (green island N 31 38 31, E 47 35 21, left side N 31 38 29, E 47 35 45). The second station was Taraba, as indicated by GPS (N 31 29 48, E 47 31 48). It was 20 km south of Um Alnaaj and represented the drained marsh now shallowly reflooded (in comparison with the first station). It had heavy growth of aquatic and emergent plants (*Phragmites australis* & *Certophyllum demersum*) (Figure 1.1).

Suq Al-Shuyukh: This marsh is located south of Euphrates River, the source of its water. It had been completely desiccated, but was reflooded in April 2003. It represents the western part of the Hammar marsh. Two stations were chosen. The first was Amia station, after the union of Amia River and the marsh. Its location GPS reading is (N 30 51 41, E 46 38 13). The second station, Alwineas, was in the middle of the marsh, located at GPS reading (N 30 51 50, E 46 40 42). It was characterized by heavy growth of emergent and aquatic plants, especially *Phragmites australis* & *Ceratophyllum demersum* (Figure 1.1).

East Hammar Marsh: This eastern part of the huge original Hammar marsh receives its water from the Euphrates and Shatt al Arab Rivers. It was completely desiccated, except for the connection with the Karmat Ali River. This area was originally affected by the tidal regime of the Arabian Gulf. Two stations were chosen. The Saddah, GPS reading (N 30 40 04, E 47 38 06), represents a natural marsh environment. The second sampling station, Burkah, as indicated by GPS reading (N 30 40 22, E 47 33 03), was previously desiccated, but is now in open shallow water with scattered *Typha domingensis* islands and the aquatic plant *Myrophyllum verticillatum* (Figure 1.1).

Marsh River Inputs (Water Source): In order to study the input water quality entering the monitored marshes, one station was selected in each marsh at the source. The Al-Hawizeh marsh water source was theTigris River at the town of Qalat Salah, GPS (N 31 31 51, E47 16 45). The Suq Al-Shuyukh marsh water source was the Al Haffar River (a tributary of the Euphrates), GPS (N 30 53 49, E46 28 03). The East Hammar's water source was the Shatt al Arab River at Karmat Ali, GPS (N 30 34 29, E 47 36 51).

1.3.3 Field Activities Schedule

Our main field activities were performed monthly, with monitoring occurring at Al-Hawizeh, Suq Al-Shuyukh, and East Hammar (2 stations in each marsh). Less intensive surveys were done as part of the monthly monitoring of water quality at the three marsh tributaries—the Tigris, Euphrates, and Shatt Al Arab Rivers.

1.3.4 Problems Encountered

Security was a problem for the sampling regimen. The threat of team members being kidnapped and held for ransom limited our activity, preventing the team from expanding its movements and taking extra samples in the marshes. Local inhabitants were suspicious about the purpose of our studies, which was not surprising, considering the horrifying events of past years. This made our activities difficult, and considerable effort was made—and much time spent—to convince them of the scientific and management aims of our studies. Minor, but limiting, problems occurred with the lack of several chemicals and of basic instruments needed to analyze of the samples.

1.4 Results and Key Findings of the Marsh Monitoring Program

1.4.1 Water Quality, Flow Rate, and Soils

The Iraq marshlands can be classified generally as oligohaline. The water quality values of each marsh depend on the water sources of either the Tigris, Euphrates, or Shatt Al-Arab Rivers. Water temperature exhibited large seasonal variations, with lowest winter temperatures about 10^{o}C, and summer highs over 30^{o}C—typical of the arid climate of southern Iraq. Water currents in the marshland play a substantial role, affecting light penetration through re-suspension of fine sediments.

All water parameters were found to be within ranges that would support growth of the historic main marsh species. The water of the restored marshes exhibited nearly the same quality recorded in historical times, except for higher nutrients and slightly elevated sodium at some locations. Water parameters of the monitored marshes showed the same seasonal variation as previous studies. Monitored marshes retained their role as a sedimentation sink, due to slow water currents. Water transparency remained high but not as good as in historic times. Higher nutrients support the restoration process of the marshes and improve primary productivity. Water leaving the monitored marshes was characterized by lower nutrients, indicating uptake by bacteria, phytoplankton, and macrophytes. Specific findings are:

Air and water temperature: Maximum temperature values were recorded during the summer months and lowest in winter months (Figures 1.2, 1.3). Variations in water temperature were synchronized with air temperature; again the maximum values were encountered in July and the lowest in January for all monitored stations (Figures 1.2, 1.3). All stations showed similar patterns, with minor differences in the fall of 2005. Water sources (Tigris, Euphrates and Shatt al Arab Rivers) showed the same temperature trends as the monitored marshes (figures not shown).

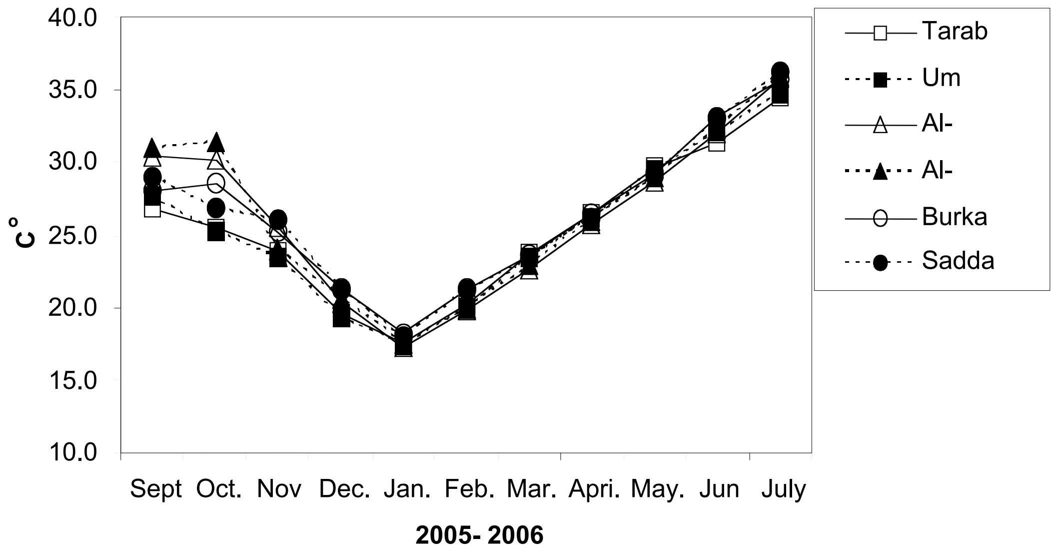


Figure 1.2. Mean monthly air temperature at study stations

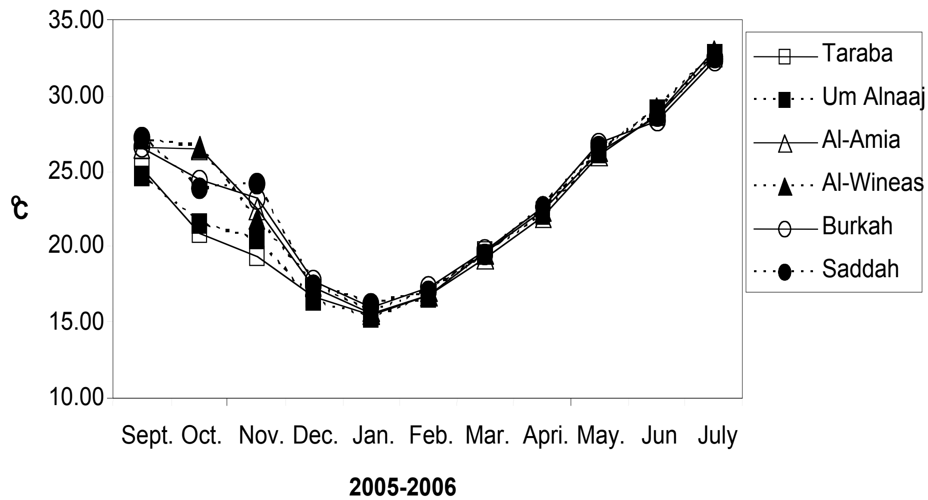


Figure 1.3. Mean monthly water temperature at study stations Sept. 2005-July 2006.

Salinity & conductivity (E.C): Monthly changes in salinity and conductivity values reveal three types of chemistry patterns. The first was that of the East Hammar, which is considered an oligohaline marsh (tidal marsh), compared to other two (Figures 1.4, 1.5). The second type appeared in Suq Al-Shuyukh marsh, and the third was Al-Hawizeh, a fresh water marsh. These trends were similar to those noted in the 2004-2005 studies (Richardson and Hussain 2006). The water sources had salinity and conductivity values showing the same trends as the stations/marshes, except that the Euphrates in spring months had higher salinity figures (data not shown).

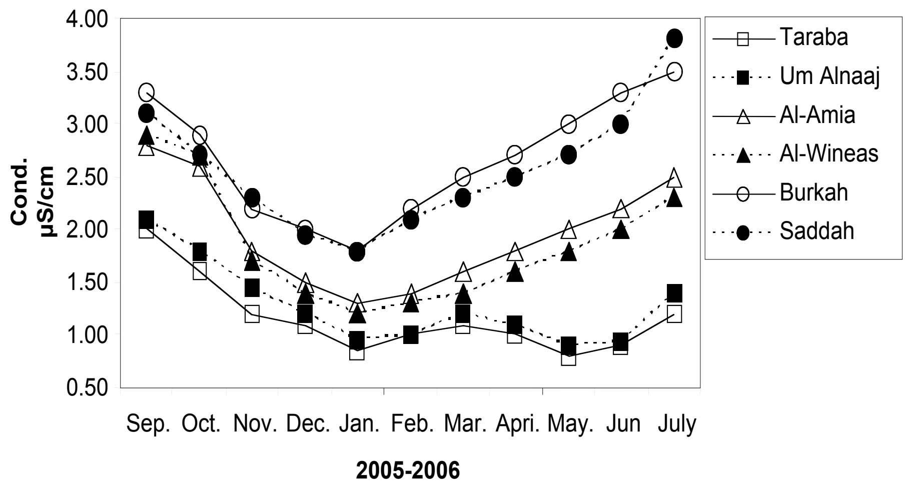


Figure 1.4. Mean monthly conductivity in study stations

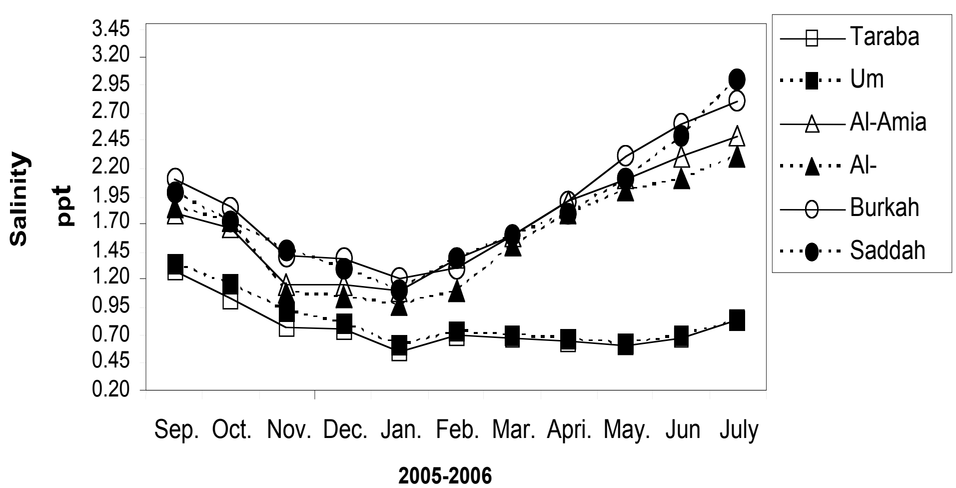


Figure 1.5. Mean monthly salinity in study stations

Total dissolved solids (TDS): The monthly changes in TDS at the Al-Hawizeh marsh stations (Um-Alnaaj and Taraba) were comparable to those of the Suq Al-Shuyukh stations (Al-Wineas and Al-Amia) (Figure 1.6). The highest values were recorded in East Hammar at the Saddah and Burkah stations. Two phases appeared, a winter-spring phase, in which the three marshes had similar low values, and the second a summer and fall phase, in which each station/marsh had its own pattern—the highest in East Hammar and the lowest in the Al-Hawizeh marsh. The Shatt Al-Arab water source had the same seasonal behavior as the three monitored marshes, with higher values in the fall and spring and lowest in the summer, while the other sources had lower input TDS values (Figure 1.7).

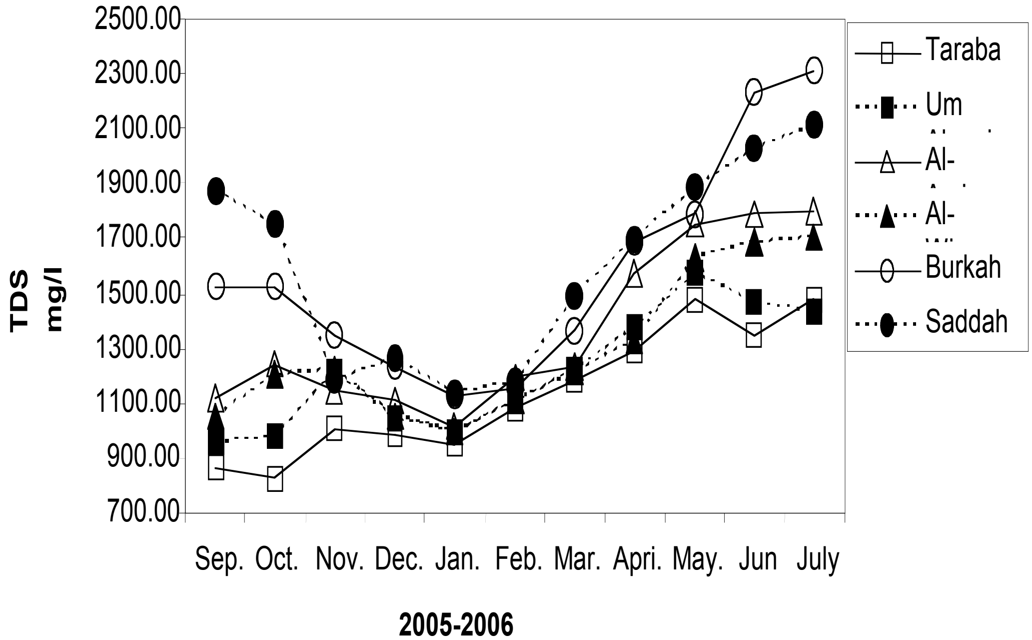


Figure 1.6. Mean monthly Total Dissolved Solids in study stations.

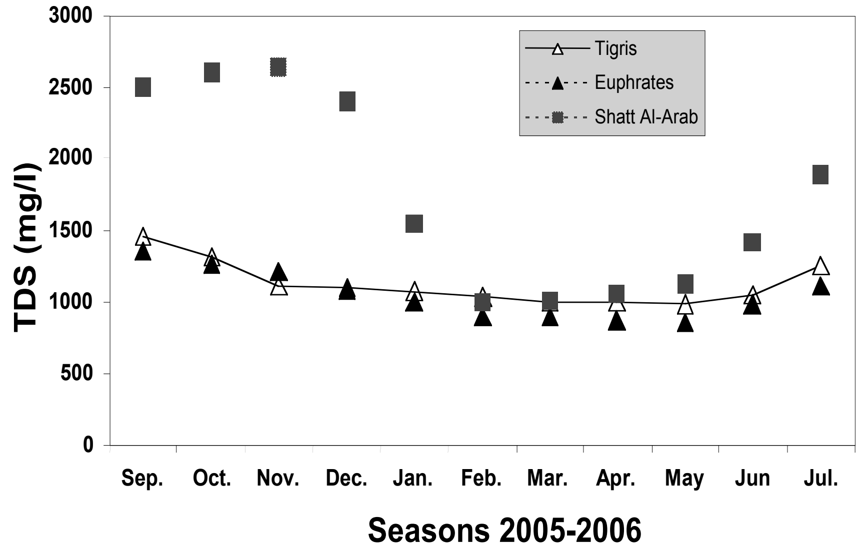


Figure 1.7. Monthly changes in TDS (mg/l) in the water quality of the sources of the monitored marshes.

Light transparency: The highest transparency value was recorded in Al-Hawizeh marsh. The lowest transparency was recorded in East Hammar, due to tidal action (Figure 1.8). In general, three patterns appeared, depending on whether the current is fast or slow at the station. The highest transparency was recorded in stations with low current, as at Taraba in Al-Hawizeh and Al Wineas in Suq Al-Shuyukh. With medium current, transparency values were intermediate in Saddah and Um Alnaaj. The highest current in Al Amia and Burkah produced the lowest transparency due to re-suspension of particles. The sources of water exhibited three modes that were different from the monitored marshes. The highest transparency was found in the Euphrates and lowest in Tigris, with the Shatt Al-Arab having intermediate values (data not shown).

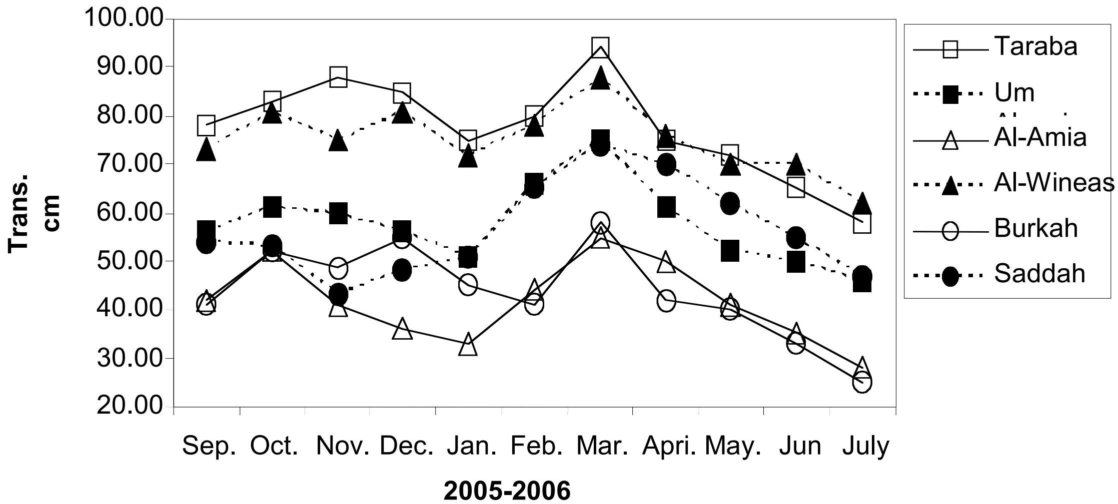


Figure 1.8. Mean monthly Transparency in study stations.

Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD): All the marshes showed the same seasonal oxygen trend in water (Figure 1.9). The highest values were recorded in winter (January) and the lowest in summer (July). However, the marshes were well oxygenated, and values never dropped to less than 5 mg/l at the monitored stations. River water bodies showed a similar trend, except for the Shatt Al-Arab, which had higher values of DO than the Tigris (Figure 1.10). The lowest values were recorded during the warm period (summer and spring) and the highest in the cold seasons (winter and fall). The oxygen curves and BOD curves are inversely related with highest DO and lowest BOD in the winter. The source with the highest BOD was the Tigris and lowest the Euphrates (Figure 1.11). The marsh water sources and marshes showed a similar seasonal trend, but the marshes had the highest BOD in the summer of 2006. The Tigris and Shatt Al-Arab have slightly higher values than the marshes most of the year, but still have values that show the rivers are not polluted (Figures 1.11, 1.12).

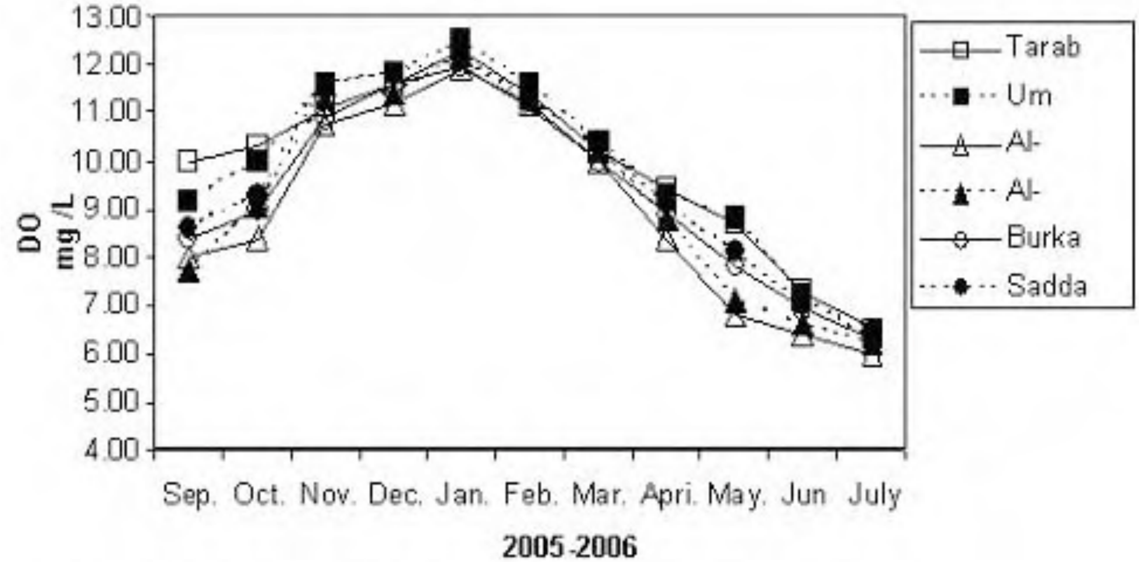


Figure 1.9 Mean monthly Dissolved Oxygen in study stations.

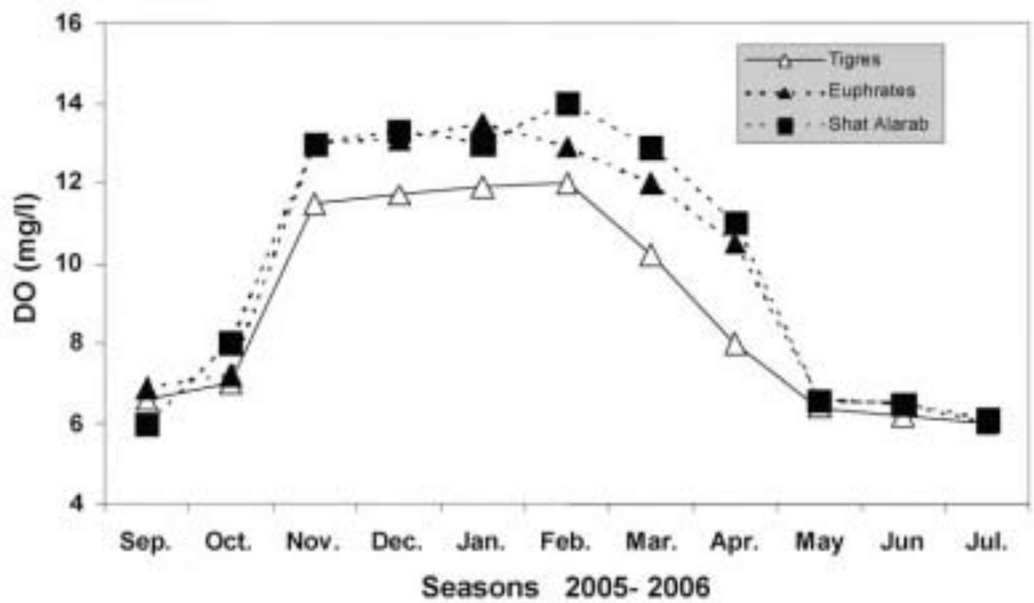


Figure 1.10 Monthly changes in DO (mg/l) in the water source of the monitored marshes.

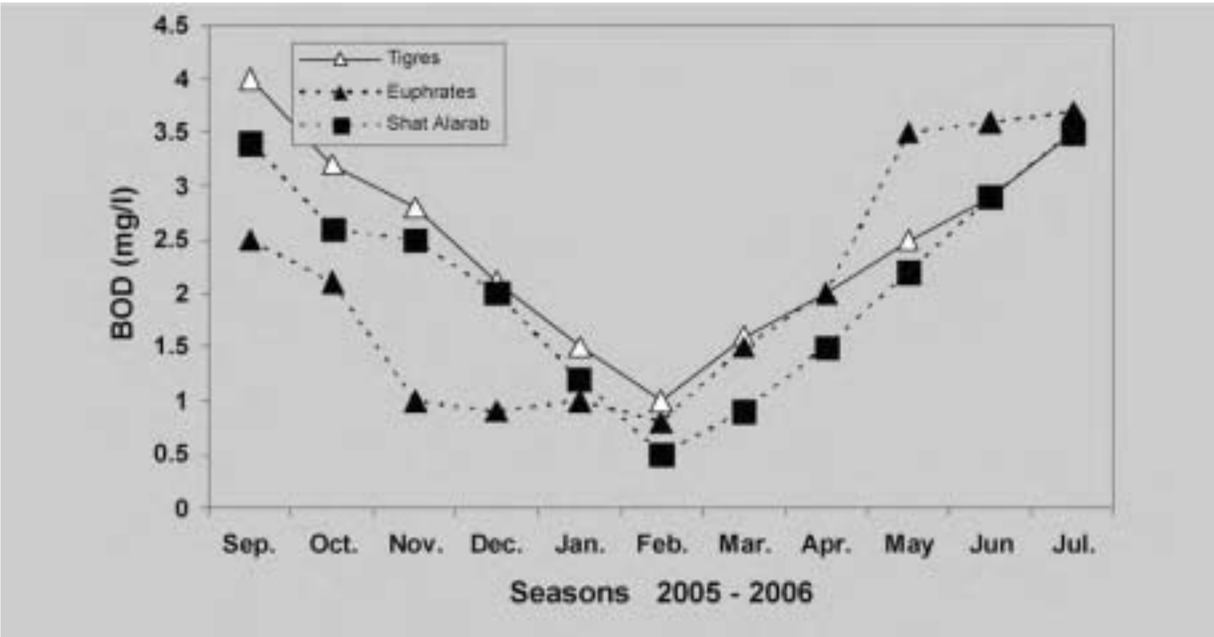


Figure 1.11 Monthly changes in BOD (mg/l) in the water source of the monitored marshes.

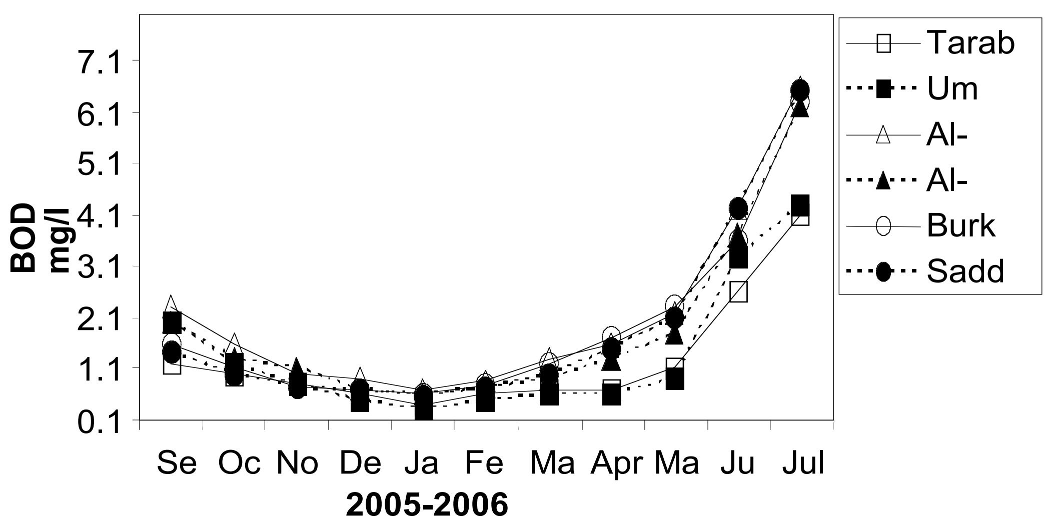


Figure 1.12 Mean monthly BOD in study stations,

Nitrate (NO_3-N) and reactive phosphate (PO_4-P): The highest values for nitrate-N were recorded during winter months and the lowest in spring (Figure 1.13). Nitrate-N values were highest in Al-Hawizeh and Suq Al-Shuyukh marshes and lowest in the East Hammar (Figure 1.13). Riverine sources of marshes illustrated more dramatic seasonal changes (Figure 1.15). In general, the highest values were recorded during summer months and the lowest in spring. Water sources showed the same seasonal trend with some differences, especially that of Tigris had higher values of NO_3-N (> 29 mg/L) during the summer of 2006, while the Shatt-Al-Arab and Euphrates exhibited values nearly 50% lower. The highest values for phosphate were recorded in East Hammar during winter months and the lowest were recorded in Al-Hawizeh marsh. Suq Al-Shuyukh values were in between (Figure 1.14). Phosphate concentrations were higher in the winter and lowest in the early spring when plants and algae are growing and taking up PO_4-P from the water column. The river sources for the marshes illustrated more dramatic seasonal changes in both nitrate and phosphate (Figures 1.15, 1.16).

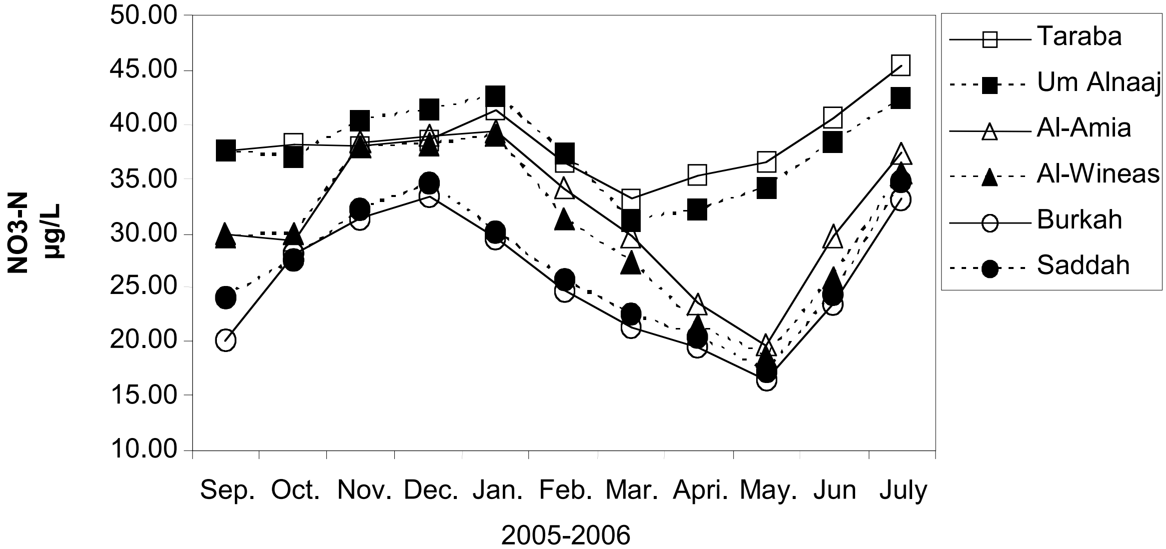


Figure 1.13. Mean monthly concentrations of nitrate in study stations.

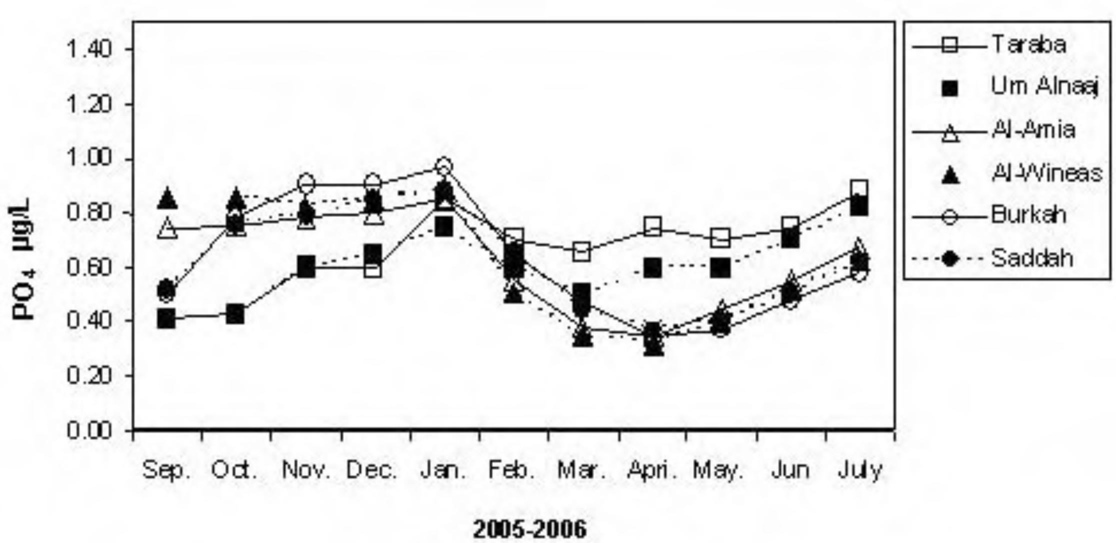


Figure 1.14 Mean monthly values of reactive phosphate in study

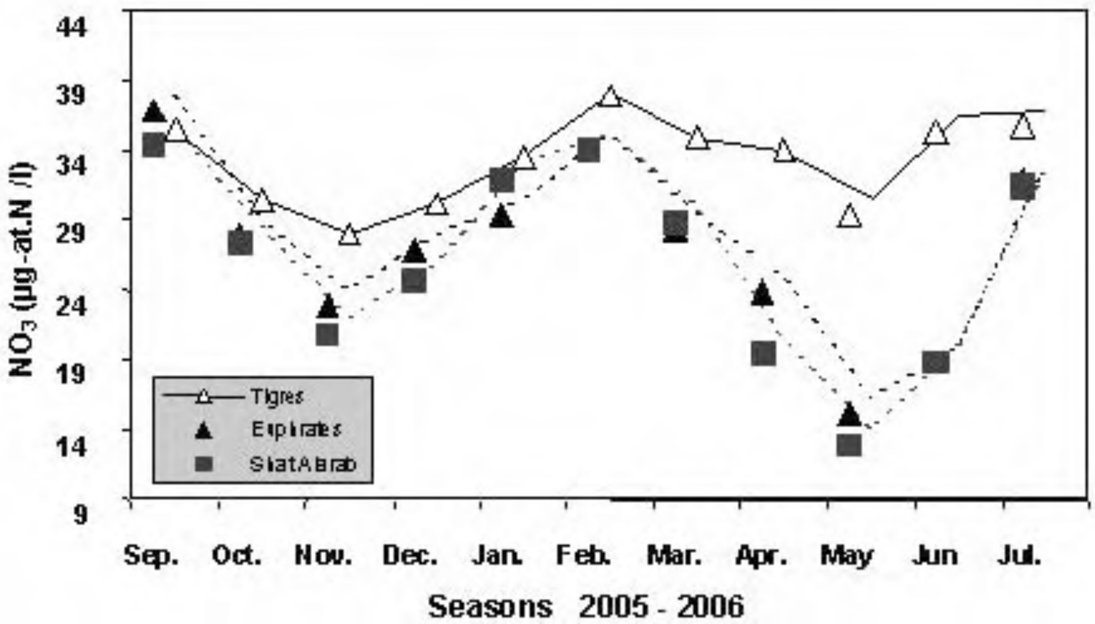


Figure 1.15 Monthly changes in Nitrate quality of the sources of the monitored marshes.

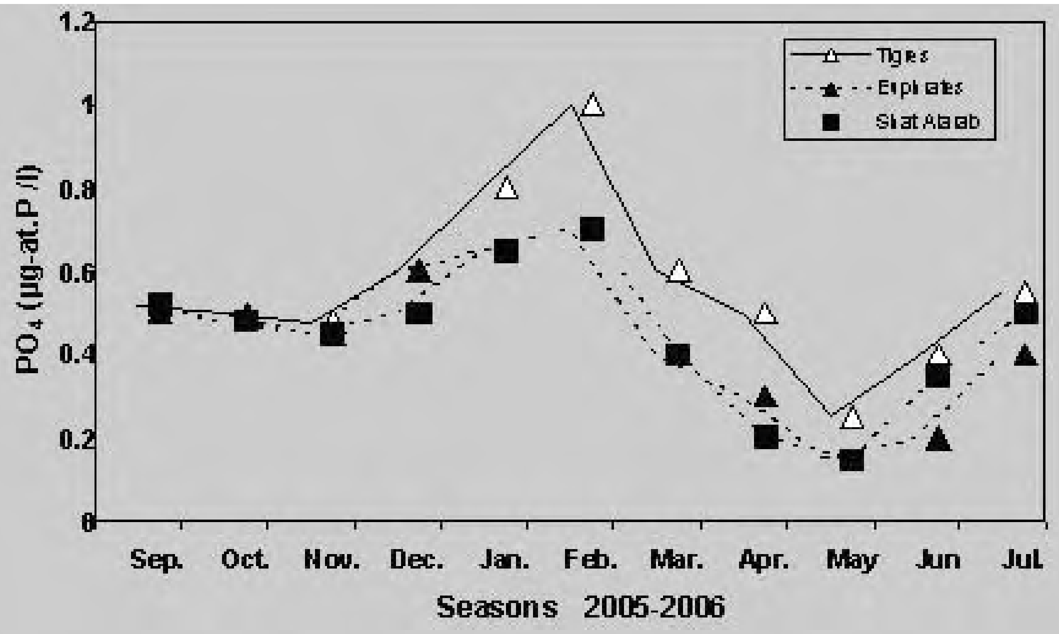


Figure 1.16 Monthly changes in PO_4-P in the Water quality of the sources of the monitored marshes.

Total Nitrogen (TN) and Ammonium (NH_4): Monthly values show a slight winter increase in TN in all marshes, with concentrations being slightly higher at Al-Hawizeh. The lowest values were recorded in East Hammar (Figure 1.17). Total N values decreased in the spring in all marshes, with Al-Hawizeh maintaining slightly higher values. In contrast, ammonium values were low most of the year and increased in the summer of 2006 (Figure 1.18). Monthly values were comparable in all monitored marshes (stations). The Tigris River source displayed the largest amount of TN, with peaks in the fall and summer. The highest values of ammonium in the river sources were in the summer and fall seasons, and the lowest in the winter months (Figure 1.20). The sources of water to marshes did not display the same exact patterns as the those of the monitored marshes.

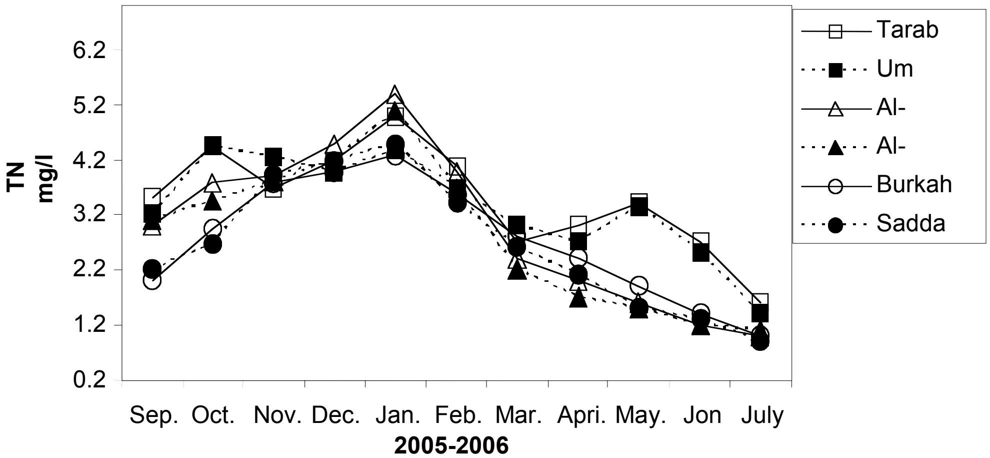


Figure 1.17. Mean monthly values of Total N in study stations.

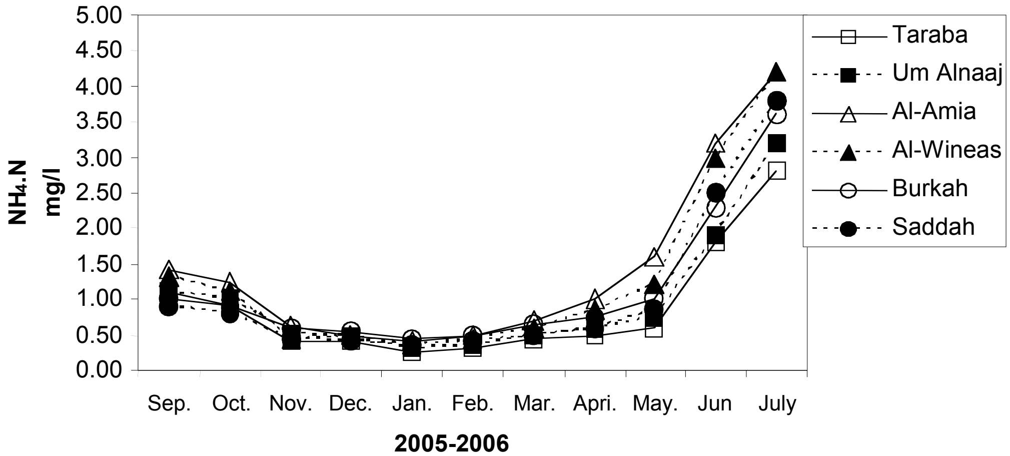


Figure 1.18. Mean monthly values of Ammonium in study stations.

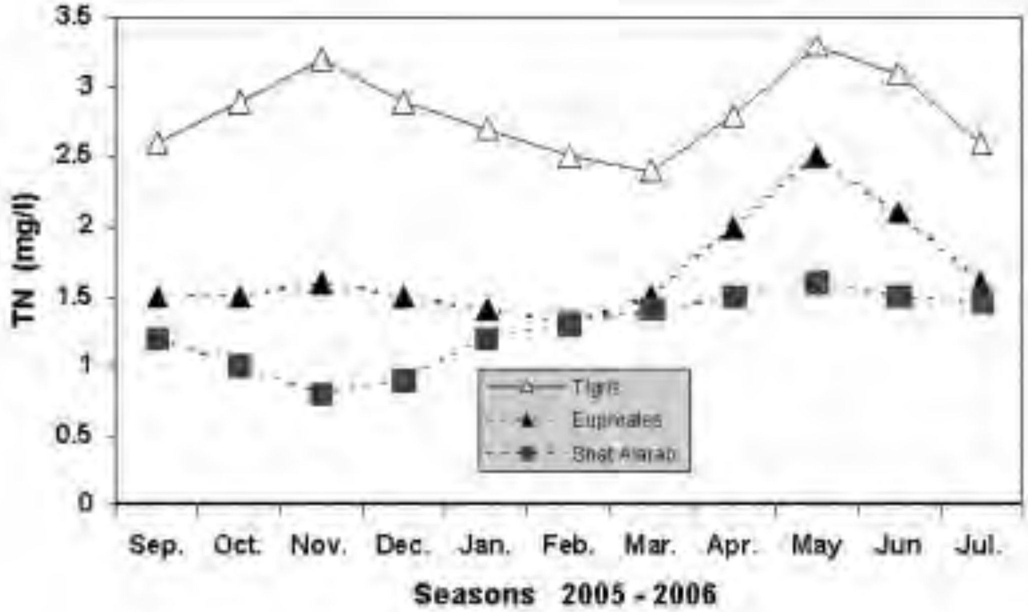


Figure 1.19 Monthly changes in TN in the Water quality of the sources of the monitored marshes.

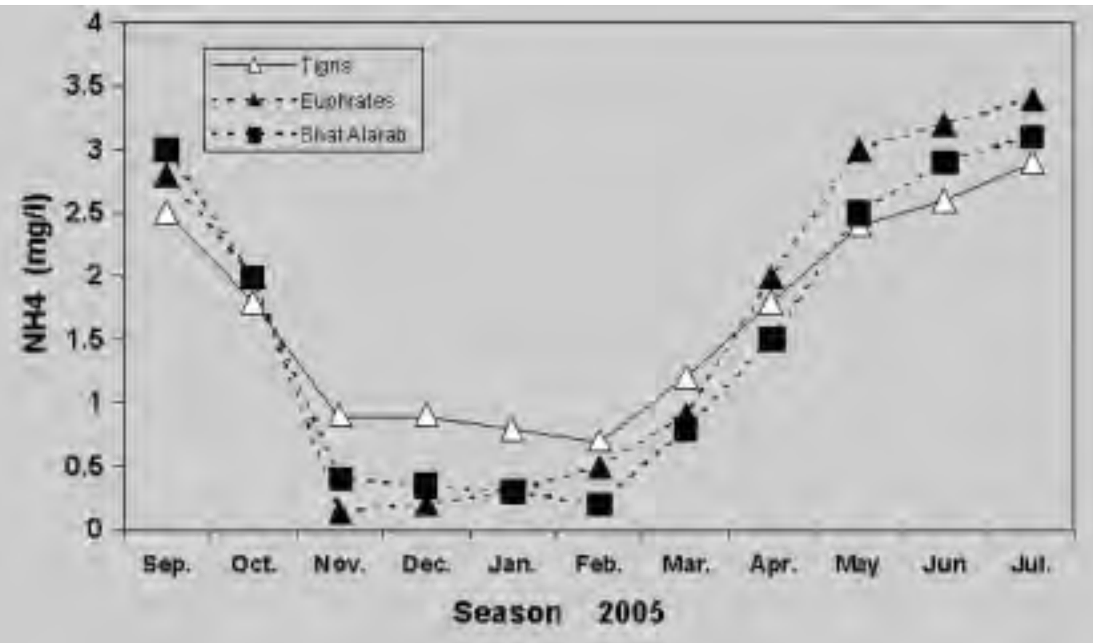


Figure 1.20 Monthly changes in the Water quality of the sources of the monitored marshes.

pH and total alkalinity: Two levels of monthly changes in pH were recognized, the first being slightly higher alkaline values in East Hammar and the second representing lower values in Al-Hawizeh marsh (Figure 1.21). These values represent the amounts of dissolved CO_2 and bicarbonate in the waters. Higher HCO_3^- (alkalinity) values occur in summer months in the marshes (Figure 1.22). Water sources for the marshes presented the same general pattern for pH and alkalinity as the marshes (Figures 1.23, 1.24). The Tigris River had the highest HCO_3^- values, which peaked in the winter months (Figure 1.24).

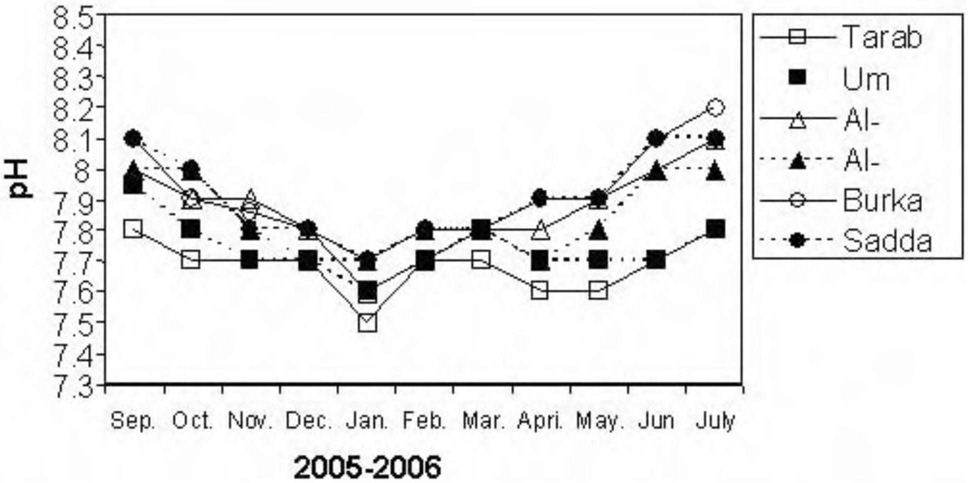


Figure 1.21. Mean monthly values of pH in study stations

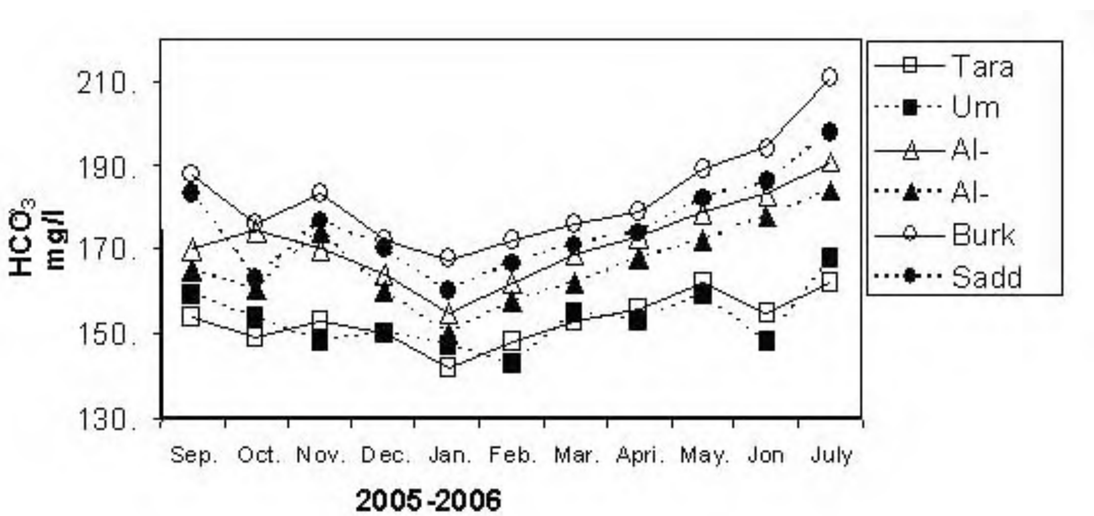


Figure 1.22. Mean monthly values of HCO_3^- in study stations.

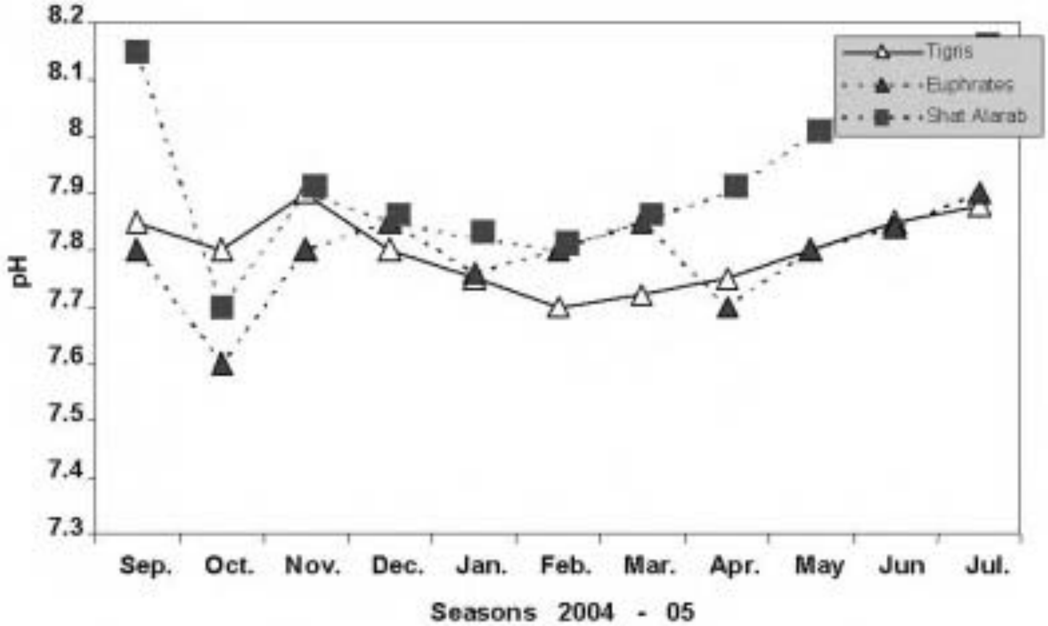


Figure 1.23. Monthly changes in pH in the water sources of the marshes.

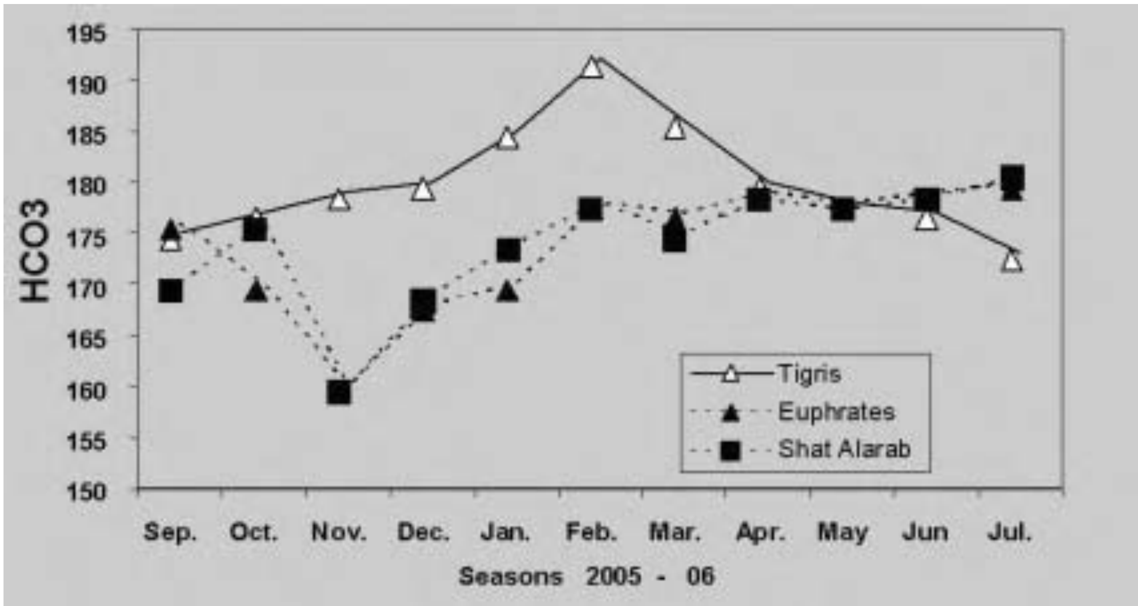


Figure 1.24. Monthly values of the water sources of the monitored marshes.

Sodium (Na) and sulphate (SO_4): Monthly values of sodium were highest in East Hammar and lowest in Al-Hawizeh (Figure 1.25). In general, lower values occurred in the winter and higher concentrations in the summer. Riverine waters showed a slight increase in peaks (spring/summer months) as compared to lower values in the fall (Figure1.26). Sulfate concentrations were highest in East Hammar due to the influence of Persian Gulf water inputs (Figure 1.27). Sulfate values varied little over the year and Al-Hawizeh and Suq Al-Shuyukh had similar values. Sulfate concentrations were highest in the Shatt Al-Arab, due to the tidal influence, and peaked during the winter months (Figure 1.28). The sulfate values were lowest in the Tigris River.

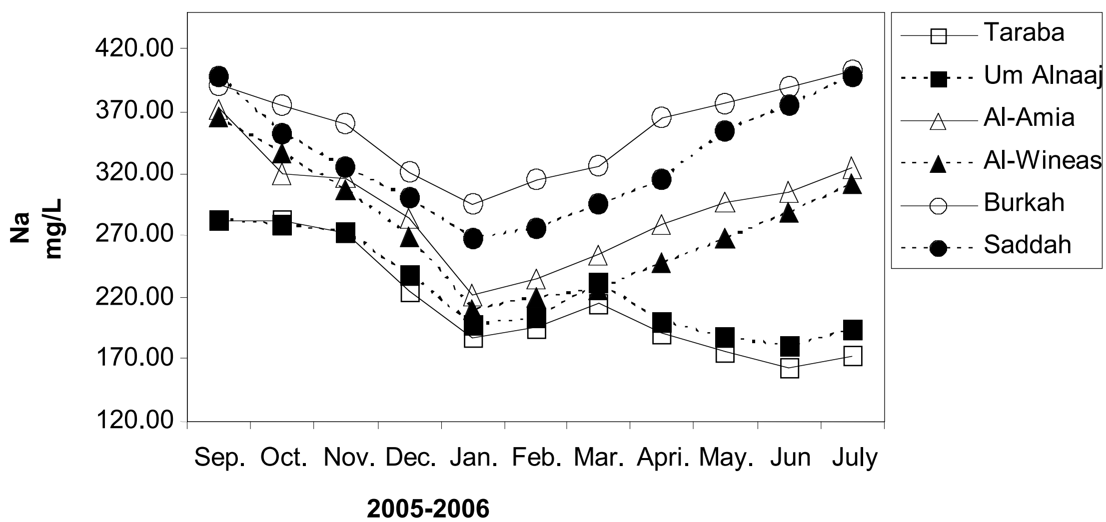


Figure 1.25 Mean monthly values of sodium in study stations.

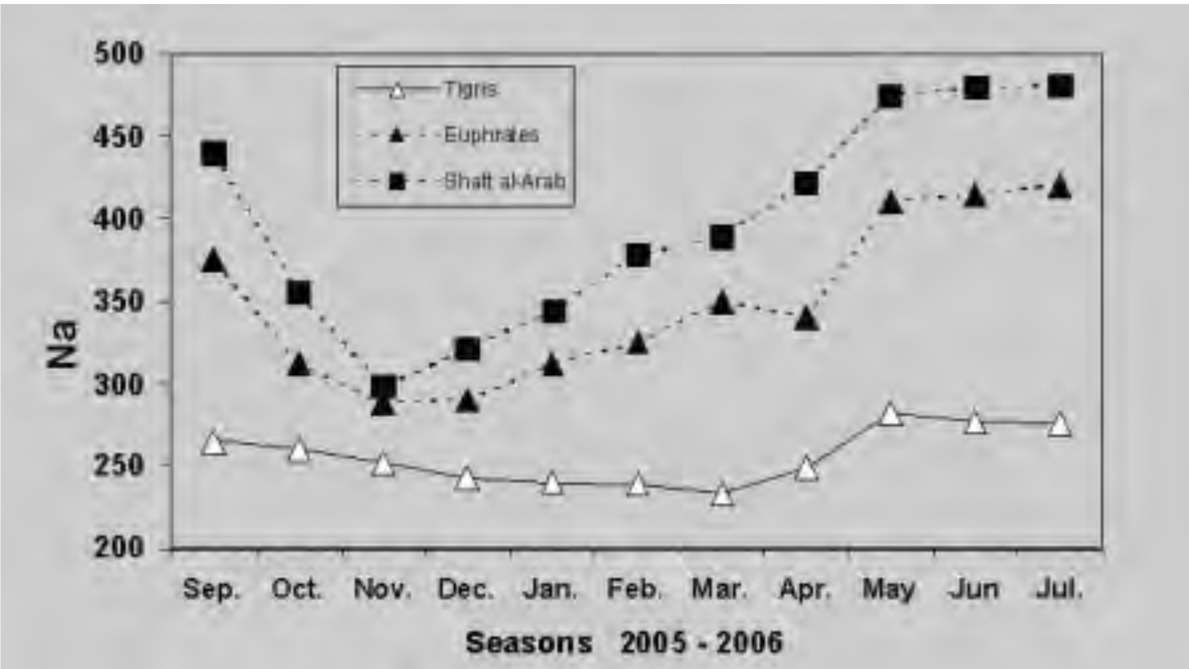


Figure 1.26. Monthly changes in Na (mg/l) in the Water quality of the sources of the monitored marshes.

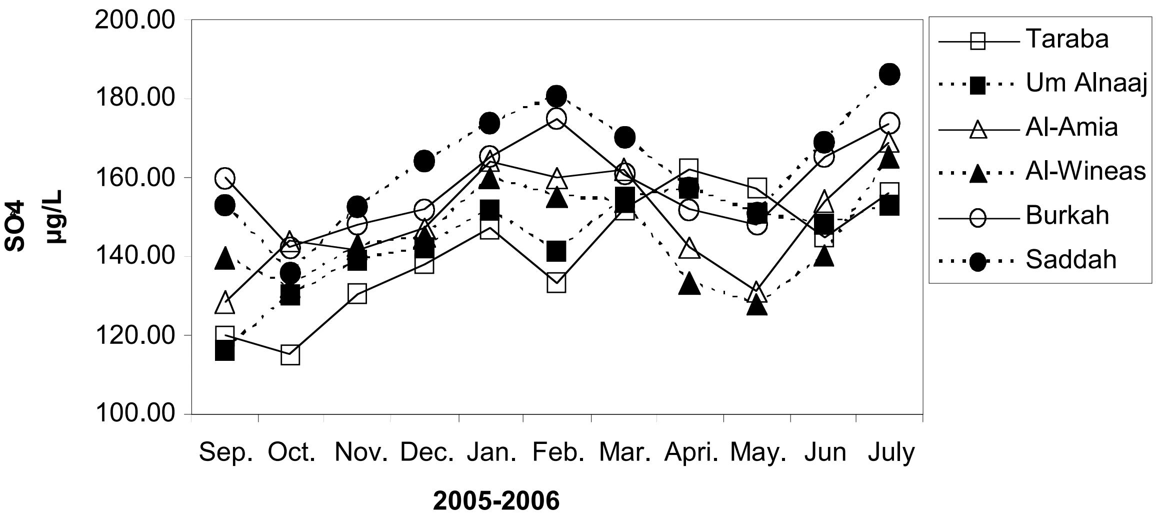


Figure 1.27. Mean monthly values of sulphate in study stations.

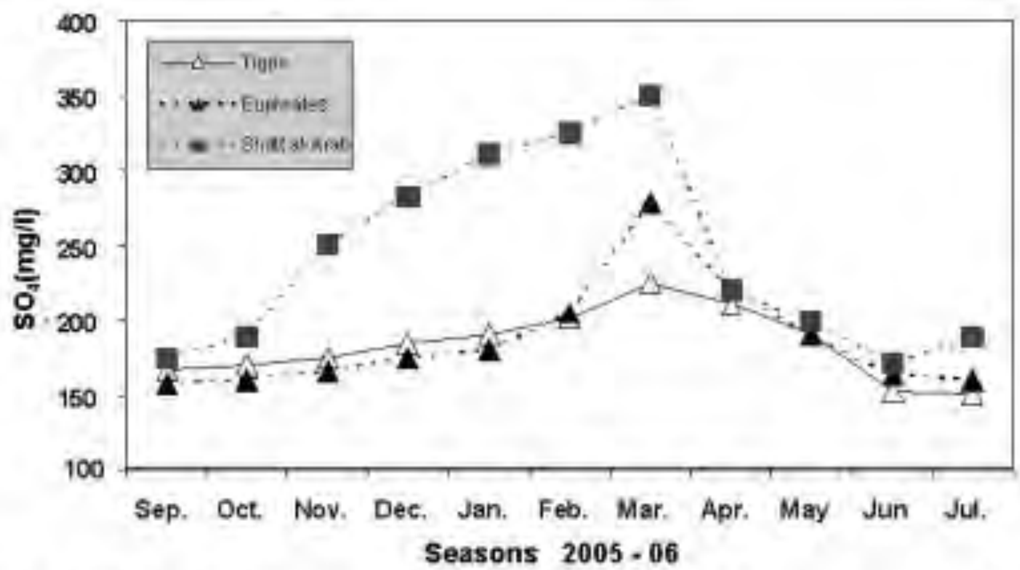


Figure 1.28. Monthly changes in quality of the sources of the monitored marshes

Mean of Flow rate (cm/sec.): The flow rate values of monitored marshes revealed two trends, with the highest flows in the East Hammar and the lowest in the Suq Al-Shuyukh. Highest values for all stations were recorded during autumn, and the lowest in the summer months (Figure 1.29).

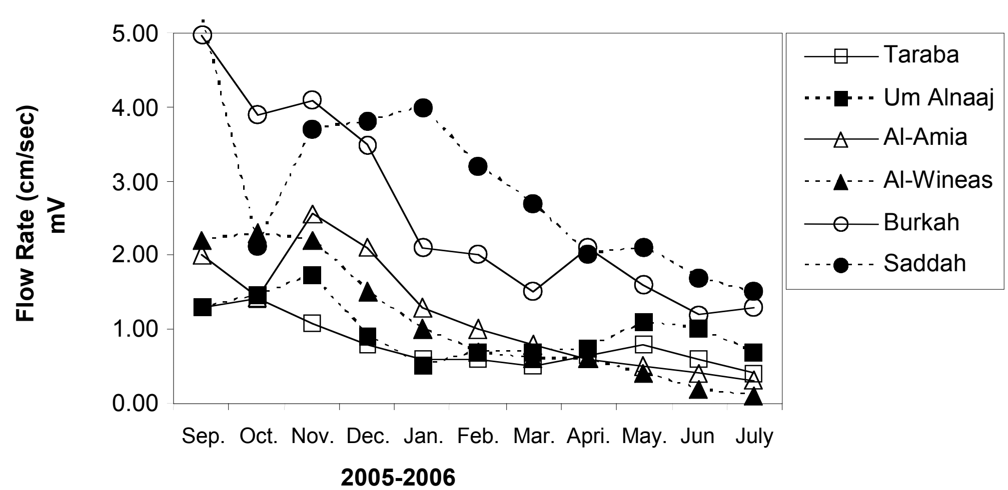


Figure 1.29. Mean monthly flow rates in study stations.

N:P ratio: The N:P ratio for water was estimated for the three monitored marshes, as shown in Figures 1.30, 1.31, and 1.32. Al-Hawizeh marsh had the highest means ratio, 25.5; Suq Al-Shuyukh and East Hammar marshes were lower, with 19.7 and 19.3, respectively. These ratios suggest that all three marshes are P limited according to the classic Redfield ratio (Wetzel 1983).

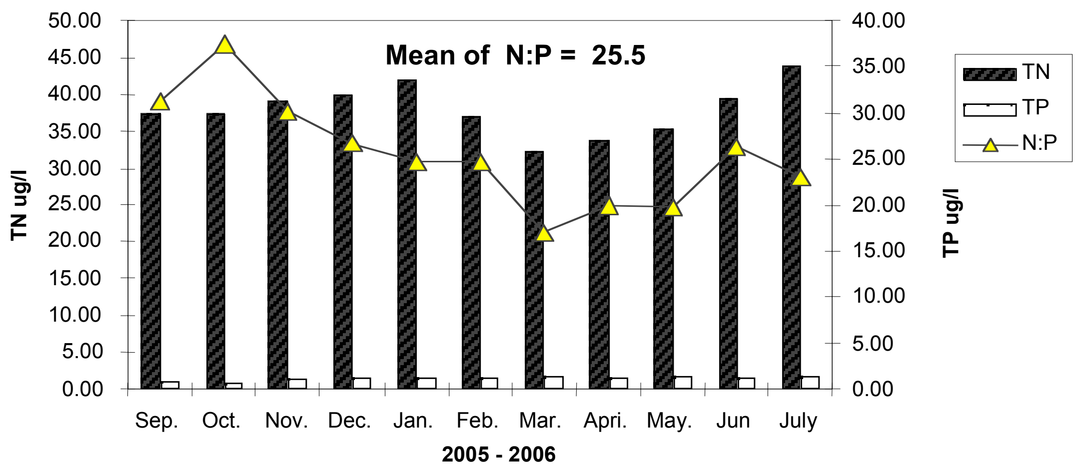


Figure 1.30. N:P Ratio in AL-Hawizeh marsh

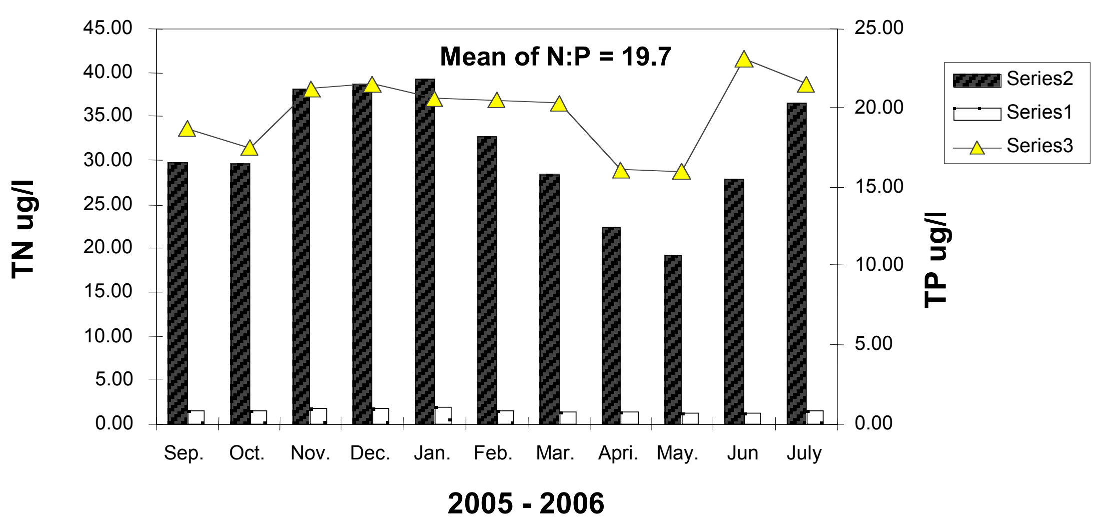


Figure 1.31. N:P Ratio in Suq Al-Shuyukh

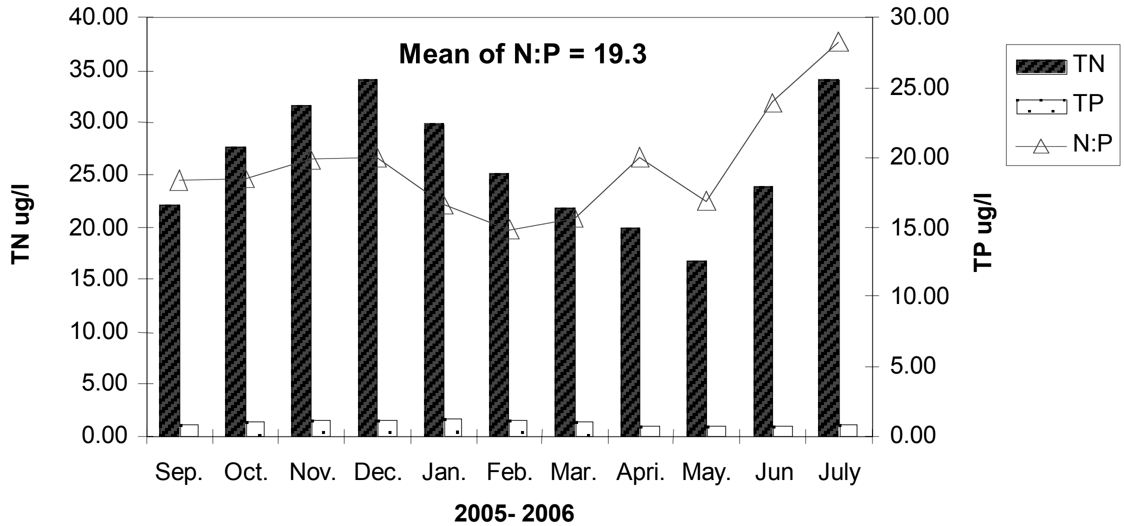


Figure 1.32 N:P Ratio in East Hammar marsh

1.4.2 Soil Analysis

Soil analysis: Three types of soil texture–silt-clay, sandy-clay, and clay–were found in the three monitored marshes (Table 1.2). Al-Hawizeh was dominated by silt-clay sediments, East Hammar by clay soils, and Suq Al-Shuyukh by sandy-clay soils. The total organic carbon (TOC) was highest in Al-Hawizeh and lowest in East Hammer, although all values were low. East Hammer had virtually no organic matter in the top sediments. pH values were nearer neutral in Al-Hawizeh marsh and slightly alkaline in East Hammer and Suq Al-Shuyukh marshes. Soil conductivity was lowest in Al-Hawizeh and highest in East Hammer Marsh. These conductivities followed the amount of fresh versus saltwater sources of inputs for Al-Hawizeh and East Hammar, respectively.

Table 1.2. Comparison of soil texture, pH and conductivity in sediments of study marshes taken during 2005-2006

EC (mS/cm^2) (SD$\pm$)	pH (SD$\pm$)	TOC % (SD$\pm$)	Type of sediment	Station
2.0 – 1.2 0.5	7.7 – 7.7 0.0	2.8 – 3 0.14	SILT-CLAY	Um-Alnaaj
2.2 – 1 0.8	7.7 – 7.5 0.14	3 - 3.1 0.07	SILT-CLAY	Taraba
4.3 – 4.0 0.21	7.9 – 8 0.07	2.1 – 2.6 0.35	SAND-CLAY	Al-Wneas
4.2 – 3.9 0.21	7.9 – 8 0.07	1.3 – 1.7 0.28	SAND-CLAY	Al-Amia
5.3 – 5.5 0.14	8 – 8.2 0.14	0.7 – 0.85 0.10	CLAY	Saddah
5.5 – 5.6 0.07	8 – 8.2 0.14	1.2 – 1.3 0.07	CLAY	Burkah

1.4.3 Phytoplankton

Chlorophyll-a concentrations showed a bimodal pattern in all stations of the three monitored marshes. The highest peaks occurred in spring (May) and a second smaller peak in autumn (October). The lowest values in general were in winter (January). The highest value of chlorophyll-a during spring bloom was recorded from East Hammar marsh at the Burkah station. Um Alnaaj station in Al-Hawizeh marsh showed a different pattern, with the highest peak in the autumn bloom (October) and the lowest peaks in winter (January) (Figure 1.33). Primary productivity was estimated by using measurements of dissolved oxygen and converting these to C fixed for summer months (June, July, August). Values averaged 420, 250, and 207 mgC/m^2/h, respectively. Values demonstrated a decline in phytoplankton production as the summer progressed.

Monthly variations in chlorophyll-a concentrations from June 2004 to July 2006 exhibited a winter-summer trend of high values in the summer months and lowest values in the cooler winter period (Figure 1.37). The pattern was clearly repeated each year, with highest chlorophyll values recorded at um Alnaaj in the Al-Hawizeh marshes and lowest values at Al Wineas in Suq Al-Shuyukh. Of interest in the long-term trend was the great increase in chlorophyll-a concentrations in the restored East Hammar by summer 2006, the highest values recorded in that year.

The number of phytoplankton cells revealed monthly variations, with a major peak in spring (May) and the lowest values in winter (January). The second smaller peak was in autumn (October). This was true for all monitored stations. The highest number of cells was recorded from Burkah station in East Hammar marsh and the lowest in Al Wineas in Suq Al Shuyukh (Figure 1.35).

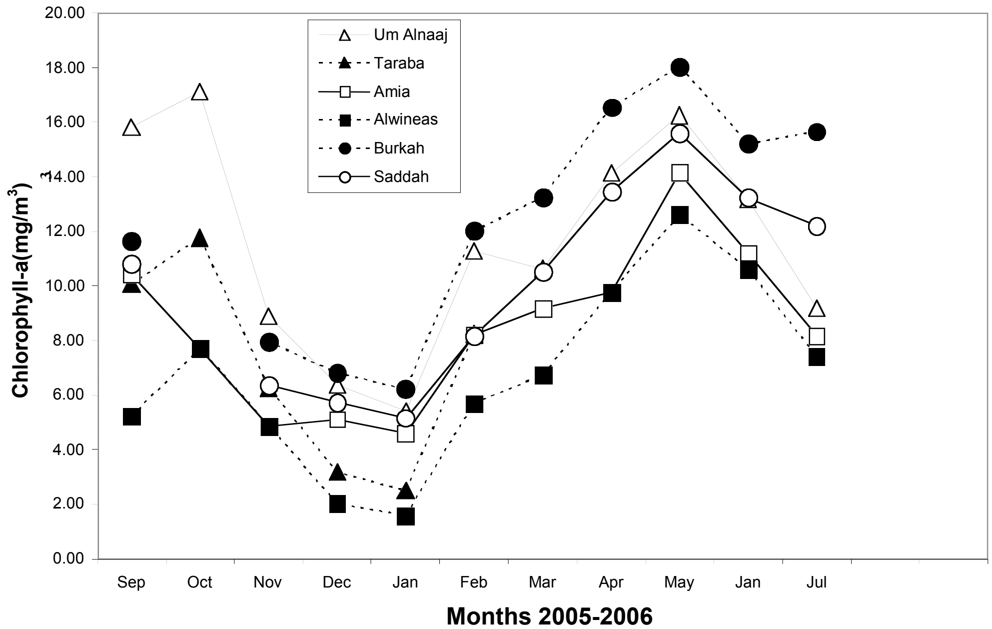


Figure 1.33. Monthly variations of chlorophyll-a in Al-Hawizeh, Suq Al-Shuyukh Hammar marshes

Figure 1.34. An Iraqi scientist collects phytoplankton samples.

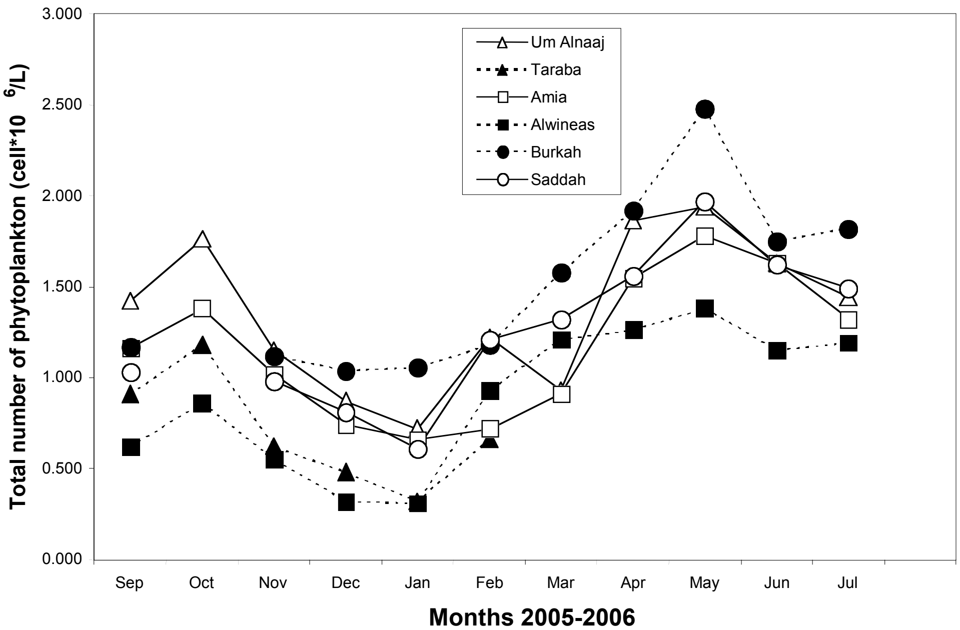


Fig 1.35. Monthly variations in total number of phytoplankton in Huwayzah Alshuyukh and East Hammar marshes

Phytoplankton groups in all the marshes were dominated by diatoms (*Bacillariophyta*), which–with 81 taxa–represented 58.3% of total phytoplankton. The majority belonged to Pennales (93.8%) and Centrals (6.2%), followed by green algae (*Chlorophyt*a) at 20.15% with 28 taxa, then blue green algae (*Cyanophyta*) at 15.1% with 21 taxa, euglena (*Euglenophyta*) at 2.9% with 4 taxa, golden algae (*Chrysophyta*) at 1.45% with 2 taxa, and one taxa of red aglae (*Rhodophyta*) in all monitored marshes. The same was true for all stations (Figure 1.36).

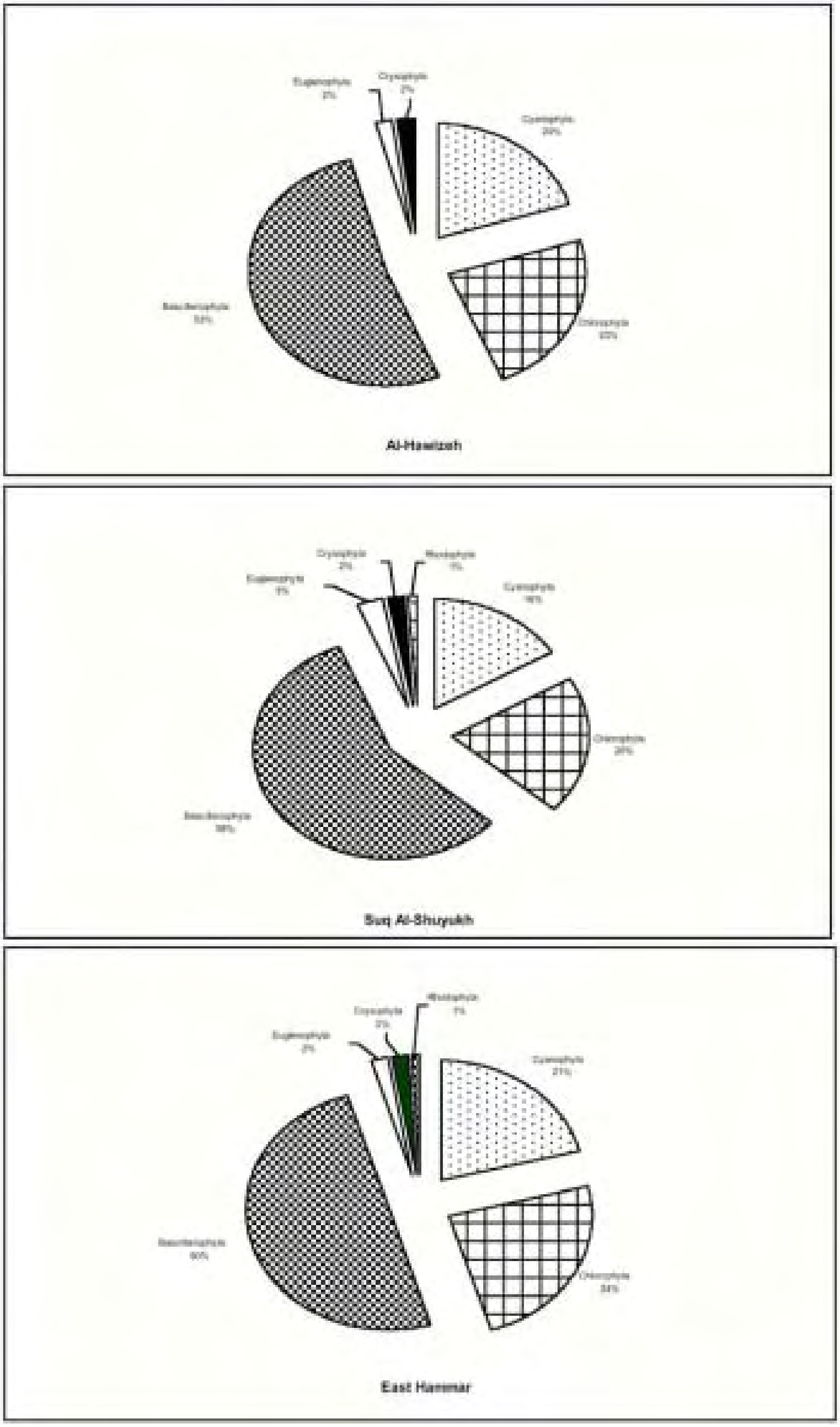


Figure 1.36. Percentage of phytoplankton groups in the two restored marshes of East Hammar and Suq Al-Shuyukh and the natural Al-Hawizeh in 2005-2006

Monthly variations in total number of phytoplankton cells for the last two years of the monitoring (June 2004 to July 2006) had a pattern similar to that of chlorophyll-a (data not shown). Two peaks were detected in 2005 and again in 2006, with the largest peak occuring in May both years.

Assessment of average chlorophyll-a indicated that Burkah, Um Alnaaj, Saddah, and Amia were eutrophic, while other stations were mesotrophic. Peak chlorophyll-a concentrations indicate that Burkah and Um Alnaaj were mesotrophic and the others oligotrophic (Table 1.3).

Table 1.3. Assessment of studied marsh stations trophy on basis of chlorophyll-a (according to Zalewski *et al.*, 2004)

Parameter	Stations	Oligotrophic<2.5	mesotrophic2.5-8.0	Eutrophic8.0-25	Hypertrophic>25
Average chlorophyll-a (μg/l)	Um Alnaaj			*	
	Taraba		*		
	Alamia			*	
	Alwineas		*		
	Burkah			*	
	Saddah			*	
	Stations	Oligotrophic 4.2-16.1	mesotrophic 16.1-42.6	Eutrophic42.6-500	Hypertrophic>500
Chlorophyll-a (peak concentration) (μg/l)	Um Alnaaj		*		
	Taraba	*			
	Alamia	*			
	Alwineas	*			
	Burkah		*		
	Saddah	*			

Table 1.4. Comparison between the chlorophyll-a, total of phytoplankton and number of species in the present study and the historical data.

Chlorophyll-a (mg/m^3)	Total number of phytoplankton ($cell*10^6/l$)	Number of species	Location of study	References
-	0.044 - 0.15	68	East Hammar Marsh	Maulood *et al.*, (1981)
0.14 - 22.18	0.3 - 21.717	-	Qurna Marsh	Al-Zubaidi (1985)
0.15 - 8.46	0.839 - 17.052	113	East Hammar Marsh	Al-Laami (1986)
0.24 - 10.7	0.309 - 4.021	-	East Hammar Marsh	Al-A'argy (1988)
		129	Qurna Marsh	Pankow *et al.*,(1979)
		178	Brakish water of southern Iraq	Hinton and Maulood *et*al,.(1980,1982)
	0.00043-0.01856	149	Samarra Reservoir	Al-Lami *et al.*,(1996)
0.28-68.5	0.15-521.25	126	Al-Qadisia Lake	Kassim *etal.*,(1999)
		169	Tigris and Euphrates rivers	AL-saadi *et al* ., (1999)
>0.4 - <7.5	>1 - <16.5	103	East Hammar Marsh	Al-Saadi and Al-Lami (1992)
2.51-16.26	**0.32-1.94**	**94**	**Al-Hawizeh Marsh**	**Present study in 2005- 2006**
1.6-14.16	**0.31-1.78**	**98**	**Suq Al-Shuyukh Marsh**	
5.16-18.04	**0.61-2.48**	**104**	**East Hammar Marsh**	
Recovery index of Al-Hawizeh's phytoplankton species =**91.04%**				
Recovery index of Suq Al-Shuyukh's phytoplankton species =**94.91%**				
Recovery index of East Hammar's Phytoplankton species = **100.72%**				

Note: The mean of number of species for historical data = (68+113+129+103)/4=103.25)

Comparisons of the present results for chlorophyll-a, total number of cells, and number of species with historical data indicate that the recovery is well under way. Comparing recent figures with an index of species historically present shows that 100% of species have returned to East Hammar and 94% to Al-Hawizeh (Table 1.4).

Spatial differences in phytoplankton species occurence were as follows: Al Hawizeh–94 total species; Suq Al-Shuyukh–98 total species; East Hammar–104 total species. Many species were found in only one of the three marshes (Appendix 1). A few genera were represented by higher numbers of species, such as *Nitzschia* (16 species)*, Navicula* (9)*, Fragiralira* (6) *and Cymbella* (5). Twelve genera occurred throughout the monitoring period, while others occurred seasonally (Appendix 2). A list of identified species is given in Appendix 1, showing the occurrence of different species in the monitored marshes.

1.4.4 Zooplankton

Total numbers of zooplankton individuals in the three monitored marshlands are shown in Figure (1.37). A pattern appears with two peaks, one in spring and a smaller one in autumn. This pattern was more obvious in 2005-2006**.** Suq Al-Shuyukh generally had the lowest number of individuals throughout the year. In 2005 Al-Hawizeh displayed the highest counts, but in 2006 East Hammar had the highest overall counts throughout most of the year.

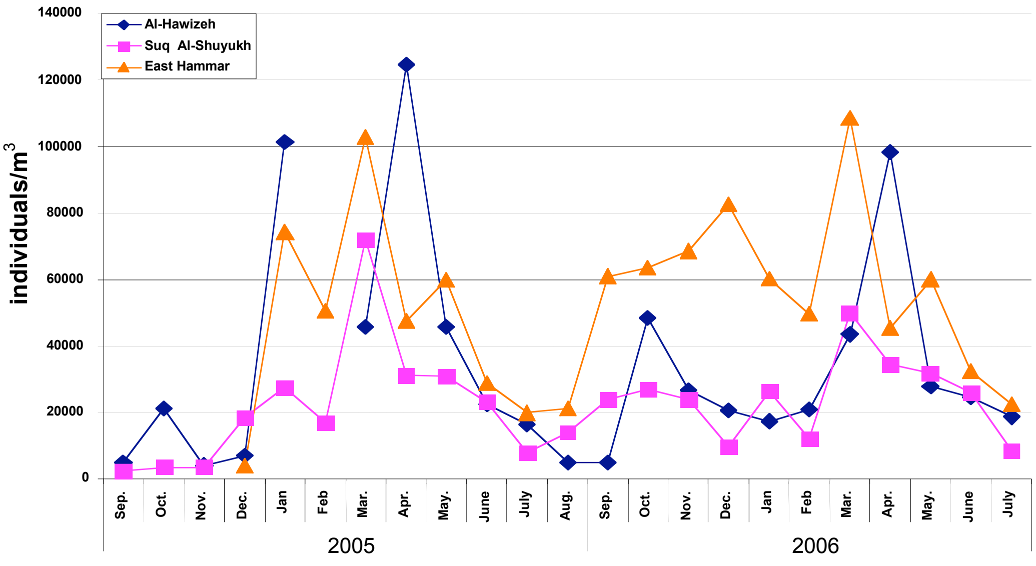


Figure 1.37. Total number of zooplankton individuals in all marshes

Each marsh had its own timing for zooplankton peaks but still followed a general seasonal pattern. In Al-Hawizeh, two peak patterns existed. The first appeared in April and a second smaller one in October. The fewest individuals were recorded in September. In Suq Al-Shuyukh, more pronounced peaks could be detected in March and a smaller one in October, with the lowest values occuring in December and again in July (Figure 1.37). In the East Hammar marsh the picture was slightly different, with peaks occurring in March at both stations in both years, and the lows in July. Several secondary peaks appeared in November, December, and January at both stations. The number of zooplankton during the monitoring period June 2004 to July 2006 indicates a closer pattern relationship between Al-Hawizeh and Suq Al-Shuyukh than East Hammar.

A comparison of the number of individuals in each order of zooplankton in Al-Hawizeh marsh during 2004-2005 and 2005-2006 reveals that Rotifers were the dominant order, comprising a larger proportion in 2006 than 2005 (Figure 1.38ab). The mean number of copepods decreased, compared to that of 2005, but still ranked second. Cladocera occupied the third position in both periods (Figure 1.38ab).

Comparing the number of individuals in each order of zooplankton in Suq Al-Shuyukh marsh 2004-2005 and 2005-2006 revealed that Rotifers were dominant and comprised a higher share of the total population in 2006 than 2005. The mean number of copepods decreased compared to that of 2005, but still occupied the second position. Free nematodes were in third place in both periods (Figure 1.39ab).

In East Hammar marsh during 2004-2005 and 2005-2006, Rotifers were dominant, with lower composition in 2006 than 2005. The mean number of copepods increased above that found in 2005, but still ranked second. Cladocera occupied the third place in both periods (Figure 1.40ab).

The grand total of zooplankton in the three monitored marshes exhibited clear differences between 2004-2005 and 2005-2006. In the first period of sampling in 2004-2005, East Hammar had the highest number of zooplankton (45%), followed by Al-Hawizeh (35%) and Suq Al-Shuyukh (20%) (data not shown). In the second period (2005-2006) East Hammar scored an even higher percentage (51%), followed by Al-Hawizeh with a lower percentage compared to the first period (28%). Suq Al-Shuyukh exhibited a similar percentage in both sampling periods. Comparison between the monthly numbers of zooplankton in the first period (2004-2005) and with that of second (2005-2006) indicated a general increase in numbers of zooplankton in all three investigated marshes (Appendix 3).

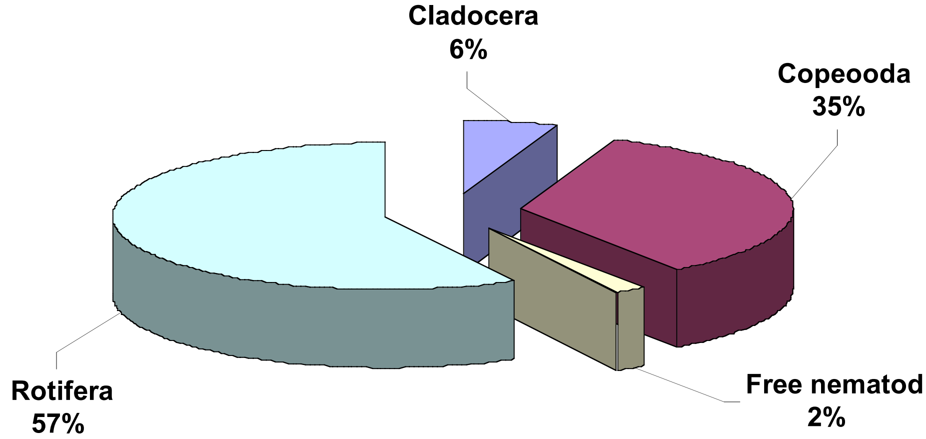


Figure 1.38a. Mean number of individuals in each order of zooplankton at Al-Hawizeh Marsh, 2004 - 2005

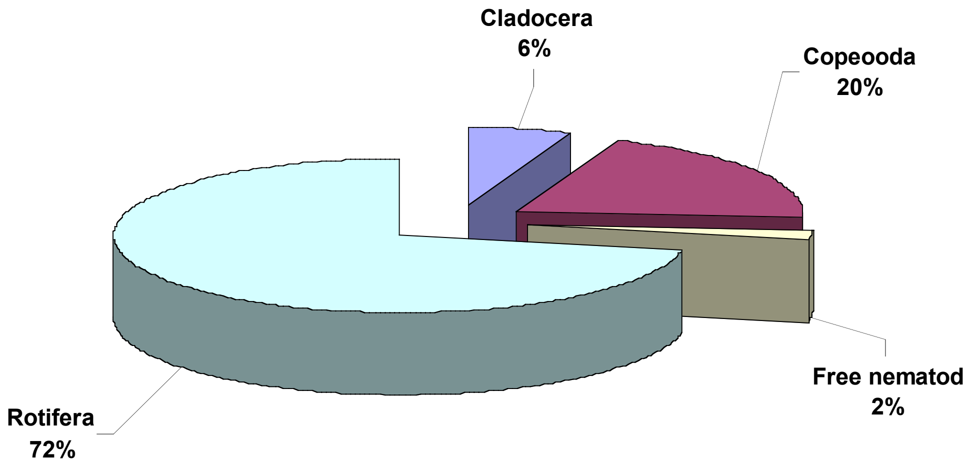


Figure 1.38b. Mean number of individuals in each order of zooplankton at Al-HawizehMarsh, 2005 - 2006

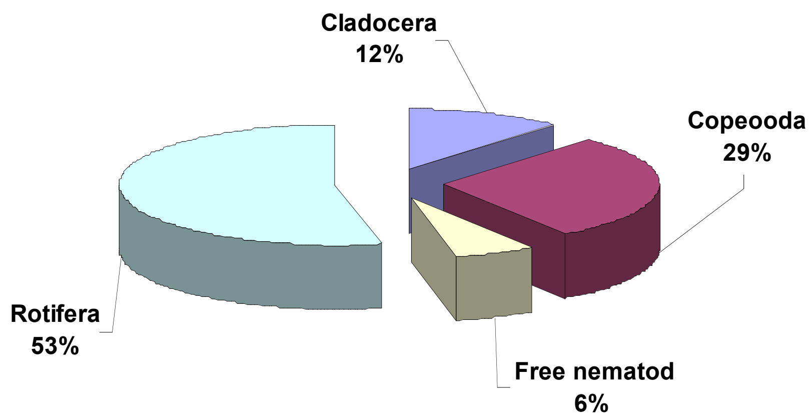


Figure 1.39a Mean number of individuals in each order of zooplankton at Suq Al-Shuyukh Marsh, 2004 - 2005

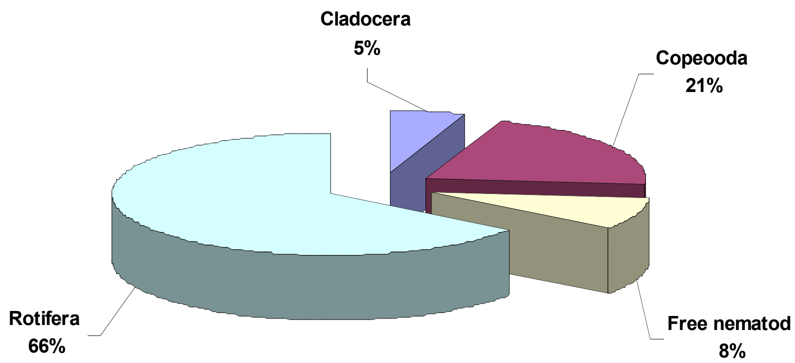


Figure 1.39b. Mean number of individuals in each order of zooplankton at Suq Al-Shuyukh Marsh, 2005 - 2006

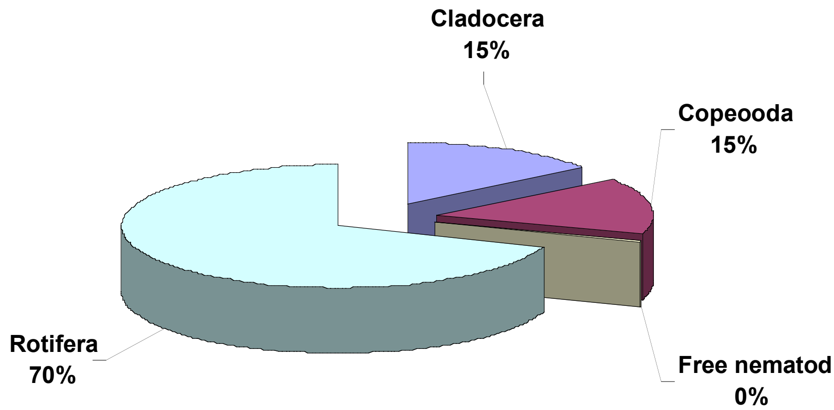


Figure 1.40a. Mean number of individuals in each order of zooplankton at East Hammar Marsh, 2004- 2005

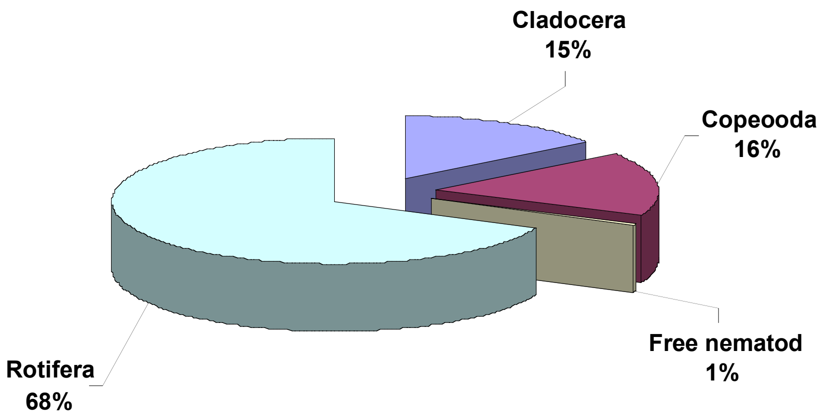


Figure 1.40b. Mean number of individuals in each order of zooplankton at East Hammar Marsh, 2005- 2006

1.4.5 Macroinvertebrates

The number of macroinvertebrates species found in the three marshes during 2005 and 2006 is presented in Tables 1.5 and 1.6. The highest total number of species recorded in all monitored marshes was 84 in 2006. The numbers were composed of 13 snail species, 48 insect, 5 shrimp, 5 spider, 4 annelid, and 3 for mussel and crab, with only one amphipod, isopod, and cirriped species. This represented a 25% increase (or 17 species) from 2005, with insects and snails dominating the species list in both years. The specific number of macroinvertebrate species in 2006 in Al-Hawizeh, Suq Al-Shuyukh, and East Hammar were 62, 58, and 56, respectively. A comparison of the numbers of macroinvertebrates showed an increase from 2005 to 2006 in each marsh (Figure 1.41).

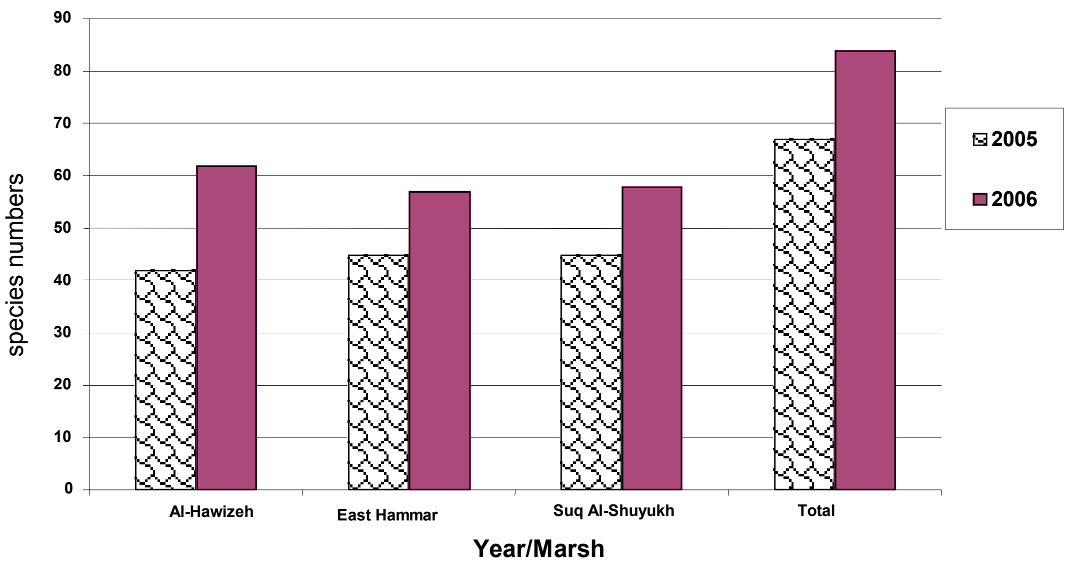


Figure 1.41. Comparison in the total number of macroinvertebrates species

Table 1.5. Number of macroinvertebrates species in three monitored marshes during 2005

	Snail	Insect	Shrimp	Mussel	Spider	Annelid	Isopod	Amphipod	Crab	Cirriped	total
Al-Hawizeh	12	22	3	-	1	3	-	1	-	-	42
Hammar	13	14	5	2	3	2	2	1	2	1	45
Shuyukh	13	17	3	3	3	2	1	1	1	1	45
Total	14	31	5	3	3	4	2	1	3	1	67

Table 1.6. Number of macroinvertebrates species in three monitored marshes during 2006

	Snail	Insect	Shrimp	Mussel	Spider	Annelid	Isopod	Amphipod	Crab	Cirriped	total
Al-Hawizeh	10	37	3	2	4	4	-	1	1	-	62
Hammar	12	25	5	2	5	3	1	1	2	1	56
Shuyukh	13	31	3	3	2	2	1	1	2	-	58
Total	13	48	5	3	5	4	1	1	3	1	84

Student research teams surveying in the marshes are shown on Figure 1.42 and 1.43. The density of main groups of macroinvertebrates in the three monitored marshes is given in Tables 1.7 and 1.8 and Figure 1.44. Maximum and minimum densities recorded for snails were 56.8 ind/m^2 in East Hammar and 21.9 ind/m^2 in Suq Al-Shuyukh. Recorded densities for insects were 33.2 ind/m^2 in Al-Hawizeh and 19.7 in Suq Al-Shuyukh. Shrimp densities were 110.2 ind/m^2 in Al-Hawizeh and 65.3 ind/m^2 in Suq Al-Shuyukh, while those for amphipods were 142.5 ind/m^2 in East Hammer and 22.2 ind/m^2 in Suq Al-Shuyukh. Some groups were absent from certain marshes, e.g., isopoda from Al-Hawizeh. Cirriped were not present in either the Al-Hawizeh or Suq Al-Shuyukh marshes.

Figure 1.42. Iraq students in a boat along the dike in the Al-Hawizeh preparing to sample for macro-invertebrates in June 2006.

Figure 1.43. Iraqi graduate students collect macroin-vertebrates during a sampling trip into the marshes.

Table 1.7. Density of macroinvertebrates species (ind. /m^2) in three monitored marshes during 2005

	Snail	Insect	Shrimp	Mussel	spider	Annelid	Isopod	Amphipod	Crab	Cirriped
Al-Hawizeh	5.6	4.3	15.96	-	2.2	10.26	-	-	-	-
Hammar	30.6	5.27	19.5	2.9	2	11.3	36.6	17.8	10.8	6.9
Shuyukh	4.6	1.98	12.06	1.18	1	3.14	30	3	1	1
Total										

Table 1.8. Density of macroinvertebrates species (ind. /m^2) in three monitored marshes during 2006

	Snail	Insect	Shrimp	Mussel	spider	Annelid	Isopod	Amphipod	Crab	Cirriped
Al-Hawizeh	45.4	33.2	110.8	21.3	43.6	86.3	-	32.6	4	-
Hammar	56.8	21.6	65.3	49.6	58	27.9	19	142.5	26.18	37.3
Shuyukh	21.9	19.7	82.9	38.2	19.9	13.6	12.9	22.2	13.25	-
Total										

A comparison of the distribution percentages for the main groups of macroinvertebrates suggests some differences between the two restored marshes and the Al-Hammar marsh (Figure 1.44). Al-Hawizeh had the highest density of isopods and annelids, East Hammar the highest density of amphipods and ciripeds, and Suq Al-Shuyukh the most mussels. There was a clear increase in species number in all groups and also sharp rises in densities for all groups in 2006 (Figures 1.41,1.45). These results apply to all three monitored marshes.

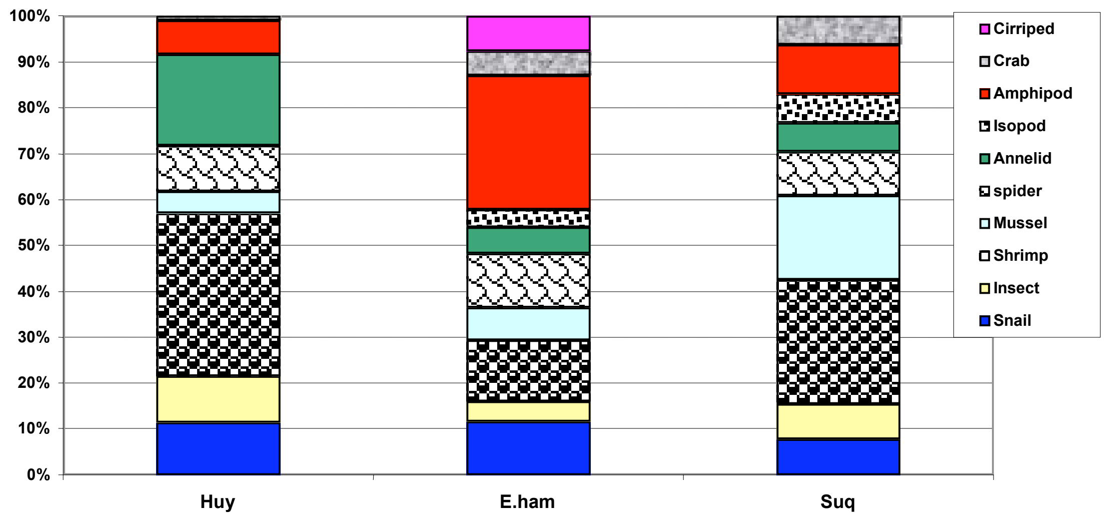


Figure 1.44. Density (ind./m^2) of macroinvertebrates group in all restored marshes in 2006

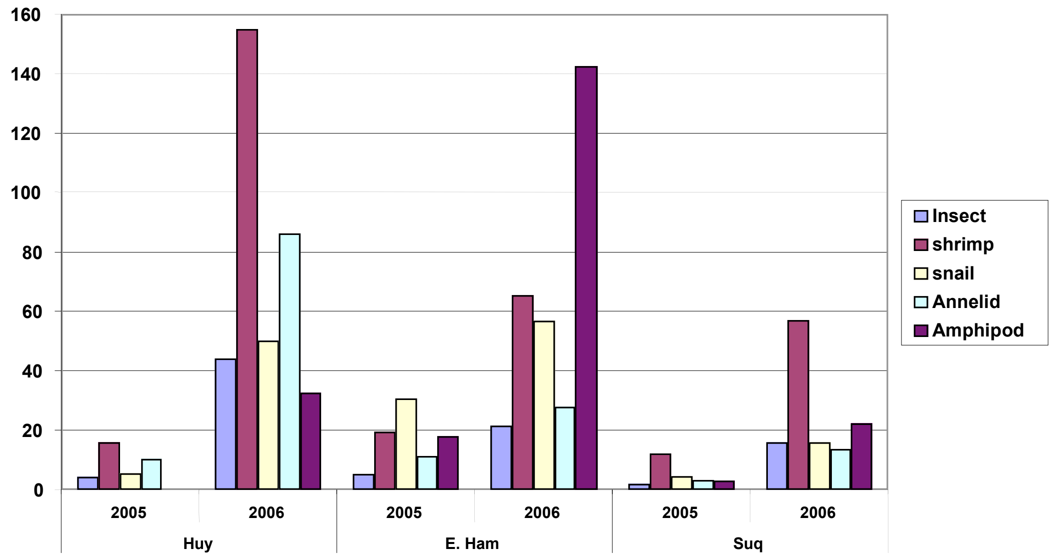


Figure 1.45. Comparison in density of macroinvertebrates species between 2005-2006

A comparison of the diversity, richness, and evenness of each group of macroinvertebrates in the three monitored marshes between 2005 and 2006 showed that insects responded better than all other groups in all marshes. The overall diversity and evenness were similar among the marshes in 2006, but richness was slightly higher at Suq Al-Shuyukh (Figure 1.46). A similarity analysis among the three monitored marshes indicated a higher similarity existed between the East Hammar and Suq Al-Shuyukh marshes (73.7%), than between East Hammar and Al-Hawizeh (69.2%). The lowest was between Al-Hawizeh and Suq Al-Shuyukh (64.0). The occurrence of different species of macro-invertebrates groups in the three monitored marshes are shown in Appendix 4.

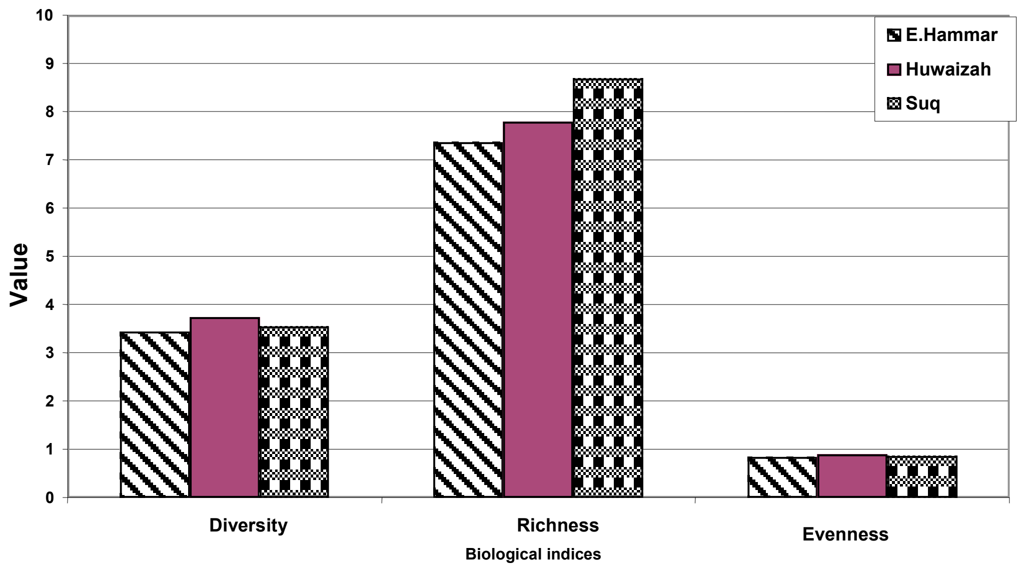


Figure 1.46. Comparison of biological indices of macroinvertberates in the 3 marshes during 2006

1.4.6 Aquatic Macrophytes

The richness of aquatic macrophyte species in Al-Hawizeh, Suq Al-Shuyukh, and East Hammar, expressed as species composition, is shown in Tables 1.9 and 1.10. There was a slight increase in the number of species recorded in comparison with that of 2005, indicating improved species richness and improved macrophyte restoration. The number of species found during the monitoring period, compared with historical records, indicates a significant amount of plant restoration has occurred (Table 1.11). A restoration percentage calculated as the number of species now present compared to historical records indicated that recovery was 100% in Suq Al-Shuyukh and 71.4% in East Hammer. No historical data are available for Al-Hawizeh.

Table 1.9. Species composition of aquatic Macrophytes in Suq Al-Shuyukh and Al-Hawizeh Marshes during 2005-2006. Pluses indicate presence of species and minuses an absence of species.

Species	Suq Al-Shuyukh		Al-Hawizeh	
	Alwineas	Amia	Um Alnaaj	Taraba
Wholly submerged				
Ceratophyllum demersum	+	+	+	+
Najas armata	+	-	+	+
Vallisneria spiralis	+	+	-	-
***Chara* sp.**	-	+	-	-
Partly submerged				
Jussiae repens	-	-	+	+
Potamogeton crispus	+	+	-	-
P. pectinatus	+	+	-	-
Ranuculas sphaerospermus	-	-	+	-
Floating				
Lemna minor	-	-	+	+
Salvinia natans	+	+	+	+
Nymphoides indica	-	+	-	-
Seasonally submerged land				
Bacopa monnieri	+	+	-	-
Cyperus longus	+	-	-	-
Panicum repens	-	+	-	-
Phragmites australis	+	+	+	+
Polygonium salicifolium	-	-	+	-
***Rumex* sp.**	-	+	+	-
Schoenoplectus litoralis	+	+	+	+
Typha domengensis	+	+	+	+
Occasionally wet land Xerohalophytic				
Juncus rigidus	-	+	-	-
Species richness	**11**	**14**	**11**	**8**

Table 1.10. Species composition of aquatic Macrophytes in East Hammer Marsh during 2005-2006. Pluses indicate presence of species and minuses an absence of species.

Species	East Hammar	
	Burkah	Saddah
Wholly submerged		
Vallisneria spiralis	+	+
Ceratophyllum demersum	+	+
Myrophyllum verticillatum	+	+
Najas armata	+	-
***Chara* sp.**	+	-
Partly submerged		
Potamogeton crispus	+	+
P. pectinatus	+	+
P. perifolitus	+	+
Jussiaea repens	+	+
Seasonally submerged land		
Bacopa monnieri	-	+
Phragmites australis	+	+
Schoenoplectus litoralis	+	+
Typha domengensis	+	+
Cyperus malaccensis	-	+
Species richness	**12**	**12**

Absent species until 2006
Nymphoides peltata,
Potamogeton nodosus

Table 1.11. Comparison of the number of species in 2005 & 2006 with historical recorded number of species.

Marsh	Recorded 2005	Total 2006 (T)	Recruitment	References (H)	Restoration % T / H
Suq Al-Shuyukh	12	15	3	Hilli (1977) 15	100
Al-Hawizeh	9	11	2	No Record	-------------
East Hammar	11	15	4	Al- Saadi & Al-Mousawi (1988) 21	71.4

Densities of major species in the three monitored marshlands have increased over the past three years for all species (Table 1.12). When comparing the improvement in densities during the three years of restoration from 2004 to 2006, common reeds (*Phragmites australis*) increased in all three monitored marshes. In Suq Al-Shuyukh, the marsh submerged plant species *C. demersum and* emergent *S. litoralis* had the highest densities (See Figure 1.47 for pictures of *Phragmites* in background and submerged aquatics in foreground.) In Al-Hawizeh, *C.demersum* and another submerged aquatic plant, *S. natans*, formed the main densities. East Hammar was dominated by the submerged plants *M.verticillatum* and emergent *S. litoralis.* Importantly, densities increased each year in the marshes for all species.

Variations in densities among stations revealed that highest densities of common reeds (*P. australis*) were recorded at the Um Alnaaj and Taraba stations during summer (Figure 1.48), which was considered as the season of maximum growth for this species.


Figure 1.47


Figure 1.48

For *C. demersum*, the highest densities were recorded in autumn at the Amia station in Suq Al Shuyukh and at Taraba in Al-Hawizeh (data not shown). In general, autumn was the highest peak season for this species.

Table 1.12. Comparison of densities of major species 2004/2005/2006 in SuqAl-Shuyukh, Al-Hawizeh, and East Hammar. Proportional density measurements based on weight per unit area (g/m^2) along a 100 m transect.

Species in Suq Al-Shuyukh	2004	2005	2006
Phragmites australis	21	26	30
Ceratophyllum demersum	153	176	201
Schoenoplectus litoralis	23	29	36
Typha domengensis	3	4	4
Species in Al-Hawizeh	**2004**	**2005**	**2006**
Phragmites australis	20	24	28
Salvinia natans	133	156	193
Ceratophyllum demersum	154	169	197
Typha domengensis	3	3	5
Species in East Hammar	**2004**	**2005**	**2006**
Phragmites australis	-	23	27
Myrophyllum verticillatum	-	143	166
Schoenoplectus litoralis	-	42	54
Jussiaea repens	-	53	61

The cover of major species for each marsh is given in Table 1.13. Common reeds (*P. australis*) provided the main cover in all marshes. *S. Natans,* followed by *C. demersum* and *M. Verticillatum,* were next in importance.

Table 1.13 A comparison of the plant cover of major plants species during 2004/2005/ 2006 in each marsh along surveyed transects.

Al-Hawizeh	Suq Al-Shuyukh	East Hammar
Phragmites australis	*Phragmites australis*	*Phragmites australis*
Salvinia natans	*Ceratophyllum demersum*	*Myrophyllum verticillatum*
Ceratophyllum demersum	*Schoenoplectus litoralis*	*Schoenoplectus litoralis*
Typha domengensis	*Typha domengensis*	*Jussiaea repens*

To estimate the biomass of the marshes, we harvested a series of plots to determine the standing crop of the major species. The average harvests of the two major species were compared, and the biomass of common reeds (*P. australis*) in 2006 exceeded the historical record in most stations in the monitored marshes (Table 1.14). The average biomass of *C. demersum* harvested in East Hammar also exceeded the historical record, while the other stations had values below historical levels.

Variations in biomass between stations revealed that the highest amount of standing crop of common reeds (*P. australis*) was recorded in the Um Alnaaj and Taraba stations during summer. This was considered as the season of maximum growth for this species. For *C. demersum*, the highest densities were recorded in autumn at the Amia station in Suq Al-Shuyukh marsh and at Taraba in Al-Hawizeh. In general, the highest biomass for this species was recorded in autumn.

Additional measurements of some dominant species found at each station were done in 2006, to determine maximum biomass for these species (Table 1.15). *Schoenoplectus litoralis, Typha domengensis,* and *Salvinia natans* were the dominant species, with the top two species averaging nearly 3000 g/m^2 of peak biomass. *Salvinia* biomass was less than 20% of that for *Typha* and *Schoenoplectus.*

The most frequent species in the Al-Hawizeh marsh at both the Taraba and Um Alnaaj stations was *C. demersum*, followed by *S.natnas*. In general, the numbers for other species were low, indicating localized or confined population (Figures 1.49, 1.50).

The most frequent species in Suq Al-Shuyukh at the Amia and Al-Wineas stations was *C. demersum*, followed by *M verticillatum.* In general, the number of species found along the transects was higher than in Al-Hawizeh, reaching 10 and 8 respectively (Figures 1.51, 1.52).

Table 1.14. Average harvest field (g/m^2 dry wt.) for macrophytes during July 2005 and 2006 compared with historical records.

Species	Huyawzah				Suq Shuyukh				East Hammar		Historical studies	
	Um Al-Naaj		Tarabah		Al-Wineas		Amia				Hilli,1977	Al-Mayah,1994
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006		
Phragmites australis	**2906.6**	**3831.5**	**3866.6**	**4932.4**	**2266.6**	**3431.2**	**2016.6**	**3109.4**	**3383**	**4211.3**	**3608.7**	**883.5**
Ceratophylum demersum	**466.6**	**576.3**	**433.3**	**620.4**	**833.3**	**914.7**	**703.3**	**820.2**	**1200**	**2320.4**	**-**	**1294.4**

Table 1.15 Average harvest field (g/m^2 dry wt.) for macrophytes during July 2006

Species	Al-Hawizeh		Suq Al-Shuyukh		East Hammar
	Um Al-Naaj	Tarabah	Al-Wineas	Amia	
Schoenoplectus litoralis	**2721.5**	**2451.3**	**2420.5**	**2613**	**2108.7**
Typha domengensis	**2811.3**	**2623.7**	**2730.3**	**2851.2**	**2368.4**
Salvinia natans	**451.2**	**432.4**	**621.5**	**590.6**	**358.3**

The most frequent species in East Hamma, at both the Burkah and Saddah stations, was *C. demersum*, followed by *M.verticillatum.* In general, the number of species measured along the transects was higher than at Al-Hawizeh, but similar in number to Suq Al-Shuyukh, scoring 10 and 9 respectively (Figures 1.53. 1.54).

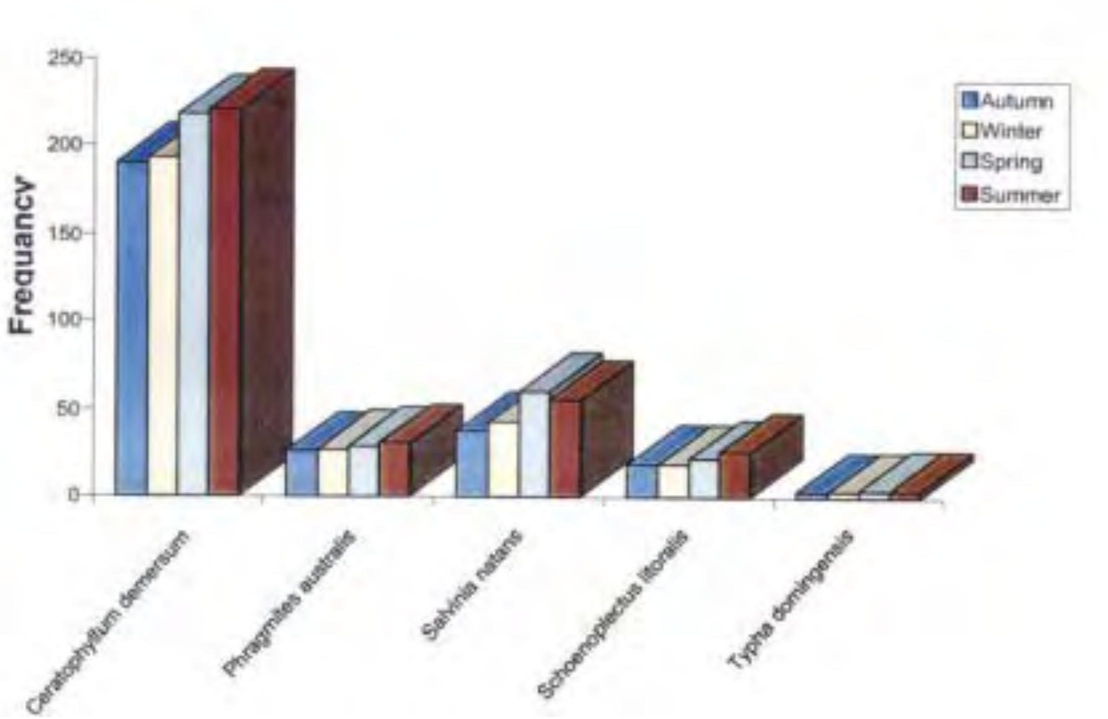


Figure 1.49. Frequency of plant species in Tarabah station during 2005-2006

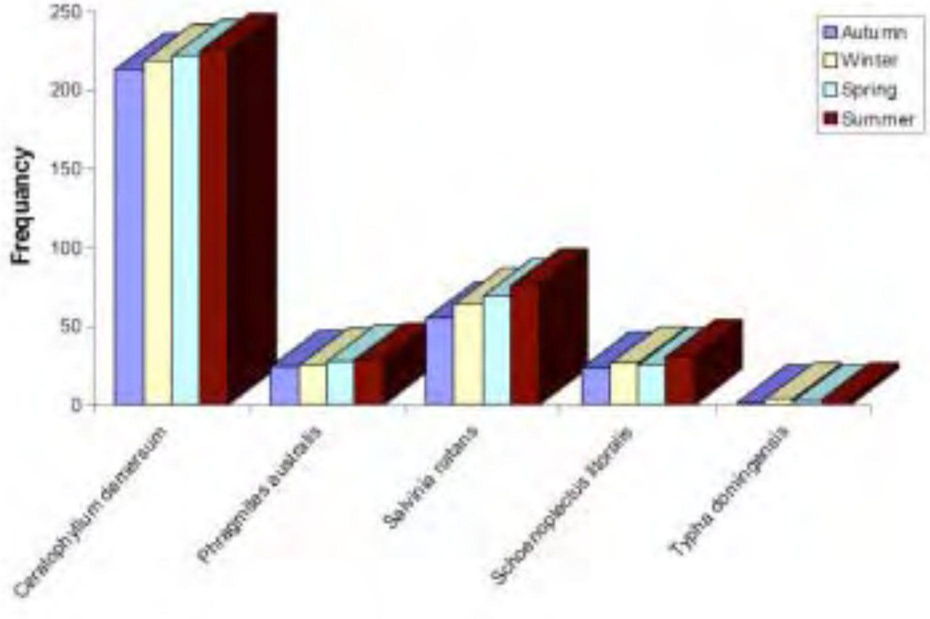


Figure 1.50. Composition of plant species in Um Alnaaj station during 2005-2006.

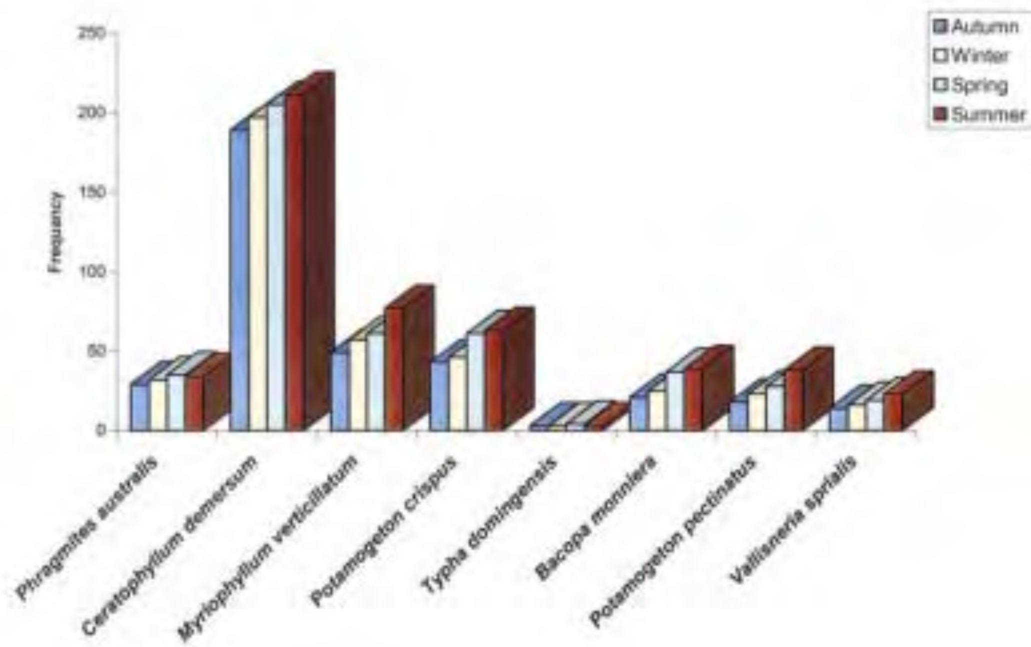


Figure 1.51. Composition of plant species at the Al-Amia station during 2005-2006

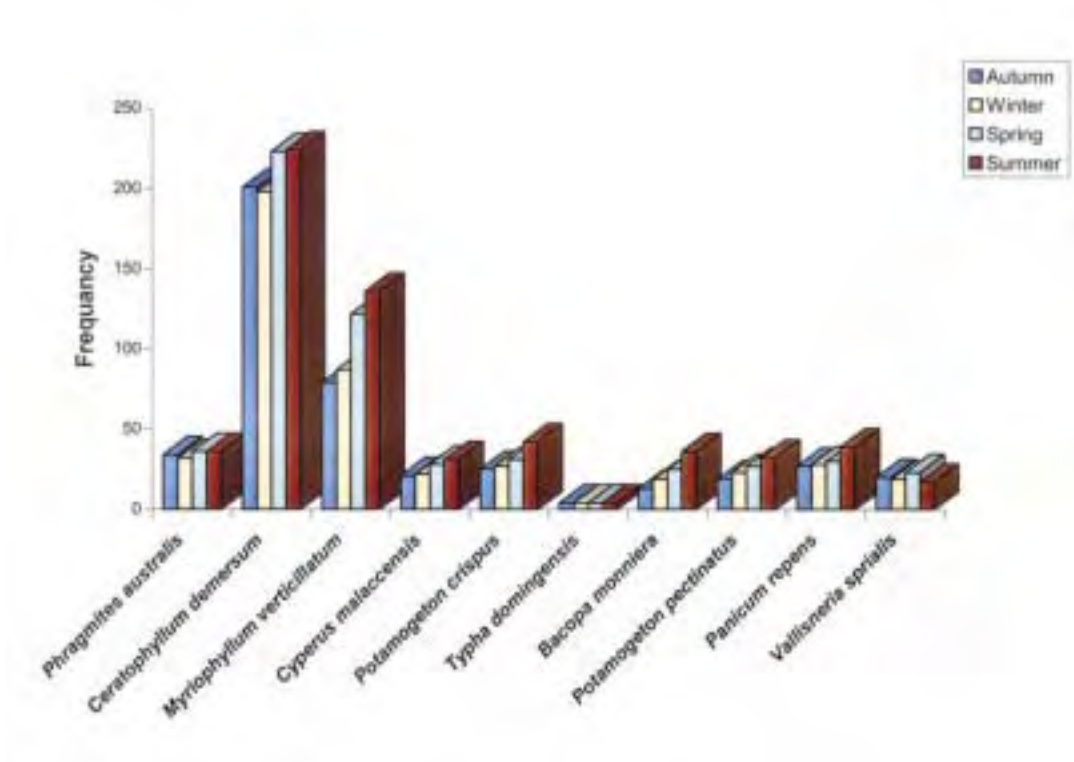


Figure 1.52. Composition of plant species at Al-Wineas station during 2005-2006

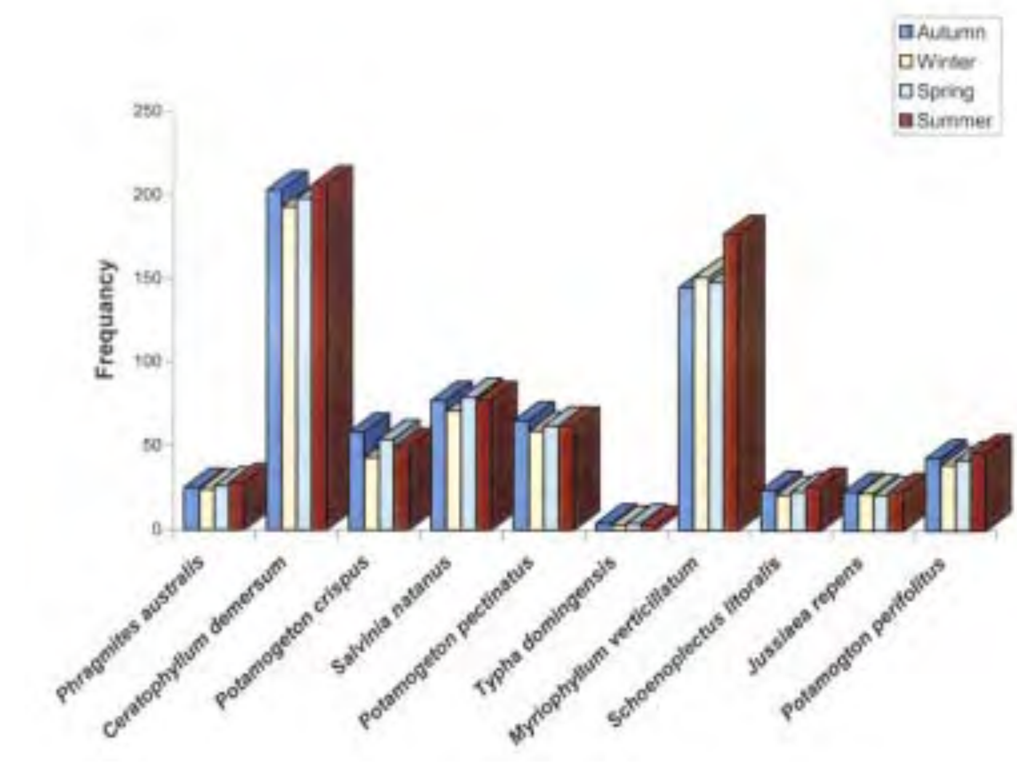


Figure 1.53. Composition of plant species at Al-Burkha station during 2005-2006

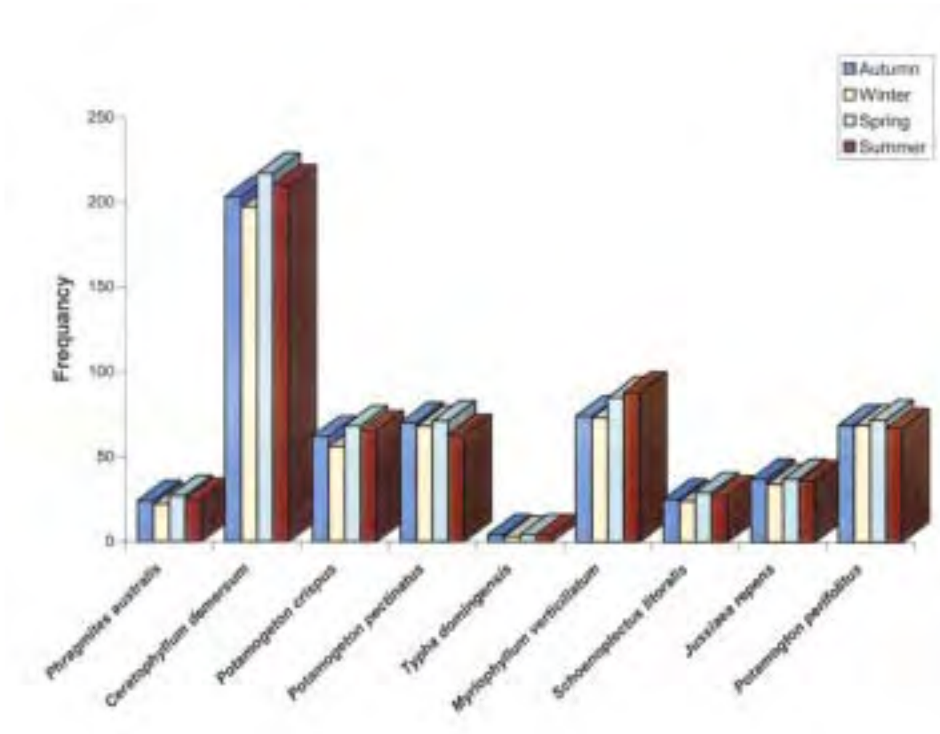


Figure 1.54. Composition of plant species at Saddah station during 2005-2006

1.4.7 Fish

The abundance of fish species in Suq Al-Shuyukh marsh is shown in Table 1.16. Seventeen species were collected from that marsh. The numerical values of abundance differed from those in 2005, but species ranking was the same for the first three species. The assemblage shows a better balance between number of species and number of individuals in 2006 than in 2005. The numerical abundance of fish in Al-Hawizeh marsh differed from that in 2005 and was more similar to Suq Al-Shuyukh in 2006 (Table 1.17). Eighteen species were collected from this marsh. *L. abu* ranked first in 2006, up from 2005 when it was the fourth most abundant species. *C. carassius* was second most abundant in 2006, but in 2005 it was in third position. The numerical abundance of fish in 2006 in East Hammar was similar to that of 2005, but with different dominant species. In total, eighteen species were reported. *C.carassius* ranked first, followed by *L. abu* and *A.mossulensis* in 2006 (Table 1.18). Figure 1.55 shows Iraqi fisherman casting their nets, and in Figure 1.56 we see their fish catch being analyzed for abundance, size, and food preferences.

Figure 1.55

Figure 1.56

Native species exhibited higher abundances compared to migratory and alien species. Some alien species (introduced) with high commercial value, like carp (C*. carpio*) and grass carp (*C. idellus*), and the marine migratory fish sabour (*T. ilish*) had high abundances as well (Tables 1.19 –1.21). Other noncommercial species are shown in Table 1.21, indicating the occurrence of ornamental species like *P. velifera* in both East Hammar and Suq Al-Shuyukh.

The size of the sampled fish increased dramatically from 2005 to 2006, with some species achieving historic records for total length (Table 1.22). These results indicate that the restored marshlands support better fish growth and reproduction, both excellent indicators that the restored marshes are providing habitat and water quality conditions conducive to fish productivity.

Table 1.16. Numerical abundance of fish species in Suq Al-Shuyukh

Species	No. of individuals					Numerical abundance %	
	Autumn	Winter	Spring	Summer	Total	2005	2006
Liza abu	211	203	91	107	612	42.21	28.39
Carassius carassius	107	249	167	84	607	25.88	28.16
Barbus luteus	41	59	122	34	256	13.82	11.87
Alburnus mossulensis	123	29	78	19	249	3.20	11.55
Acanthobrama marmid	4	57	43	8	112	2.95	5.19
Aspius aspius vorax	26	38	14	3	81	3.50	3.75
Ctenopharyngodon idella	53	7	-	-	60	0.30	2.78
Cyprinus carpio	10	26	9	-	45	2.65	2.08
Barbus sharpeyi	15	-	-	20	35	2.65	1.62
Cyprinion macrostomum	-	-	8	18	26	0.35	1.20
Silurus triostegus	10	-	7	6	23	1.50	1.06
Mastacembelus mastacembelus	2	-	8	5	15	-	0.69
Heteropneustes fossilis	2	-	1	11	14	-	0.64
Tor grypus	1	-	6	4	11	0.10	0.51
Gara rufa	-	-	-	3	3	-	0.41
Barbus xanthopterus	3	2	2	1	8	0.45	0.37
Tenaulosa illisha	1	-	-	-	1	-	0.04
Total	609	670	556	320	2158		

Table 1.17. Numerical abundance of fish species in Al-Hawizeh

Species	No. of individuals					Numerical abundance %	
	Autumn	Winter	Spring	Summer	Total	2005	2006
Liza abu	58	326	143	49	576	9.34	28.69
Carassius carassius	95	61	59	21	236	10.96	11.75
Aspius aspius vorax	112	50	8	7	177	23.22	8.81
Barbus luteus	248	201	55	45	549	36.48	27.35
Cyprinus carpio	72	17	12	-	101	6.15	5.03
Alburnus mossulensis	18	5	41	13	77	0.42	3.83
Silurus triostegus	19	9	28	21	77	3.29	3.83
Acanthobrama marmid	6	6	50	-	62	0.33	3.08
Barbus sharpeyi	21	14	14	2	51	9.20	2.54
Heteropneustes fossilis	13	10	3	10	36	0.14	1.79
Ctenopharyngodon idella	32	-	-	-	32	0.38	1.59
Mastacembelus mastacembelus	7	1	7	4	19	-	0.94
Barbus xanthopterus	1	4	6	-	11	0.04	0.54
Mystus pelusius	2	-	-	-	2	-	0.09
Cyprinion macrostomum	1	-	-	-	1	-	0.04
Tor grypus	-	-	-	-	-	-	-
Liza carinata	-	-	-	-	-	-	-
Tenaulosa illisha	-	-	-	-	-	-	-
Total	705	704	426	172	2007		

Table 1.18. Numerical abundance of fish species in East Hammar

Species	No. of individuals					Numerical abundance %	
	Autumn	Winter	Spring	Summer	Total	2005	2006
Carassius carassius	121	242	74	35	472	29.65	34.17
Liza abu	57	159	91	85	390	29.65	28.24
Alburnus mossulensis	4	1	2	97	104	2.94	7.53
Cyprinus carpio	6	22	26	27	81	0.92	5.86
Acanthobrama marmid	11	1	-	65	77	3.31	5.57
Barbus luteus	15	7	35	5	62	4.97	4.48
Liza carinata	29	8	13	-	50	14.73	3.62
Aspius aspius vorax	5	33	5	6	49	2.39	3.54
Tenaulosa illisha	-	-	39	8	47	0.73	3.40
Silurus triostegus	2	-	9	14	25	0.18	1.81
Barbus sharpeyi	-	3	5	-	8	1.10	0.57
Tor grypus	-	-	8	-	8	0.73	0.57
Heteropneustes fossilis	3	-	3	1	7	1.65	0.50
Thrysa mystix	-	-	-	1	1	-	0.07
Barbus xanthopterus	-	-	-	-	-	0.36	-
Ctenopharyngodon idella	-	-	-	-	-	0.18	-
Cyprinion macrostomum	-	-	-	-	-	0.18	-
Mastacembelus mastacembelus	-	-	-	1	1	-	0.07
Total	253	476	310	342	1381		

Table 1.19. Numerical abundance of migratory fish species

Migratory Species	Suq Al-Shuyukh	Al-Hawizeh	East Hammar
Liza carinata	-	-	3.62
Tenaulosa illisha	0.04	-	3.40
Thrysa mystix	-	-	0.07

Table 1.20. Numerical abundance of alien fish species

Alien Species	Suq Al-Shuyukh	Al-Hawizeh	East Hammar
Carassius carassius	28.16	11.75	34.17
Ctenopharyngodon idella	2.78	1.59	-
Cyprinus carpio	2.08	5.03	5.86
Heteropneustes fossilis	0.64	1.79	0.50

Table 1.21. Other noncommercial fish species in restored marshes

Suq Al-Shuyukh	Al-Hawizeh	East Hammer
Aphinus dispar	*Aphinus dispar*	*Aphinus dispar*
Aphinus spp.	*Aphinus* spp.	*Aphinus* spp.
Gumbosia holbroki	*Gumbosia holbroki*	*Gumbosia holbroki*
Poecilia (mollienesia) velifera		*Poecilia (mollienesia) velifera*

Table 1.22. The size of fish individuals in the restored marshes

Species	Al-Hawizeh		Suq Al-Shuyukh		East Hammar	
	2005	2006	2005	2006	2005	2006
Acanthobrama marmid	6.5-8.0	3.6-14.0	4.0-15.0	4.0-12.0	10.3-19.0	4.3-11.5
Aspius aspius vorax	22.7-70.0	16.5-70.0	19.5-60.0	77.6-60.0	15.2-40.0	10.0-45.0
Alburnus mossulensis	5.3-20.0	3.6-19.2	2.1-15.3	5.0-16.3	11.3-17.0	5.0-18.1
Barbus luteus	6.5-30.0	6.5-35.0	6.1-25.2	4.0-26.8	12.5-29.5	10.0-33.4
Barbus sharpeyi	16.0-50.0	9.0-52.0	17.6-50.0	24.0-60.0	30.0-45.0	13.0-48.9
Barbus xanthopterus	10.7	10.0-83.0	22.5-45.0	7.5-31.5	28.2-95.0	-
Carassius carassius	7.4-38.2	5.5-38.1	5.7-25.5	5.5-32.3	8.9-26.7	5.8-29.0
Ctenopharyngodon idella	21.1-38.5	15.0-73.0	29.5-70.0	17.6-82.2	48.2	-
Cyprinion macrostomum	-	10.5	6.0-11.0	4.5-8.2	14.1	-
Cyprinus carpio	11.2-95.0	10.0-97.5	13.4-45.0	12.7-75.0	14.0-65.0	9.0-66.0
Heteropneustes fossilis	13.4-17.8	7.5-25.5	-	8.0-16.5	9.5-21.2	10.0-23.0
Liza abu	6.4-10.0	4.4-19.0	7.7-16.5	5.2-17.8	9.0-16.2	5.4-22.0
Liza carinata	-	-	-	-	9.9-17.9	6.0-21.0
Mastacembelus mastacembelus	16.0-26.0	12.0-90.0	24.4-37.5	10.0-45.5	-	-
Mystus pelusius	-	13.0-13.2	-	-	-	-
Silurus triostegus	25.0-95.0	7.0-101.0	25.4-75.0	6.0-90.0	73.9	6.0-90.0
Tenaulosa illisha	-	-	-	13.0	18.5-36.0	9.2-37.0
Tor grypus	-	-	20.2-39.9	5.5-15.1	19.7-45.5	29.5-47.0

In general, the biological indices (Diversity, Richness, and Evenness) reflected better values in 2006 than 2005, emphasizing environmental improvement in the restored marshes. Diversity was slightly improved in Al-Hawizeh and Suq Al-Shuyukh marshes. In East Hammer there was a slight decrease in diversity (Table 1.23 & Figure 1.57). Richness improved in all monitored marshes, revealing an increased number of individuals to number of species collected (Table 1.23). Evenness was also improved, but no species was dominant in the fish assemblage in the three marshes, and species were represented by a balanced number of individuals (Table 1.23).

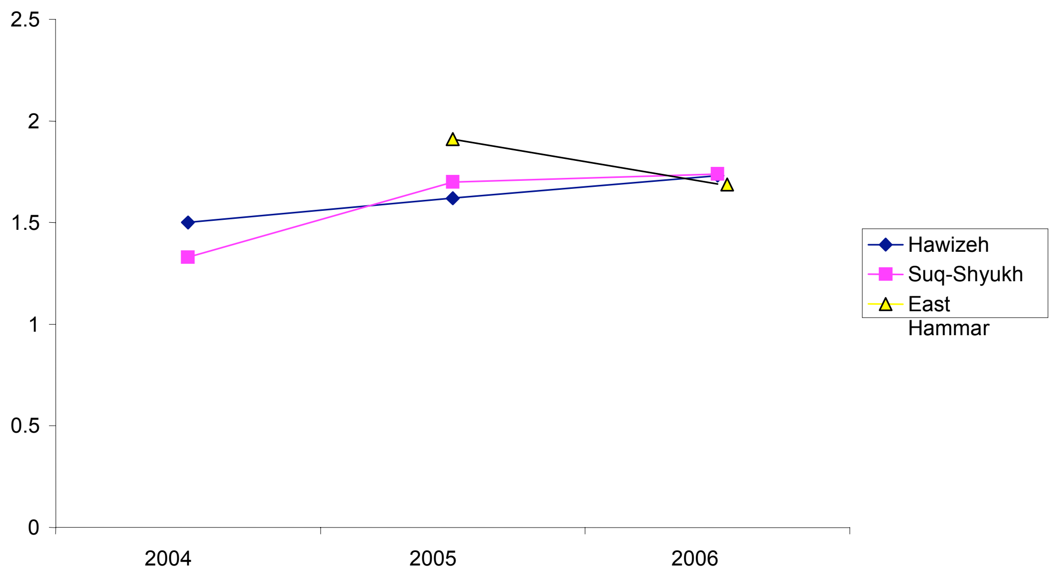


Figure 1.57. Fish diversity in the monitored marshes from 2004-2006

Table 1.23. Ecological indices in the marshes during the period study

Indices	Suq Al-Shuyukh		Al-Hawizeh		East Hammar	
	2005	2006	2005	2006	2005	2006
Diversity	1.62	1.73	1.70	1.74	1.91	1.69
Richness	1.71	1.95	1.43	1.84	1.70	1.79
Evenness	0.61	0.62	0.68	0.64	0.60	0.64

The highest similarity in fish assemblages was recorded between Al-Hawizeh and Suq Al-Shuyukh marshes. The lowest was between East Hammar and Al-Hawizeh (Table1.24). The same trend was recorded in 2005. Fish catch in kg/h was highest in Al-Hawizeh marsh and lowest in East Hammar (Table 1.25). An estimate of fish recovery was based on the percent of species return. The index reached 71% in Al-Hawizeh and Suq Al- Shuyukh marshes, and it was slightly lower, 64%, in East Hammar (Table1.26).

Table 1.24. A similarity index between the monitored marshes according to Jaccard (1908)

Similarity between Al-Hawizeh & Suq Al-Shuyuk	80.9 %
Similarity between East Hammar & Suq Al-Shuyuk	66.6%
Similarity between East Hammar & Al-Hawizeh	55.5%

Table 1.25. The amount of fish catch by electrical fishing in kg per hour

Marsh	The catch kg /hour
Al-Hawizeh	17.16 kg/h
SuqAl-Shuyuk	9.75 kg/h
East Hammar	4.45 kg/h

Table 1.26. A calculated recovery index (R I) based on present species / historical species number for each marsh.

Marsh	P/H	RI
SuqAl-Shuyuk	20/28	71%
Al-Hawizeh	18/28	64 %
East Hammer	20/28	71%

Food pyramids for all the fish in the monitored marshes are shown for 2005 and 2006 (Figures 1.58, 1.59, 1.60). These figures show an improvement in the shape of the food pyramid as the numbers of herbivores are increasing over time (from 2005 to 2006), approaching the normal state for a sustainable fish food pyramid. This was especially true for East Hammar. Importantly, the width of the herbivore base is wider in respect to predators at the apex, which indicates a more balanced and stable fish population.

Figure 1.58. Food pyramid of fish in Suq Al-Shuyukh

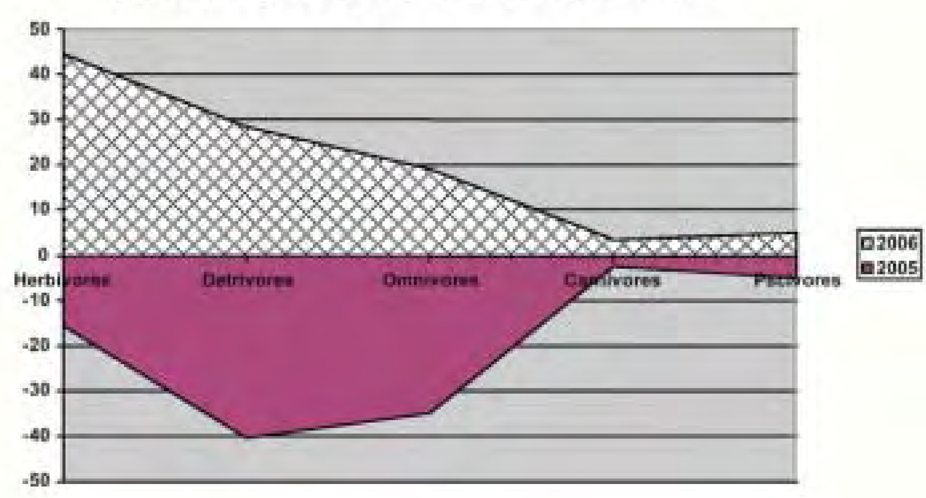


Figure 1.59. Food pyramid of fish in Al-Hawizeh

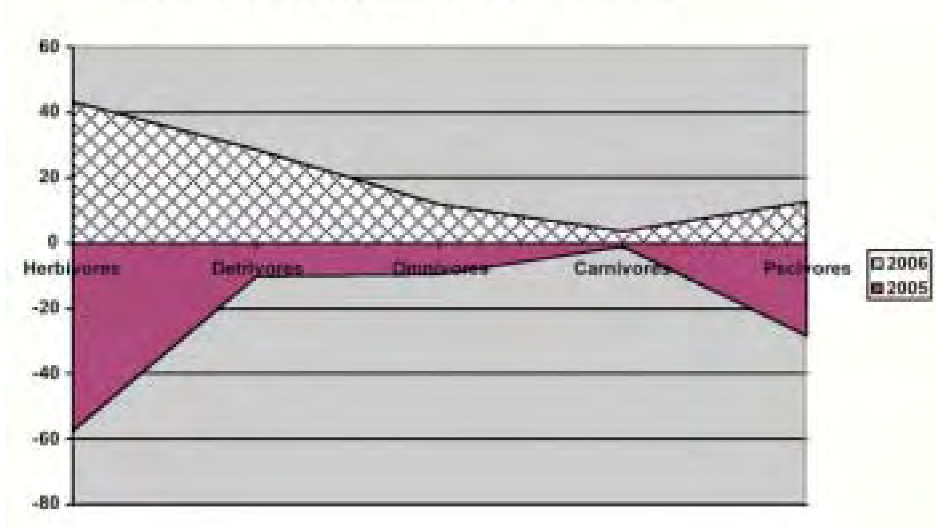
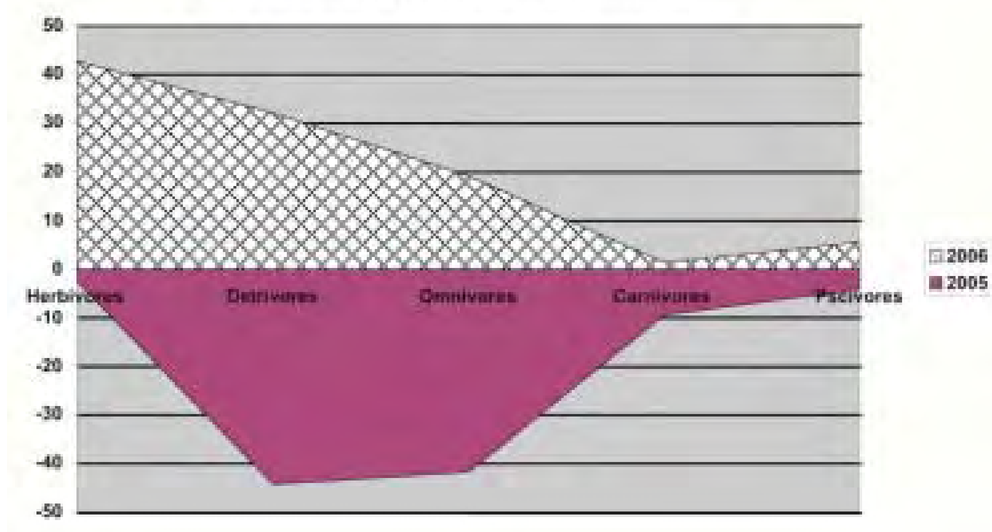


Figure 1.60. Food pyramid of fish in East Hammar



To determine the food source, a diet composition was completed for the major fish species by checking gut contents. The food sources of these species are shown in Appendix 5. *B. sharpeyi (*Bunni), in the three monitored marshes, consumed mostly aquatic plants. The analysis indicated that this species is herbivorous. The diet composition of *C. carassius* (Curcian) in the three monitored marshes was also herbivorous, but algae composed the highest amount of food. The diet composition of *C. carpio* (carp) in the three monitored marshes varied among the sites; however, snails, insects, and organic matter made up the main diet, thus the species was classified as a carnivore. The diet composition of *A. vorax* (Shilig) in the three monitored marshes was almost 100% fish, and it was classified as a predator. The diet composition of *B. luteus* (Himri) in the three monitored marshes was primarily algae and plants, and it was consider a herbivore. The diet composition of *S. triostegus* in the three monitored marshes consisted mostly of fish (> 95%), with a few percent crustaceae, and it was classified as a predator. The diet composition of *L. abu,* in contrast to the other species, was mostly clay and detritus in the three monitored marshes, and it was classified as a detritivore (Appendix 5).

1.4.8 Water Birds

Figures 1.61 and 1.62 show examples of the birds surveyed for species numbers recorded in the three monitored marshes during 2005-2006 samplings.

Figure 1.61

Figure 1.62

The Al-Hawizeh marsh had the highest number of species in all months except April 2006, with a peak (37) detected in January 2006 (Figure 1.63). The peak bird populations in Suq Al-Shuyukh and East Hammar marshes (25) were recorded in December and September, respectively. The lowest number of species recorded (13) was in East Hammar marsh.

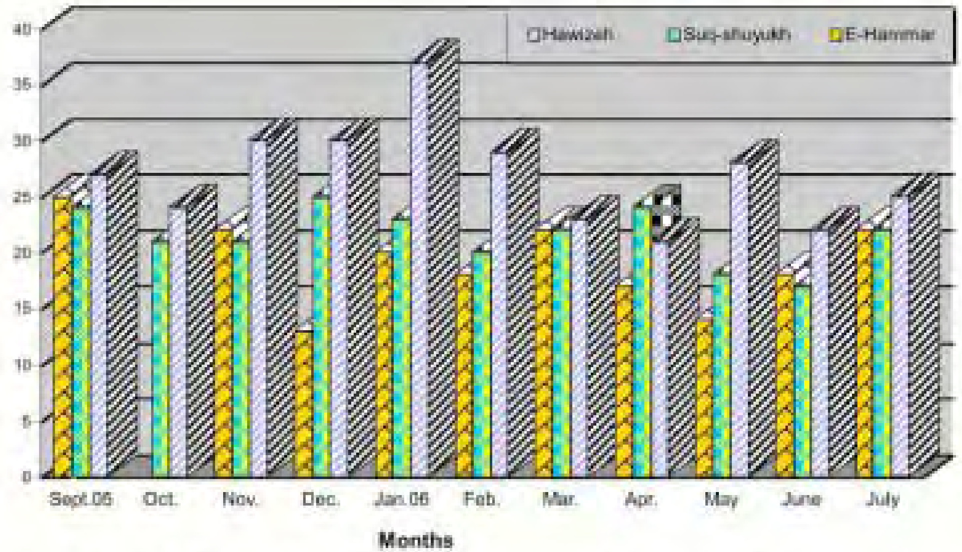


Figure 1.63. Number of bird species recorded in the monitoring marshes.

The number of individual birds counted in the Al-Hawizeh marsh topped 6,500 in the winter months (Figure 1.64). Al-Hawizeh marsh had the highest number of individuals except during March, April, and July 2006. The peak numbers in our survey were 6893, 760, and 2222 individuals in Al-Hawizeh, Suq Al-Shuyukh, and East Hammar marshes respectively.

Figures 1.65 and 1.66 show the avifauna percentages of species (species composition) and number of individuals within each order in the Al-Hawizeh marsh. Charadriiformes ranked first followed by Ciconiiformes (Figure 1.65). Ralliformes occupied the first rank followed by Pelecaniformes in number of individuals (Figure 1.66).

The avifauna percentage of species and individuals of each order in Suq Al-Shuyukh marsh are shown in Figures 1.67 and 1.68. Charadriiformes occupied the first rank in species and individuals composition, followed by Ciconiiformes. Anseriformes ranked third in species and Coraciiformes in individuals. Pelecaniformes, however had the lowest numbers in species and individuals. The avifauna species and individuals percentages in East Hammar marsh are shown in Figures 1.69 and 1.70. Charadriiformes ranked first in species followed by Ciconiiformes, while they were similar in number of individuals. Anseriformes ranked third in species and individuals, and Pelecaniformes occupied last position in species and individuals.

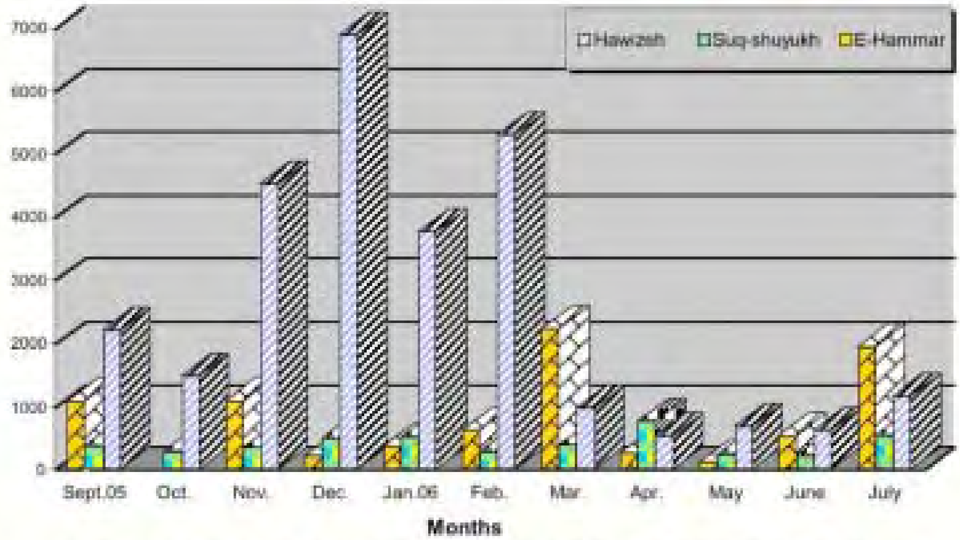


Figure 1.64 Number of individual birds recorded in the monitored marshes.

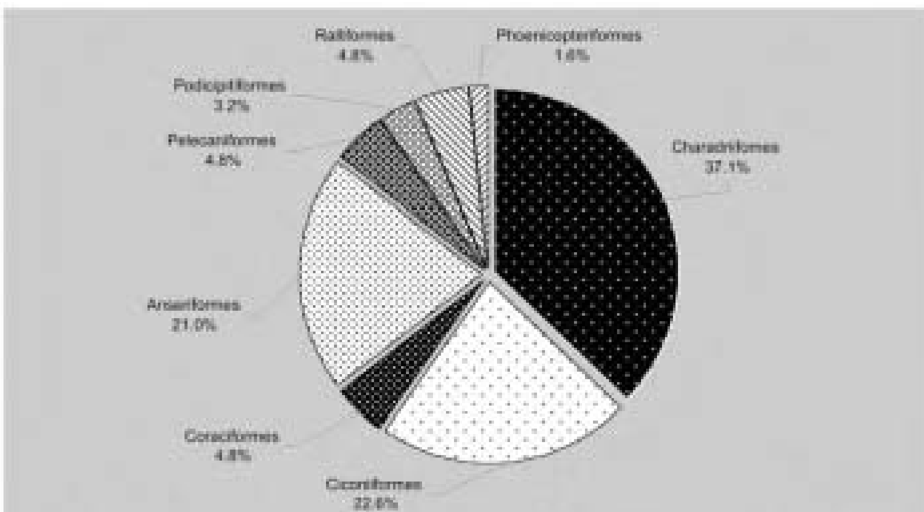


Figure 1.65. Avifauna percentage of species in each order in Al-Hawizeh

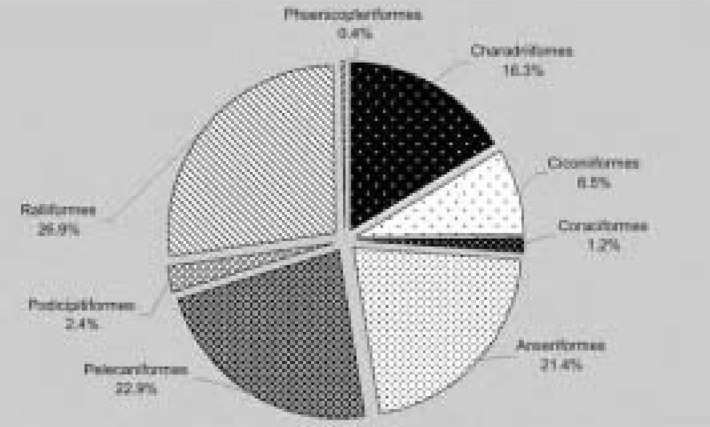


Figure 1.66. Avifauna percentage of individuals in each order in Al-Hawizeh

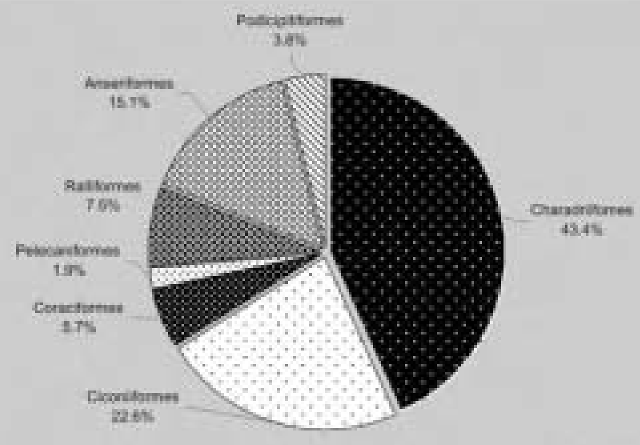


Figure 1.67 Avifauna percentage of species in each order in Suq Al-Shuyukh

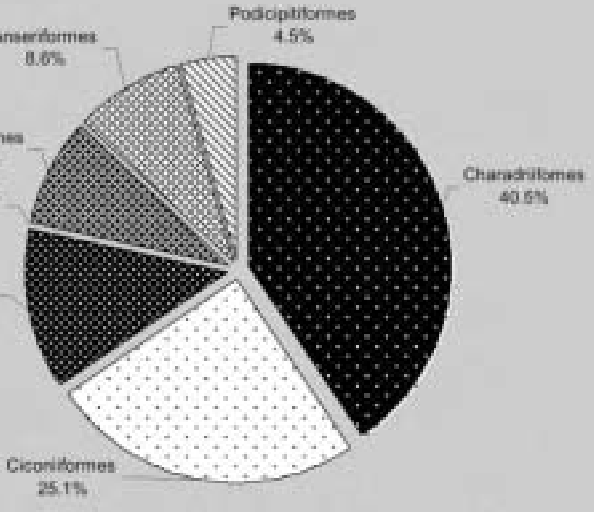


Figure 1.68. Avifauna percentage of individuals in each order in Suq Al-Shuyukh

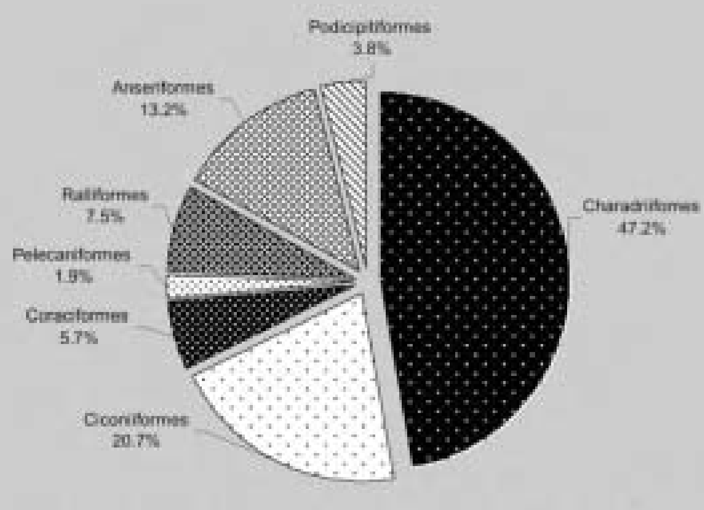


Figure 1.69. Avifauna percentage of species in each order İn East-Hammar

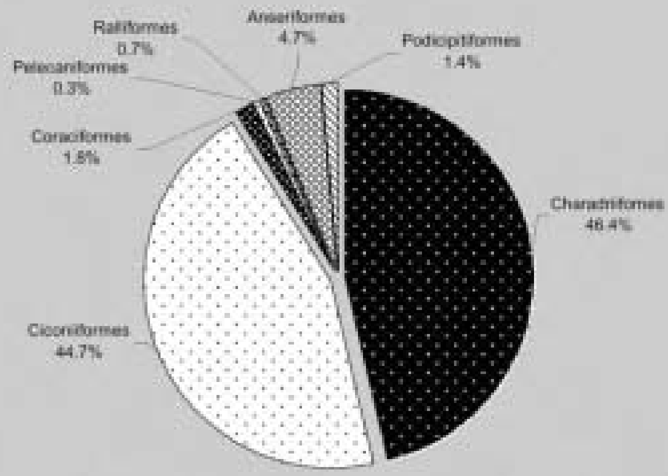


Figure 1.70. Avifauna percentage of individuals in each order in East Hammar

Several peaks for diversity were seen in Al-Hawizeh marsh (Figure 1.71). Values ranged from 2.9 in May to 1.6 in July 2006. The peaks of diversity were encountered in December and January in Suq Al-Shuyukh and Al-Hawizeh. Bird diversity in East Hammar peaked in December. Lowest values were recorded in July, February, and November. Values of evenness ranged from 0.5-1.0 in Suq Al-Shuyukh and East Hammar, which reflected the highest month values, while Al-Hawizeh had the lowest at about 0.75 most months (data not shown). Species richness was higher in Al-Hawizeh than Suq al-Shuyukh during some months, with the ranking reversed in others. East Hammar had the lowest richness values. Higher evenness values indicated that total numbers were not dominated by a few species. Equal numbers of several species were reported. The peaks were recorded in June, December, and May in Al-Hawizeh, Suq Al-Shuyukh and East Hammar marshes, while the lowest values were recorded in July, April, and November in the same order as above.

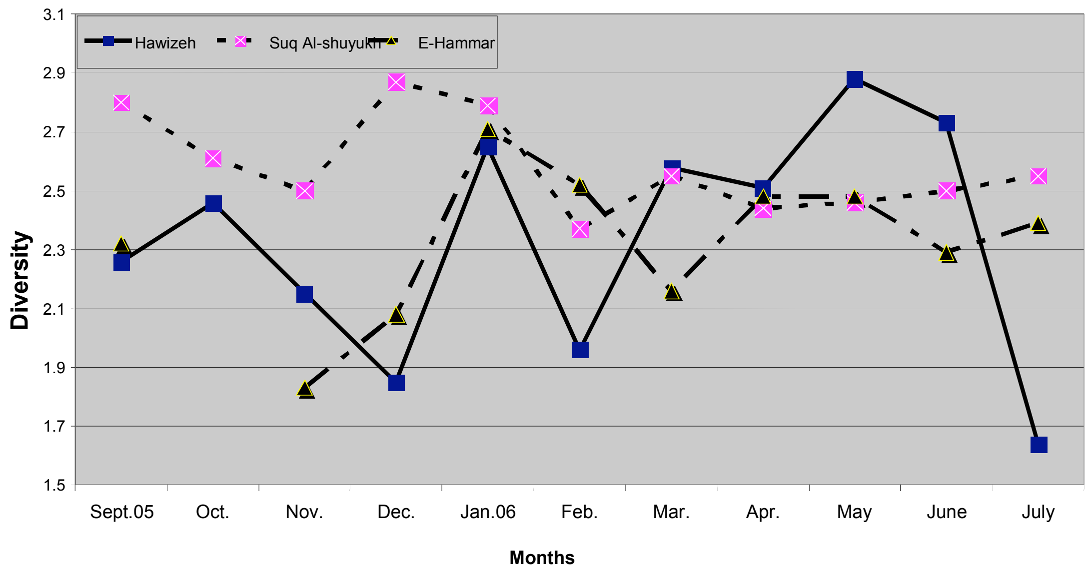


Figure 1.71. Monthly bird diversity in the monitored marshes

Table 1.27 shows the number of species recorded within each order in the three monitored marshes. Al-Hawizeh marsh recorded 62 species, while Suq Al-Shuyukh and East Hammar recorded 53 species. Charadriiformes had the highest recorded number, followed by Ciconiiformes in the monitored marshes. Phoenicopterifomes were seen only in Al-Hawizeh.

Table 1.27. Number of species recorded within orders in the 3 marshes

Order	Al-Hawizeh	Suq-Al-Shuyukh	East Hammar
Charadriiformes	23	23	25
Ciconiiformes	14	12	11
Coraciiformes	3	3	3
Pelecaniformes	3	1	1
Ralliformes	3	4	4
Anseriformes	13	8	7
Podicipitiformes	2	2	2
Phoenicopteriformes	1	0	0
Total	62	53	53

The number of bird species counted and total number of individuals in the marshes in 2006 was higher than found in 2005 (Table 1.28). This indicated that the marshes were providing an improved habitat for the bird populations. This information and the number of breeding birds found in the marsh provide evidence for an improved population of birds in the future in the restored marshes. The number of ducks also increased dramatically in Al-Hawizeh in 2006, compared to 2005 (Table 1.29). Duck counts also increased in the other marshes but not as significantly.

A comparison of the number of bird species and individual birds with historical records indicates that in 2004-2005 there was a 65% recovery in species (Table 1.30). In the 2005-2006 bird survey the number of species increased and the recovery index was 88%. This meant that 88% of the historically recorded bird species had returned to the restored marshes, but the numbers are much lower than the historical ones.

Table 1.28 A comparison of the 2005-6 counts of birds with previously collected data (2004-2005) in the monitored Iraqi southern marshes

Marsh	2004-2005		2005-2006	
	species	individuals	species	individuals
Al-Hawizeh	52	9,399	62	28,331
Suq Al-Shuyukh	37	1,975	53	4,443
East Hammar	29	1,998	53	8,465

Table 1.29. Comparison of the number of ducks recorded in 2005-06 with the previous monitoring in 2004-2005.

Species	Al-Hawizeh		Suq Al-Shuyukh		East Hammar	
	04-05	05-06	04-05	05-06	04-05	05-06
Marbled teal	104	1089	-	104	-	77
Teal	69	1161	34	90	-	2
Mallard	60	234	28	38	-	60
Wigeon	140	1420	4	-	-	128
Pochard	50	150	-	52	-	-
Gadwall	32	300	4	-	-	63
Gargany	10	9	2	23	-	4
Tufted duck	8	1480	-	-	-	-
Shoveler	-	35	13	3	-	70
Pintail	-	158	24	-	-	-
Ferruginous duck	-	50	4	-	-	-
Red-crested pochard	-	-	-	20	-	-
Greylag goose	6	26	-	43	-	-
Scup	-	50	-	-	-	-
Total	479	6162	115	373	-	404

Table 1.30. The number of species and individuals recorded in previous surveys compared to current bird surveys

Study	Marsh	No. of species	Total individuals all species
Georg and Vielliard, 1970	Lower Mesopotamia	55	59,378
Koning and Dijksen, 1973	Lower Mesopotamia	58	128,004
Carp, 1975	Lower Mesopotamia	45	52,151
Scott, 1995 (for 1972, 1975, 1979 census)	Hammar	73	288,222
Present work, 2005-2006	Al-Hawizeh	62	28,331
	Suq Al-Shuyukh	53	4,443
	East Hammar	53	8,465
	Total	74	

1.5 Discussion of Major Findings

1.5.1 Water Quality

The water quality of the marshes is largely affected by the arid climate, soil conditions, and upstream waters on the Tigris and Eupharates (Richardson and Hussain 2006). The three marshes, Al- Hawizeh, Suq Al-Shuyukh, and East Hammar, are in general on the alkaline side and resemble other Iraqi fresh water bodies (Al-Laami et al. 1996, IMRP 2005). Seasonal changes of different parameters in the marshes were more or less similar, especially during winter, while in other seasons they had their own distinct patterns. East Hammar had more fluctuations and exhibited different values in most measured parameters, due to the tidal effect of Arabian Gulf via Shatt Al-Arab.

Monthly changes in BOD values in the marshes were affected by the amount of organic material oxidized by the action of bacterial and other organisms (Best and Ross 1971, Stirling 1985), which represents a vital natural function of the marshes that increased in the summer months (Figure 1.12).

Fluctuations in values of nutrients were seasonal, with values highest in winter and lowest in summer, and generally followed the input values of the inputs sources. Marsh productivity responded through the uptake of nutrients by phytoplankton and aquatic macrophytes, with Al-Hawizeh and Suq-al-Shuyukh reflecting higher values than East Hammar. In general, these values were higher than historical records. This could be attributed to the rise in the use of fertilizer for agricultural purposes and the impact of domestic sewage. The low values of phosphorus, compared to previous recorded data, could be related to the large growth demand by phytoplankton and aquatic macrophytes, which have dramatically increased in the marsh during the past two years.

The changes in ammonium values are explained by the natural cycle of decomposition and decay in the marshes, a similar conclusion being reached earlier by Hussain et al. (1991). Nutrients (nitrate and phosphate) showed monthly changes, especially in the summer, and increased in winter months (Figures 1.13, 1.14). The seasonal patterns of parameters monitored were the same as historically recorded; even the ranges were similar to previous records, with the exception of nutrients. Nitrate and sodium were higher than before, but the majority of values indicate that water quality was more or less the same as historically recorded.

From the above results, we concluded that the water quality is good and supports the natural life cycles of restored marshes. No significant differences exist between previous studies and the present one. The water quality of restored marshes allowed different organisms to grow, reproduce, and disperse in a manner similar to that of natural healthy water bodies that were historically recorded.

1.5.2 Phytoplankton

Primary production of phytoplankton is often considered the base of the aquatic food chain in open water marshes. The amount of net productivity changed seasonally and was affected by several limiting factors, such as concentration of nutrients, light penetration, and water temperature (Figures 1.3, 1.8). Primary production of the restored marshes was higher than in other Iraqi water bodies, which supports the existence and growth of numerous organisms including fish and birds (Mohammed 1994).

The highest peak of chlorophyll-a concentrations was recorded in Burkah station in East Hammar (18.4 mg C/m^3). The lowest peak was in Al-Wineas station in Suq Al-Shuyukh marsh (1.6 mg C/m^3). The total number of phytoplankton cells followed the same pattern. The high level of chlorophyll-a in East Hammar marsh could be due to the influx of nutrients from the Shatt Al-Arab River. These results were higher than historical studies in the area (Al-Lami et al.1998, Al-Saadi et al. 2000, Hussein et al. 2002). Interestingly, Um Alnaaj station in Al-Hawizeh marsh had a different timing for higher peaks, which happened in autumn instead of spring. In temperate regions, there are two peak patterns for high primary productivity of phytoplankton (Cushing 1975). This may indicate that the phytoplankton biomass in the marshes belongs to a temperate type of primary productivity, controlled by temperature and nitrogen:phosphorus ratios (Al-Saadi et al. 2000).

The algal population of East Hammar was found to be characterized by the occurrence of some genera that did not exist in the Shatt Al-Arab estuary. Species such as *Gomphonema, Navicula, Bacillaria, Nitzschia, Cocconeis, Diploneis, Mastogloia, Melosira, Pleurosigma, Gyrosigma, Amphora* and *Oscillatoria,* mostly of marine origin, were found in East Hammar. In general, the timing of algal blooms in the southern marshes is not uniform, as it is dependant on several environmental factors (Al-Lami et al. 1997; Kasim et al.1999,2006; Salman et al. 2002). The dominance of diatoms found in the present monitoring program at restored marshes was reported to be common in other Iraqi water bodies, as indicated by several earlier studies (Al-Mousawi et al. 1990, Al-Saadi and Al-Lami 1992, Moulood et al. 1993, Al-Saadi 1994, Al-Saadi et al. 2000). The occurrence of Rhodophyte (a red phytoplankton group or class) can be considered to be a unique feature of the Iraqi marshes.

1.5.3 Zooplankton

Differences were found in the total number of zooplankton individuals at monitoring stations of open water and others more densely vegetated, due to slow current and thick submerged aquatic macrophytes. Rotifera was the dominant group in all studied stations, followed by Copepoda and then Cladocera. The same was recorded in previous studies of Iraq's inland waters by Al-Saboonchi et al. (1986), Sabri (1988), Al Laami et al. (1996 and 1998), and Nasha't (2001).

There were seasonal changes in the density of zooplankton (ind/m^3) during the spring, with a peak in April 2006, while values were the lowest in September (Figure 1.37). This pattern was shown previously by Al-Zubaidy (1988) and is in agreement with Ajeel (1998). The peak found in March and April is also in agreement with Mangol and Akbar (1986 a, 1986b, 1986c). Late summer declines in populations could be due to the feeding of fish larvae after the spawning season in early spring. Comparing the density (ind/m^3) obtained in

2005 with 2006 (Appendix 3) showed that the densities of zooplankton in 2006 were higher than in 2005, and approached those of previous studies (Ajeel1998, Mangalo and Akber 1998, Al-Zubaidy 1998). The orders of zooplankton were the same as recorded previously, similar to those in other Iraqi inland water bodies.

1.5.4 Aquatic Macrophytes

Ecological factors or man-made changes in an aquatic ecosystem play an important role in the distribution and productivity of aquatic macrophytes (i.e., temperature, salinity, content of organic substances, and grazing) and cause most of the variation in percentage of plant cover (Kheder and Loveit-Doust 2001). Quantitative characteristics of plant species were varied in the monitored stations. *C. demersum* was the dominant submerged aquatic species because it possessed a wide range of distribution and occurred in many aquatic habitats, like small narrow and shaded canals, ponds, and rivers, and also expanded to invade marshes and lakes. These habitats had different depths and salinity ranges, from 20-200 cm in depth and 0.4 -7.41 ppt salinity (Al-Mayah 1994) and more as shown by data of the IMRP program. Our ARDI monitoring program showed that *P. australis* was the dominant emergent macrophyte species, due to its tolerance to the drought conditions and its rapid regrowth from the seed imports or the soil seedbank, which was able survive through many years of dessication. The density of *P. australis* at Taraba station in Al-Hawizeh marsh was higher than at other stations, which was reflected in the high content of organic matter (TOC) in the substratum (Table 1.2, soil analysis/water quality section). Sanchez-Carriblle et al. (2001) pointed out that the percentage of cover of *P. australis* correlated with the degree of the sedimentation of organic matter in the freshwater wetlands of Spain. In contrast to the effect of the flooding regime and organic matter on structuring the vegetation, the variation in soil salinity between marshes appears to control the distribution of this plant species in Iraq. Higher values of salinity closer to East Hammar marsh are probably attributed to the complex interaction between daily and seasonal tidal input of salt (Brewer and Grace 1990) and may have resulted in the lower *P. australis* cover in this marsh and its absence in 2004 (Table 1.12).

The restoration index of macrophytes in Suq Al-Shuyukh was 100%, compared to the historical data. This means that water quality criteria and substrate are good enough to accommodate a diverse population of plants. However, the picture was different with East Hammar, as our comparison with previous data indicates that this marsh is not as healthy, because of higher salinity and low concentrations of organic matter.

1.5.5 Macroinvertebrates

The number of species in the three restored marshes increased in 2006 to 84. Insects composed more than half of the species (48), and snails the second largest number (13). The dominance of insects over the other groups is a healthy sign in water bodies, as it is known that insects make up 95% of the animal kingdom and are an important part of the trophic pyramid. The same is true of marshland fauna. Increased densities of individuals from 2005 to 2006 in all macroinvertebrate groups pointed to improved conditions in marsh communities, but densities were still below recorded values in natural Iraqi habitats (see Hamzah 1980, Ali and Salman 1986, Abdullah 1989, Rahma and Jaweir 1990, Ali et al. 1995, Ali and Salman, 1998, Hassan et al. 2000, Ali et al. 2002, Abdul-Saheb et al. 2003). However, the epiphytic fauna of Iraqi lakes and marshes have not been studied thoroughly, although the are considered an essential food resource for fish (Kornijow et al. 2001a), while studies of macrobenthos are very rare in lakes in Iraq (Kornijow et al. 2001b).

Our results indicate that densities and number of species in each square meter of plant cover were higher than those in the substratum. We found 1776-5381 individuals/m^2 on aquatic plants, in comparison to less than 500 individuals in the bottom substrate. These findings are similar to previous records in Habbaniya Lake (Kornijow et al. 2001a). In regard to species composition, Kornijow et al. (2001a) found 13 species from 14 taxa were insects on aquatic plants in the Thurthar and Habbaniya Lakes, and Kornijow et al. (2001b) recorded 20, 25, and 10 Insect species out of 40, 33, and 13 taxa in Thurthar and Habbaniya and Razzazah Lakes, respectively.

Our number of species in the three restored marshes in 2006 was slightly different from 2005. Al-Hawizeh had more species than the other marshes, in contrast to Suq Al-Shuyukh in 2005. This suggests that restoration in Al-Hawizeh was better and more developed than that in the other marshes, which may be related to its environmental characteristics (physical, chemical, and biological). For example, three of the macroinvertebrate groups that increased in Al-Hawizeh need high concentrations of calcium to build their shells. These groups include mussels, amphipods, and crabs. We speculate that the calcium, salinity, and hardness in Al-Hawizeh waters were higher in 2006 than in 2004 and 2005 (however, the hardness of Al-Hawizeh was about half that of Suq Al-Shuyukh in 2005). The minimum values in densities of macroinvertebrates were found in Suq Al Shuyukh marsh, which may be due to the presence of vast numbers of predators represented with Charadriiformes, especially plover, black stilit, etc. that feed mostly on snails, insects, shrimp, etc. This avian order comprised 40.5 % of total bird individuals in Suq Al-Shuyukh, in comparison to 16.3 and 46.4% in Al-Hawizeh and East Hammar, respectively, in 2006 (Abed/IRD 2006).

The decrease in richness in Al-Hawizeh and Suq Al Shuyukh was due to the huge increase in the number of individuals. The change in the number of species was not in the same sequences as individuals. The altered richness and evenness in East Hammar in 2006 could be related to the increased densities of pisivorous birds like Charadriformes, gulls and terns, which prey heavily on certain macroinvertebrate species.

Specific species of macrophytes were chosen by macroinvertebrates for feeding, shelter, and reproduction. *Ceratophyllum demersum* was the plant species to harbor the maximum species of macroinvertebrates (Hassan et. al 2000, Kornijow et al. 2001a, IRD 2006). The increased number of species of macroinvertebrates and their densities in 2006, compared to 2005, indicated that restoration is continuing to progress. A higher similarity was found been Suq Al-Shuyukh and East Hammar macroinvertebrates since both marshes were receiving Euphrates stream water. Overall densities of macroinvertebrates were still below natural values in comparison with other marshlands of the world.

1.5.6 Fish

There was a large improvement in the size of fish collected or observed in the fish market over the survey period, indicating that the restored environment of the marshes supports the growth of these species. Moreover, there appeared to be plenty of resources available for the expansion of grass carp and common carp. Kishni (*L. abu*) was the most abundant species in the restored marshes, and this trend was the same as recorded in other Iraqi lakes by a Polish company in mid-1980s. An alien species (*C. carassius)* introduced in the early nineties was the second most common species, but in East Hammar it was the most prevalent species (Table 1.20). The introduced (alien) species may survive in the restored environment of the marshes better than native species, since no local enemies or predators have been recognized. The lack of the effect of local fish diseases for these species may also explain their large abundance in the restored marshes. The restored marshes are now considered a healthy environment, even after ten years of desiccation, and the species that survived are more resistant and their spawning has resulted in a high numbers of individuals for those species.

Improvement in the ecological indicators (diversity, richness, evenness) during 2006, compared with 2005, suggests that restoration is taking place and that the restored marsh environment is progressing towards recovery. The diversity index is important, since it can be used as an indicator of balanced restoration. Our restoration index (species present /historical record) was higher in 2006 than in 2005, meaning that more species have returned to the restored marshes. The highest percentage was in East Hammar marsh (71%).

The similarity index between Suq Al-Shuyukh and Al-Hawizeh was 80.9%, which reflects that fish species compositions in the two restored marshes was very close. This was probably due to the fact that the fish stock for both was derived from the same riverine fish assemblages (Tigris and Euphrates). A lower similarity encountered between East Hammar and other marshes was due to the intrusion of few marine species to East Hammar. East Hammar is considered as a tidal oligohaline marsh.

The presence of several trophic levels, i.e., herbivorous, omnivorous, carnivorous, detritovorous, and predators reveals that a healthy trophic assemblage occurred in the restored marshes. A deviation in the trophic nature of studied fish species from historical records indicated that the restored environment did not match or resemble the previous natural one. The trophic pyramid of the monitored marsh was more natural in 2006 than 2005, because it more closely followed an ideal natural one, with a larger herbivorous base (Figures 1.58-1.60). The fish catch effort showed that Al-Hawizeh was more productive, because it was only partly desiccated and it has low salinity (Figure 1.5). East Hammar was less productive compared with other marshes, because of its higher salinity that is considered unsuitable for several fresh water species. Also, many marine species that cannot freely enter because of the oligohaline nature of the water. Heavy fishing pressure has also reduced the fish populations in this marsh.

1.5.7 Water birds

The Iraqi marshes have long been a refuge for millions of birds migrating from Europe and Northern Asia, and have contributed greatly as feeding, resting, and spawning sites (Allouse 1960, 1961; Georgae and Vielliard 1970; Carp 1975; Scott and Carp 1982). The 2006 monitoring of Iraq's restored southern marshes indicates that they still retain their original ability to attract migratory birds, mainly Anseriformes. In comparison with the previous monitoring period 2004-2005 in the southern marshes (Table 1.28), there were increases in the number of species and individuals recorded. The number of species increased 1.2 times in Al-Hawizeh, 1.4 times in Suq Al-Shuyukh, and 1.8 times in East Hammar. Considerable incremental increases were recorded in the number of indivuduals– 3 times in Al-Hawizeh, 2.4 times in Suq Al-Shuyukh, and 4.2 times in East Hammar. The total number of individuals in Al-Hawizeh was 6.4 times higher than Suq Al-Shuyukh and 3.4 times higher than East Hammar. The number of species in Al-Hawizeh was 1.2 times higher than in the two other marshes.

For Anatidae, our latest survey indicates 13, 8, and 7 species of Anseriformes in Al-Hawizeh, Suq Al-Shuyukh, and East Hammar marshes respectively, and in all marshes 14 species of Anseriformes were seen (Table 1.27). The number of ducks in Al-Hawizeh was 16.5 times higher than in Suq Al-Shuyukh and 15.3 times higher than in East Hammar. The total number of recorded species was 74, of which 39 species were common in all marshes, seven species occurring in both Al-Hawizeh and Suq Al-Shuyukh. Five species appeared in both Al-Hawizeh and East Hammar, while four species were seen in both Suq Al-Shuyukh and East Hammar. There were eleven species that were seen only in Al-Hawizeh. There were 27 resident species that occurred more than nine months each year in the marshes. In addition to darter and goliath herons in Al-Hawizeh, certain territorial species appeared, like the pygmy cormorant (which was dominant in Al-Hawizeh), little egret (in Suq Al-Shuyukh), and gulls and terns (mainly whiskered terns) in East Hammar.

Historical surveys of water birds (Table 1.30) recorded the occurrence of 84 species in Hammar marsh and in lower Mesopotamia in winter, as shown by Georg and Viellared (1970), Koning and Dijksen (1973), Carp (1975), Scott and Carp (1982), and Scott (1995), while Allouse (1960, 1961) listed 134 species of water birds. Our current survey recorded 74 species of water birds in the three monitored marshes. Our bird restoration index, based on Scott's historical number of species (1995), was 88% for species and 14.3% for individuals.

Salem (1995) recorded 15 species of Anseriformes in some wetlands in the south of Iraq (Basrah province) during the ducks' migratory season in 1993-1994 (62,228 individuals), and the same researcher recorded 10 species of Anatidae (15,060 individuals) in middle wetlands (Razzaza Lake). Our current survey recorded 14 species of Anseriformes in the monitored marshes, with 6,162 individulals in Al-Hawizeh, 373 in Suq Al-Shuyukh, and 404 in East Hammar. Total numbers of individuals recorded by Salem (1995) were 9 times higher than our current survey. Salem (1995) also recorded three species of Anseriformes (Goldeneye, Ruddy shelduck, and Mute swan) that were not encountered in the present survey. Our restoration index, according to Salem (1995) and Scott (1995), was 93%. Marbled teal (*Marmonetta angustirostris*) were also known to breed in Mesopotamia (Green 1993). Our current survey and nesting area visits agreed with Green (1993) and confirmed the breeding of this species in the marshes. In addition, other species were breeding in nesting areas in Al-Hawizeh, SuqAl-Shuyukh, and East Hammar, especially terns. Finally, migratory ducks and other water birds play an important economic role as an edible meat for the local people, and many of the species of Anseriformes and other species are again being sold in the local market.

1.5.8 Recovery Status of the Marshes

Although the marshes now cover a vast area—40% of the original area has been flooded (Richardson and Hussain 2006)—the arid weather still dominates southern Iraq. Consequently, the southern marshes are characterized by hot, long summers and short winters with prevailing northwestern winds. The restored marsh ecosystems have retained many of their previous functions from before their desiccation. Biogeochemical processes in winter that contribute to the transformation of nutrients and organic matter in the system have been retained. Processes such as primary productivity, nutrient uptake by algae and aquatic macrophytes, and feeding of zooplankton and fish larvae on phytoplankton in late spring are occurring.

The winter is unique for the marshland ecosystem. As the air and water temperature drop considerably, biological functions slow down or temporarily halt (i.e., primary productivity and decomposition of material slow greatly). Some of the species disappear, whereas cold-adapted species flourish, so the structure of the ecosystem differs from season to season. In winter, accumulation and elevated levels of nutrients occur, but levels are reduced in the spring and summer blooms. Moderately cold winters in the marshes encourage migration of ducks and geese to the southern marshes from Siberia and northern Asia to feed and rest.

Spring and summer are considered as the seasons of energy generating in wetland. The first bloom of primary productivity happens during the April-May period, and the maximum harvest yield occurs in midsummer. Decomposition increases rapidly, to reach its peak in autumn, when the productivity and decomposition process rates converge. The second bloom of phytoplankton and maximum yield of hornwort occur in the same timeframe, and the peak of decomposition occurs.

When considering the rate and efficiency of wetland ecosystem processes, a higher functional diversity may be more important than just a higher number of species (Bronmark and Hansson 2005). Many studies have shown that species richness changes with increasing productivity of the habitat, but the exact shape of this relationship is still obscure. Most empirical studies in aquatic systems suggest a unimodle (hump-shape). The relationship between species richness and productivity (Bronmark and Hansson 2005) was recognized in Iraq's restored marshes. Huge increases in the number of individuals, accompanied by a slow recovery of species, led to biological indices that did not reflect the total image of the restored wetland. In general, the restoration of Iraqi wetlands is progressing rapidly, according to data collected during the last 24 months. One major question that remains is related to macroinvertebrates, since there are limited historical data for comparison with our current surveys.

1.5.9 Overall Percentage of Similarity Among Marshes

The highest similarity was between flora and fauna populations of Suq Al-Shuyukh and East Hammar marshes (Table 1.31), with values ranging from 73.7% for macroinvertebrates to 84.3 % for birds. Fish assemblages were more similar between Al-Hawizeh and Suq Al-Shuyukh marshes, because both contain only freshwater species. East Hammar and Al-Hawizeh were the least similar.

1.5.10 Overall Recovery Index

In general, there was an improvement in the overall recovery index in each trophic level in 2006, when compared to 2005 values (Table 1.32, Figure 1.72). Certain trophic levels approached a very high percentage of recovery, as in the case of phytoplankton and macroinvertebrates (100%). Other groups scored high to medium levels, like aquatic macrophytes, water birds, and fish, especially in 2006. East Hammar showed the lowest rate of recovery for most groups. However, the overall increase from 2005 to 2006 clearly demonstrates a dramatic recovery rate for most functional groups in the marshes.

Table 1.31. Percent similarity of the major groups of flora and fauna among the three restored marshes

Trophic Group	Hawizeh & Shuyukh	Hammar & Shuyukh	Hammar & Hawizeh
Fish	80.9	66.6	55.5
Macroinvertebrates	64	73.7	69.2
Macrophytes	62	63.6	55.9
Birds	76.7	84.3	73.3
Phytoplankton	67.2	68.5	67.9
Zooplankton	68.6	84.2	67.5

Table 1.32. A comparison of recovery index of major groups in three restored marshes between 2005 and 2006

Marsh	**Al-Hawizeh**		**Suq Al-Shuyukh**		**Hammar**	
Year	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
Phytoplankton	65.9	91.0	69	94.9	45.5	100.7
Macrophytes	65.9	73.8	69.0	100.0	45.1	71.4
Macroinvertebrates	--------	---------	100.0	120.6	100.0	120.6
Fish	57.1	64	60.7	71	55.5	64.2
Birds	61.9	73.8	44.1	63.1	34.5	63.1

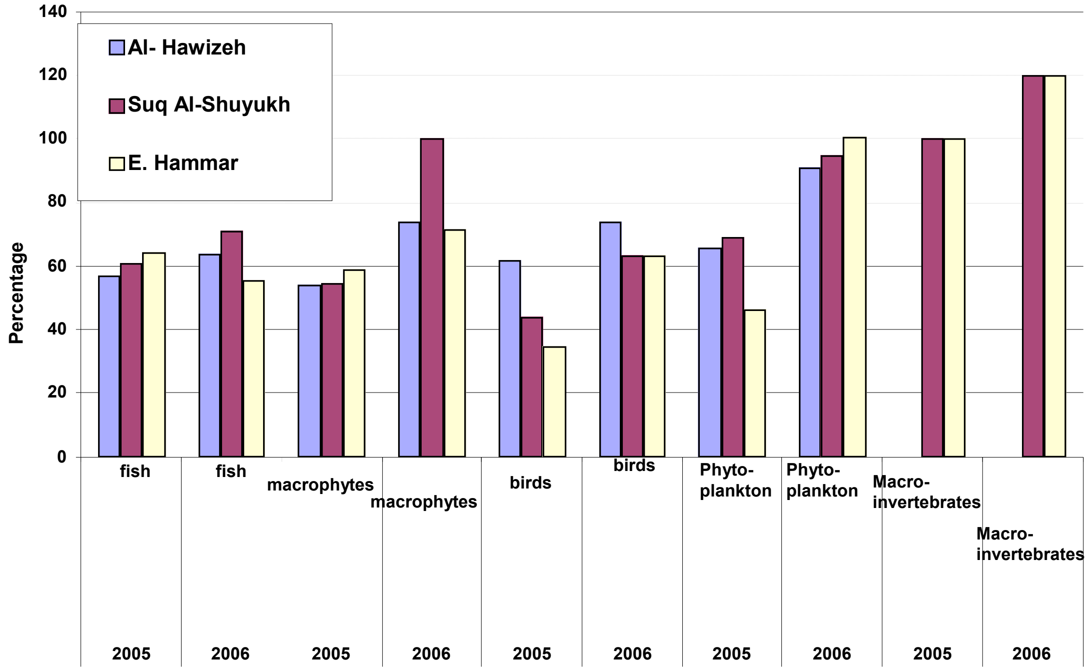


Figure 1.72 A comparison of the recovery index (%) of major groups in three restored marshes between 2005 and 2006.

1.6 Summary and Conclusions

1.6.1 Water Quality

The Iraq marshlands can be classified generally as oligohaline. The water quality values of each marsh depend on the water sources of the Tigris, Euphrates, or Shatt Al-Arab Rivers. Water temperature exhibited large seasonal variations, with lowest temperatures in winter about 10 ^{o}C and higher than 30 $^{\circ}$C in summer; typical of the arid climate of southern Iraq. Water currents in the marshland played a substantial role, affecting light penetration through resuspension of the fine sediments.

All water parameters were found to be in ranges to support growth of the historic main marsh species. The water of restored marshes exhibited nearly the same quality as recorded in historical times, except for higher nutrients and slightly elevated sodium at some locations. Water parameters of the monitored marshes showed the same seasonal variation as previous studies. Monitored marshes retained their role as a sedimentation sink, due to slow water currents. Water transparency remained high, but not as good as in historic times. Higher nutrients support the restoration process of the marshes and improve primary productivity. ,Water leaving the monitored marshes was characterized by lower nutrients, indicating uptake by bacteria, phytoplankton, and macrophytes. Specific findings are as follows:

- The marsh waters were always well oxygenated, i.e. above 5 mg/l (above the fish-critical level).
- Hypoxia was rare except in certain areas with heavy vegetation. Low BOD values indicate that limited organic pollution occurred in the restored marshes.
- Moderate to low levels of NO_3-N and total N suggest the importance of nitrate as a limiting factor for growth of phytoplankton. Decomposition processes in the marshes were illustrated by higher fall, spring, and summer ammonia levels in contrast to low winter levels of ammonia.

- The pH of the three restored marshes was slightly alkaline, indicating availability of bicarbonates and a slight increase in free CO_2 in water. Iraq marshland's waters are regarded as hard.

- Sulphate concentrations in marshlands closely correspond to water composition values of the input values of Tigris, Euphrates, and Shatt Al-Arab rivers.

- Sodium values showed the influence of the Persian Gulf on the marshes, as in the case of East Hammar marsh where higher salinity values were found.

- High levels of water column oxygenation were found in both restored and natural marshes.

1.6.2 Phytoplankton

Primary productivity as expressed by chlorophyll-a showed two peaks, the biggest in the spring and the other in autumn. This was the same pattern found in the historic studies. The number of phytoplankton cells showed a dual mode seasonal pattern, also previously found in historical records. Diatoms were the dominant algal group in all monitored marshes, the same as was recorded in Iraqi rivers and lakes. An inverse relationship existed between chlorophyll-a, number of cells of phytoplankton, and nutrients as shown by most past studies. Specific findings were:

- The number of species of phytoplankton in East Hammer was higher than in the other marshes, and approached historic levels.

- Bascillariophyta (Diatoms) were the dominant group of phytoplankton in all marshes, resembling other Iraqi water bodies.

- Maximum levels of chlorophyll-a and total number of phytoplankton cells in the East Hammer Marsh were higher than found in other restored marshes.

- Recovery indices of phytoplankton species were 91%, 95%, and 100% in Al-Hawizeh, Suq Al-Shuyukh, and East Hammer marshes, respectively.

- Values of primary productivity were high in comparison to historical data.

1.6.3 Zooplankton

Rotifera, Copepoda, Cladocera, and free Nematodes were the dominant orders of zooplankton populations, the same as were recorded previously in Iraqi rivers and lakes, which indicates that restoration is taking place. Peak zooplankton counts were recorded in the spring, the same trend as before marsh desiccation. Specific findings are:

- A double seasonal peak occurs in zooplankton populations with the first peak in the spring (bigger) and the second in the fall (smaller).
- The lowest number of individuals seems to occur in summer.
- There was a significant increase in the number of zooplankton counts in 2006, compared with 2005.
- Composition of zooplankton groups (orders) and densities were similar to those of other Iraqi water bodies.
- Spatial and temporal differences exist in zooplankton taxa in the monitored marshes.

1.6.4 Aquatic Macrophytes

Plant restoration in the monitored marshes was well under way, as noted by the number of recorded species, seasonal variations in species, and percent cover, density, and frequency. Historically dominant species were dominant once again, as noted by high densities of *Phragmites australis* and *Ceratophyllum demersum.* Other species like cattail (*Typha domingensis*), and rush (*Schoenoplectus litoralis*) were present but in low density. Water lilies, which historically were recorded in the area, are still absent from most of the monitored marshes. Specific findings are:

- There was an increase in the number of plant species recorded in 2006, in comparison to 2005.
- The plant species restoration index of the marshes reached 100% in Suq Al-Shuyukh and 71% in East Hammer. No historical records were available for comparison for Al-Hawizeh marsh.

- Plant restoration is progressing in the monitored marshes, as indicated by the reoccurrence of species, spatial and temporal increases in densities, percentage of cover, frequency, and increased productivity harvests.

- Historical species are appearing again, with the dominance of common reeds (*P. australis)* and Hornwort (*C. demersum*). Other species occurred like cattail (*T. domengensis*) and rush (*S. litoralis).*

- The difference in aquatic plant communities in the three monitored marshes could be due to water regime, salinity of substratum, and physical and chemical characteristics of the water.

1.6.5 Macroinvertebrates

The recovery in species composition was good, especially for snails, shrimp, and crabs, but other species were low in numbers and apparently need more recovery time. Numbers of individuals were low in all groups in the restored marshes, except for shrimp. Aquatic plants maintained their previous role as a host for macroinvertebrates. Clear relationships existed between the types of aquatic plants and species of macroinvertebrates. Restoration of the bottom fauna was slow, partly due to the hardness of the bottom (former desiccated marsh soils), which hinders recolonization of bivalves, Annelids, and crustaceans. Seasonal increases in abundance of different groups of macroinvertebrates suggest that restoration is taking place for this trophic level. Specific findings are:

- Improvement in the number of species of macroinvertebrates groups indicates that the restored marshes have a suitable environment for recolonization.

- Huge increases in the number of individuals of macroinvertebrate taxa imply that the restored marshes are a suitable area for reproduction.

- Increases in diversity, evenness, and richness of the major group of macroinvertebrates further demonstrate restoration.

- Al-Hawizeh marsh showed better improvement in number of species and their densities than did other restored marshes.

- High similarity existed between Suq Al-Shuyukh and East Hammar, and could be due to the fact they have the same source of water.

- Improvement in insect populations is a positive sign, since they form a major food item for fish and birds, and they also constitute a major part of the macroinvertebrates population in a healthy natural wetland.
- Recurrence of marine shrimp (*Metapeanus affinis*) in East Hammar marsh indicated the return of this commercial shrimp, a source of food to the marsh inhabitants and other local peoples.

1.6.6 Fish

Restoration of fish assemblages in Al-Hawizeh marsh was more complete than was found in Suq-Al Shuyukh and East Hammar. Higher fish catches in Al-Hawizeh were another indication that restoration was further advanced at this site than in Suq Al-Shuyukh and East Hammar. Al-Hawizeh was a better environment for economic species such as *B. sharpeyi.*

Silurus triostegus, a predator species, constituted a high percentage of the fish biomass in Suq Al-Shuyukh and East Hammar. This has upset the normal food pyramid in these marshes. Collection of ichthyoplankton, juveniles of *Barbus spp.,* and other native species gave clear indication that the southern marshes have retained their original role as a spawning ground, nursery site, feeding area, and refuge for fish. Specific findings are:

- Immature sbour (*T. ilisha*), shabbot (*Barbus*=*Tor grypus)* and *Gara rufa* were recorded in Suq Al-Shuyukh marshlands during 2006.
- Silver molly (*Poecilia mollienesia velifera*) was recorded in Suq Al-Shuyukh and East Hammar marshes during 2006.
- *L. abu* was the dominant species in Al-Hawizeh and Suq Al-Shuyukh marshes and *C. carassius* was more abundant in East Hammar.
- *Grass carp (C. idella*) and silver molly (*Poecilia mollienesia velifera*) have invaded the restored marshes.
- Ecological indices (Richness, Diversity, and Evenness) in general show an incremental increase from 2004 to 2006, except for East Hammar.
- The similarity index for fish was higher (81%) between Al-Hawizeh and Suq Al-Shuyukh than between East Hammar and Suq-Shuyukh (67%).

- Fish catch per unit time by using electro fishing was as follows:
  - Al Hawizeh < Suq Al-Shuyukh < East Hammar
  - 17.16 kg/h < 9.75 kg/h < 4.45 kg/h

- The marsh fish community was affected by a number of factors mainly water level, catch per unit effort (CPUE).

- The fish restoration index scored 71% in Suq Al-Shuyukh and East Hammar and 64% in Al-Hawizeh.

1.6.7 Water birds

Our discovery of numerous breeding and nesting sites was an obvious indication that bird habitat restoration is in progress, but numbers of birds are still low compared to the previous natural environment bird counts.

A return of winter visitors like ducks, geese, and coots is another indication that the southern reflooded marshes have retained their previous role as wintering grounds. Recovery of resident species was a good sign, reaching 60% less than two years after reflooding. Recovery on the anatidae was more than 80%. Specific findings are:

- Seventy-four species were recorded in all the monitored marshes. Sixty-two species were recorded in Al-Hawizeh marsh, and fifty-three species in both Suq Al-Shuyukh and East Hammar marshes.

- The total numbers of individual birds recorded were 28,331 in Al-Hawizeh, 4,443 in Suq Al-Shuyukh, and 8,465 in East Hammar. The species composition greatly increased from 2004 to 2006, reaching historical levels in certain general groups.

- Species similarity in the monitored marshes was closest between Suq Al-Shuyukh and East Hammar.

1.6.8 Ecosystem Recovery

Various indices were used to assess ecosystem recovery. Assessments were made for all trophic levels, and comparisons with historical records provided a basis for determining recovery rates.

- The percentage of recovery was different for various trophic levels, but in general the percentage was more than 60%. In some cases organism recovery, in terms of species numbers or plant biomass, etc. reached more than 100% of historical values.

- The species composition was highly improved from 2004 to 2006, reaching historic records in certain groups.

- Species similarity in tha monitored marshes was closest between Suq Al-Shuyukh and East Hammar.

- The number of individuals within many groups is still behind the historical data. In some areas, bird populations were 10% to 15% of historical counts.

- Biodiversity shifts are taking place in the restored marshes. Seasonal changes in numbers of species and individuals occur, or some species disappear, as a result of decreased temperature or water level changes.

- Ecosystem functions were returning, as shown by increases in primary productivity, bimonthly peaks in zooplankton biomass, aquatic macrophyte cover and biomass, increases in fish numbers and sizes, and increases in bird numbers and species richness.

- Decomposition of organic material and oxidation and reduction of minerals are taking place in the bottom sediments of the reflooded marshes, and indicate the return of normal biogeochemical processes.

1.7 Recommendations

1.7.1 Water Quality

The following recommendations are made based on three years of monitoring in the marshes. It is clear that continued monitoring is needed to see if the marshes will continue to recover and progress towards normal ecosystem functions on the landscape. Specific recommendations are:

- A separate and adequate water quota for the marshes is needed to maintain at least the present level of recovery.

- A continuous monitoring program is needed for the restored marshes, to be sure that restoration continues to progress and that serious problems of water quality or soil pollution are not occurring.

- Creation of marsh sanctuaries is needed to provide for high-quality water habitat to protect rare and endangered species.

1.7.2 Phytoplankton

- An expansion of open water areas (reducing density of *Phragmities* or dense vegetation in some locations) is needed due to the importance of open water areas to fishery life cycle requirements and to increase landscape diversity.

- Detailed study of phytoplankton blooms and dominant species is needed to assess food chain dynamics for fish.

- Measurement of the primary production of phytoplankton in marshes is needed to assess recovery and growth rates in the future.

1.7.3 Aquatic Macrophytes

- Reintroduction of rare species, which were previously recorded in the marshes, is essential for ecosystem diversity (e.g. water lilies).

- A fixed water quota (maintain historic hydroperiod conditions) for southern marshes is needed to maintain the plant communities that are vital to restoration.

- The use of some aquatic plants, which are present in high biomass, is encouraged for animal food or crafts. Historical cutting by marsh dwellers also maintained open water areas for fish

1.7.4 Macroinvertebrates

- Continuous monitoring of species composition in the southern marshes for important species like mussels is needed. Set up a mussel watch program to assess future pollution problems.

- Complete an investigation of the dispersal of rare species found in this study, such as snail *Pila ovatus*, Caddis fly, and crab *Sesarma spp*.

- More detailed studies of the biology, ecology, and culturing of giant shrimp *Macrobrachium spp.* are needed, due to it's high commercial value.

- Detailed studies are needed of different macroinvertebrates that live on submerged plants, to determine their importance as food sources.

- We recommend that swimming in the marshes be avoided, owing to the presence of the first intermediate host (the snail *Bulinus truncatus*) of bloody urine disease (Bilharzias).

1.7.5 Fish

- A marsh release of fingerlings of *B. sharpeyi, B. xanthopterous* and *Ctenopharyngodon idella* is needed to improve the fishing stock.
- Release silver carp to use the phytoplankton biomass.
- Form sanctuaries for fish to maintain fish stock.
- Details studies should be done of icthioplankton and spawning and nursery grounds, to better assess future fishing stocks and harvesting potential.
- Apply fishing laws and regulations.

1.7.6 Ecosystem Recovery

- Continue to monitor key ecosystem functions (productivity, biogeochemistry, hydrology, decomposition, community habitat) to assess recovery success.
- Develop an overall restoration model to assess recovery.
- Expand monitoring program, especially in the Central marsh area.
- Develop and support a network of scientists to continue research in the marshes.
- Develop a new field station for research in the marshes.
- Work with the Iraq Agricultural and Water Ministries to establish a water regulation plan for sustaining the marshes.

1.7.7 General Recommendations

- Encourage tourism and bird watching in the future as a source of local income.
- Restart the pulp factory, using common reeds, to provide local employment.

- Develop aquaculture programs in the marshes to help support the local marsh dweller populations, which would provide food and income–and in turn, stability–to the region.

1.8 Acknowledgments

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APPENDICES

Appendix 1. Spatial occurrence of phytoplankton species identified in the three restored southern marshes

TAXA	Al- Hawizeh	Suq Al-Shuyukh	East Hammar
Cyanophyta			
Anabaena affinis	+	+	+
Chroococcus dispersus	+	+	+
Gloeotrichia natans	+		
Lyngbya aerugineo-coerulea	+	+	+
L.contorta			+
Merismopedia glauca	+		+
Microcoleus laustris		+	
Nodularia paludosum		+	
Nostoc paludosum.	+		+
Oscillatoria agardhii	+		
O. angusta		+	
O. limosa	+	+	+
O. tenuis	+	+	+
Phormidium ambiguum	+		+
P. retzi	+	+	
Rivularia globiceps			+
R. habasgirgii	+		
Scytonema alatum			+
Spirulina major	+	+	+
S. princes	+	+	+
S. supsalsa	+		+
Chlorophyta			
Actinastrum angustus	+	+	+
A. grasillimum	+	+	
Chlorella vulgaris	+	+	+
Cladophora fracta	+	+	+
C. glomerata		+	
Closterium depressum	+	+	+
C. lunula	+		+
Coelastrum microsporum	+		+

TAXA	Al- Hawizeh	Suq Al-Shuyukh	East Hammar
Cosmarium cucumis	+	+	+
Cylindrocapsa geminella	+		
Microspora floccosa	+	+	
Mougoetia viridis.	+	+	
Oedogonium cripsum	+	+	
O .nanum		+	+
Oocystis borgei			+
Pandorina morum		+	+
Pediastrum duplix	+	+	+
Rhizoclonium crassipellitum	+	+	+
Scenedesmus armatus	+	+	+
S. bijuga	+	+	+
Sphaerocystis plactonica		+	
Spirogyra affinis	+	+	+
S. porticalis	+		
S. subsalina		+	+
S. ionia	+		
Volvox africanus		+	+
Ulothrix tenerrima	+	+	+
U. variabilis.	+	+	
Euglenophyta			
Euglena acus		+	+
E. elasica	+		+
Phacus pleuronectus	+	+	+
Trachelomonas crebea	+	+	+
Chrysophyta			
Dinobryon sertolaria	+	+	+
D. stipitatum	+		+
Rhodophyta			
Compsopogon coeruleus		+	+
Bacillariophyta			
Achnanthes inflata			+
Achnanthes lanceolata		+	+
Amphiprora alata	+	+	

TAXA	**Al- Hawizeh**	**Suq Al-Shuyukh**	**East Hammar**
Amphiprora plndosa	+		+
Amphora ovalis		+	+
Bacillaria paradoxa	+	+	+
B. paxillifer	+	+	+
Campylodiscus noricus		+	
Coccneis placentula	+		+
C. placentula var.eugypta	+	+	+
C. pediculus	+		
Cyclotella atomus	+		
C. striata			+
C. meneghiniana	+	+	+
C. pseudostelligera	+	+	
Cylindrotneca gracilis		+	+
Cymbella affinis	+	+	+
C. cistula	+	+	+
C. prostrata			+
C. turgida	+		+
C. ventricosa		+	
Diatoma vulgare	+	+	+
Diploneis ovalis	+		+
Epithema argus		+	+
E. sorex	+	+	
E. zebra		+	+
Fragilaria argus		+	+
Fragilaria capucina	+		+
F. crotonensis	+	+	+
F. pinnata		+	
F. pirescens Var. capitata	+		
F. vaucheriae	+	+	+
Gomphonema acuminatum		+	
Gomphonema constrictum	+	+	+
G. olivaceum	+	+	+
G. vibrio		+	

TAXA	Al- Hawizeh	Suq Al-Shuyukh	East Hammar
Gyrosigma fasciola	+		
G. attenuatum	+	+	
Mastogloia braunii		+	+
Mastogloia grevillei	+	+	
Melosira italica	+		+
Melosira varians	+	+	+
Navicula cryptocephala	+	+	+
N. cuspidata	+	+	+
N. lanceolata		+	+
N. mutica		+	+
N. parva	+	+	+
N. perrotettii			+
N. placetula	+	+	+
N. salinarum			+
N. spicula	+		+
Nitzschia aciclaris		+	+
N. (Nitzschiellae) aciclaris		+	
N. amphibia	+		+
N. apiculata	+		+
N. dissipata		+	+
N. fasciolata		+	+
N. frustulum		+	+
N. longissima	+	+	+
N. linearis		+	+
N. obtusa	+	+	+
N. palea	+	+	+
N. paleacea			+
N. philipinarum	+	+	
N. punctata var.coarctata		+	
N. sigma		+	
N. viridula	+		+
Neidium affine			+
Pinnularia major		+	+
P. viridis	+	+	

TAXA	Al- Hawizeh	Suq Al-Shuyukh	East Hammar
Pleursigma delicatulum	+	+	
Rhoicosphenia curvata	+	+	+
Rhopalodia gibba	+	+	+
R. gibba var.ventricosa	+		+
R. rhopala			+
Surirella biseriata	+		+
Surirella robusta		+	+
Synedra capitata	+	+	+
S. fasciolculata	+	+	+
S. ulna	+	+	+
Tabellaria fenestrata	+	+	+
TOTAL SPECIES RECORDED	**94**	**98**	**104**

Appendix 2. Seasonal occurrence of phytoplankton species in the monitored Iraqi marshes. H=Al-Hawizeh. S=Suq Al-Shuyukh. E=East Hammar.

Taxa	Autumn	Winter	Spring	Summer	Sum
Cyanophyta					
Anabaena affinis		HSE	HE	HE	HSE
Chroococcus dispersus	HSE	HSE	HSE	HSE	HSE
Gloeotrichia natans			H	H	H
Lyngbya aerugineo-coerulea	E	SE	HSE	HSE	HSE
L.contorta			E	E	E
Merismopedia glauca	E	E	HE	HE	HE
Microcoleus laustris	S		S	S	S
Nodularia paludosum	S	S	S	S	S
Nostoc paludosum.			HE	HE	HE
Oscillatoria agardhii	H	H	H	H	H
O. angusta			S	S	S
O. limosa	HSE	HSE	SE	SE	HSE
O.tenuis	HS	HSE	HSE	HE	HSE
Phormidium ambiguum			HE	H	HE
P. retzi	HS	S	H	H	HS
Rivularia globiceps			E		E
R.habasgirgii			H		H
Scytonema alatum			E		E
Spirulina major	HSE	HSE	SE	SE	HSE
S.princes	HE	HE	HS	HSE	HSE
S.supsalsa	E	E	HE	E	HE
Chlorophyta					
Actinastrum angustus	SE		HS	H	HSE
A. grasillimum	H		S	S	HS
Chlorella vulgaris	HS	HSE	HSE	HE	HSE
Cladophora fracta	HSE	HSE	HSE	HSE	HSE
C.glomerata			S		S
Closterium depressum	HS	HSE	HS	HS	HSE
C.lunula	H		HE	HE	HE

Taxa	Autumn	Winter	Spring	Summer	Sum
Coelastrum microsporum	HE	HE	H	E	HE
Cosmarium cucumis	HE	HSE	HE	E	HSE
Cylindrocapsa geminella	H		H		H
Microspora floccosa	HS	HS	HS	HS	HS
Mougoetia viridis.	H		S	S	HS
Oedogonium cripsum	HS	HS	HS	HS	HS
O.nanum			SE	E	SE
Oocystis borgei			E		E
Pandorina morum	SE	SE	SE	SE	SE
Pediastrum duplix	HE	HSE	SE	SE	HSE
Rhizoclonium crassipellitum	HS	HS	HS	HS	HS
Scenedesmus armatus	HSE	HSE	HSE	HSE	HSE
S. bijuga	HSE	HSE	HS	HS	HSE
Sphaerocystis plactonica	S		SE	E	SE
Spirogyra affinis	HS	HSE	HS	HE	HSE
S. porticalis	H		H		H
S.subsalina	S		SE	E	SE
S. ionia	H	H	H	H	H
Volvox africanus	S	S	SE	E	SE
Ulothrix tenerrima	S	SE	S		SE
U. variabilis.	HS	HS	HS	S	HS
Euglenophyta					
Euglena acus	SE	SE	S	S	SE
E. elasica	H	H	HE	E	HE
Phacus pleuronectus	HSE	HSE	E	E	HSE
Trachelomonas crebea			HSE	HE	HSE
Chrysophyta					
Dinobryon sertolaria	HE	HSE	H	E	HSE
D.stipitatum	H	H	E		HE
Rhodophyta					
Compsopogon coeruleus	SE	SE	SE	E	SE
Bacillariophyta					
Achnanthes inflata	E	E	E		E

Taxa	Autumn	Winter	Spring	Summer	Sum
Achnanthes lanceolata	SE	SE	S	E	SE
Amphiprora alata	HE	HSE	H	E	HSE
Amphiprora plndosa	E		HE		HE
Amphora ovalis	SE	SE	SE	E	SE
Bacillaria paradoxa	HSE	HSE	SE	SE	HSE
B. paxillifer	HSE	HSE	HSE	HSE	HSE
Campylodiscus noricus	S		S		S
Coccneis placentula	HE	HE	HE	HE	HE
C. placentula var.eugypta	HSE	HE	HS	HS	HSE
C. pediculus	H	H	E	E	HE
Cyclotella atomus	H	H	H	H	H
C. striata			E		E
C. meneghiniana		HSE	HE	H	HSE
C. pseudostelligera	H		HS	H	HS
Cylindrotneca gracilis			SE	S	SE
Cymbella affinis	HSE	HSE	HSE	HSE	HSE
C. cistula	HSE	HSE	SE	SE	HSE
C. prostrata	E	E	E	E	E
C. turgida	H	HE	H	H	HE
C. ventricosa	HSE	HSE	SE	E	HSE
Diatoma vulgare	H	H	HE	H	HE
Diploneis ovalis	SE	SE	S	S	SE
Epithema argus	HS	HE	H	H	HSE
E. sorex	SE	SE	SE	E	SE
E. zebra	HE	HE	E	E	HE
Fragilaria argus	HSE	HSE	HSE	HSE	HSE
Fragilaria capucina	E	E	SE	E	SE
F. crotonensis	H		H		H
F. pinnata	HE	E	HE		HE
F. pirescens Var. capitata	E		SE	E	SE
F. vaucheriae	HSE	HSE	HSE	HSE	HSE
Gomphonema acuminatum	HSE	HSE	H	H	HSE
Gomphonema constrictum	S		S		S

Taxa	Autumn	Winter	Spring	Summer	Sum
G. olivaceum	H	H	H	H	H
G. vibrio	HS	H	HS	H	HS
Gyrosigma fasciola	S	S	SE	S	SE
G. attenuatum	S	S	HS	S	HS
Mastogloia braunii	H		E		HE
Mastogloia grevillei	HSE	HSE	HSE	HSE	HSE
Melosira italica	HSE	HSE	HS	HS	HSE
Melosira varians	HSE	HSE	HSE	HSE	HSE
Navicula cryptocephala			SE	E	SE
N. cuspidata	HSE	HSE		E	HSE
N. lanceolata	HSE	HS	HS	HS	HSE
N. mutica			E		E
N. parva	HSE	HSE	HSE	HSE	HSE
N. perrotettii			E		E
N. placetula	HE	H	HE	E	HE
N. salinarum	SE	S	SE	S	SE
N. spicula			S		S
Nitzschia aciclaris			HE	E	HE
N. (Nitzschiellae) aciclaris			HE	H	HE
N. amphibia			SE	E	SE
N. apiculata	SE	E	SE	SE	SE
N. dissipata			SE	E	SE
N. fasciolata	HE	H	HSE	HSE	HSE
N. frustulum			SE	S	SE
N. longissima	HSE	HSE	HSE	HSE	HSE
N. linearis	HSE	HSE	HSE	HSE	HSE
N. obtusa			E		E
N. palea			HS	H	HS
N. paleacea	SE		SE	E	SE
N. philipinarum	S		S		S
N. punctata var.coarctata			HE		HE
N. sigma			E		E
N. viridula			SE		SE

Taxa	Autumn	Winter	Spring	Summer	Sum
Neidium affine	HS		HS	H	HS
Pinnularia major	HSE	HS	HS	HS	HSE
P. viridis	HSE	HSE	HSE	HSE	HSE
Pleursigma delicatulum	HSE	HSE	SE	SE	HSE
Rhoicosphenia curvata	HE		HE		HE
Rhopalodia gibba	E		E		E
R. gibba var.ventricosa	H	H	HE	H	HE
R. rhopala	SE	SE	S	S	SE
Surirella biseriata	HSE	HSE	SE		HSE
Surirella robusta	SE		HSE	E	HSE
Synedra capitata	HSE	HS	HSE	HSE	HSE
S. fasciolculata	HSE	HSE	HSE	HSE	HSE

Appendix 3. Comparison of total number (individuals/M^3) of zooplankton between 2005 and 2006 in all marshes

East Hammar		Al-Hawizeh		Suq Al-Shuyukh		
2006	**2005**	**2006**	**2005**	**2006**	**2005**	Yr. / mo.
60950	**(no data)**	4940	4830	24010	2350	**Sept.**
63625	**(no data)**	48370	21250	26880	3435	**Oct.**
68600	**(no data)**	26720	4125	24005	3450	**Nov.**
82460	3915	20545	6945	9675	18435	**Dec.**
60145	74335	17405	101390	26435	27420	**Jan.**
49560	50590	20890	**(no data)**	11960	16935	**Feb.**
108585	102810	43410	45575	49870	71925	**Mar.**
45515	47470	98350	124630	34470	31290	**Apr.**
60100	59960	27850	45710	31700	30800	**May**
32400	28650	24450	22350	26025	23125	**June**
22475	19925	18700	16550	8400	7740	**July**
(no data)	21170	**(no data)**	4860	**(no data)**	14025	**Aug.**

Appendix 4. Spatial occurrence of macroinvertebrate species in three restored marshes (H:Al-Hawizeh, S: Suq Al-Shuyukh and E: East Hammar) in 2006

Species	Group	Marsh
Agrion sp.	Insect	H
Aschnidae	Insect	H, E, S
Belostoma sp.	Insect	E
Blue dragon adult	Insect	H, E, S
Brachythemis fuscopalliata adult	Insect	H, E, S
Chironomidae	Insect	H, E, S
Coleoptera (brown)	Insect	H, E, S
Coleoptera (gold)	Insect	H
Coleoptera (green)	Insect	H S
Coleoptera (grey)	Insect	H
Coleoptera (yellow)	Insect	H, E, S
Coleoptera Larvae	Insect	H
Corixidae	Insect	H, E, S
Damselfly (blue)	Insect	H, E, S
Damselfly (pink)	Insect	H
Damselfly (orange)	Insect	E
Diptera epifauna	Insect	E
Diptera 1	Insect	H, E, S
Diptera 2	Insect	H E
Diptera 3	Insect	S
Diptera 4	Insect	H
Diptera black	Insect	H
Diptera grey	Insect	S
Diptera long legs	Insect	H S
Dragon adult	Insect	H S
Dragon fly nymph	Insect	H
Dytsidae	Insect	H, E, S
Gerris sp.	Insect	E S
Green dragon adult	Insect	S
Hemiptera	Insect	H, E, S

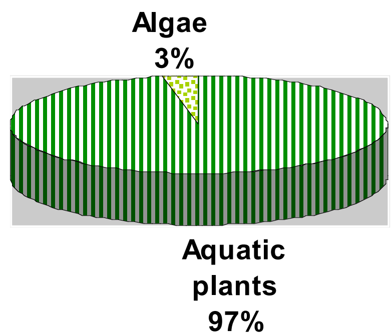
Species	Group	Marsh
Hydrophilidae	**Insect**	**H**
Insect larvae (Diptera)	**Insect**	**H**
Insect larvae 1	**Insect**	**H, E, S**
Ischnura sp.1	**Insect**	**H, E, S**
Ischnura sp.2	**Insect**	**H, E, S**
Ischnura sp.3	**Insect**	**H, E,S**
Large dragon nymph	**Insect**	**H, E, S**
Libellulidae 1	**Insect**	**H, E, S**
Libellulidae 2	**Insect**	**H, E, S**
Marsh grasshopper	**Insect**	**S**
May fly	**Insect**	**H**
Mosquito	**Insect**	**H E**
Old women needle	**Insect**	**S**
Orange dragon adult	**Insect**	**H**
Plecoptera	**Insect**	**H, E, S**
Predator insect	**Insect**	**H E**
Unidentified insect 1	**Insect**	**S**
Unidentified insect (orange)	**Insect**	**H**
Bellamya bengalensis	**Snail**	**H, E, S**
Bellamya unicolor	**Snail**	**H, E, S**
Bulinus truncatus	**Snail**	**H, E, S**
Gyraulus costulatus	**Snail**	**H, E, S**
Lymnaea auricularia	**Snail**	**H, E, S**
Lymnaea gedrosiana	**Snail**	**H, E, S**
Lymnaea natalensis (arabica)	**Snail**	**H, E, S**
Melanoides tuberculata	**Snail**	**E S**
Melanopsis nodosa	**Snail**	**E S**
Melanopsis praemorsa	**Snail**	**H, E, S**
Physa acuta	**Snail**	**H, E, S**
Theodoxus niloticus (jordani)	**Snail**	**H, E, S**

Species	Group	Marsh
Ataephyra desmarsti mesopotamica	**Shrimp**	**H, E, S**
Caridinia baboulti basrensis	**Shrimp**	**H, E, S**
Macrobrachium equidens	**Shrimp**	**H, E, S**
Macrobrachium rude	**Shrimp**	**E**
Metapenaeus affinis	**Shrimp**	**E**
Lumbricus sp.	**Annelida**	**H S**
Oligochaet 1	**Annelida**	**H, E, S**
Oligochaet 2	**Annelida**	**H E**
Polychaet	**Annelida**	**H E**
Aranidae 1	**Spider**	**H, E, S**
Aranidae 2	**Spider**	**H E**
Aranidae 3	**Spider**	**H E**
Aranidae 4	**Spider**	**H**
Aranidae 5	**Spider**	**H E**
Elamenopsis kempi	**Crab**	**E S**
Sesarma boulangeri	**Crab**	**H, E, S**
Sesarma sp.	**Crab**	**S**
Corbicula fluminaea	**Mussel**	**H, E, S**
Corbicula fluminalis	**Mussel**	**H, E, S**
Unio tigridis	**Mussel**	**S**
Paryhale basrensis	**Amphipod**	**H, E, S**
Sphaeroma ananndelli	**Isopoda**	**E S**
Balanus amphitrite	**Cirripedia**	**E**

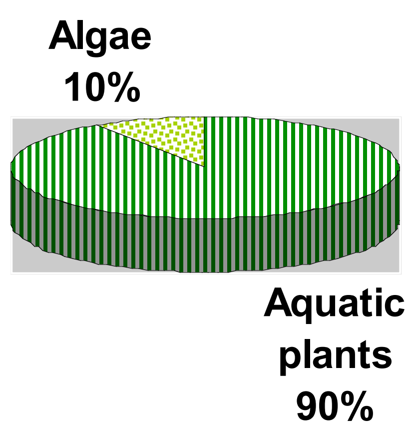
Appendix 5. Food sources for the major fish species in the monitored marshes are shown below. These data support the food pyramid diagrams (1.58, 1.59, and 1.60) shown in the main text, Section 1.47.

Figure 1. Diet composition of *B.sharpeyi* in restored marshes

(Fig.1a)*: B. sharpeyi* in Suq Al-Shuyukh



(Fig.1b)*: B. sharpeyi* in Al-Hawizeh



(Fig. 1c)*: B.sharpeyi* in East Hammar

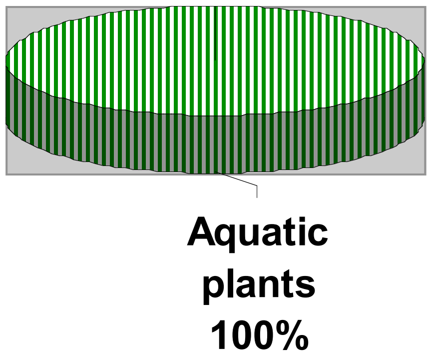
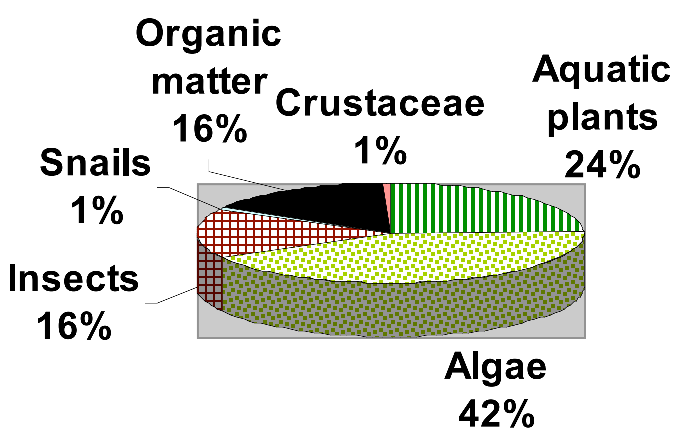
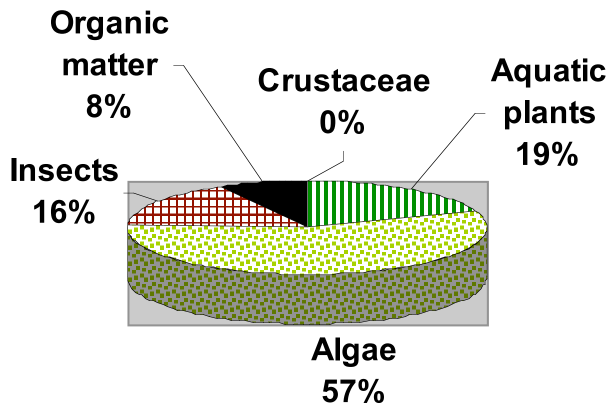


Figure 2. Diet composition of *C. carassius* in restored marshes

(Fig. 2a*) : C. carassius* in Suq Al-Shuyukh



(Fig. 2b)*: C. carassius* in Al-Hawizeh



(Fig. 2c)*: C. carassius* in East Hammar

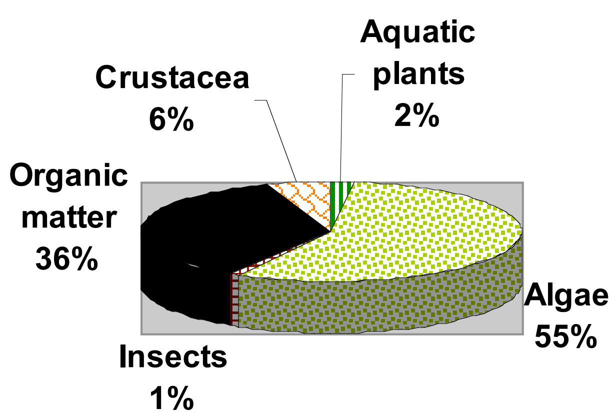
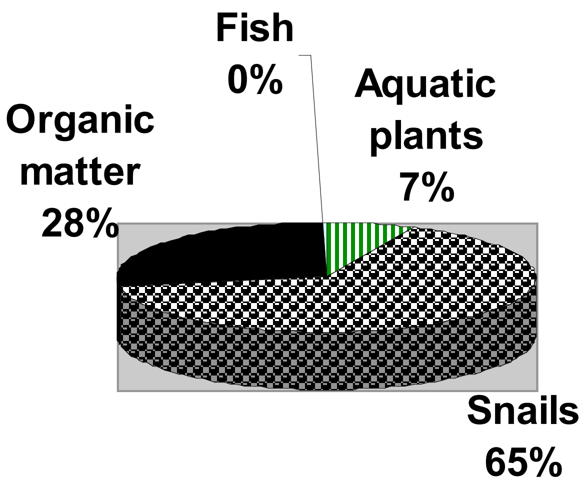
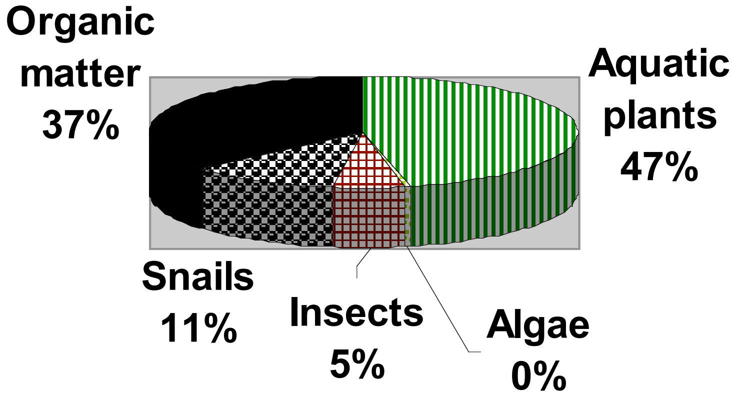


Figure 3. Diet composition of *C. carpio* in restored marshes

(Fig. 3a) :*C. carpio* in Suq Al-Shuyukh



(Fig. 3b):*C. carpio in Al-Hawizeh*



(Fig. 3c)*: C. carpio* in East Hammar

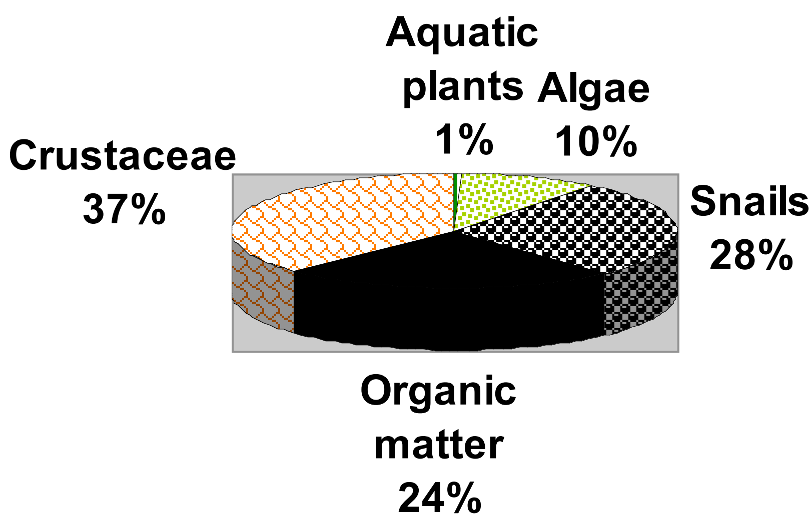
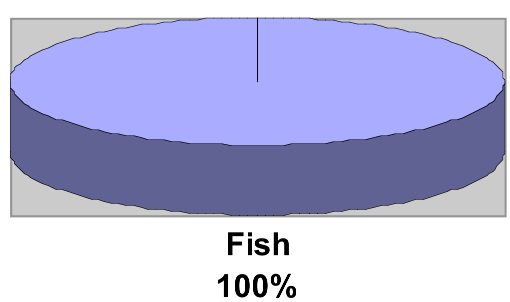
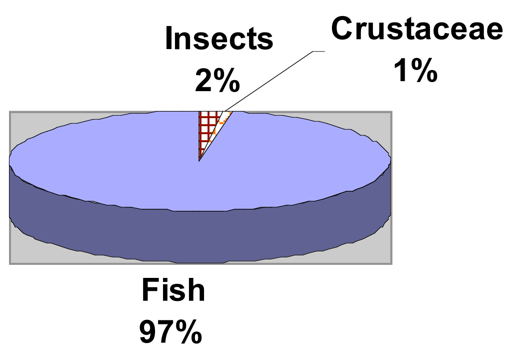


Figure 4. Diet composition of *A. vorax* in restored marshes

(Fig. 4a)*: A.vorax* in Suq Al-Shuyukh



(Fig. 4b): *A. vorax* in Al-Hawizeh



(Fig. 4c): *A.vorax* in East Hammar

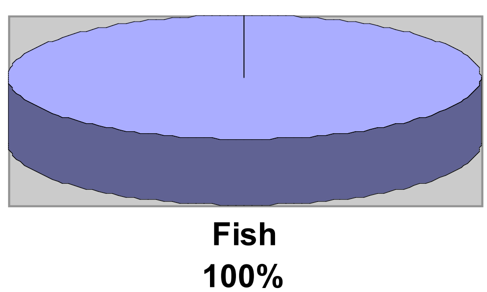
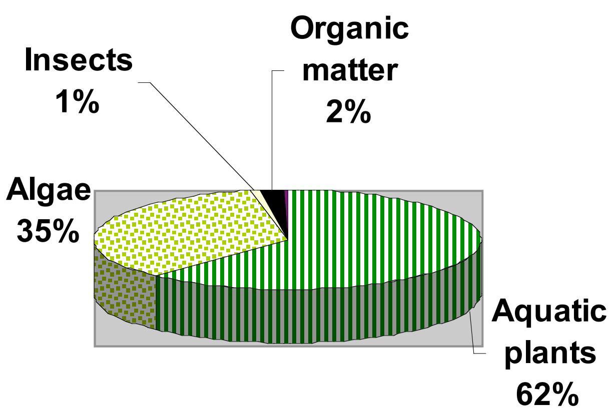
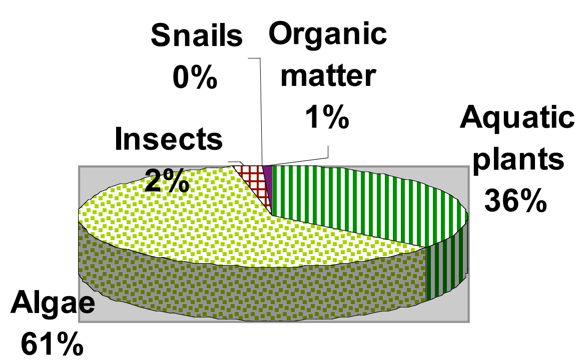


Figure 5. Diet composition of *B. luteus* in restored marshes

(Fig. 5a)*: B. luteus* in Suq Al-Shuyukh



(Fig. 5b)*: B. luteus* in Al-Hawizeh



(Fig.5 c): *B. luteus* in East Hammar

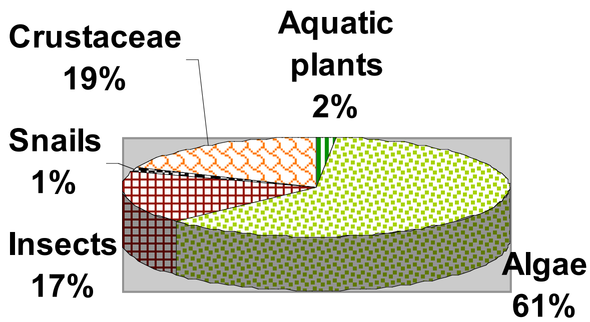
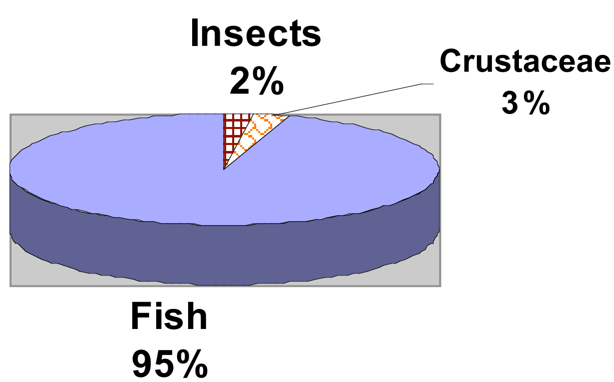
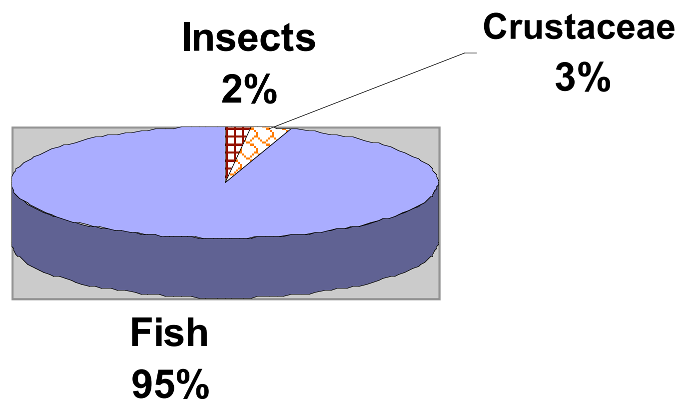


Figure 6. Diet composition of *S.triostegus* in restored marshes

(Fig. 6a)*: S. triostegus* in Suq Al-Shuyukh



(Fig. 6b)*: S. triostegus* in Al-Hawizeh



(Fig. 6c)*: S. triostegus* in East Hammar

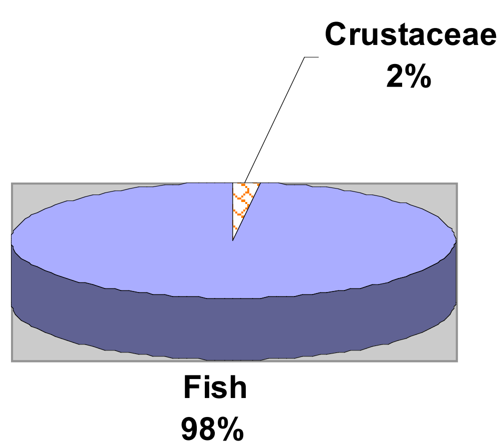
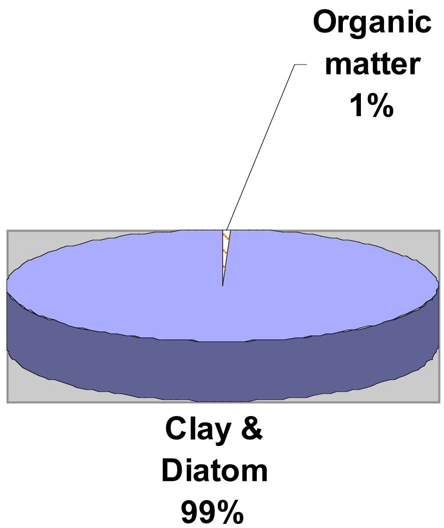
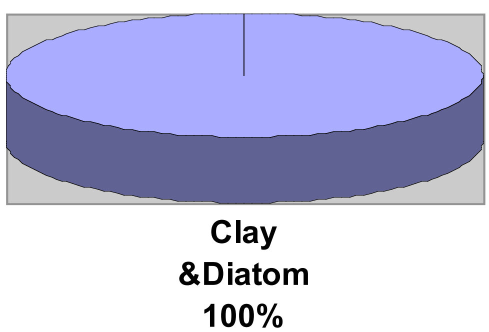


Figure 7. Diet composition of *L.abu* in restored marshes

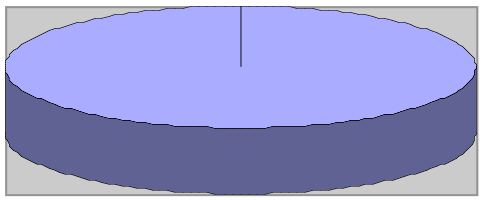
(Fig. 7a)*: L.abu* in Suq Al-Shuyukh



(Fig. 7b): *L. abu* in Al-Hawiyzeh



(Fig. 7c): *L. abu* in East Hammar



Appendix 6. Methods

Water Quality

Field measurement:

Parameter	Methods/Instrument
Air Temp.	YSI 556MPS
Water Temp.	" " "
Conductivity	" " "
Salinity	" " "
pH	" " "
TDS	" " "
DO	" " "
Flow rate	Sontek (Flow Tracker)
Transparency	Secchi disc
Depth	Sontek (Flow Tracker)

Water Chemistry Analysis:

Phosphate	Parsons et al. 1984
Nitrate	" " "
Na	Standard Methods 1975
SO_4-S	" " "
NH_4-N	" " "
Total N	" " "
BOD	" " "
CO_3	" " "

Phytoplankton

QUALITATIVE STUDY/ FIELD	Plankton net at 20 μm mesh/15 min
IN THE LABORATORY	Hickman and Klarer 1974
QUANTITAVE STUDY	Maulood and Boney 1980
Chlorophyll-a	Vollenweider 1974
Identification	Smith 1950, Prescott 1970, Al-Handal et al. 1989, Hadi et al. 1984

Zooplankton

QUANTITATIVE MEASUREMENTS	Hundred liters of water & filter net of mesh size of 60 µm
QUALITATIVE MEASUREMENTS	plankton net of 60 µm mesh size was dragged for about ½ hr.
LABORATORY MEASURMENTS	numbers of individuals counted then the average was calculated for 100 liters
Abundance =	no. of species n / total no. of species) X 100

Aquatic Macrophytes

Field collection	Transect perpendicular at 20 m intervals. Vegetation was evaluated in ($1m^2$) quadrate. Biomass according to Lind 1979
Estimation cover	Braun-Blanquet method (1965)
Calculations n	Frequency = total number of quadrats in which species occurs / total number of quadrats. Density = number of individual sampled per quadrat / total number of quadrats

Macroinvertebrates

Field procedure	Wooden quadrate $625cm^2$ with aquatic plants and with bottom sediments. Small conical hand net (mesh size 1mm), mouth diameter 220mm. Ekman dredge (30x15x15) cm
Laboratory procedure	Clay materials laid in aquarium, separated by washing them with plenty of water over sieve (mesh 0.4-0.6 mm)
Identification	Sultan 1987, Hameed 1989, Abdul-Sahib 1989, Edmondson 1959.

Fish

Field work	Different mesh size nets and electrical fishing device.
Identification	Khalaf 1961, Beckman 1962, Coad1990
Laboratory examinations	Frequency and point methods for food analysis Hynes1950. Diet items Edmondson 1959, Schmitt 1950, Smith 1971, Macan 1972, Piplein et al. 1977
Ecological calculations	Similarity-Jaccard 1908, Abundance-Odum 1979, Richness-Margalef 1968, Diversity-Shannon & Weaver 1949, Evenness-Pielou 1966

Water Birds

Field work	Watching by binocular and census individuals
Identification	Porter et al. 1996
Ecological calculations	Similarity-Jaccard 1908, Abundance-Odum 1979, Richness-Margalef 1968, Diversity-Shannon & Weaver 1949 Evenness-Pielou 1966