UNITED NATIONS ENVIRONMENT PROGRAMME
SUPPORT FOR THE ENVIRONMENTAL MANAGEMENT
OF THE IRAQI MARSHLANDS

WATER QUALITY MONITORING PROGRAMME IN THE IRAQI MARSHLANDS

APRIL – DECEMBER 2005

SUMMARY REPORT

April 2007

United Nations Environment Programme
Division of Technology Industry and Economics
International Environmental Technology Centre
(UNEP DTIE IETC)

Support for the Environmental Management of the Iraqi Marshlands

Water Quality Monitoring Programme in the Iraqi Marshlands (2005)
Executive Summary

1. The Water Quality Monitoring Programme has been implemented to collect and analyze baseline data for environmental conditions within the Iraqi Marshlands, especially in communities selected for pilot water and sanitation implementation of water and sanitation provision. The work was implemented through a Memorandum of Understanding (MOU) concluded between UNEP DTIE IETC and Ministry of Environment (MOE), Iraq, within the framework of UNEP Support for Environmental Management of the Iraqi Marshlands Project.
2. MOE collaborated with Ministry of Water Resources (MOWR), Marsh Arab Forum and Nature Iraq/Iraq Foundation in the execution of the work. UNEP DTIE IETC coordinated the work and finalized the report.
3. Sampling surveys were conducted five times during April 2005 to December 2005 at six sites namely Al-Jeweber, Al-Kirmashiya, Badir Al-Rumaidh, Al-Sewelmat, Al-Hadam and Al-Masahab.
4. Al-Jeweber, Al-Kirmashiya and Badir Al-Rumaidh are located in the central marshes in the Thi-Qar governorate. Al-Sewelmat and Al-Hadam are also located in the central marshes along the border with Al-Hawizheh marshes in the Missan governorate. Al-Masahab is located in the Al-Hammar marshes in the Basrah governorate. Pilot projects on drinking water provision have also been implemented in these six sites within the UNEP Project.
5. Water and sediment samples were analyzed for 73 parameters, including physical, chemical, bacteriological indicators, heavy metals, radiation, pesticides, and polynuclear aromatic hydrocarbons (PAHs). Samples for phytoplankton, zooplankton, macrophytes, benthic fauna and fish were also taken to identify species and their density to analyze for biodiversity parameters (Shannon index and species richness). Most of the analyses were conducted in the laboratories in Iraq whereas analysis for heavy metals, hydrocarbons and pesticides were made at an overseas laboratory (USA) on pre-treated samples shipped by courier.
6. Water quality, sediment quality and biodiversity data obtained in May 2005 (flooding season) and September 2005 (draught season) were analyzed statistically to find any correlations among them. In particular, detrended correspondence analysis (DCA), principal components analysis (PCA) and canonical correspondence analysis (CCA) were used for this purpose.
7. In all samples collected, the presence of high levels of total dissolved solids (TDS) and fecal coliform was reported. The concentrations of these pollutants were above the drinking water quality limits, indicating the necessity to treat the marshland water for human consumption. As such, efforts to provide treatment facilities for drinking water provision in the marshlands are recommended in order to protect the human health.
8. Trace pollutants including PAHs, pesticides and heavy metals in the water samples were found to be within the WHO and US Environmental Protection Agency water quality limits for use as raw water source. No radiation was detected in the samples collected.
9. The diversity and richness of phytoplankton, fish, macrophytes and macrobenthos populations showed an increasing trend between May 2005 and September 2005 in all sites, indicating an increase of biological communities. While longer-term monitoring and analysis is necessary to determine the level of recovery of the marshlands, these results show encouraging snap shots of

the environmental conditions of the area, and may be indicative of the recovery/improvement of biological communities of the Iraqi Marshlands.

10. Heavy metals contents of the sediment samples collected were found to be within acceptable limits of European Union soil standards for heavy metals (EC Directive 86/278/EC). The concentrations of pesticides and PAHs were detected at low levels. No radiation was detected in the samples collected.

11. Extensive analysis carried-out during the short period may form a basis for improvement of monitoring and for the monitoring of ecosystem recovery of marshlands. As the marshlands reflooding and revegetation conditions continue to change, periodical monitoring of water quality and biodiversity is recommended to assess the conditions and the trends of marshland ecosystem recovery, and to protect the health of marshland residents who have returned to these villages.

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Water Quality Monitoring Programme in the Iraqi Marshlands (2005)

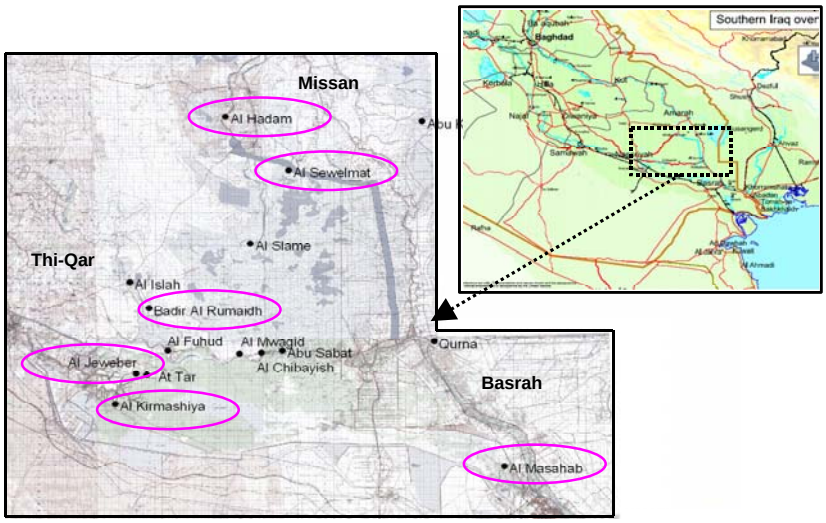
1. Introduction

UNEP carried out the Water Quality Monitoring Programme (WQMP) in the Iraqi Marshlands within the framework of UNEP Support for Environmental Management of the Iraqi Marshlands Project. This Monitoring Progamme was implemented through a Memorandum of Understanding (MOU) between UNEP and the Ministry of Environment (MOE), Iraq. The purpose of the WQMP was to collect base data on the water quality and biodiversity in the six villages identified for implementation of pilot projects on drinking water, sanitation and wetland restoration so that environmental conditions of these marshland communities can be better understood. MOE collaborated with Ministry of Water Resources (MOWR), Marsh Arab Forum and Nature Iraq/Iraq Foundation in the execution of the monitoring work.

The monitoring work was conducted at the villages of Al-Jeweber, Al-Kirmashiya, Badir Al-Rumaidh, Al-Sewelmat, Al-Hadam and Al-Masahab. Figure 1 and 2 show the locations of the six sites and the photographs respectively. Al-Jeweber, Al-Kirmashiya and Badir Al-Rumaidh are located in the central marshes in the Thi-Qar governorate. Al-Sewelmat and Al-Hadam are also located in the central marshes along the border with Al-Hawizheh marshes in the Missan governorate. Al-Masahab is located in the Al-Hammar marshes in the Basrah governorate.

2. Field Work

Sampling surveys were conducted five times during April 2005 to December 2005 at the six sites. Water and sediment samples were analyzed for 73 parameters, including physical, chemical, and bacteriological indicators, heavy metals, radiation, pesticides and polynuclear aromatic hydrocarbons (PAHs). Samples for phytoplankton, zooplankton, macrophytes, benthic fauna and fish were also taken to identify species and their number to analyze for biodiversity parameters (Shannon Index and species richness). Most of the analyses were conducted in the laboratories in Iraq whereas analysis for heavy metals, hydrocarbons and pesticides were made at a reputed overseas laboratory in the United States of America, utilizing pre-treated samples shipped by courier.



Site		Governorate	Latitude (N)			Longitude (E)		
			°	'	"	°	'	"
Al-Jeweber	(UNEP 1)	(Thi-Qar)	30	56	45	46	36	55
Al-Kirmashiya	(UNEP 2)	(Thi-Qar)	30	48	42	46	36	24
Badir Al-Ramaidh	(UNEP 3)	(Thi-Qar)	31	5	30	46	39	51
Al-Sewelmat	(UNEP 4)	(Missan)	31	28	27	47	3	41
Al-Hadam	(UNEP 5)	(Missan)	31	35	56	46	53	9
Al-Masahab	(UNEP 6)	(Basrah)	30	38	41	47	41	7

Figure 1 Water quality monitoring sites

Al-Jeweber

Al-Kirmashiya

Badir Al-Ramaidh

Al-Sewelmat

Al-Hadam

Al-Masahab

Figure 2 Photographs of the monitoring sites

3. Results and Discussion

Based on the laboratory analysis results, the project analyzed the conditions and trends of the water quality, sediment quality and biodiversity in the Marshlands. Statistical programme Canoco Version 4.5 was used to determine correlations among the analyzed data. Detrended correspondence analysis (DCA), principal components analysis (PCA) and canonical correspondence analysis (CCA) were utilized. Analysis and discussion on biodiversity and species richness were based on the data obtained in May 2005 (flooding season), referred to as the first trip and September 2005 (draught season),

referred to as the second trip in the succeeding paragraphs of the document. These two sampling events in the context of overall reflooding of the Iraqi Marshlands are as shown in Figure 3.

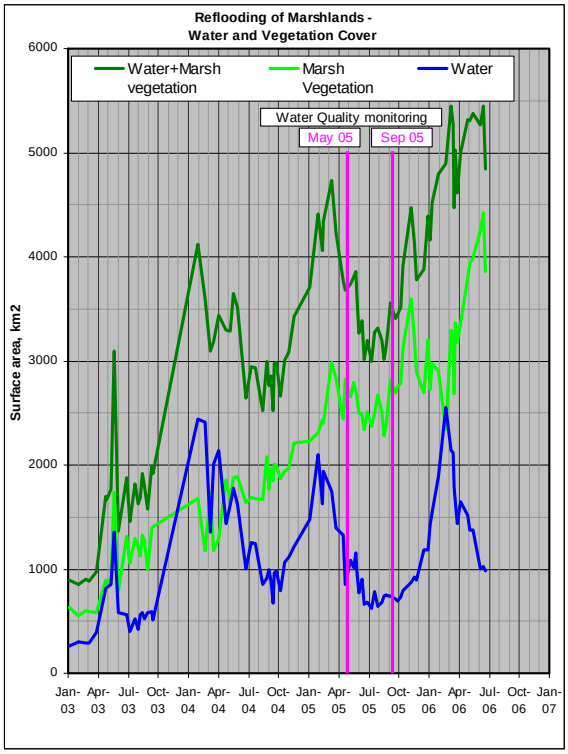


Figure 3 Water quality sampling events and the reflooding of Iraqi Marshlands

3.1 Water Quality

a) Physico-chemical parameters

The water samples were found to be alkaline with pH values ranging from 7.36 to 9.52, and hard with hardness values ranging from 420 mg/L to 1,460 mg/L as $CaCO_3$/L. Dissolved oxygen (DO) levels were between 0.34 mg/L to 12.2 mg/L and were observed to be lower during draught season (September 2005). Mean values of total dissolved solids (TDS) for each site were between 822 mg/L to 2411 mg/L. These values consistently exceeded permissible values for drinking water quality adopted by Ministry of Municipalities and Public Works (MMPW) for the long-term planning, which is 500 mg/L. Nutrient levels were low with Total Kjeldahl Nitrogen (TKN) below 0.50 mg/L except in Al-Sewelmat and Al-Masahab where the concentration reached 0.65 mg/L. Phosphate concentrations were in the range of 2 µg/L to 11 µg/L. Chlorophyll-a concentrations ranged from 1 µg/L to 38.5 µg/L.

Annex 1 shows the variation of selected physico-chemical parameters, including temperature, pH, electrical conductivity, DO, TDS, alkalinity, total hardness, sulphates and chlorides. Annex 2 shows the summary of water quality parameters.

b) Bacteriological quality

Fecal coliforms were detected in all samples in the range of 11 CFU/100 mL to 229 CFU/100 mL, indicating the presence of fecal matter and water contamination. The water needs to be treated for drinking to reduce health risks.

c) Heavy metals and pesticides

Heavy metals and pesticide concentrations were compared to the WHO Drinking Water Guidelines (2004) and USEPA National Primary Drinking Water Standards (2003) and the levels were within acceptable limit, indicating that the water can be used as drinking water source without special treatment for these pollutants. No radiation was detected in the samples.

3.2 Sediment Quality

Heavy metals content of sediment samples were found to be within acceptable limits compared to soil standards for cadmium, lead, zinc, arsenic, mercury, copper and nickel (European Commission Directive 86/278/EC). The low levels of pesticides and PAHs were detected, and radiation was not detected.

3.3 Macrophytes

a) Diversity and richness of macrophytes

Figure 4 shows the variation of diversity and richness of macrophytes in May and September 2005. The diversity is represented by the Shannon Index, which incorporates both the number and the evenness of the species in a given area. The richness is a count of the number of different species in a given area.

In Al-Masahab and Badir Al-Rumaidh, both diversity and richness increased while in Al-Jeweber, Al-Kirmashiya and Al-Sewelmat, there was no change. Only one species of *Ceratophyllum demersum* (hornwort) was found in Al-Hadam and thus resulting in lowest diversity and richness among all the sites.

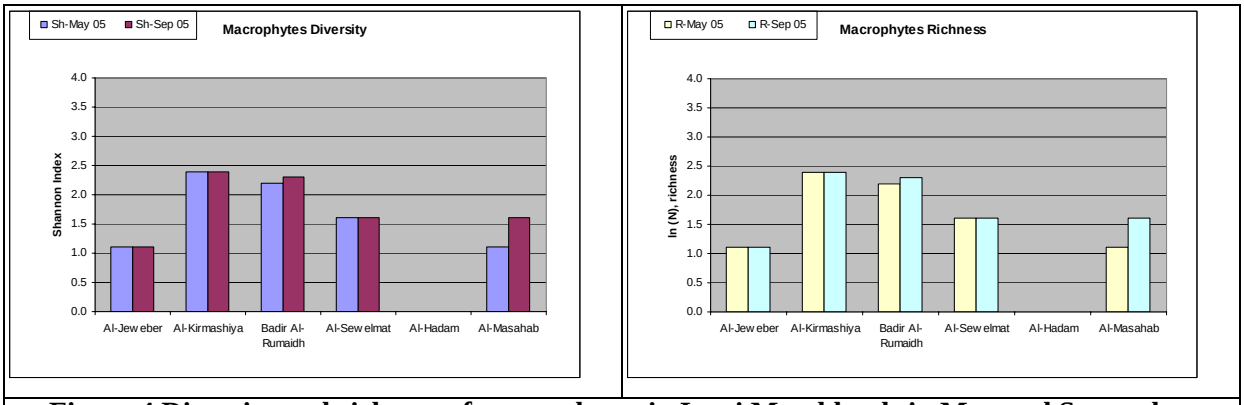


Figure 4 Diversity and richness of macrophytes in Iraqi Marshlands in May and September 2005

b) Macrophytes community ordination

The occurrence of submerged, emergent and floating macrophytes was also analyzed at each station for May and September 2005 sampling events, as shown in Figure 5. The distance between the symbols in the diagram approximates the dissimilarity of their species composition, measured by their Chi-square distance. The segmentation of these symbols into slices is based on the classification of the species. The relative size of a particular pie-slice corresponds to the relative importance (measured either by the number of occurrences or by its number) of the species belonging to a particular class in the corresponding sample (Ter Braak and Šmilauer, 2002).

Al-Jeweber (UNEP 1) and Al-Hadam (UNEP 5) were exclusively dominated by the submerged plants during the May and September 2005 sampling events. In Badir Al-Rumaidh (UNEP 2) and Al-Sewelmat (UNEP 4), the same abundance of plant groups was observed during both trips. In Badir Al-Rumaidh (UNEP 3) the submerged plants were the dominant group in both trips. In Al-Masahab (UNEP 6), the submerged plants were dominant during the first trip, and the presence of the floating plants was reported during second trip.

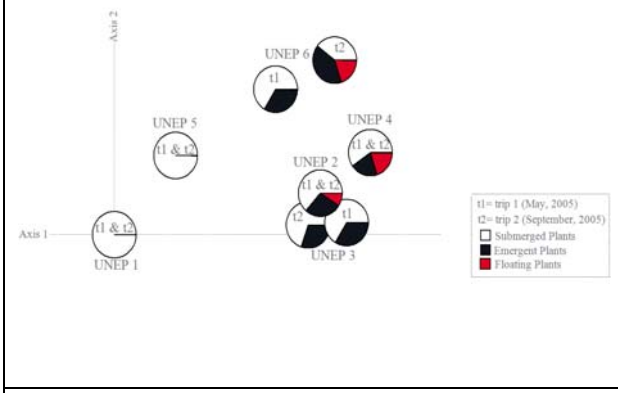


Figure 5 Ordination diagram of macrophytes' classes in Iraqi Marshlands in May and September 2005

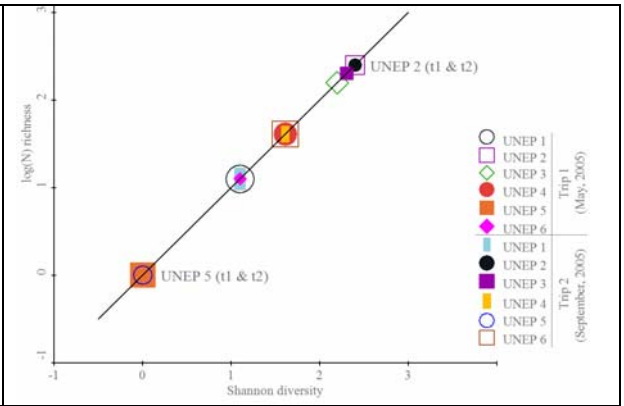


Figure 6 Macrophytes diversity & richness in Iraqi Marshlands in May and September 2005

Figure 6 shows the variation of diversity and richness of macrophytes in both trips. The increase in diversity and richness from May to September 2005 is best observed in Al-Masahab (UNEP 6). The lowest diversity and richness values (0) were observed in Al-Hadam (UNEP 5) during both trips. The highest overall macrophytes diversity and richness was observed in Al-Kirmashiya (UNEP 2).

c) Macrophytes community ordination and habitats

Figure 7 shows the ordination of macrophytes communities in relation to their observed habitats. The species symbols can be projected perpendicularly onto the line overlaying the arrow of a particular habitat. These projections can be used to approximate the occurrence of individual species in respect to that habitat. Based on this analysis, Al-Hadam (UNEP 5) and Al-Masahab (UNEP 6) were found to have the lowest occurrences of species among the locations sampled. Al-Kirmashiya (UNEP 2) and Badir Al-Rumaidh (UNEP 3) are the richest stations, with the occurrence of emergent and floating plants and with most submerged plants.

Figure 8 shows another representation of the occurrence and abundance of Macrophytes' species. The distance between the symbols in the diagram approximates the dissimilarity of distribution of relative abundance of those species across the habitats, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Species symbols in Figure 7 are replaced by pie symbols in Figure 8. The segmentation of these symbols into slices is based on the classification of habitats. The relative size of a particular pie-slice corresponds to relative importance (measured either by number of occurrences or its quantity) of the current species in the particular class of habitats (Ter Braak and Šmilauer, 2002).

Ceratophyllum demersum was the dominant species; appearing in all stations and on both trips, whereas the other species vary in their distribution and abundance in the different stations as shown in Figure 7. For instance, *Phragmites australis* and *Potamogeton lucens* occurred only in Al-Kirmashiya (UNEP 2) and Badir Al-Rumaidh (UNEP 3) on both trips.

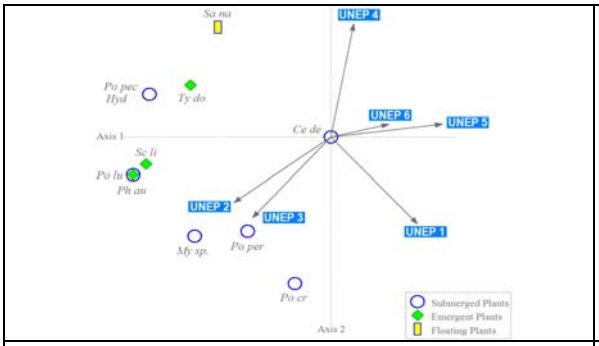


Figure 7 Ordination diagram of macrophytes communities in relation to observed habitats, in Iraqi Marshlands in May and September 2005

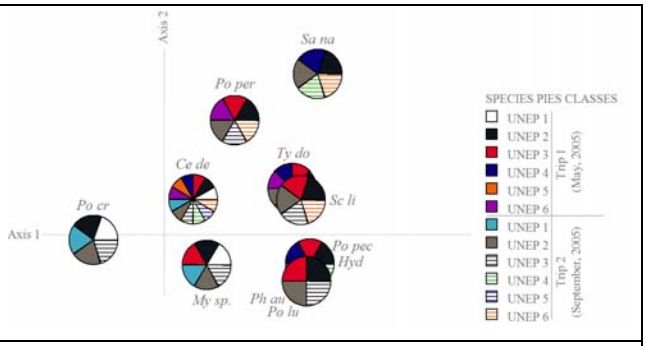


Figure 8 Ordination diagram of macrophytes species in relation to observed habitats in Iraqi Marshlands in May and September 2005

3.4 Phytoplankton

a) Diversity and richness of phytoplankton

Figure 9 shows the variation of diversity and richness of macrophytes in May and September 2005. The diversity of phytoplankton increased in all sites while the richness of species increased or remained at the same level at five sites. At Al-Masahab, a decrease in the richness of phytoplankton was observed.

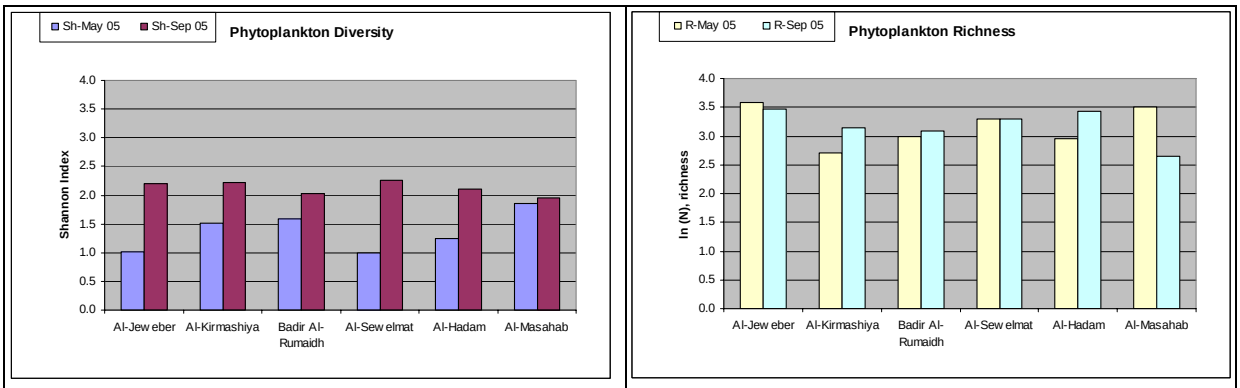


Figure 9 Diversity and richness of phytoplankton in Iraqi Marshlands In May and September 2005

b) Phytoplankton community ordination

The results of the detrended correspondence analysis, as shown in Figure 10, indicate that *Bacillariophyceae-Pennales* are the dominant genera in all sites and the abundance of other Families differ. The results may indicate that the phytoplankton community was changing and establishing itself from May until September 2005.

For instance, Al-Jeweber (UNEP 1) was characterized by the occurrence of *Bacillariophyceae-Centrales, Chlorophyceae, & Cyanophyceae* beside the dominant genera: *Bacillariophyceae-Pennales*, as shown in Figure 10. This composition changed in the second trip (September 2005) to the occurrence of *Pyrrophyceae* in addition to the preceding families and the enlargement of *Chlorophyceae* and the shrinking of *Bacillariophyceae-Pennales*.

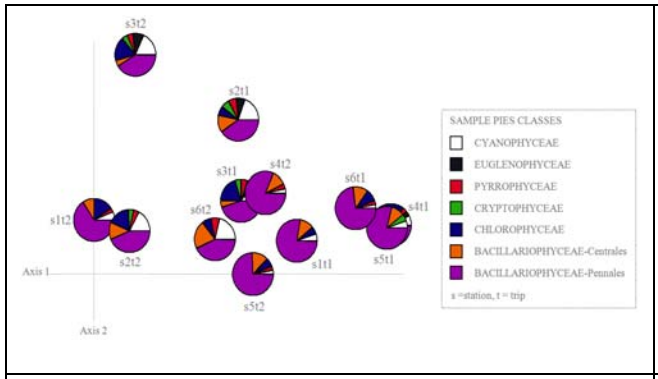


Figure 10 Ordination diagram with phytoplankton' classes in Iraqi Marshlands in May and September 2005

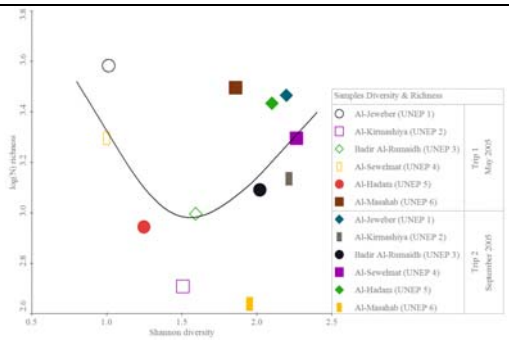


Figure 11 Phytoplankton diversity & richness in Iraqi Marshlands in May and September 2005

Figure 11 shows the variation of diversity and richness of phytoplankton in both trips. The greatest increase in the phytoplankton diversity and richness between first and second trips is observed in Al-Sewelmat (UNEP 4) and Al-Hadam (UNEP 5). In most of the sites with low levels of biodiversity in May 2005, the level increased by September 2005.

c) Phytoplankton community ordination and Habitats

The distribution of *Bacillariophyceae-Centrales genera* was analyzed, and the results, as shown in Figure 12, indicate that *Cyclotella atomus* and *Cyclotella meneghiniana* are distributed in most sites, whereas other species such as *Cyclotella sp.* inhabited Al-Masahab (UNEP 6) in September 2005 exclusively.

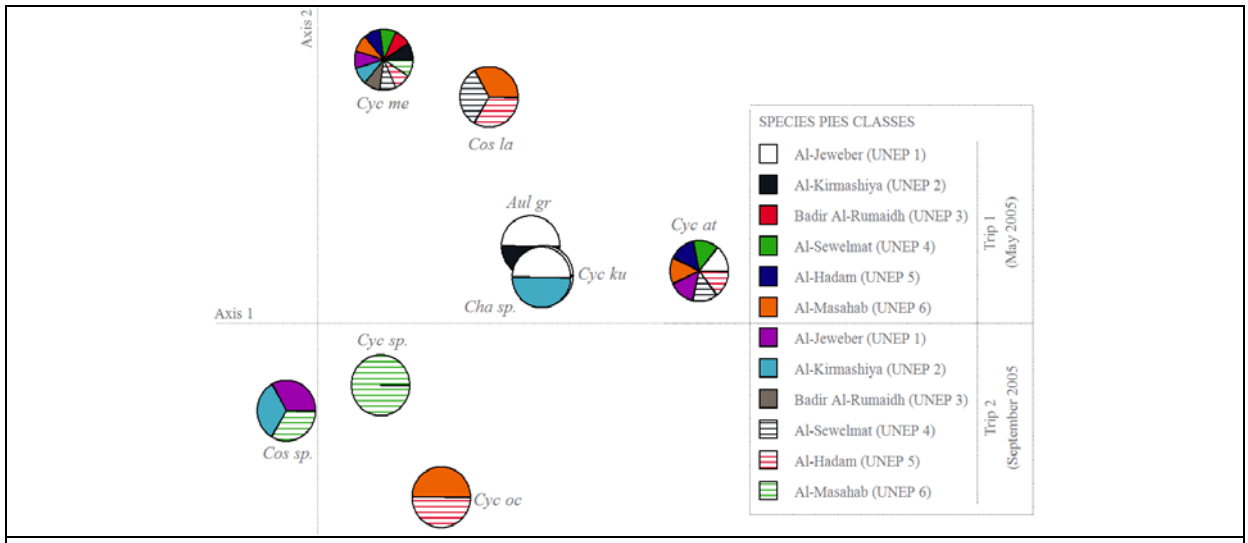


Figure 12 Ordination of Bacillariophyceae-Centrales classes in relation to observed habitats in Iraqi Marshlands in May and September 2005

3.5 Zooplankton

a) Diversity and richness of zooplankton

Figure 13 shows the variation of diversity and richness of zooplankton in May and September 2005. Diversity and richness of zooplankton decreased in Al-Jeweber, Al-Kirmashiya, Badir Al-Rumaidh and in Al-Masahab between the sampling periods, while both parameters increased in Al-Hadam. In Al-Masahab, the diversity increased while there was slight decrease in the richness of zooplankton.

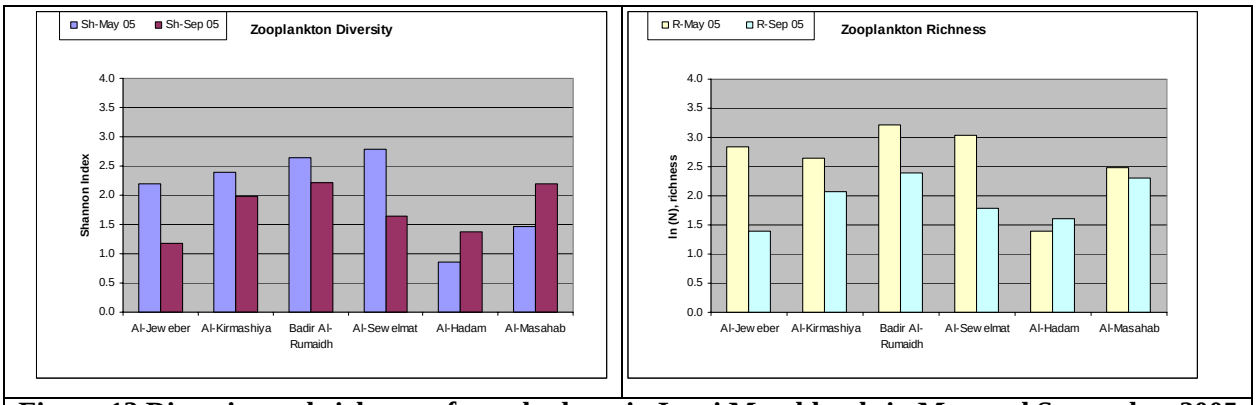


Figure 13 Diversity and richness of zooplankton in Iraqi Marshlands in May and September 2005

b) Zooplankton community ordination

From Figure 14, it can be observed that Al-Jeweber (UNEP 1), Al-Kirmashiya (UNEP2), Badir Al-Rumaidh (UNEP 3), and Al-Sewelmat (UNEP 4) during both trips were dominated by the presence of the class Rotifera, whereas Al-Hadam (UNEP 5) during trip one was dominated by the class Copepoda, with equal presences of Copepoda and Cladocera and low abundance of Rotifera during trip two. Al-Masahab (UNEP 6) during trip one and trip two was mainly dominated by the presence of Cladocera.

The variation of zooplankton diversity and richness is shown in Figure 15. The diversity and richness of the samples were higher in May 2005 than in September 2005 in five sites except for Al-Hadam. This decrease may have been due to the seasonal variation of the zooplankton community after stabilizing in the preceding few years. Additional sampling analysis will be necessary to confirm the trends.

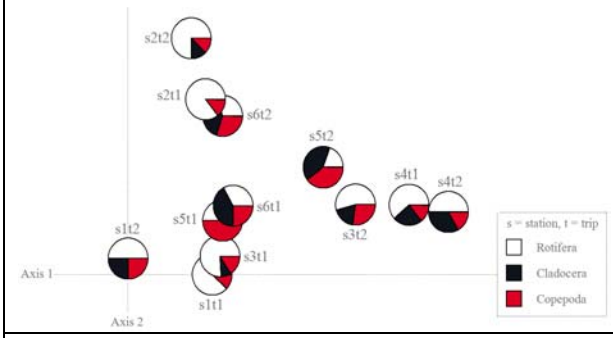


Figure 14 Ordination diagram with zooplankton' classes in Iraqi Marshlands in May and September 2005

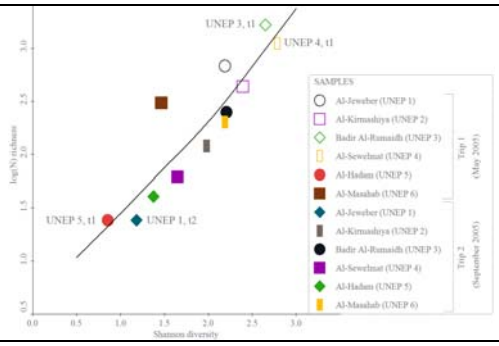


Figure 15 Zooplankton diversity & richness in Iraqi Marshlands in May and September 2005

From Figure 15, it can be seen that the lower diversity and richness values were recorded in Al-Hadam (UNEP 5) and Al-Jeweber (UNEP 1) during the first and second trip, respectively. The higher values were recorded in Badir Al-Rumaidh (UNEP 3) and Al-Sewelmat (UNEP 4) respectively, during trip one.

c) Zooplankton community ordination and habitats

Figures 16, 18 and 20 show the ordination of zooplankton (Rotifera, Cladocera and Copepod) in relation to their observed habitats, while Figures 17, 19 and 21 show distribution of species in each site and each trip as pie diagram.

As shown in Figure 16, the Rotifera species had higher abundance and distribution in Al-Jeweber (UNEP 1), Badir Al-Rumaidh (UNEP 3), and Al-Masahab (UNEP 6) with lower distributions in the

other sites. As shown in Figure 18, Al-Sewelmat (UNEP 4) and Al-Masahab (UNEP 6) had higher abundance and distribution of Cladocera species than the other UNEP sites.

While only a few Copepoda species were identified (compared with the Rotifera and Cladocera), they were found in abundance and were distributed in most of the UNEP sites (Figure 20).

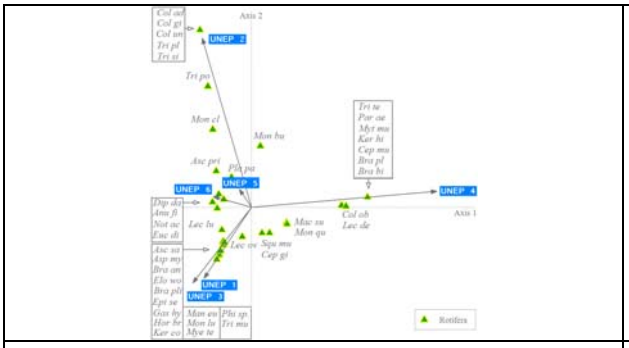


Figure 16 Ordination of Rotifera genera in relation to observed habitats in Iraqi Marshlands in May and September 2005

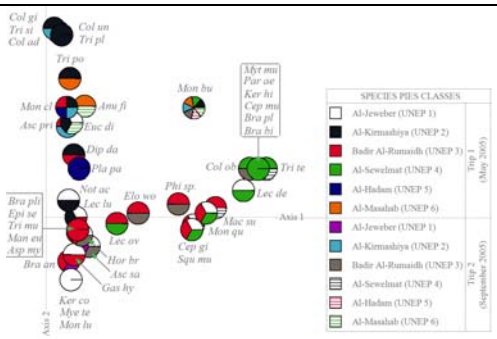


Figure 17 Ordination of Rotifera genera pies classes in relation to observed habitats in Iraqi Marshlands in May and September 2005

Figure 17 shows that most of the Rotifera species were present in Al-Jeweber (UNEP 1), Al-Kirmahiya (UNEP 2), Badir Al-Rumaidh (UNEP 3), Al-Sewelmat (UNEP 4), and Al-Hadam (UNEP 5) during the first trip only. Al-Jeweber (UNEP 1), Badir Al-Rumaidh (UNEP 3), and Al-Sewelmat (UNEP 4) had more variety in Rotifera species, especially during the first trip compared with the other sites. *Monostyla bulla* was the main species that had a wider distribution in the different sites compared to the other species.

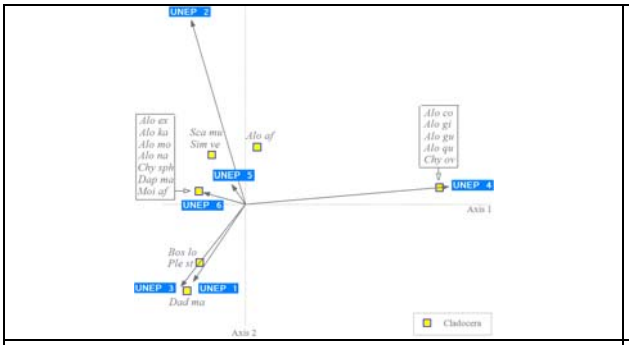


Figure 18 Ordination of Cladocera genera in relation to observed habitats in Iraqi Marshlands in May and September 2005

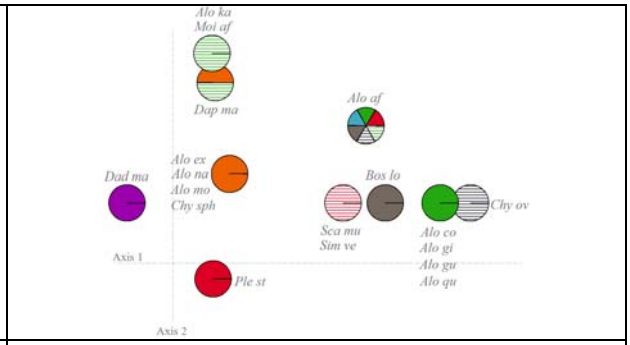


Figure 18 Ordination of Cladocera genera pies classes in relation to observed habitats in Iraqi Marshlands in May and September 2005

Most Cladocera species were present in specific sites in either trip one or in trip two with the exception of *Alona affinis* that was present in more than one site during both trips as illustrated in Figure 18.

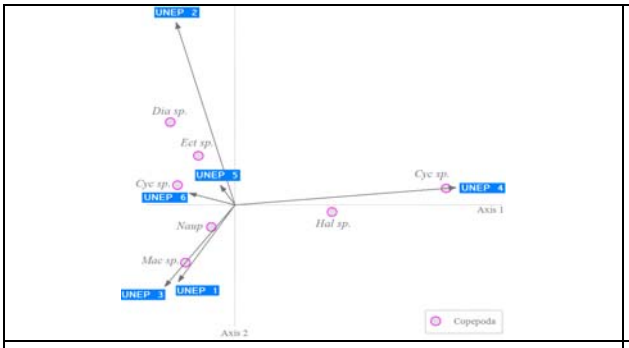


Figure 20 Ordination of Copepoda genera in relation to observed habitats in Iraqi Marshlands in May and September 2005

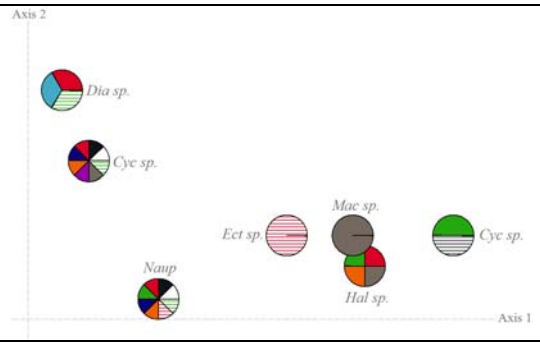


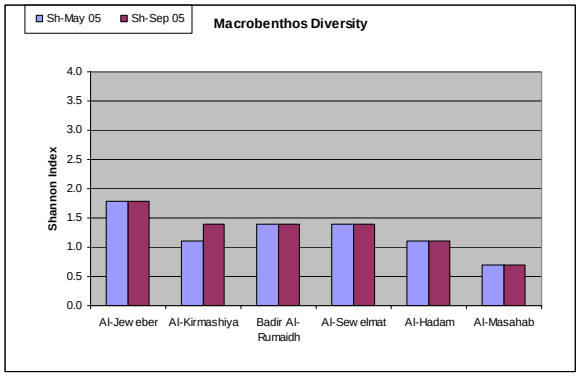
Figure 21 Ordination of Copepoda genera classes in relation to observed habitats in Iraqi Marshlands in May and September 2005

Unlike the Rotifera and Cladocera species, most of the Copepoda species identified in the sites had occurrences in different UNEP sites during both trips (Figure 20 and Figure 21). Exceptions were, *Eucyclops sp*. that occurred in Al-Hadam (UNEP 5), *Macrocyclops sp*. that occurred in Badir Al-Rumaidh (UNEP 3) during the second trip only, and *Cyclops sp.2* that occurred in Al-Sewelmat (UNEP 4) during both trips.

3.6 Macro-Benthos

a) Diversity and richness of macro-benthos

Figure 24 shows the variation of diversity and richness of macro-benthos in May and September 2005. While there was a slight increase in diversity and richness of macro-benthos in Al-Kirmashiya, there was no change in other sites between May and September 2005. The highest diversity and richness was observed in Al-Jeweber while the lowest was observed in Al-Masahab.



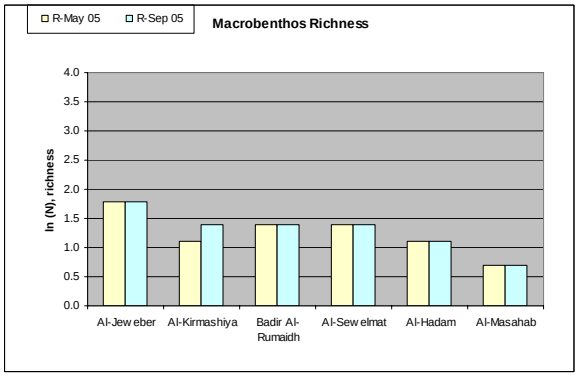


Figure 22 Diversity and richness of macro-benthos in Iraqi Marshlands in May and September 2005

b) Macrobenthos community ordination

Figure 23 shows the occurrence of classes of macro-benthos, namely Class Mollusca, Class Insecta and Class Amphibia. Across the six sites, there was no single dominant class occurrence in either of the sampling trips. Class Amphibia and Class Insecta were found in all sites in different densities, whereas Class Mollusca was not found in Al-Masahab (UNEP 6). The distribution among the three classes was found to be stable from May to September 2005 in five locations, except for Al-Kirmashiya (UNEP 2).

Al-Jeweber (UNEP 1) was dominated by the class Mollusca during both trips. The other two classes of macrobenthos were found to have less occurrences than the class Mollusca. Equal occurrences of the three classes were observed in Al-Kirmashiya (UNEP 2) during the first trip and at Al-Hadam (UNEP 5) on both trips. At Al-Kirmashiya (UNEP 2), class Mollusca had the dominant occurrence during the

second trip, similar to the observations at Al-Sewelmat (UNEP 4). At Badir Al-Rumaidh (UNEP 3), the distribution of occurrences among the three classes did not change from May to September 2005. Al-Masahab (UNEP 6) and in both trip one and trip two showed equal occurrences of both classes, Insecta and Amphibia, with the absence of Mollusca.

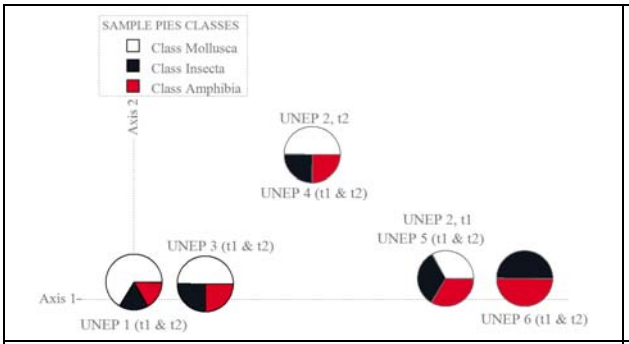


Figure 23 Ordination diagram with macro-benthos' classes in Iraqi Marshlands in May and September 2005

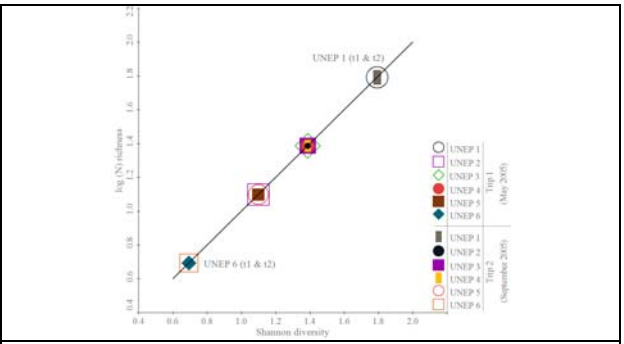


Figure 24 Macro-benthos diversity & richness in Iraqi Marshlands in May and September 2005

Figure 24 shows the variation of macrobenthos diversity and richness. Al-Kirmashiya (UNEP 2) showed marked increase in diversity and richness values in second trip compared to the values obtained in first trip. In addition, Al-Masahab (UNEP 6) had the same and lowest diversity and richness values for both trips. Al-Jeweber (UNEP 1) had the highest diversity and richness values during both trips when compared with the other stations.

c) Macro-benthos community ordination and Habitats

Figure 25 shows ordination of macro-benthos in relation to their observed habitats. *Melanoides tuberculata* was mainly present in Al-Jeweber (UNEP 1), Al-Kirmashiya (UNEP 2), Al-Sewelmat (UNEP 4), and Al-Hadam (UNEP 5). The species *Corbicula fluminalis* and *Melanopsis nodosa* were present mainly in Badir Al-Rumaidh (UNEP 3).

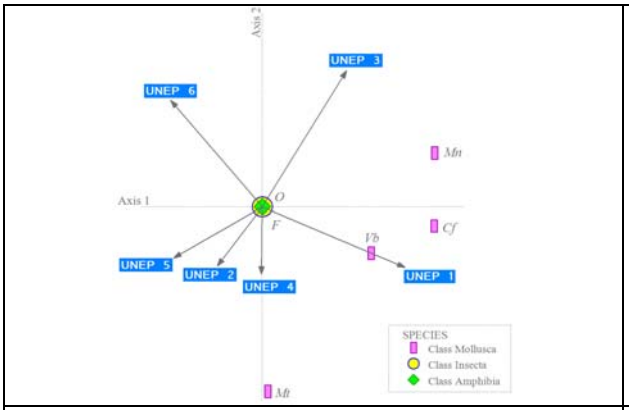


Figure 25 Ordination of macro-benthos community in relation to observed habitats in Iraqi Marshlands in May and September 2005

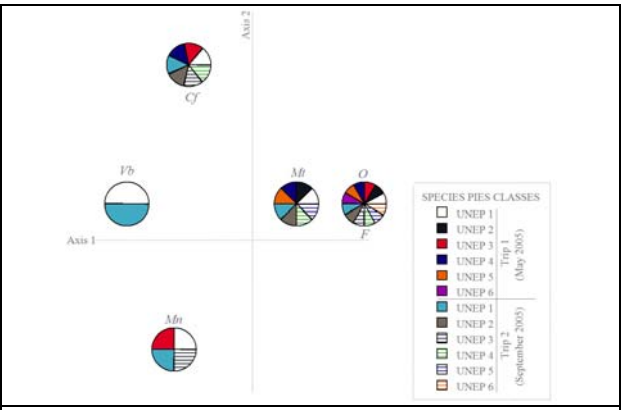


Figure 26 Ordination of macro-benthos species in relation to observed habitats in Iraqi Marshlands in May and September 2005

Figure 26 shows the occurrence and abundance of Macrobenthos' species in their habitats. Odonata and Amphibia are the dominant Classes appearing in all sites and on both trips during May and September 2005. The other species showed varying distribution and occurrence in the different sites. For instance, *Viviparus bengalensis* occurred only in Al-Jeweber (UNEP 1) on both trips.

3.7 Fish

a) Diversity and richness of fish

Figure 27 shows the variation of diversity and richness of fish in May and September 2005. Increase in diversity and richness was observed in Al-Jeweber, Al-Kirmahshiya and Badir Al-Rumaidh while there was no change in the other three sites between May and September 2005. The highest diversity and richness was observed in Al-Masahab while the lowest was both in Al-Jeweber and in Al-Kirmashiya.

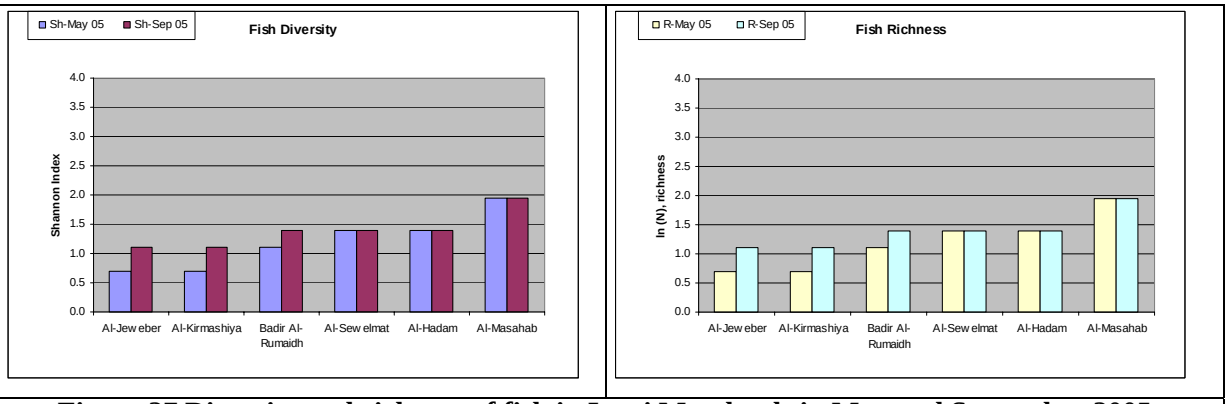


Figure 27 Diversity and richness of fish in Iraqi Marslands in May and September 2005

b) Fish community ordination

Figure 28 summarizes the fish community ordination. In three locations, the observed fish classes were similar in May and September 2005. In other locations, the observed classes changed. In Al-Kirmashiya (UNEP 2), one additional fish family was observed in September 2005, compared to the May 2005 sampling. In Al-Jeweber (UNEP 1), only one fish family (Cyprinidae) was present during the first trip, and an additional family (Mugilidae) was observed during the second trip. Badir Al-Rumaidh (UNEP 3) demonstrated an equal appearance of Cyprinidae, Siluridae, and Bagridae during the first trip, while in the second trip the abundance of Cyprinidae increased with a corresponding decrease of Siluridae, and Bagridae. As for Al-Sewelmat (UNEP 4), Al-Hadam (UNEP 5), and Al-Masahab (UNEP 6) the number of families and their distribution remained the same during the two trips.

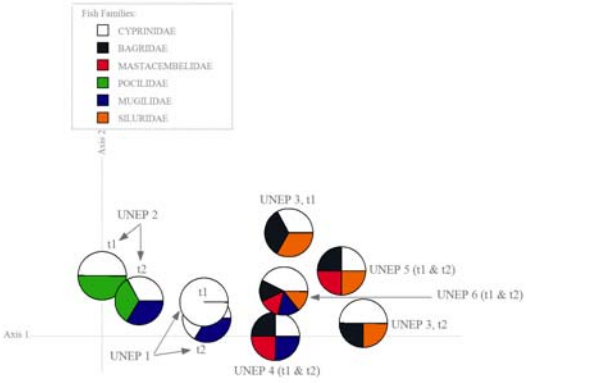


Figure 28 Ordination diagram with fish classes in relation to their observed habitats in Iraqi Marshlands in May and September 2005

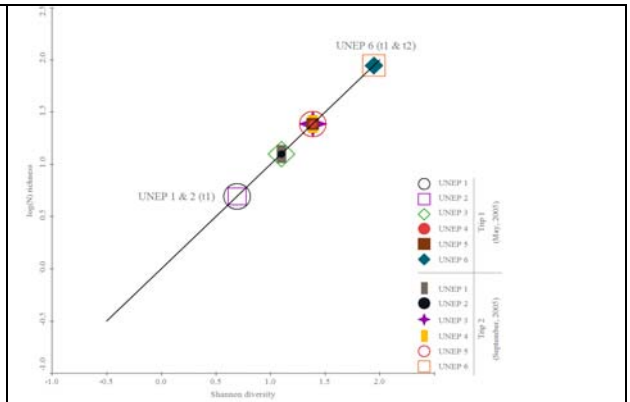


Figure 29 Fish diversity & richness in Iraqi Marshlands in May and September 2005

Figure 29 shows the variation of the fish diversity and richness. Al-Jeweber (UNEP 1), Al-Kirmashiya (UNEP 2), and Badir Al-Rumaidh (UNEP 3) showed increase in biodiversity and richness from May 2005 to September 2005. As for the fish community, the richness values were similar to the diversity values on both trips for all sites.

c) Fish community ordination and habitats

Figure 30 shows the fish community ordination and habitats. The species symbols can be projected perpendicularly onto the line overlaying the arrow of a particular habitat. These projections can be used to approximate the occurrence of individual species in respect to that habitat. Al-Kirmashiya (UNEP 2) shows the most deficient in terms of the occurrences of species, while the other stations are characterized by the occurrence of various species.

Figure 31 is another representation of the occurrence of fish species. The distance between the symbols in the diagram approximates the dissimilarity of distribution of relative abundance of those species across the habitats, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Most species are well distributed in the studied sites, except *Aspius vorax*, which occur in Badir Al-Rumaidh (UNEP 3) during the second trip (September 2005), and *Gambusia affinis*, which appear only in Al-Kirmashiya (UNEP 2) on both trips.

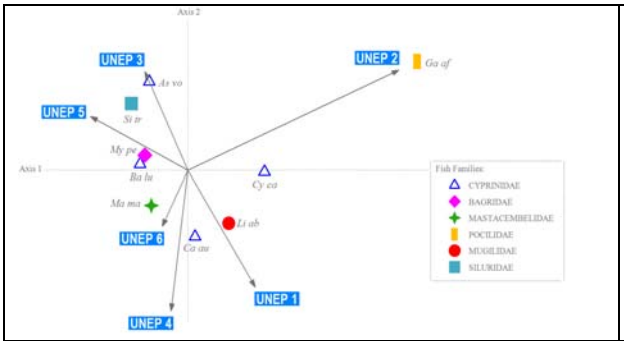


Figure 30 Ordination of fish communities in relation to observed habitats in Iraqi Marshlands in May and September 2005

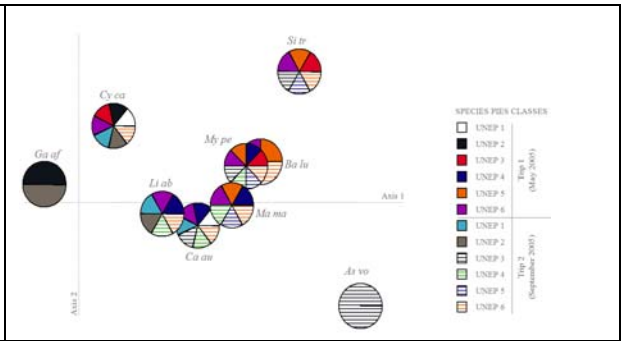


Figure 31 Ordination of fish species in relation to observed habitats in Iraqi Marshlands in May and September 2005

3.8 Relationship between Biological Communities

Figure 32 shows variation of Shannon indices of zooplankton and phytoplankton. An inverse relationship between zooplankton and phytoplankton, that is zooplankton decreased while phytoplankton increased, in each of the sites was observed between May and September 2005 in Al-Jeweber (UNEP 1), Al-Kirmashiya (UNEP 2), Badir Al-Rumaidh (UNEP 3) and Al-Sewelmat (UNEP 4). Grazing of zooplankton by fish may be one of the potential factors to explain this correlation. At Al-Hadam and Al-Masahab, both indices increased from May to September 2005. Additional regular monitoring is needed to understand the dynamics of the biological communities in the Marshland area.

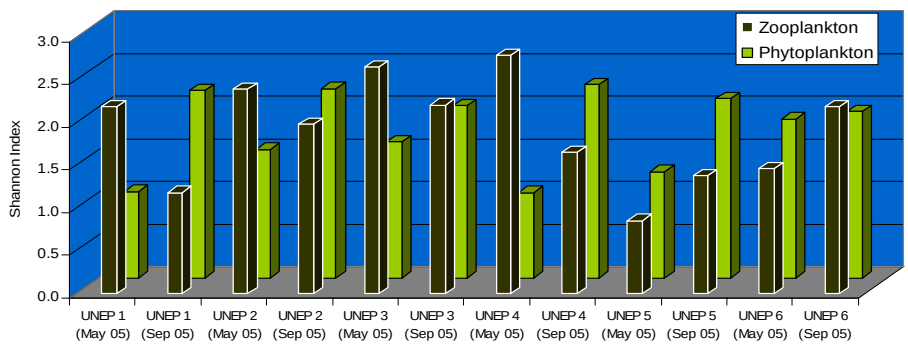


Figure 32 Diversity of zooplankton and phytoplankton in May and September 2005

Figure 33 shows variation of Shannon indices for fish and zooplankton. The diversity of fish increased while that of zooplankton decreased in Al-Jeweber (UNEP 1), Al-Kirmashiya (UNEP 2), Badir Al-Rumaidh (UNEP 3) and Al-Sewelmat (UNEP 4). While it is not feasible to make conclusive observations from two sampling events only, feeding preferences of some zooplankton-feeding fish species may be one of the potential factors to explain this inverse relationship. There was no change in fish diversity in Al-Hadam (UNEP 5) and Al-Masahab (UNEP 6) while there was an increase in zooplankton diversity.

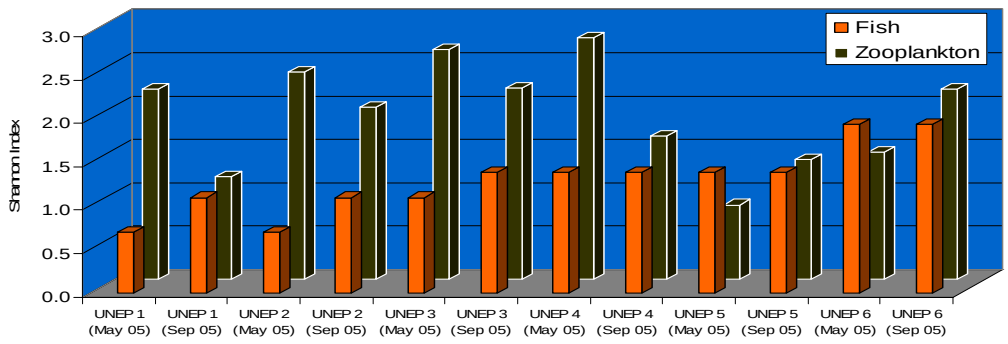


Figure 33 Diversity of fish and zooplankton in May and September 2005

Figure 34 shows variation of Shannon indices for fish and phytoplankton. The diversity of fish increased or remained the same while that of phytoplankton increased in all sites. The reduction in phytoplankton diversity may be attributed to the prevailing type of fish community (zooplanktivorous or grazers).

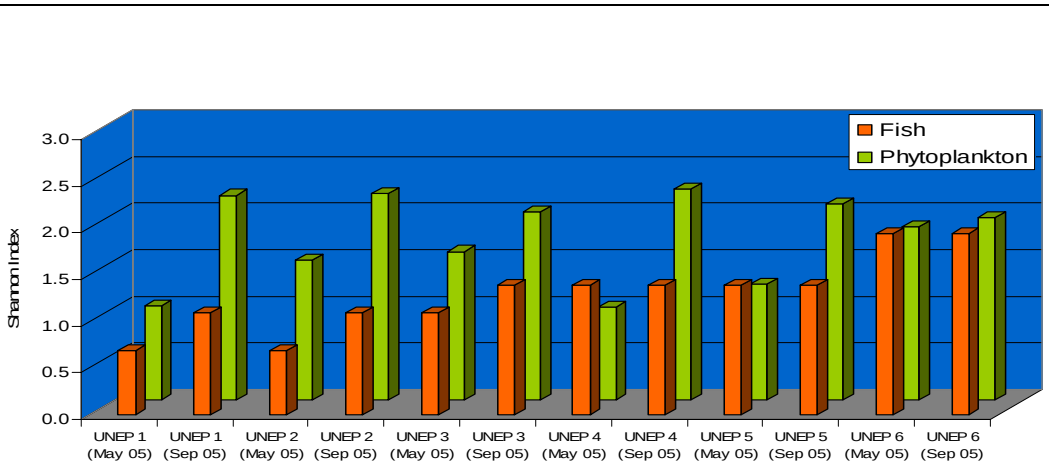
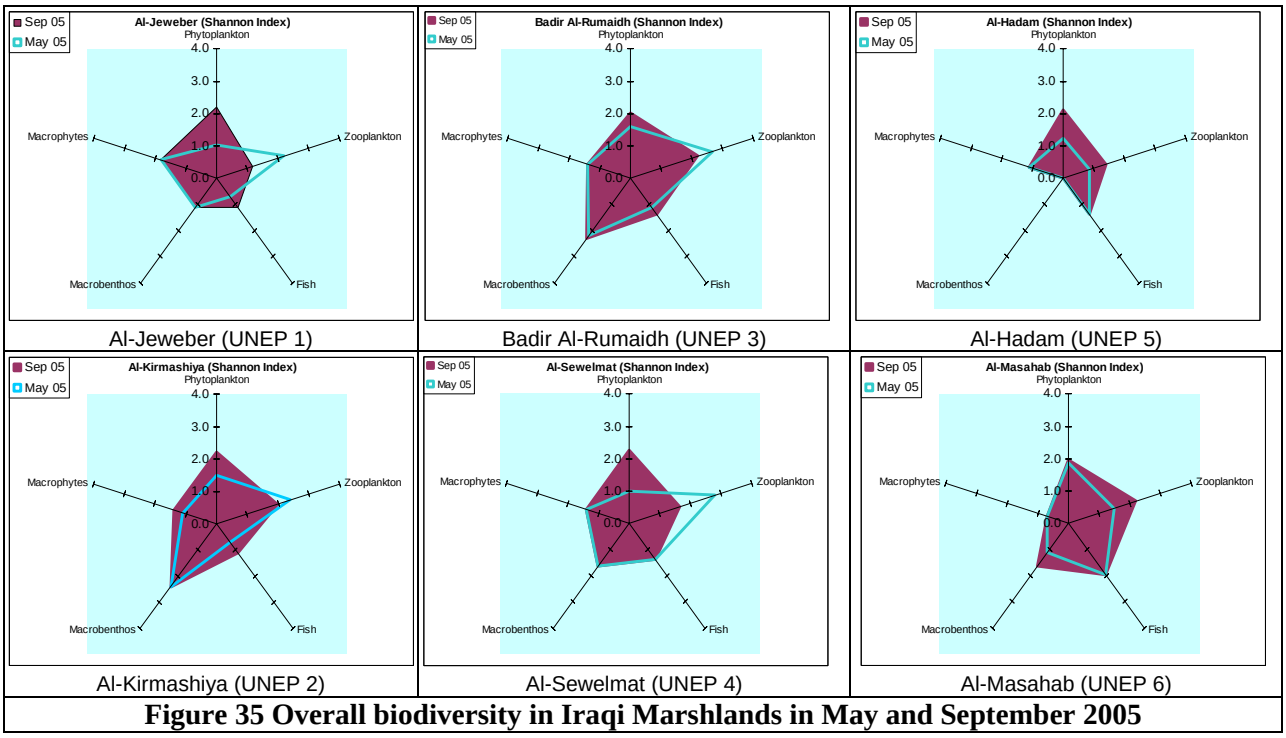


Figure 34 Diversity of fish and phytoplankton in May and September 2005

3.9 Overall Biodiversity

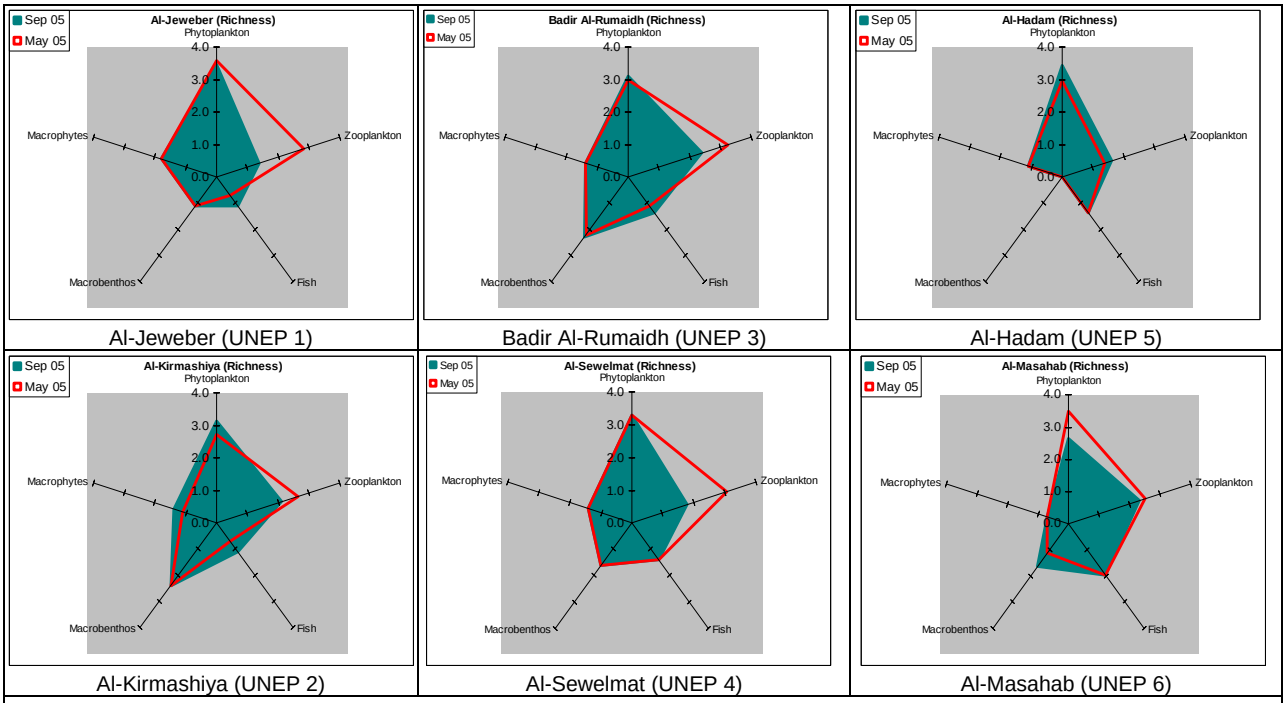
Based on the data obtained in May and September 2005, the state of overall biodiversity and species richness in each site can be summarized in Figure 35 and Figure 36 respectively. Each radar chart shows the values for phytoplankton, zooplankton, fish, macrobenthos and macrophytes in May and September 2005. The overall distribution of biodiversity increased from May to September 2005 in the six locations, as shown in Figure 35. However, the richness of species did not show similar improvement, as shown in Figure 36. Among the six locations, Badir Al-Rumaidh showed highest overall biodiversity and richness while Al-Hadam showed lowest. Overall biodiversity and richness in other four stations were found to be in between.



Al-Jeweber (UNEP 1) | Badir Al-Rumaidh (UNEP 3) | Al-Hadam (UNEP 5)

Al-Kirmashiya (UNEP 2) | Al-Sewelmat (UNEP 4) | Al-Masahab (UNEP 6)

Figure 35 Overall biodiversity in Iraqi Marshlands in May and September 2005



Al-Jeweber (UNEP 1) | Badir Al-Rumaidh (UNEP 3) | Al-Hadam (UNEP 5)

Al-Kirmashiya (UNEP 2) | Al-Sewelmat (UNEP 4) | Al-Masahab (UNEP 6)

Figure 36 Overall species richness in Iraqi Marshlands in May and September 2005

4. Recommendations

The UNEP Marshland project carried out water quality and biodiversity monitoring in the six sites in Iraqi marshlands where pilot projects for drinking water provision were implemented. Based on the analysis, the following recommendations are made:

- In all samples collected during the monitoring, the presence of high levels of total dissolved solids (TDS) and fecal coliform was reported. The concentrations of these pollutants were above the drinking water quality limits, indicating the necessity to treat the marshland water for human consumption. As such, efforts to provide treatment facilities for drinking water provision in the marshlands are recommended in order to protect the human health.

- It is recommended that periodical monitoring of water quality and biodiversity is continued at these sites to assess the conditions and the trends of marshland ecosystem recovery, and to protect the health of marshland residents who have returned to these villages.

ANNEX 1
Variation of selected physico-chemical parameters in Iraqi Marshlands

ANNEX 2
Summary of water and sediment quality in Iraqi Marshlands

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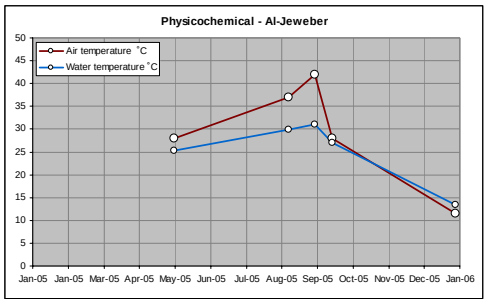
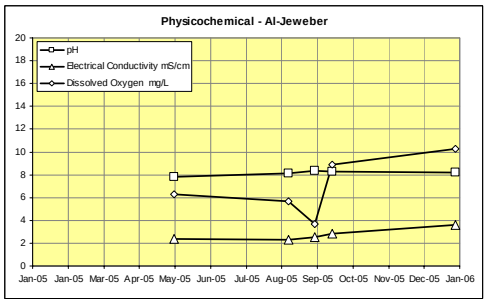
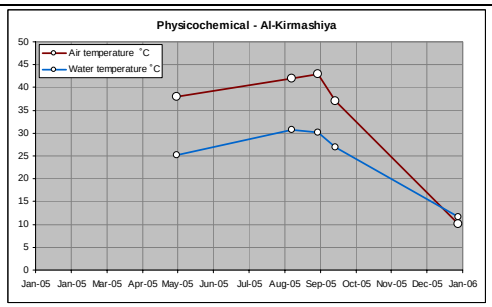
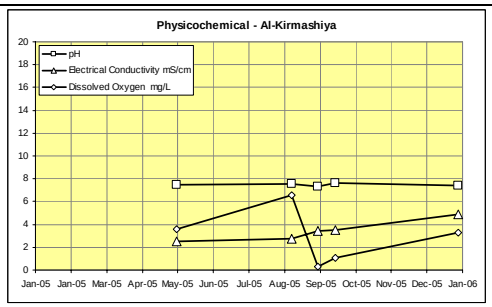
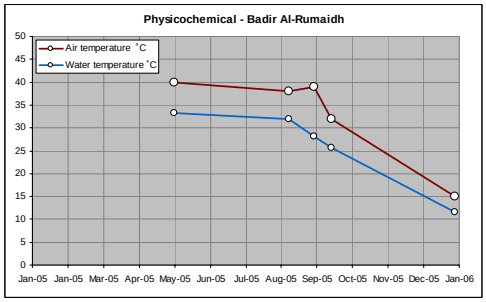
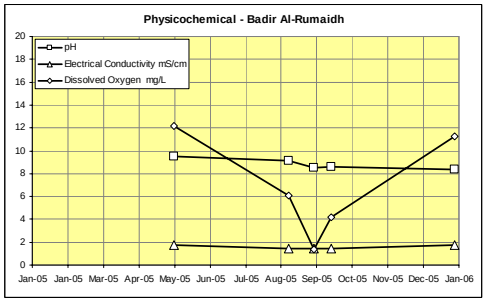


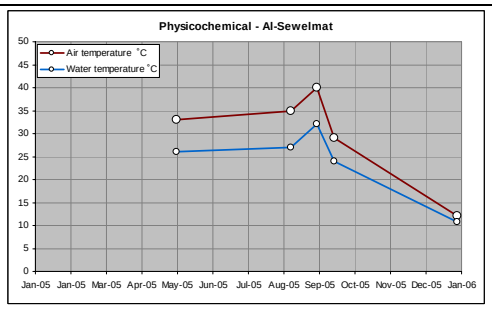


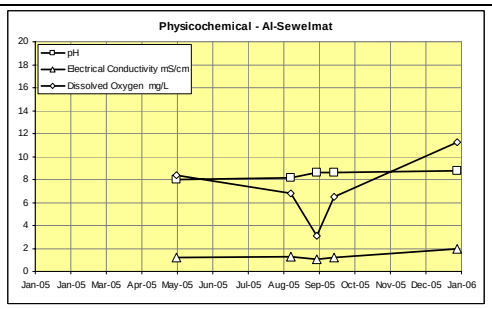


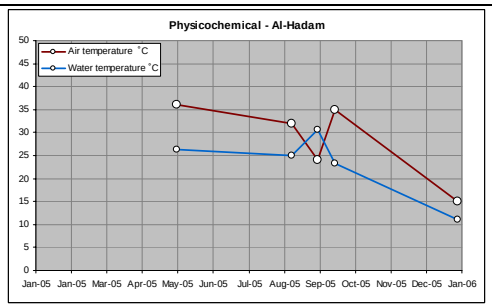


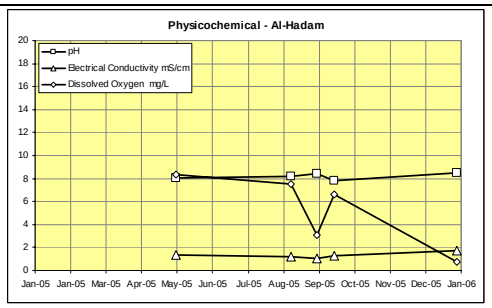


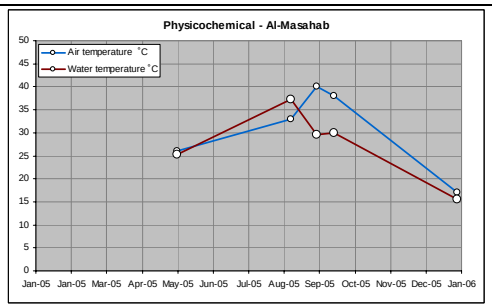


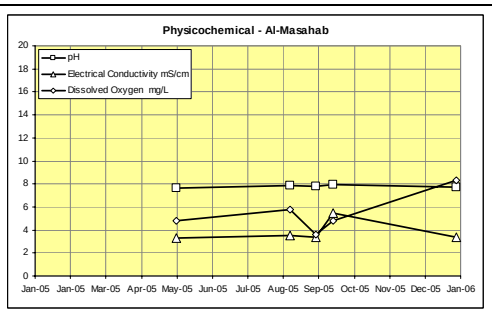




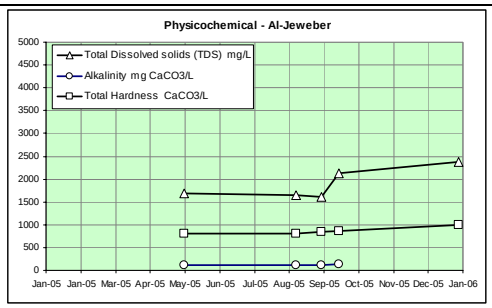


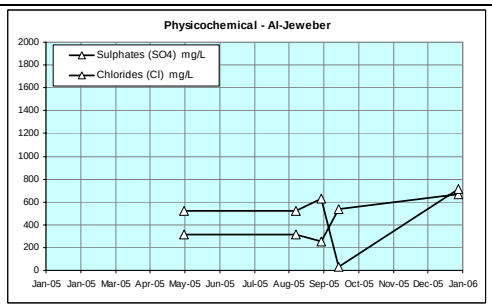


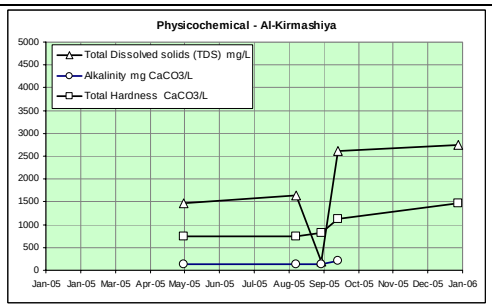


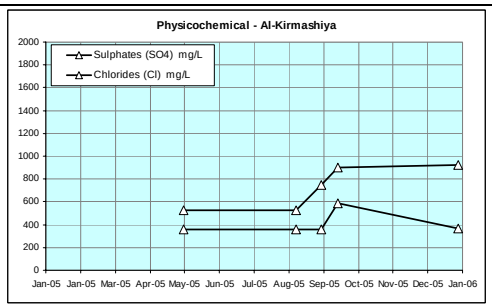


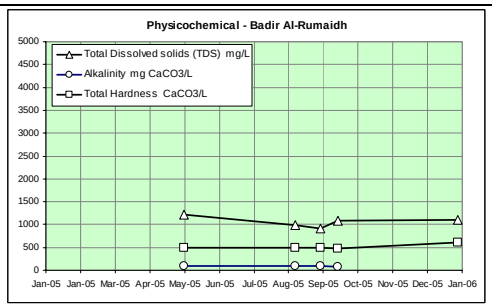
Annex 1 Variation of selected physico-chemical parameters in Iraqi Marshlands (1/2)

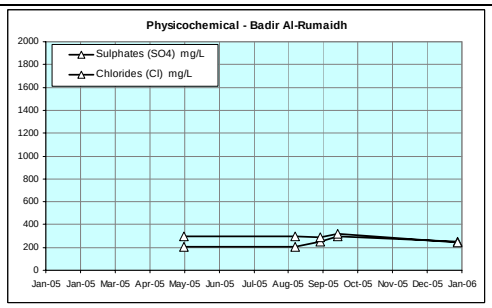


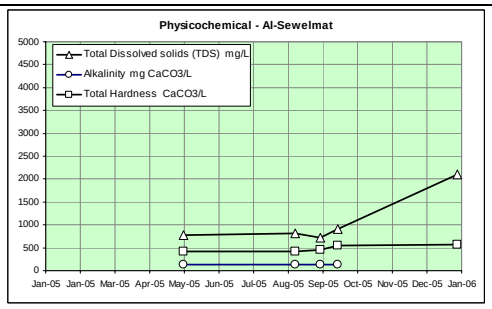


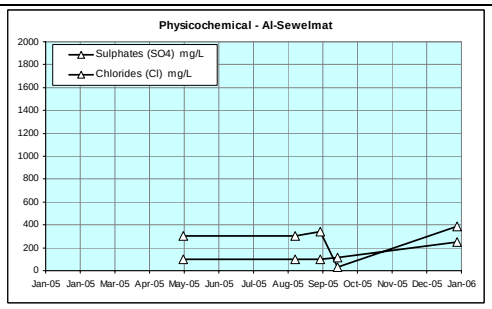


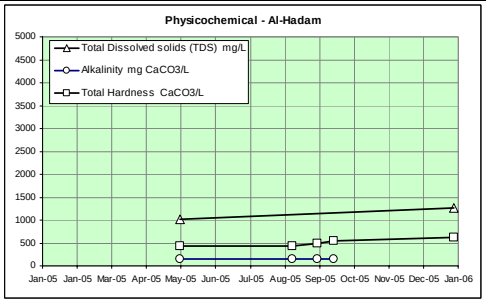


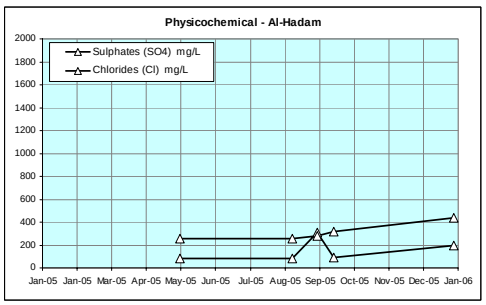


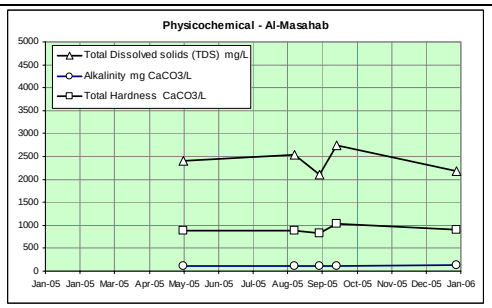


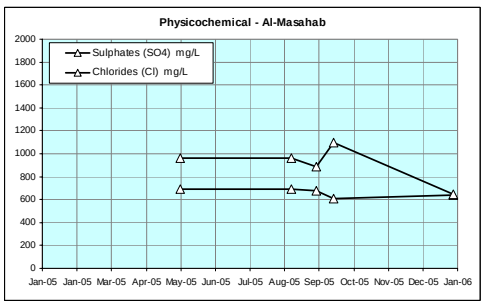












Annex 1 Variation of selected physico-chemical parameters in Iraqi Marshlands (2/2)

Annex 2 Summary of water and sediment quality in Iraqi Marshlands