UNITED NATIONS ENVIRONMENT PROGRAMME

SUPPORT FOR THE ENVIRONMENTAL MANAGEMENT OF THE IRAQI MARSHLANDS

WATER QUALITY MONITORING PROGRAMME IN THE IRAQI MARSHLANDS

APRIL – DECEMBER 2005

FINAL REPORT

DECEMBER 2006

بسم الله الرحمن الرحيم

لمناسبة انتهاء اعمال مشروع "دعم الادارة البيئية للأهوار العراقية" والمنفذ من قبل برنامج الامم المتحدة للبيئة بالتعاون مع وزارات البيئة والموارد المائية والبلديات والاشغال العامة ومجالس المحافظات في البصرة وميسان وذي قار والمجتمعات المحلية في المحافظات.

يسرني ان اضع بين أيدي القارىء الكريم هذا التقرير للافادة منه

واشكر وزارة البيئة لتحملها تكاليف طباعة هذا التقارير

د. علــي اللامــي
مستشار وزارة البيئة
المنسق الوطني للمشروع
آذار 2011

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ANNEXES

EXECUTIVE SUMMARY

1. Water Quality Monitoring Programme through a Memorandum of Understanding (MOU) concluded between UNEP DTIE IETC and Ministry of Environment (MOE), Iraq was carried-out in the Iraqi Marshlands 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.
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 Basra 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 physical, chemical, bacteriological, heavy metals, radiation, pesticides and polynuclear aromatic hydrocarbons (PAHs) totaling 73 parameters. 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 (USA) on pre-treated samples shipped by courier.
6. Water quality, sediment quality and biodiversity data obtained in this monitoring were analyzed statistically to find any correlations among them. Statistical methods such as detrended correspondence analysis (DCA), principal components analysis (PCA) and canonical correspondence analysis (CCA) were used.
7. Except for zooplankton, diversity and richness of phytoplankton, fish, macrophytes and macrobenthos showed an increasing trend between the samples taken in May 2005 and September 2005 in all sites indicating active recovery of biological communities.
8. Trace pollutants including PAHs, pesticides and heavy metals are within acceptable limits for use as raw water source.
9. Extensive analysis carried-out during the short period will form a basis for further improvement and monitoring of ecosystem recovery of marshlands.

INTRODUCTION

As per the Memorandum of Understanding (MOU) concluded between the Ministry of Environment, Iraq (MoEn) and the United Nations Environment Programme, International Environmental Technology Centre (UNEP, IETC), the MoEn undertook a water quality monitoring programme in the Iraqi Marshlands.

The MoEn collaborated with the Ministry of Water Resources, Marsh Arabs Forum and Nature Iraq/Iraq Foundation in execution of this project. A team was created from representatives of the following institutions:

From the MoEn, Dept of Environment in Basrah:

Ali Najim Abdullah

Loay Khalid

Nidhal Ahmed

Khyria Abood

Fawzia Shahaf

Bushra Abdullah

Raja Abdul Wahid

Rasha Issa

Khajack Farweez

From the MoEn, Dept of Environment in Missan:

Muhamed Sayed Hafiz

Shayma Hussain

Ibtisam Hasson

From the MoEn, Dept of Environment in Nasiriya:

Abbas Oda

From the Ministry of Environment, Baghdad:

Ibrahim Mahdi Abed

From the Ministry of Water Resources:

Nadum Abdul Ameer Faies, Basrah office

Usama Hashim Mosa, Nasiriya office

Abdul Munther Hassan, Maysan office

From the Nature Iraq/Iraq Foundation:

Prof. Ali A.Z. Douabul – Project Manager & Principal Investigator

Azzam Alwash

Haider A. Falah

Mohammed A. Taqi

Ghasaq Sabah

Mizher Sh. Minjel

Omar Ashraf Ali

Huda Samir Mohamed

Experts consulted were:

Professor Abdul Radha A. Alwan, Basrah University

Dr. Jamal Abayachi, Senior Advisor

Dr. Suzie Alwash, Senior Advisor

Anna Bachmann, Technical Editor

The Marsh Arab Forum assisted in logistics and security issues.

Objectives of field trips

First Field Trip (April 28th – May 5th 2005)

The main objectives of the first field trip were:

1. Observe the current ecological situation prevailing in six sites.
2. Test and validate sampling methodology for water and sediments.
3. Record in situ measurements of water quality parameters.

4. Take water & sediment samples to analyze for chemical parameters.
5. Collect biological samples for initial identification.
6. Photograph each station for relevant ecological phenomena (Plates 1, 2, 3, 4, 5 & 6).

A report describing the outcomes of this trip was submitted to UNEP.

SECOND FIELD TRIP (AUGUST 5TH – 11TH 2005)

The main objectives of the second field trip were:

1. Re-visit the selected sites in the Iraqi Marshes and take field measurements including water temperature, pH, dissolved oxygen, salinity, light penetration, etc.
2. Take water samples from each site for the determination of water quality.
3. Observe biota and collect biological samples to account for the biodiversity parameters.
4. Take sediment samples for the determination of sediment quality parameters.
5. Collect additional water and sediment samples to send to a well-recognized "Environmental Analytical Laboratory" abroad for the determination of hydrocarbons, trace elements, PAHs, pesticides and PCBs.

THIRD FIELD TRIP (AUGUST 28TH – 31ST 2005)

The main objectives of the second field trip were:

1. Re-visit the selected sites in the Iraqi Marshes and take field measurements including water temperature, pH, dissolved oxygen, salinity, light penetration, etc
2. Take water sample from each site for the determination of water quality.
3. Observe biota and collect biological samples to examine the biodiversity parameters.
4. Take sediment samples for the determination of sediment quality parameter.
5. Collect additional water and sediment samples to send to a well-recognized "Environmental Analytical Laboratory" abroad for the determination of hydrocarbons, trace elements, PAHs, pesticides and PCBs.

FOURTH FIELD TRIP (SEPTEMBER 13TH-15TH 2005)

The main objectives of the fourth field trip were:

1. Re-visit the selected sites in the Iraqi Marshes and take field measurements including water temperature, pH, dissolved oxygen, salinity, light penetration, etc.
2. Take water sample from each site for the determination of water quality.
3. Observe biota and collect biological samples to examine the biodiversity parameters.
4. Take sediment samples for the determination of sediment quality parameter.

5. Collect additional water and sediment samples to send to a well-recognized "Environmental Analytical Laboratory" abroad for the determination of hydrocarbons, trace elements, PAHs, pesticides and PCBs.

FIFTH FIELD TRIP (DECEMBER 26TH-29TH 2005)

The main objectives of the fifth field trip were:

1. To confirm the results of the previous field trips with respect to flood & draft seasons and to check whether raining has appreciable effects on water quality in the marshes.
2. Re-visit the selected sites in the Iraqi Marshes and take field measurements including water temperature, pH, dissolved oxygen, salinity, light penetration, etc.
3. Take water sample from each site for the determination of water quality.
4. Observe biota and collect biological samples to examine the biodiversity parameters.
5. Take sediment samples for the determination of sediment quality parameter.
6. Collect additional water and sediment samples to send to a well-recognized "Environmental Analytical Laboratory" abroad for the determination of hydrocarbons, trace elements, PAHs, pesticides and PCBs.

SITES

As per the contract, six sites were selected by UNEP. Three sites in Nasiriya, two site in Amarah and one site in Basrah. Plate 1 below shows the position of these sites on a map of southern Iraq. Table 1 provides a list of sites along with their coordinates.

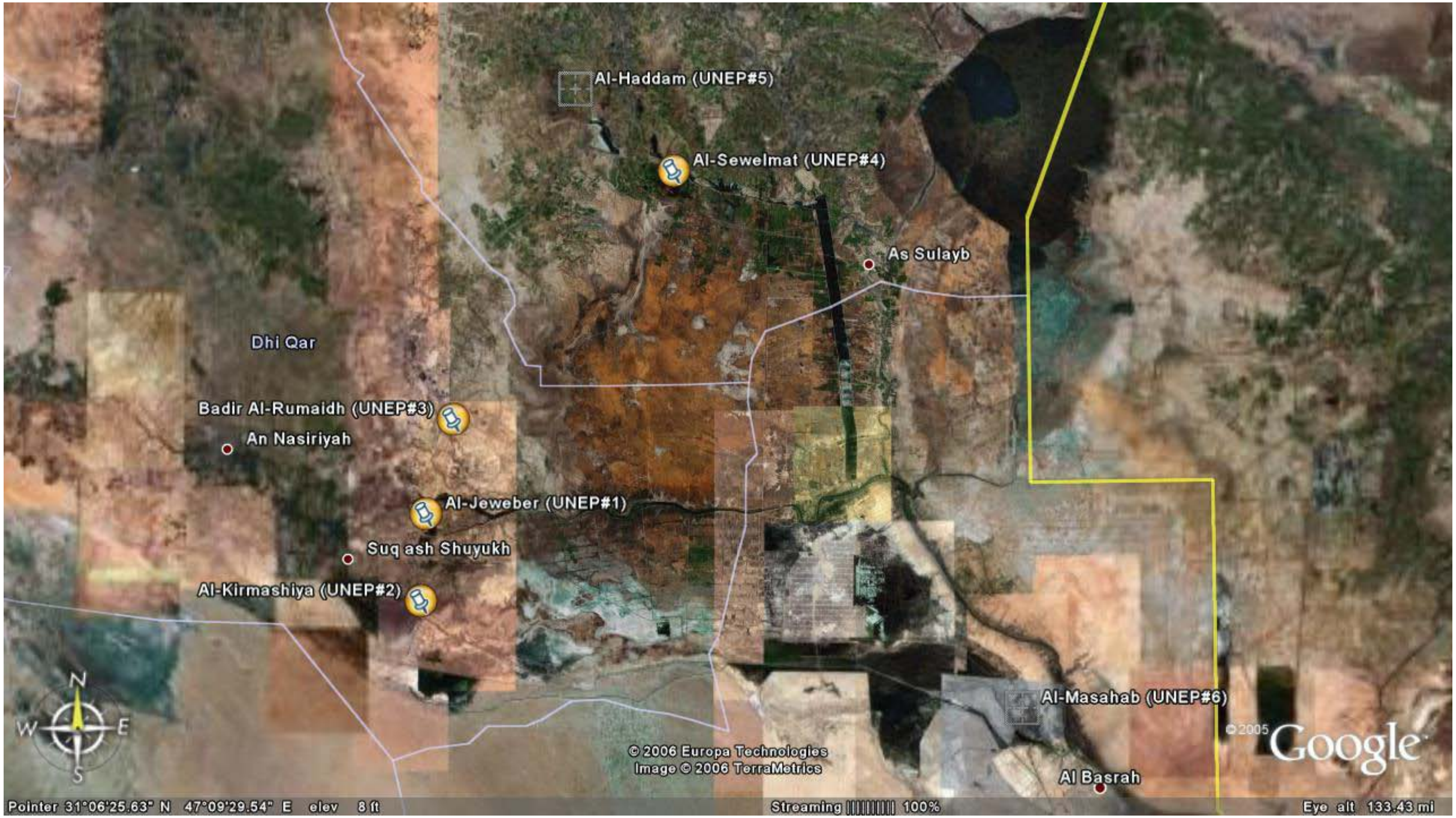


Plate 1: Location Map

Table 1: Locations of the studied sites

Site	Latitude			Longitude		
	"	'	°	"	'	°
Al Jeweber (UNEP #1)	**46**	**36**	**55**	**30**	**56**	**45**
Al Karmashia (UNEP #2	**46**	**36**	**24**	**30**	**48**	**42**
Badir Al Ramaidh (UNEP #3)	**46**	**39**	**51**	**31**	**5**	**30**
Al Sewelmat (UNEP #4)	**47**	**3**	**41**	**31**	**28**	**27**
Al Hadam (UNEP #5)	**46**	**53**	**9**	**31**	**35**	**56**
Al Masahab (UNEP #6)	**47**	**41**	**7**	**30**	**38**	**41**

SITE DESCRIPTIONS

The following is a brief description for each site.

1. AL JEWEBER (UNEP #1)

This site is located in Nasiriya Governorate in Al Taar area. The area characterized by slow flowing water and no growth for Ceratophyllum demersum. The local tribe lives in two areas or clusters. One cluster is located on both sides of Gurmet Hassan River, which is a branch of the Euphrates River. There are approximately 300 families in this cluster. The other cluster is located along a sub-branch of the Gurmet Hassan called Um Jigair and there are 120 families there. In addition, the Tribal Sheikh indicated that he is aware that approximately 350 internally displaced people may come back to the area should services be provided.

Plate 2: Al Jeweber Site (UNEP #1)

2. AL KARMASHIA

This site is located in Nasiriya Governorate in the Gurmet Bany Seied area near Karmashia River, which receives water from the Euphrates River. This area includes pipes that connect water on both sides of the "security" embankment. It is characterized by the growth of different plants and slow flowing water.

Two different clusters of communities live along the security embankment running southwesterly from the end of the Karmashia River to the railway embankment.

Plate 3: Al Karmashia Site (UNEP #2)

3. Badir Al Ramaidh (UNEP #3)

Water in this area comes from the Gharraf River, which is a distributary of the Tigris River. Water salinity is well within acceptable limits (rarely exceeding 700 ppm according to the monitoring study conducted by our teams at the Abu Zirig Marsh over the past year).

Plate 4: Badir Al Ramaidh Site (UNEP #3)

4. Al Sewelmat (UNEP #4)

This site is located in Amarah Governorate in Al Salam area near the Glory River. The Glory River is the main project responsible for the draining of the Central (Qurnah) Marshes. People living in the interior of the marshes were forcibly relocated to the southern embankment of the Glory River after the drying of the marshes. There are many communities along the southern embankment which is over 60 kilometers in length in its east-west alignment. This area was suggested by the Fartous Tribe for consideration as part of UNEP's pilot project program.

There are over 500 family compounds (about 3500 individuals) from the Fartous Tribe in this stretch of the Glory River. They are earning a living from fishing, livestock and other activities (some reportedly extrajudicial). Electrical service in the area is available; however, it is intermittent and unreliable.

The source of the water in the area is the Tigris River, and as such, the salinity is well within acceptable limits; however, there is no treatment of water in the area. The community stretches over six kilometers along the Glory River. Water distribution after treatment should be considered as an integral part of the project. Pipes with taps at regular intervals may be a solution to the problem of traveling several kilometers (most likely on foot by women) to get treated water. Also consideration should be given to providing water taps where local canoes (Mashoufs) can access them to fill water containers.

Plate 5: Al Sewelmat Site (UNEP #4)

5. AL HADAM (UNEP #5)

This site is located in Omara City in Al Maemona area near Al Hadam River, which gets its water from the Tigris and feeds the agricultural lands north of the Central (Qurnah) Marshes.

The embankments of this river, as well as the other distributaries, were raised as part of the drying scheme to prevent their overtopping in cases of high water flows that the Glory River could not handle (given its flat gradient).

A branch of the Hadam feeds Al Awdeh Marsh, which was also dried, but has been flooded since mid-2003 and was in a stage of robust recovery as early as September 2003. There are over 5000 people living in some 22 different clusters (or what could be termed villages) along the route of the Hadam, which stretches some 27 kilometers from the Maimouna Bridge to the terminus of the river into the Glory River.

The site chosen by the locals for consideration by UNEP is located mid-way along the right (western) embankment of the Hadam River. The area is large but it should be raised to be level with the embankment and the roadway. A health clinic and an elementary school were constructed recently near the site.

It should be noted that the salinity of the water is well within acceptable limits as it originates from the Tigris. No sewage services exist in the area; however, the locals seem to be unconcerned with the effects of the untreated water being so close to the groundwater (they use out-houses in this area).

Plate 6: Al Hadam (UNEP #5)

6. AL MASAHAB (UNEP #6)

This site is located in Basrah Governorate near the Garmat Ali area and receives water from the Euphrates River. It is characterized by fast flowing water and growth of *Phragmites austeralis* and *Typha domengensis*.

There are wide areas north of the breached embankment on Masahab that were used as farms prior to the drying of the marshes. Despite the fact that water was introduced in the area since April 2003, few reeds have managed to take hold along the banks of Masahab. It was observed that some people have started planting reeds along the sides of the river to reduce erosion. The area is well within the effect of tidal action.

Only 35 families have come back to various farms within the dried-out zone. However, there are many houses along the main road with few services. It is interesting to note that there exists a privately owned RO unit along the main road leading into the main village in Meshab. Electrical services are not reliable. Most of the land is privately owned even in the dried portions. Thus, it will be necessary to include compensation for the land used for the Pilot Project. According to Mr. Mahdi Saleh Fudhy, the British Department for International Development (DIFD) is scheduled to install an RO unit in the area, thus some sort of coordination is needed to prevent duplication of efforts.

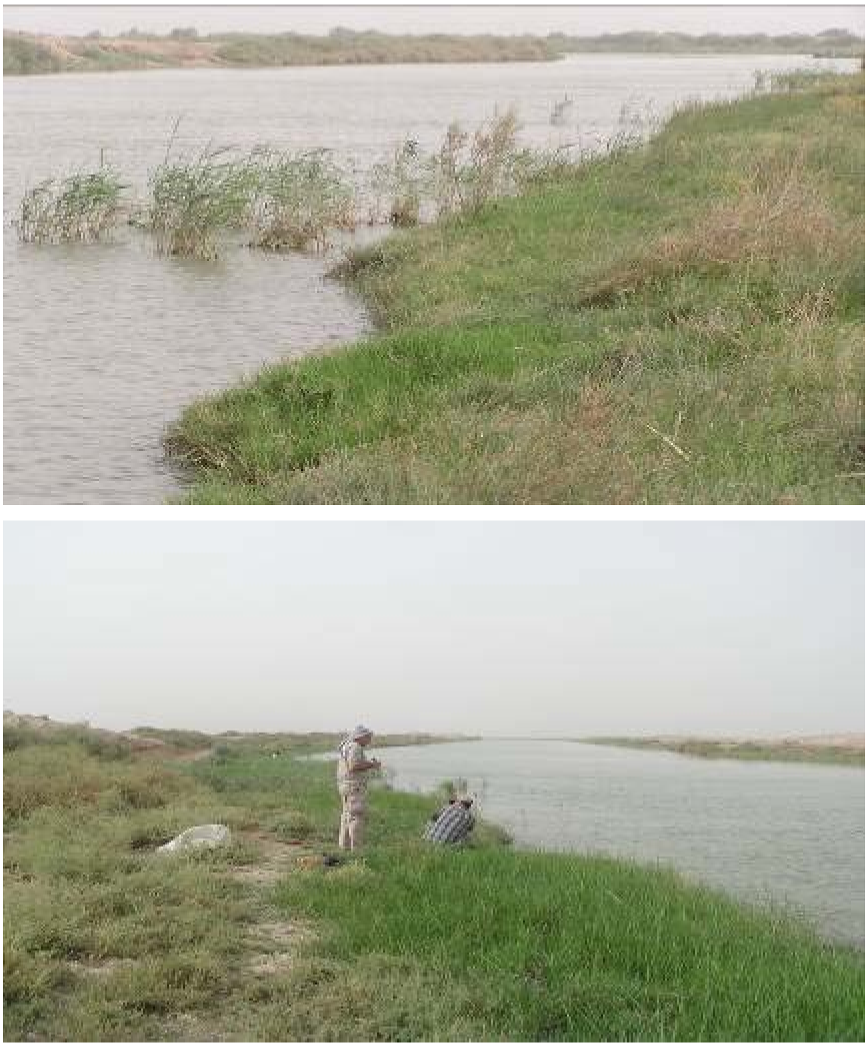


Plate 7: Al Masahab (UNEP #6)

MATERIALS & METHODS

SAMPLE COLLECTION

Water, sediment and biota were sampled five times as follows:

April 28th – May 5th 2005	**First sampling occasion**
August 5th – 11th 2005	**Second sampling occasion**
August 28th – 31st 2005	**Third sampling occasion**
September 13th-15th 2005	**Fourth sampling occasion**
December 26th-29th 2005	**Fifth sampling occasion**

Plate 8: Sampling Trip

WATER

Water samples (sub-surface) were collected by means of a Van Dorn water sampler. The water samples were immediately filtered through 0.45µ Millipore filters. The filtrates were placed in glass and/or plastic containers and frozen until the time of analysis. Standard methods were followed for the desirable parameters, however, for the determinations of nitrite, nitrate, reactive phosphate and silicates the procedures in Parsons *et. al.* (1984) were followed. For this purpose, a C≡CIL spectrophotometer model C≡7200 was used. Following recommended, additional samples of water were collected and sent via TNT courier to TDI-Brooks International in Texas, USA for the analysis of metals, hydrocarbons, pesticides and PCBs.

Plate 9: Field Activities 1

SEDIMENT

Sediment samples were collected by means of a Van Veen grab sampler. After retrieval of the sampler, the water was allowed to drain-off, avoiding disturbing the surface layer of the samples. As soon as the samples were retrieved, they were placed in glass and/or plastic containers. Before analysis, sediment samples were dried in an oven at 40oC, ground finely in an agate mortar and sieved through a 1 mm metal sieve. Standard methods were followed for the determination of the desired parameters.

Following recommended, additional samples of surface sediment were collected and sent via TNT courier to TDI-Brooks International in Texas USA for the analysis of metals, hydrocarbons, pesticides and PCBs.

Plate 10: Field Activities 2

PHYTOPLANKTON

Sampling for qualitative analysis were taken utilizing a phytoplankton net (mesh size 20µ). As for quantitative analysis of phytoplankton, one liter of marsh water was collected in plastic bottles to which 5 ml of Lugol's solution were added in the field. The collected samples were transferred to graduated cylinders equipped with a siphoning device. The samples were left to settle for 10 days. After which time the lowest-most layers were siphoned into 100 ml graduated cylinders supplied with a siphon and left to settle for further seven days. From these the lowest-most 10 ml of the samples were siphoned again into small vials. The concentrated samples of phytoplankton were then examined using an Olympus microscope type CH2 equipped with a digital camera.

ZOOPLANKTON

Sampling for qualitative analysis was carried out by filtrated 40 liters of marsh water through a mesh size 20 µ and the collected sample was placed in one liter plastic bottle to which 10 ml of formaldehyde 10% were added. The concentrated samples of zooplankton were then examined in the laboratory using an Olympus microscope type CH2 equipped with a digital camera.

MACROPHYTES

Field observations were made at the selected sites. Notes were taken to record species of aquatic plants that are dwelling at each location wherever it is possible. Photographs were taken for each species of aquatic plants. For inconspicuous species, laboratory test was necessary to ascertain proper identification. Furthermore, comparison of these specimens were made with plants collected during the 80's (before the drying of the marshes) and preserved at the Basrah University herbarium.

BENTHIC FAUNA

The Iraqi marsh survey database consists of visually estimated quadrates bisecting the area. Semi-quantitative observations were made within each quadrate (100 X 100 cm). These were based on absolute values i.e. the area covered by a particular habitat within the quadrate (1.00 m2) or the number of individuals estimated for the area.

FISH

Fish samples were collected with the help of local fishermen. The length-weight relationships were estimated to account for the condition factor, which is a good indicator of fish growth. Fish photos were taken by means of a digital camera.

BIRDS

Identification of birds was done by direct observations; doubtful and unclear identifications were excluded. Embankments, dry areas, and canoes were used as fixed and mobile observation sites; otherwise, wading and hiding were used to provide for close observation. Species in the distance were identified using a 12 x binocular. Photographs were taken using a digital camera of up to 30x digital zoom. "Collins Bird Guide" and "Field Guide to the Birds of the Middle East" were consulted when necessity (Porter 1996); (Killian 1999).

RESULTS

Five field trips were undertaken by the Nature Iraq/Iraq Foundation Team; however, in order to show the extreme flood (April-May) and draught conditions (August-September) in both the Tigris & Euphrates Rivers, the data obtained from these trips was divided accordingly. The main objective of December field trip was to check whether the winter rains were having detectable effects on water quality in the marshes. But no effects were detected none, which a due mainly to due to the huge volume of the marshes and to the small amounts of rainfall that actually occurred in the marshes during December 2005. The terms of reference did not allow the team to pursue this aspect any further.

1. MARSHLAND REFLOODING AND SAMPLING EVENTS:

The figure below shows the variation of overall water and vegetation cover during 2005 and the sampling events, which will aid in future analysis/interpretation of monitoring data.

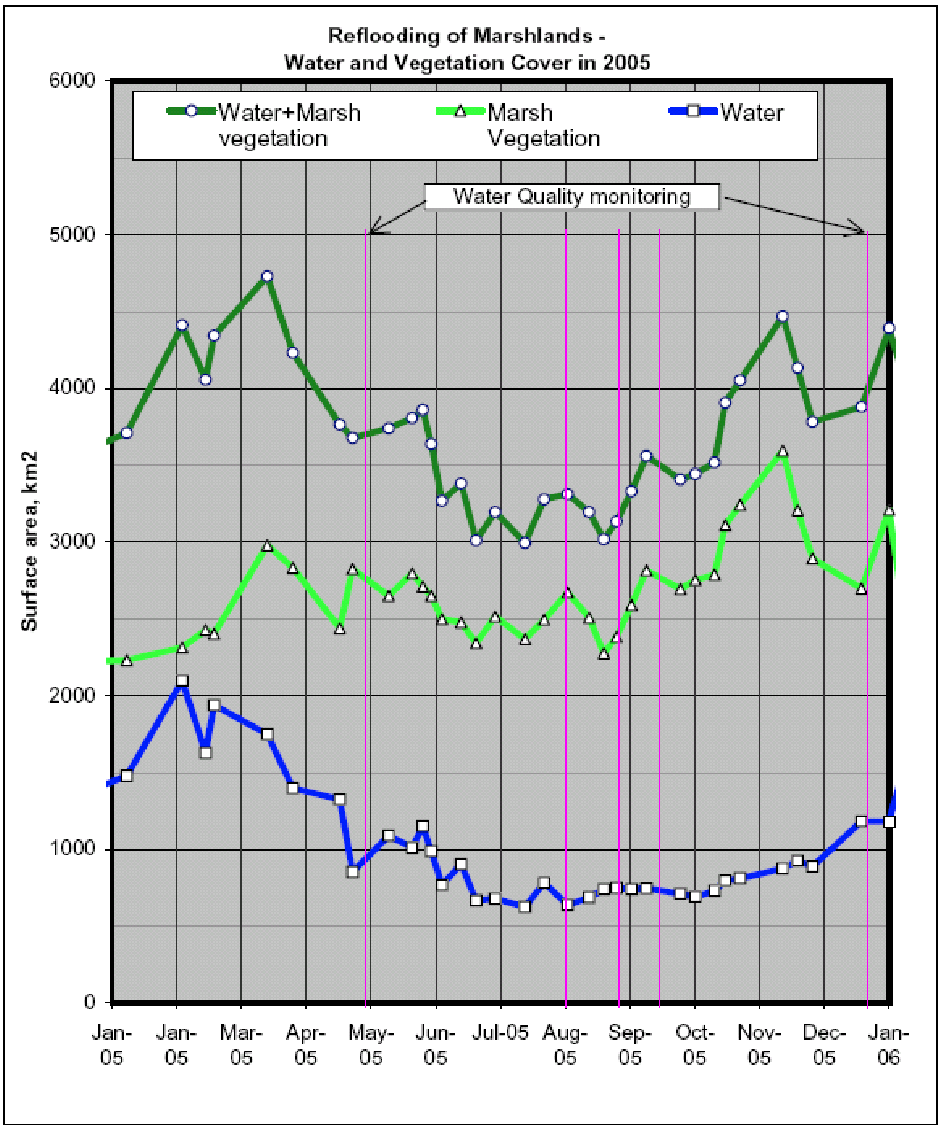


Figure 1: Sampling events and marshlands reflooding.

2. VARIATION OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS:

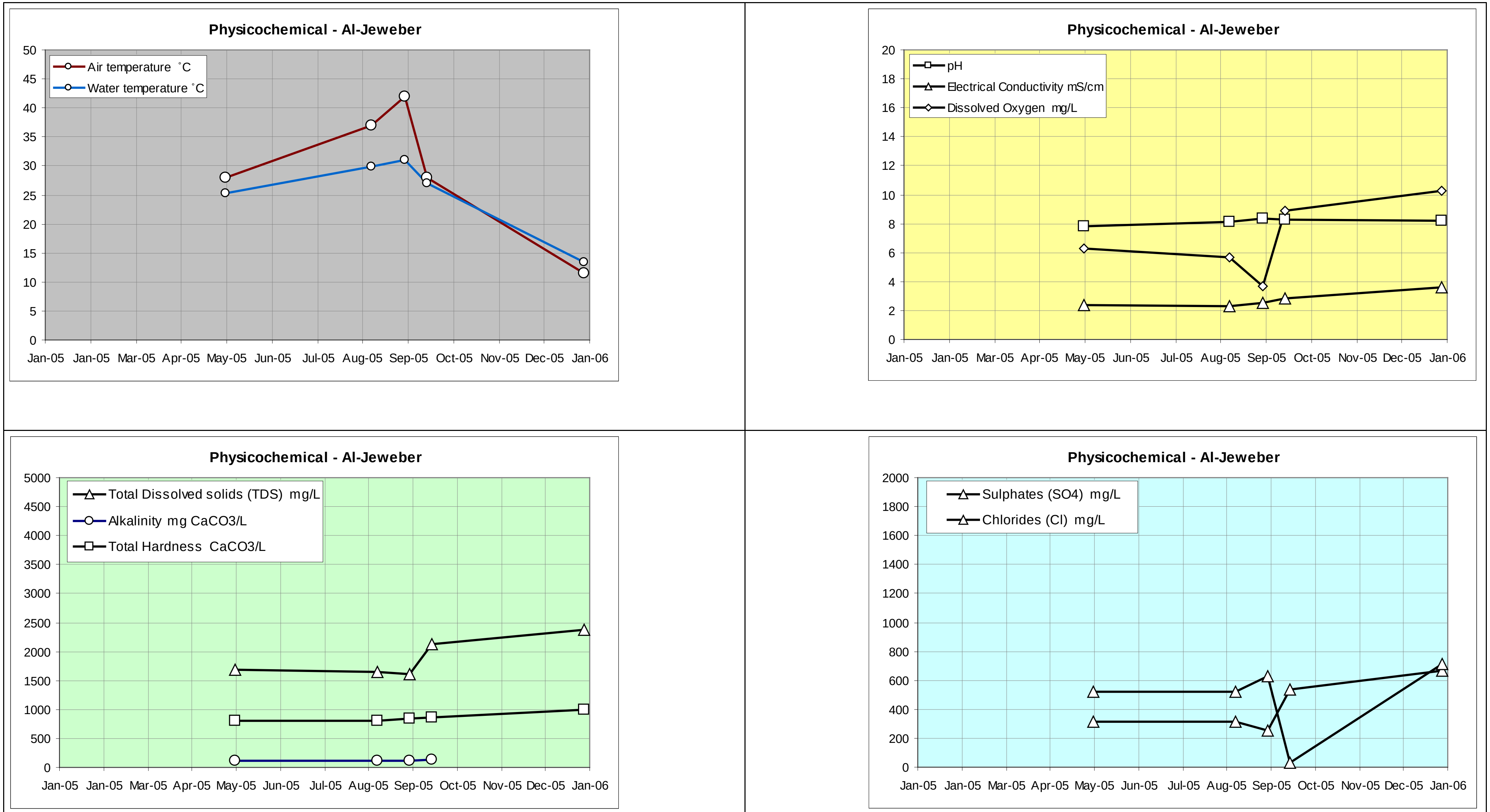


Figure 2: Variation of physico-chemical parameters in UNEP 1 (Al-Jeweber)

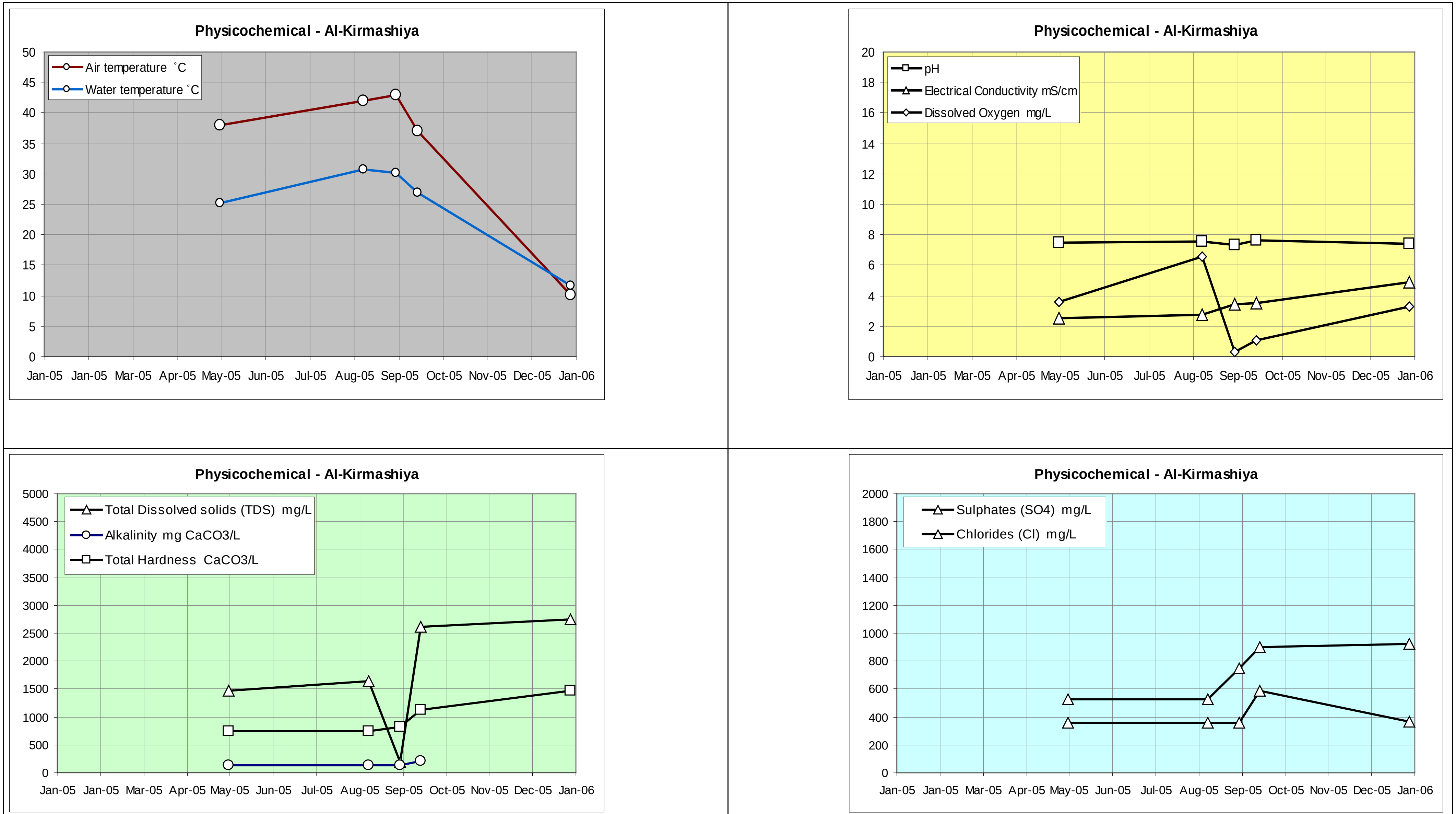


Figure 3: Variation of physico-chemical parameters in UNEP 2 (Al-Kirmashia)

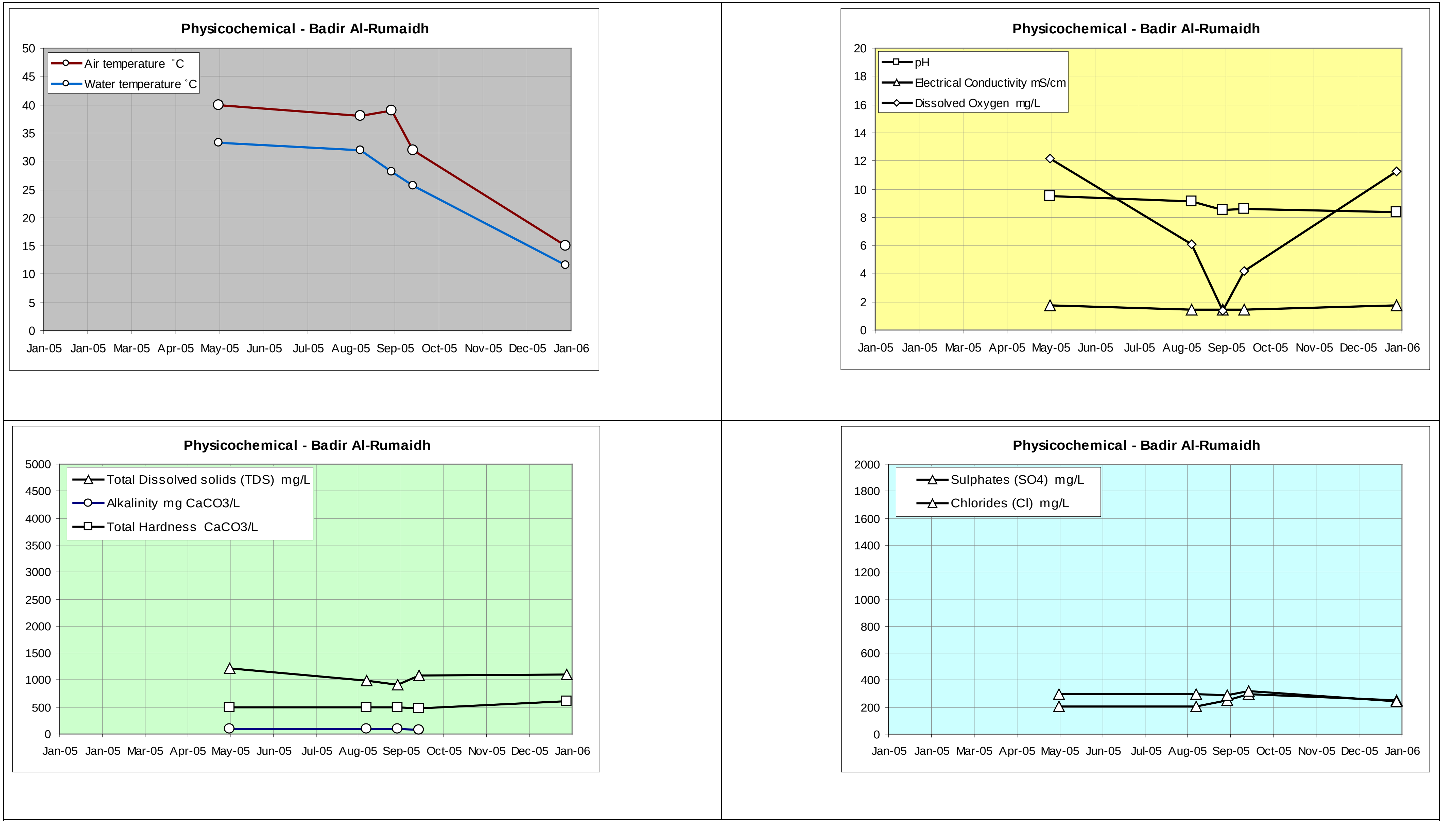


Figure 4: Variation of physico-chemical parameters in UNEP 3 (Badir Al-Rumaidh)

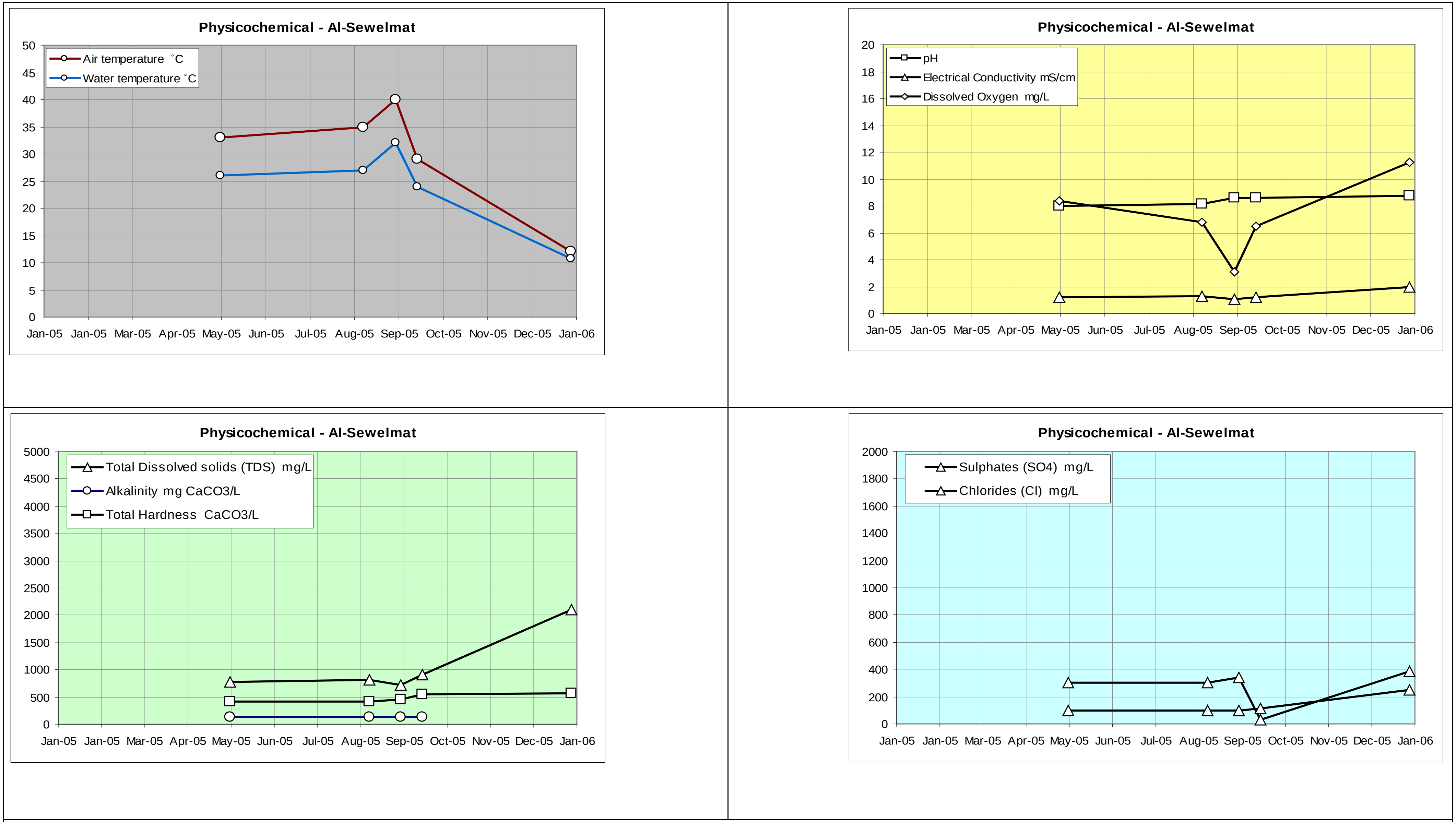


Figure 5: Variation of physico-chemical parameters in UNEP 4 (Al-Sewelmat)

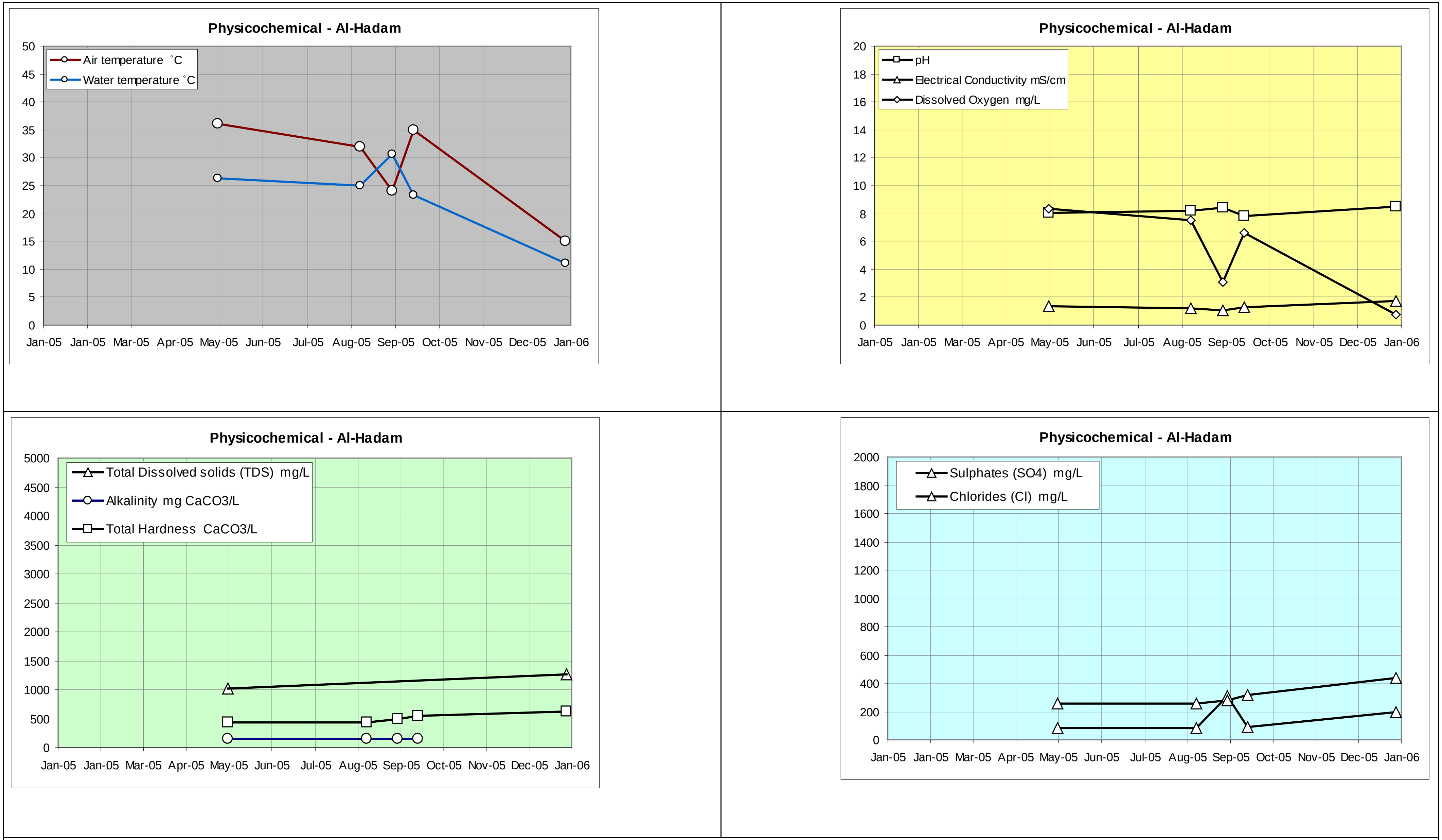


Figure 6: Variation of physico-chemical parameters in UNEP 5 (Al-Hadam)

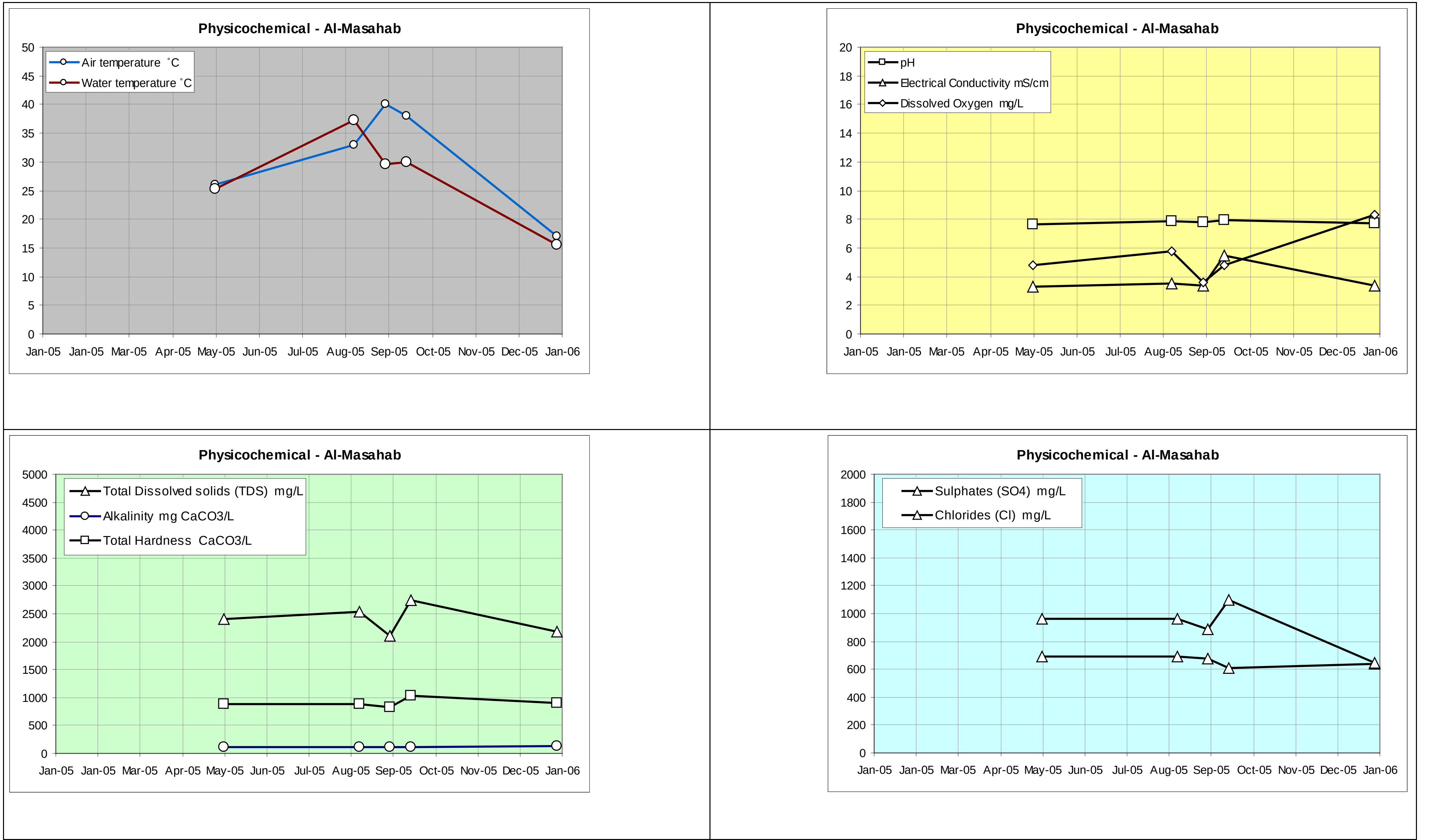
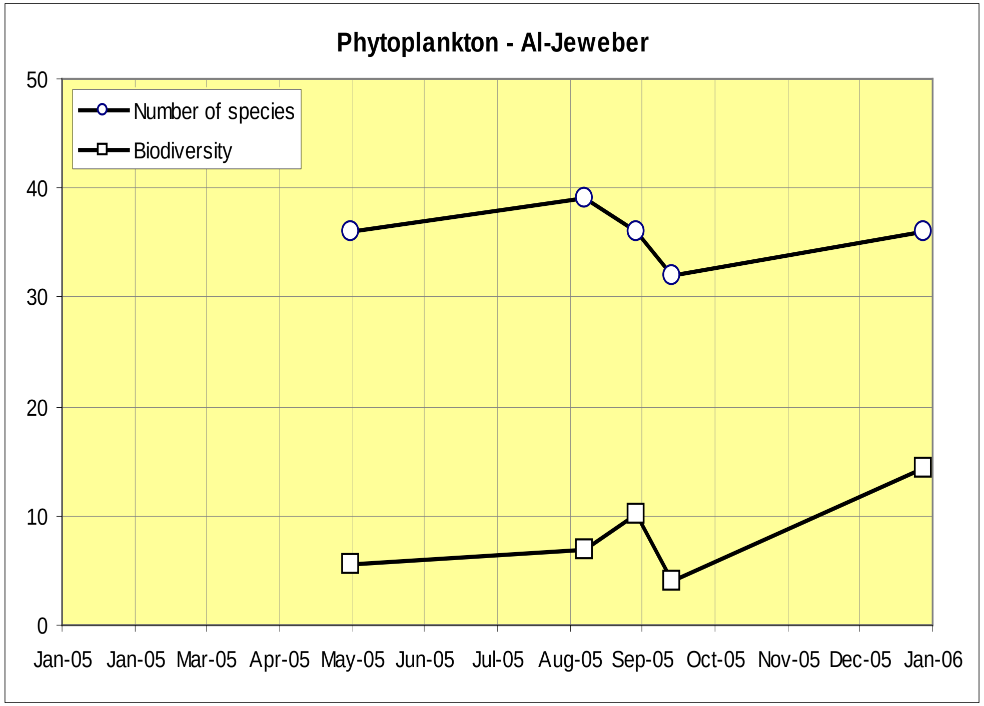


Figure 7: Variation of physico-chemical parameters in UNEP 6 (Al-Masahab)



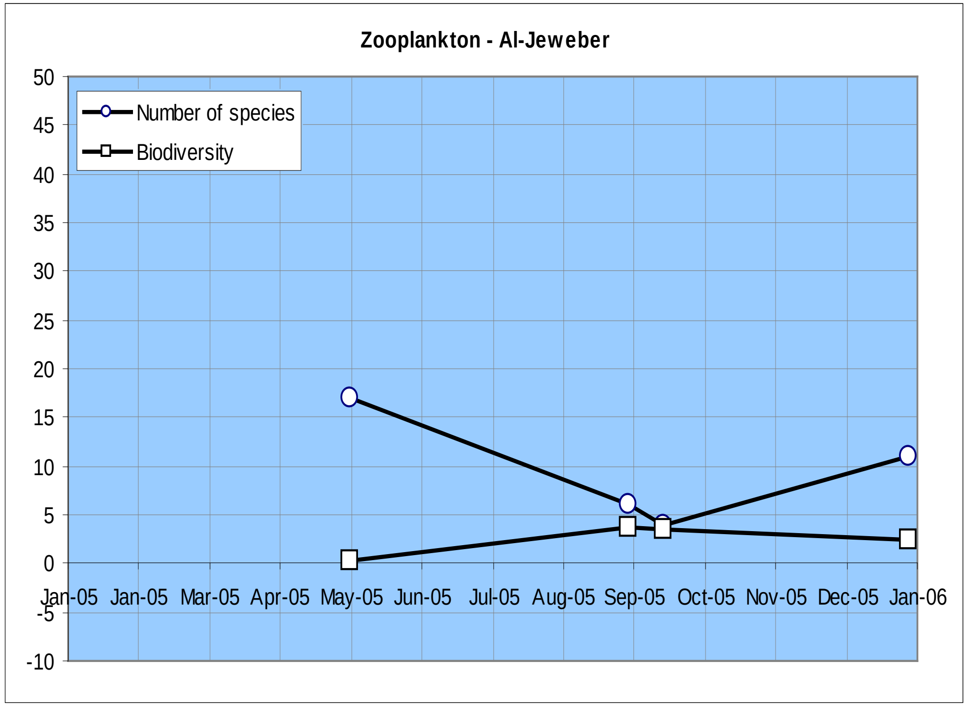
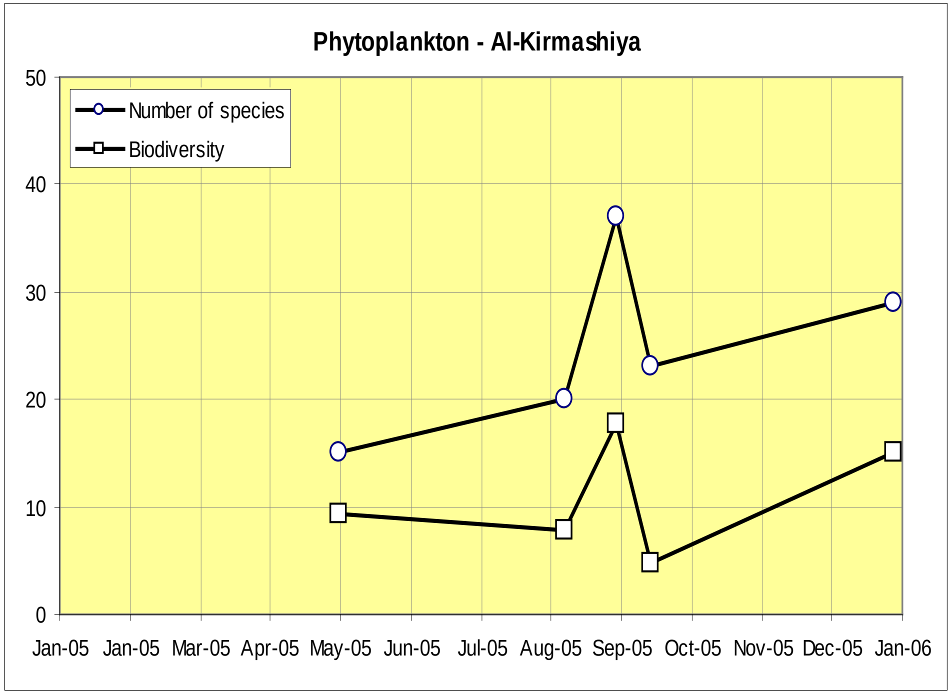


Figure 8: variation of Phytoplankton & Zooplankton in UNEP 1 (Al-Jeweber)



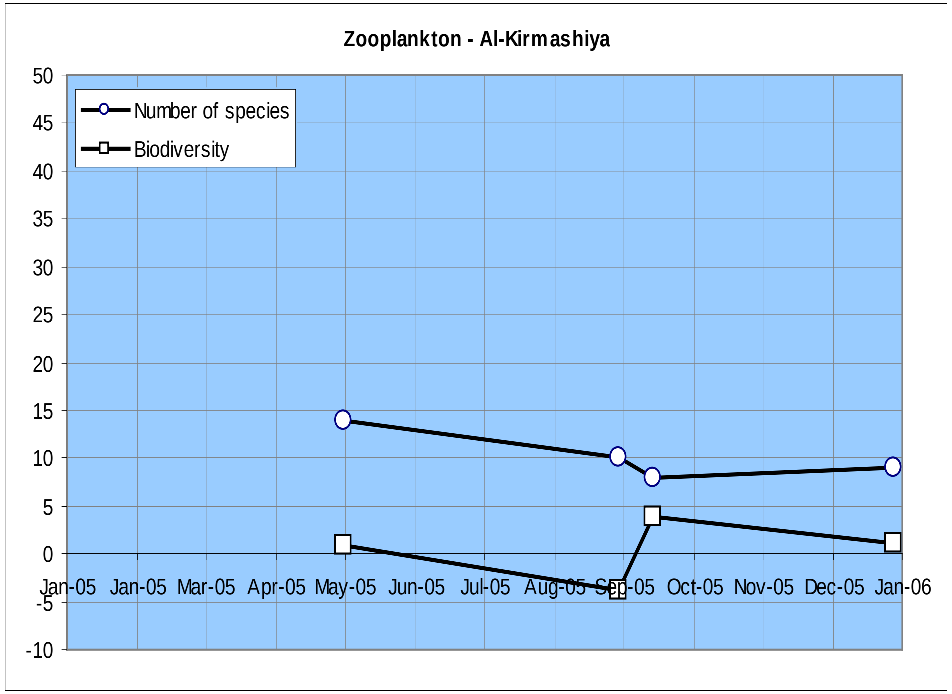
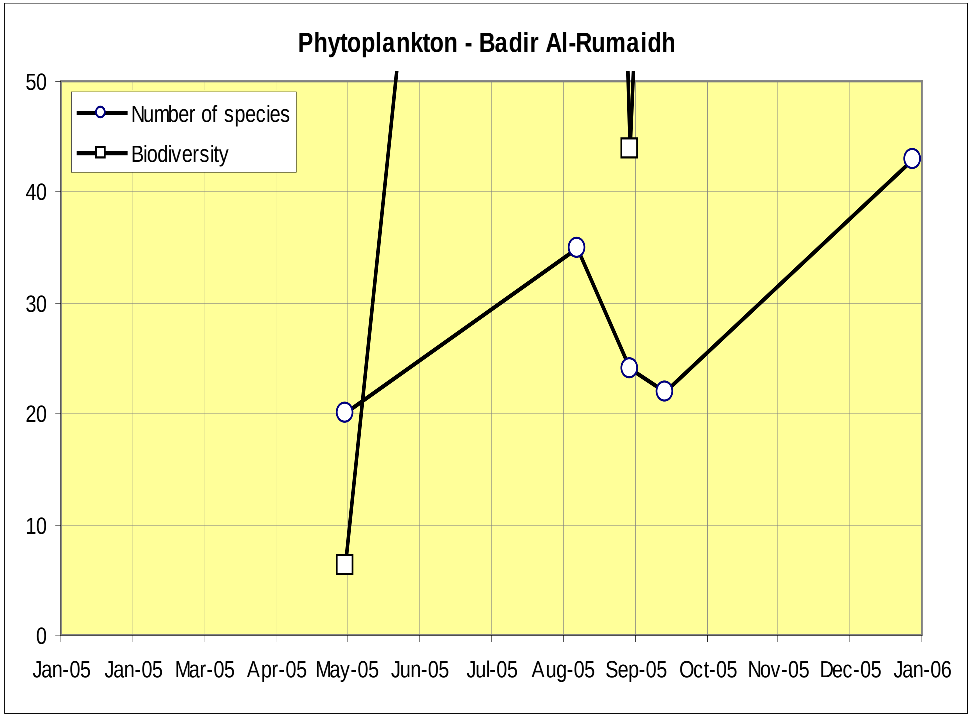


Figure 9: variation of Phytoplankton & Zooplankton in UNEP 2 (Al-Kirmashia)



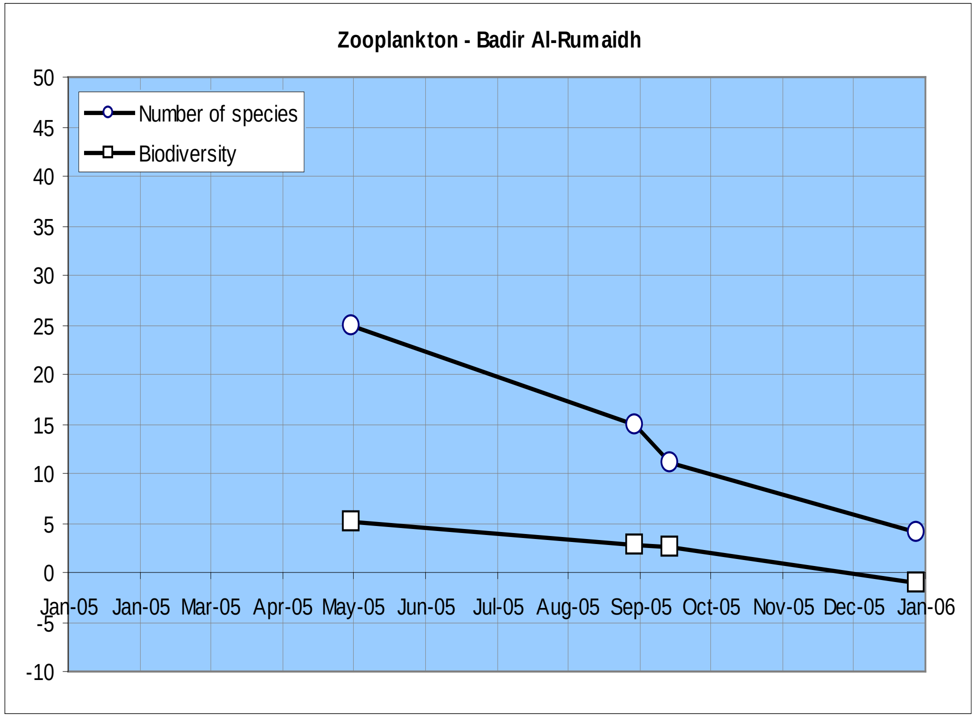
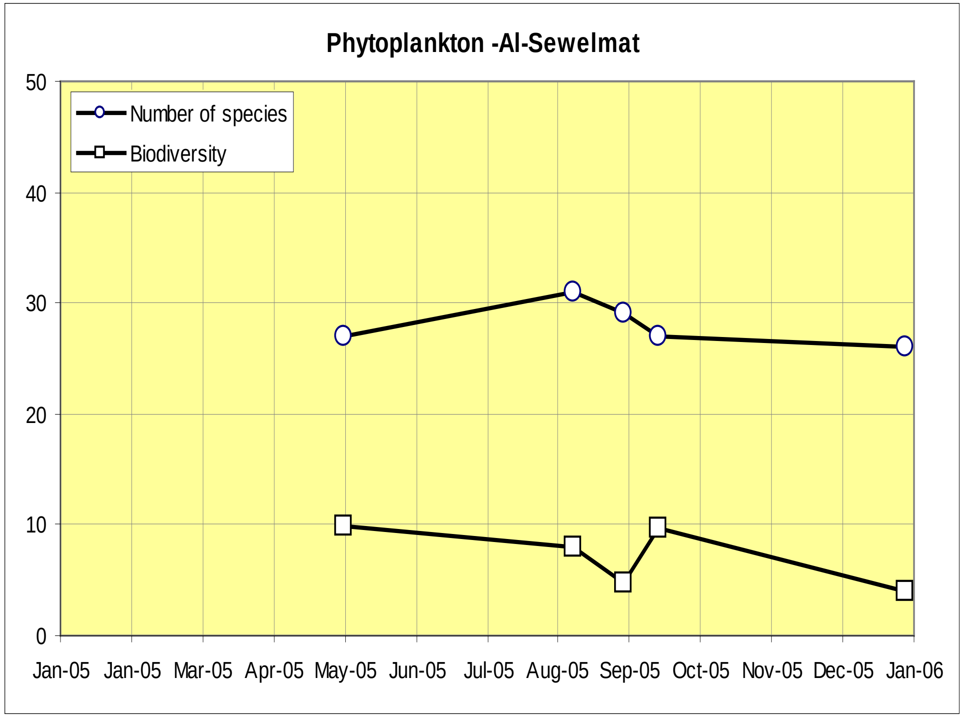


Figure 10: variation of Phytoplankton & Zooplankton in UNEP 3 (Badir Al-Rumaidh)



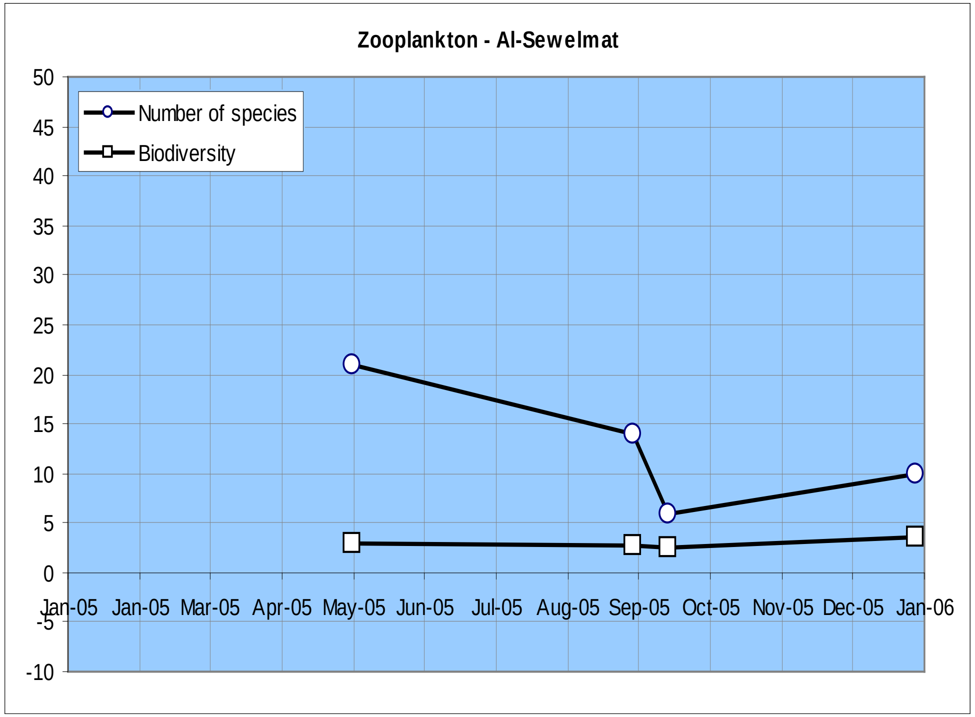
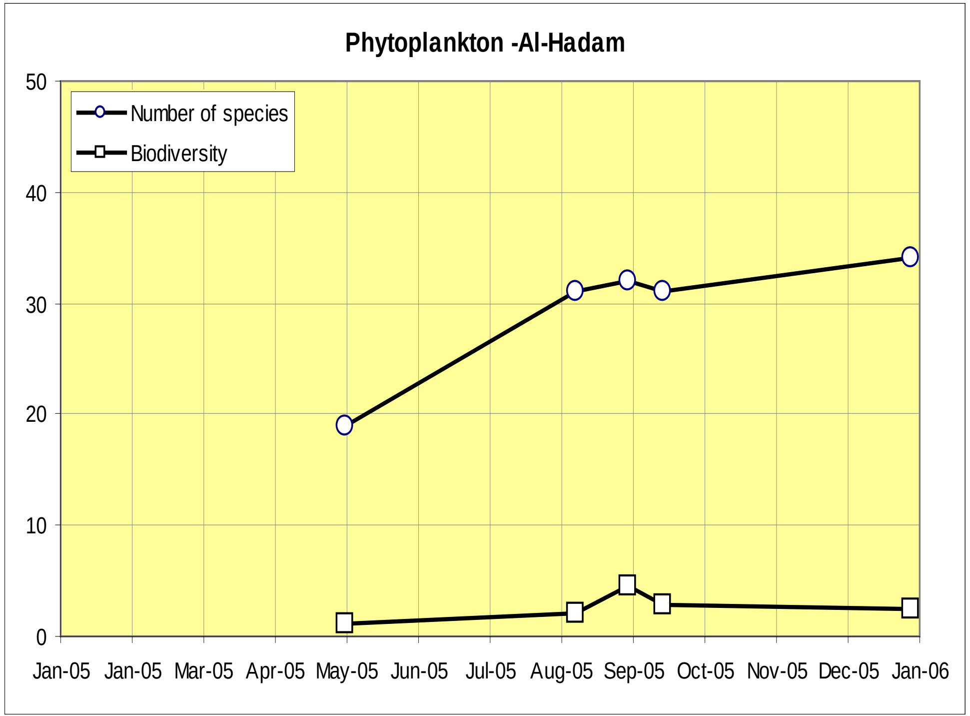


Figure 11: variation of Phytoplankton & Zooplankton in UNEP 4 (Al-Sewelmat)



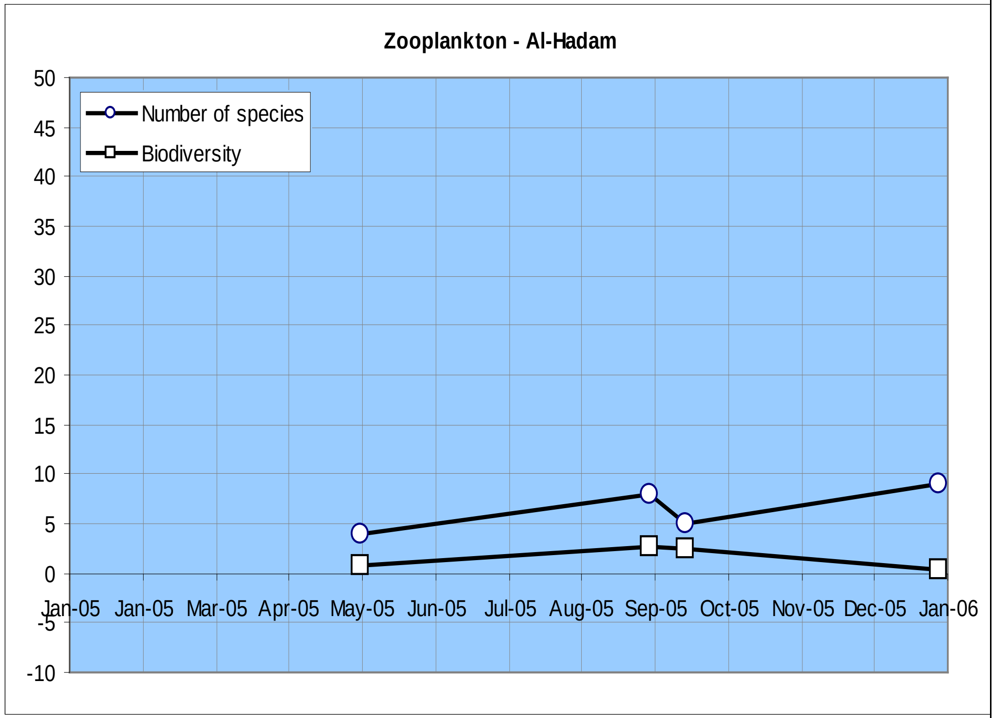
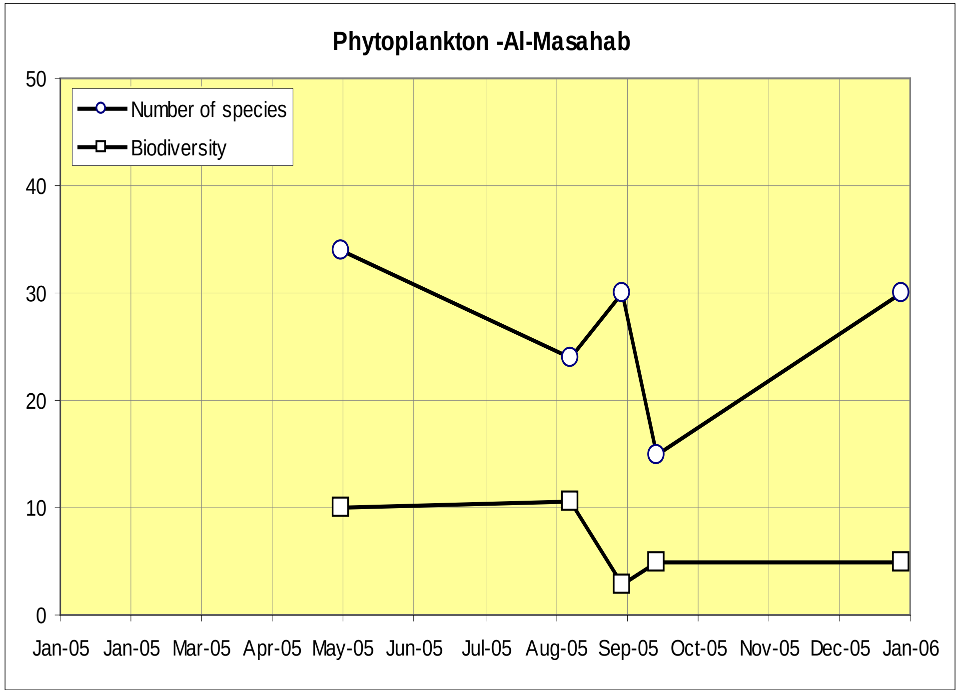


Figure 12: variation of Phytoplankton & Zooplankton in UNEP 5 (Al-Hadam)



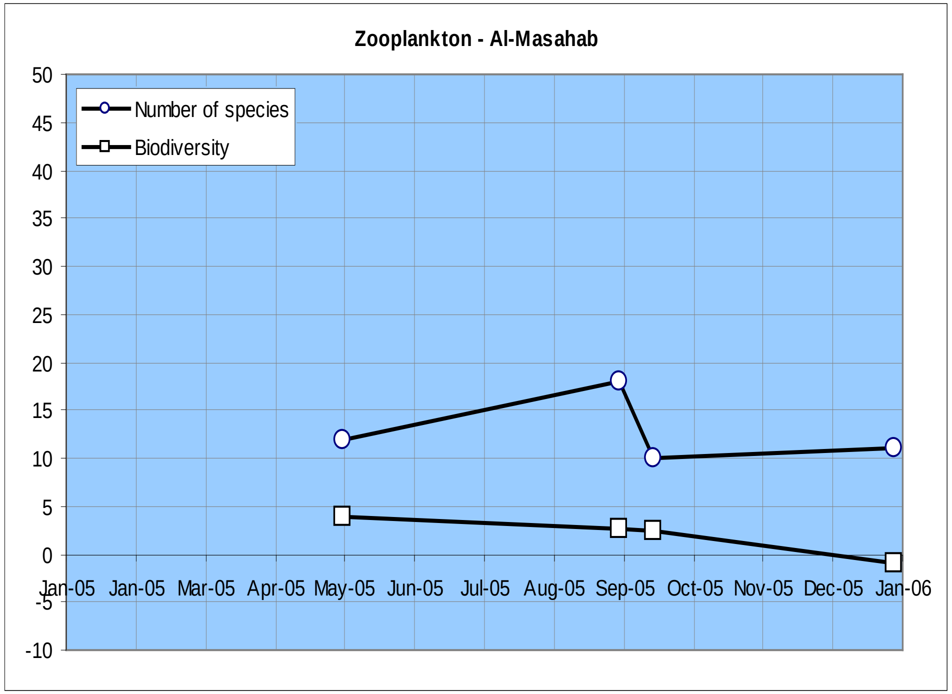
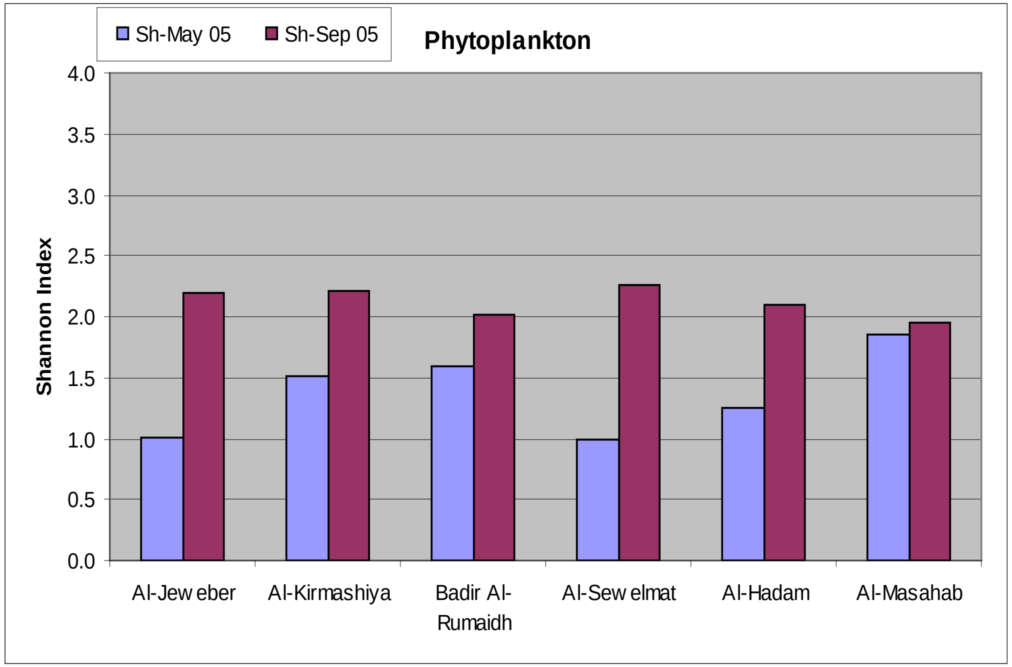


Figure 13: variation of Phytoplankton & Zooplankton in UNEP 6 (Al-Masahab), (May – September 2005)

3. Summary of Shannon Index and species richness in May 2005 and September 2005 for phytoplankton, zooplankton, fish, macrophytes and macrobenthos.



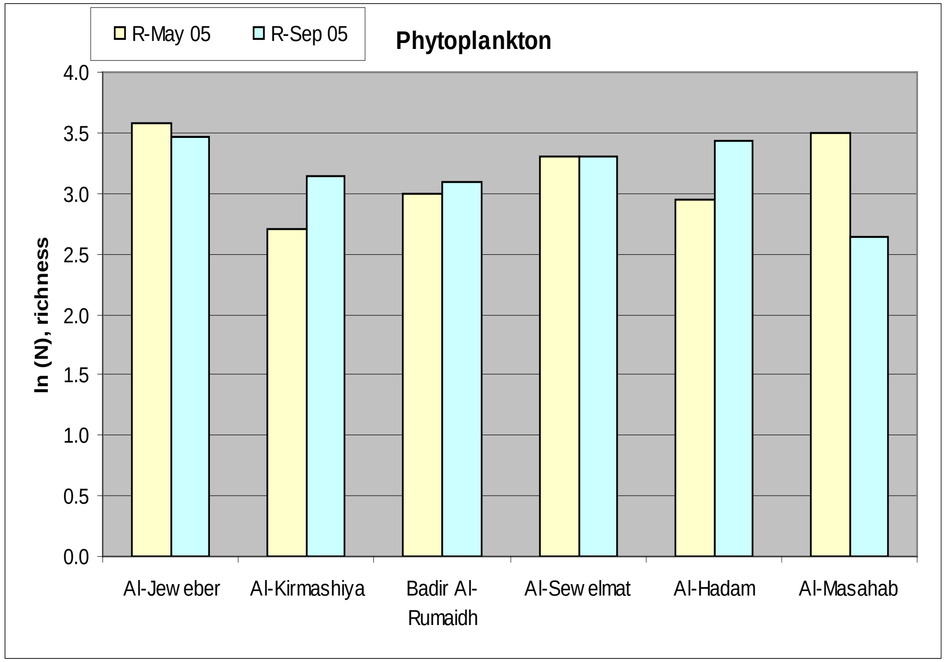
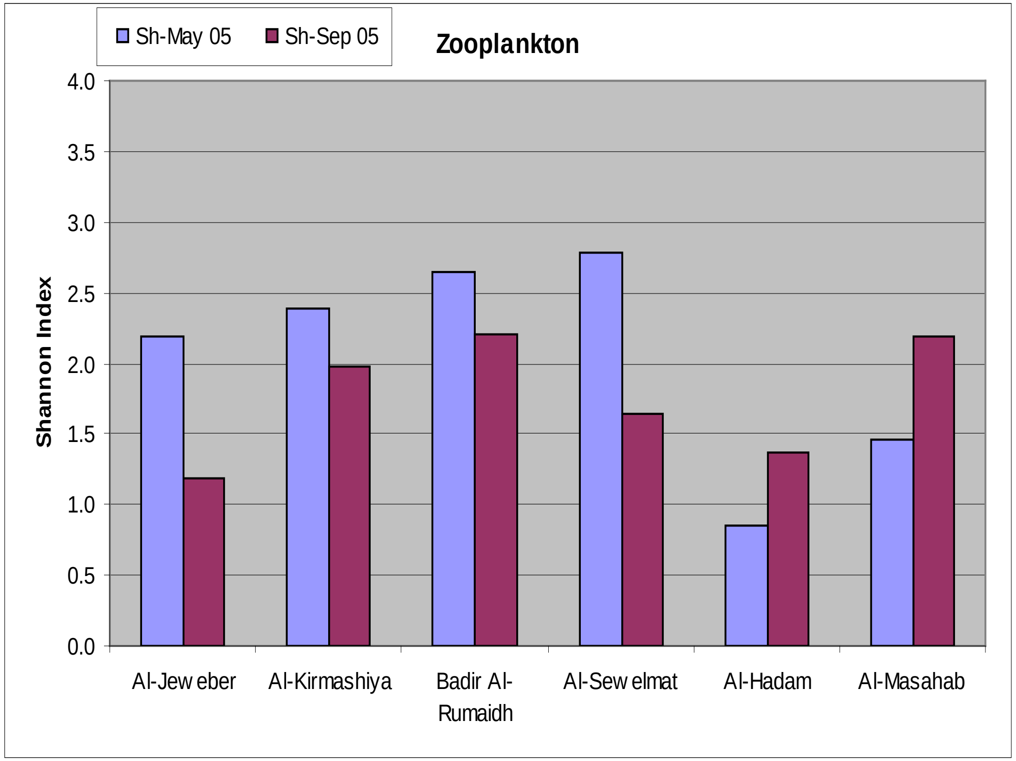


Figure 14: Phytoplankton diversity & richness in UNEP sites (May – September 2005)



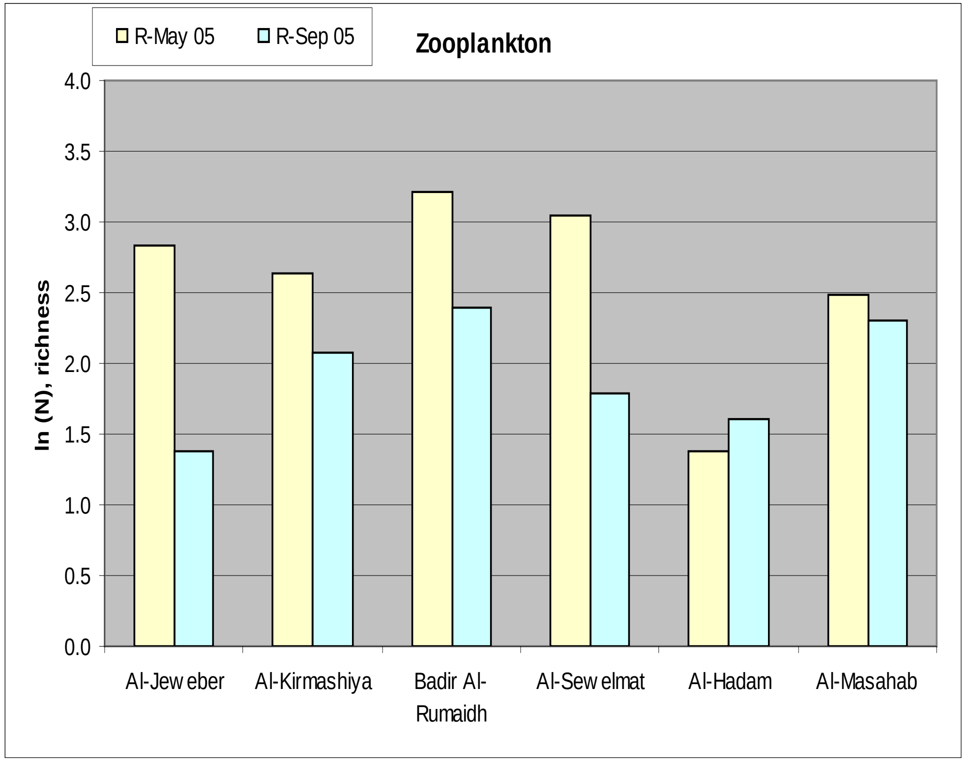
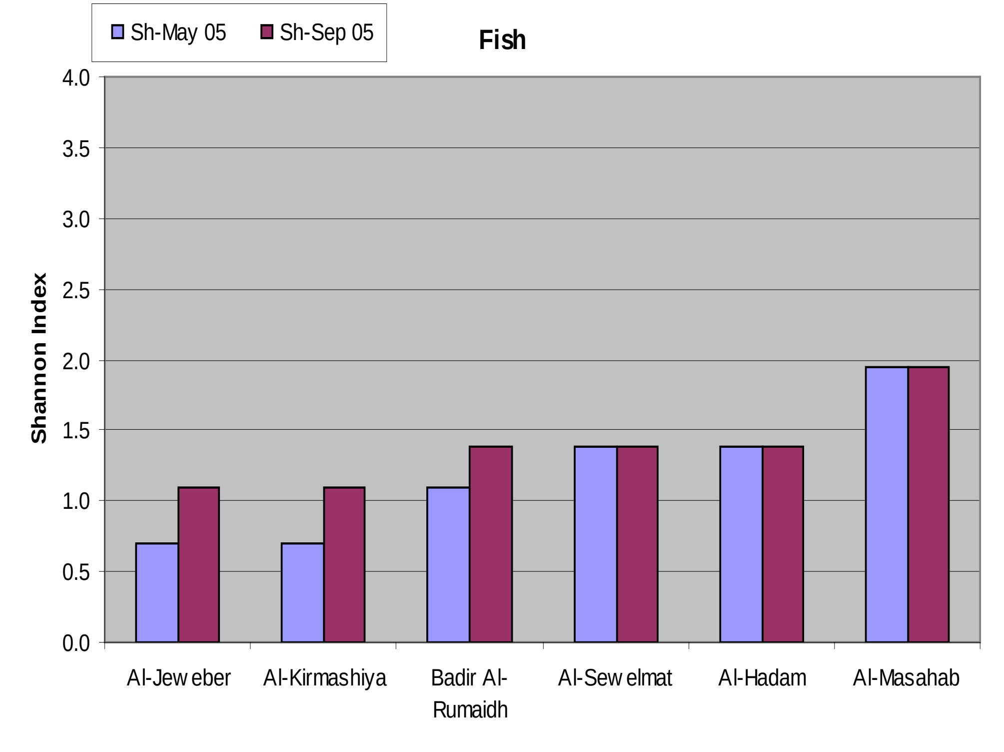


Figure 15: Zooplankton diversity & richness in UNEP sites (May – September 2005)



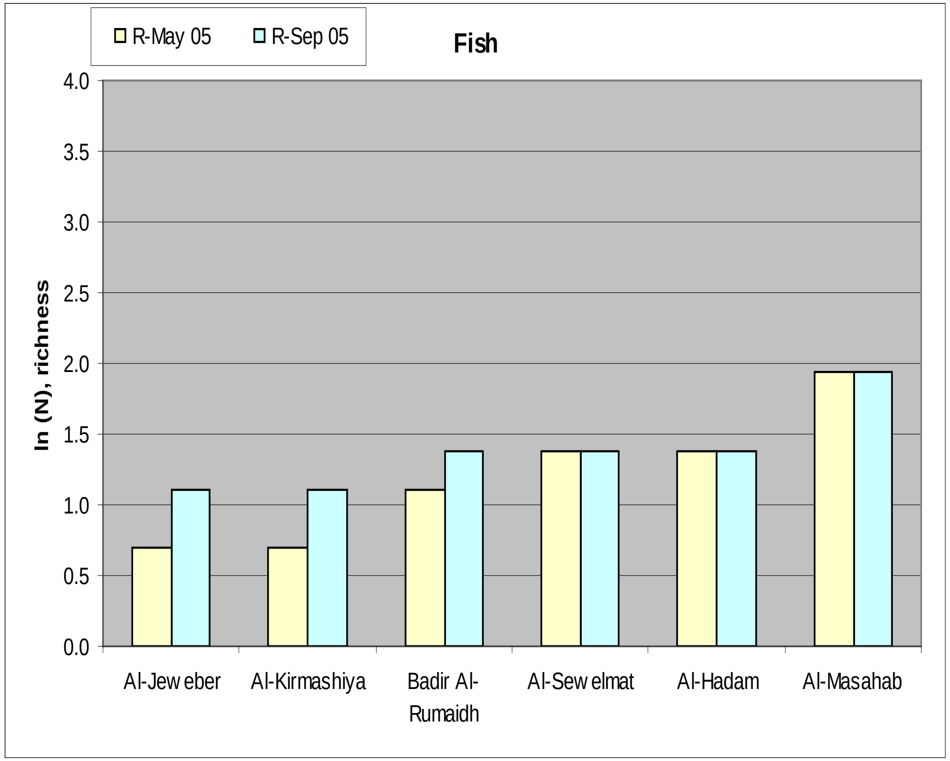


Figure 16: Fish diversity & richness in UNEP sites (May – September 2005)

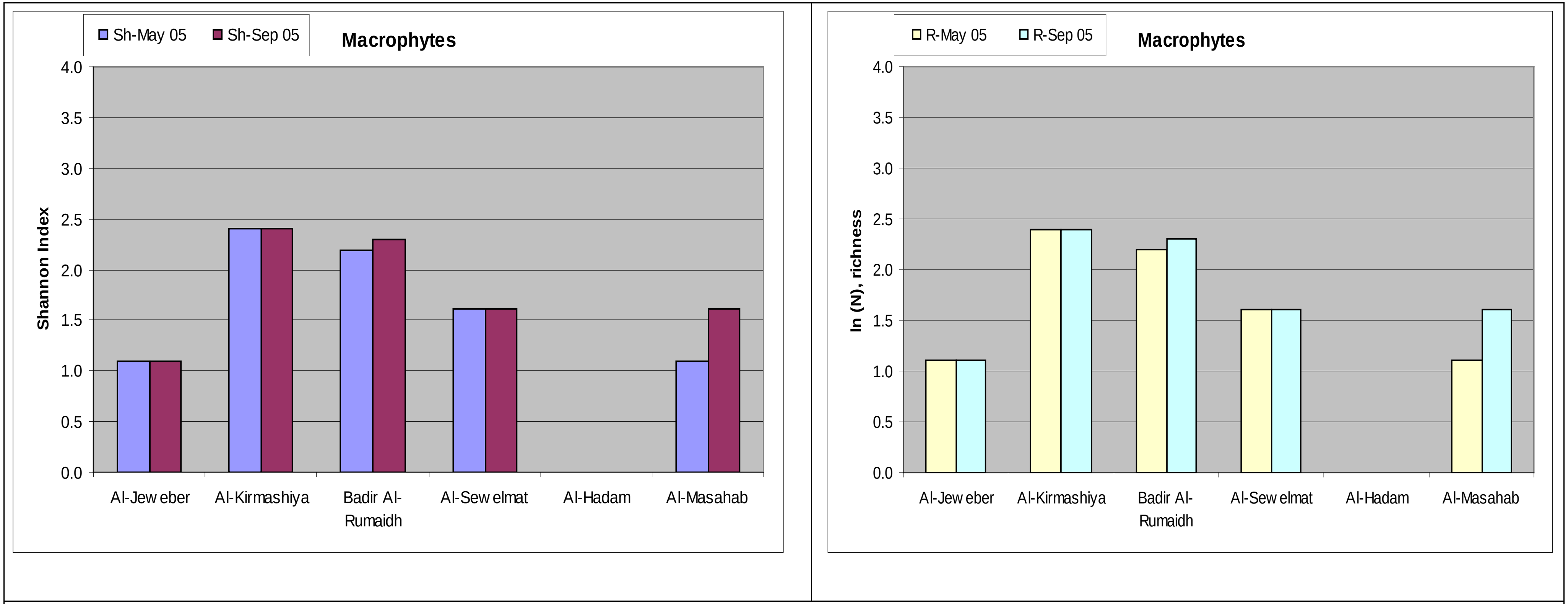


Figure 17: Macrophytes diversity & richness in UNEP sites (May – September 2005)

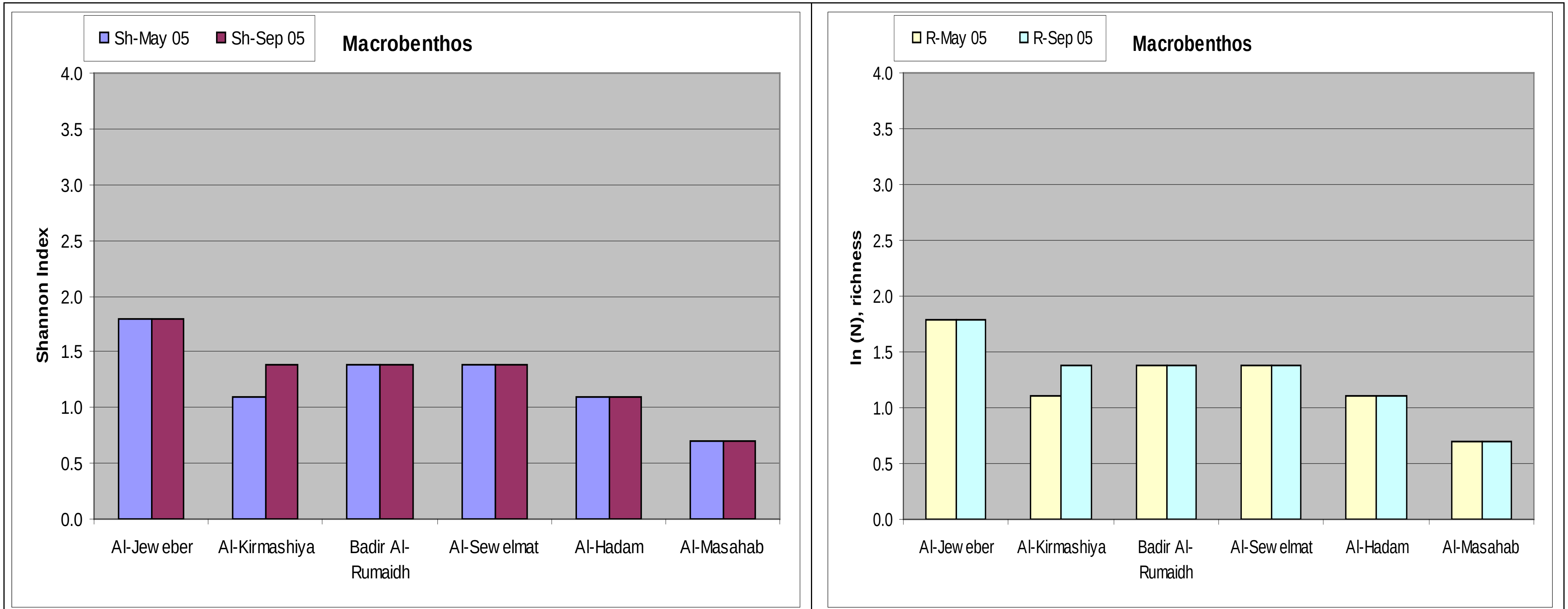


Figure 18: Macrobenthos diversity & richness in UNEP sites (May – September 2005)

Mean and standard deviations of the data obtained during the present survey are presented in Annex 1. The raw data are tabulated in Annex 2. Standards, calibrations of equipment and quality assurances are given in Annex 3.

Studying these annexes reveals that the water quality of the six sites lies within the permissible range of values reported for fresh water by the WHO (2005). The trace pollutants including hydrocarbons, PAH, pesticides and trace metals are within acceptable limits for drinking water. These pollutants have very limited effects on the studied biota. Biological communities as well as the ecological parameters of the Iraqi marshes appear to be undergoing active restoration processes leading to stabilization.

DISCUSSION

A. ENVIRONMENTAL VARIABLES:

ENVIRONMENTAL VARIABLES ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (this shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.59 and 0.006 respectively. In addition, the lengths of the gradient showed a clear linear relationship between the studied environmental variables (Table 2), which implies the use of the Principal Components Analysis (PCA) method in the next step to analyze the relations betweem the different UNEP sites (Ter Braak and Šmilauer, 2002).

Table 2: Eigenvalues and Lengths of gradient for the four axes of the environmental variables derived from the detrended correspondence analysis (DCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.59	0.006	0.001	0
Lengths of gradient	1.649	0.477	0.131	0.222

ENVIRONMENTAL VARIABLES ORDINATION AND UNEP SITES:

The matrix obtained from the PCA showed that the most important axis is the first followed by the second axis (Eigenvalues= 0.302 and 0.196 respectively). In addition, environmental variables-UNEP sites correlations is strongly related to the first and second axes of the PCA (r = 0.995 and 0.997 respectively). (Table 3)

However, there are also strong correlations with the third and fourth axes (Table 3, Table 4, &Table 5). For instance, UNEP 1 is correlated with the third and second axes respectively; therefore, it will be illustrated in a short raw when plotted with the first and second axes of the PCA.

Due to the minimal information provided by the third and forth axes regarding variation in environmental variables (Eigenvalues = 0.117, and 0.094, respectively); (Table 3), these axes are not considered further. Moreover, the correlations with the third and fourth axes imply less ecological significance than the correlations with the first and second axes (Lepš and Šmilauer, 2003).

Furthermore, the four canonical axes derived from the PCA accounted for 87.7% of the cumulative percentage variance of Environmental variables-UNEP sites relation, with the first two axes accounting for 64.4%.

Therefore, our discussion will focus mainly on the correlations with the first and second axes of the PCA. In addition, the environmental variables will be replaced by their pie classes to clarify their levels and concentrations at the different UNEP sites.

Table 3: Eigenvalues and environmental variables-UNEP sites correlations for the four axes derived from the Principal Components Analysis (PCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.302	0.196	0.117	0.094
Environmental variables –UNEP sites correlations	0.995	0.997	0.991	0.818
Cumulative percentage variance				
of Environmental variables data	30.2	49.8	61.6	71
of Environmental variables- UNEP sites relation	39	64.4	79.5	87.7

Table 4: Inter-set correlations of UNEP sites with axes.

No.	Sites	Codes	Axis 1	Axis 2	Axis 3	Axis 4
1	Al-Jeweber Site	UNEP 1	0.0564	0.3252	0.8818	-0.2326
2	Al-Karmashia Site	UNEP 2	0.4997	-0.4052	-0.3437	-0.5336
3	Badir Al-Ramaidh Site	UNEP 3	-0.5931	0.5831	-0.4724	-0.2206
4	Al-Sewelmat Site	UNEP 4	-0.2962	-0.3612	-0.044	0.4487
5	Al-Hadam Site	UNEP 5	-0.3027	-0.5415	0.1602	0.0815
6	Al-Masahab Site	UNEP 6	0.6359	0.3996	-0.1819	0.4565

Table 5: Inter-set correlations of environmental variables with axes.

No.	Environmental Variables	Codes	Axis 1	Axis 2	Axis 3	Axis 4
1	Depth of water (m)	D	-0.6896	0.0426	0.1393	0.4454
2	Air temperature (°C)	AT	-0.0247	-0.199	-0.6324	-0.4356
3	Water temperature (°C)	WT	-0.0233	0.567	-0.3523	-0.3301
4	pH	pH	-0.7141	0.4721	-0.2345	0.0032
5	Electrical Conductivity (mS/cm)	EC	0.8602	0.3741	-0.0875	0.0479
6	Dissolved Oxygen (mg/L)	DO	-0.6433	0.2168	0.246	-0.0573
7	Transparency (m)	Tra	0.3753	0.3172	-0.2448	0.058
8	Salinity (ppt)	S	0.934	0.2728	-0.0599	-0.1656
9	Total Dissolved solids (TDS) (mg/L)	TDS	0.8688	0.3775	0.0352	-0.0124
10	Turbidity (NTU)	Tur	0.081	-0.2459	0.04	0.5464
11	Total Suspended Solids (TSS) (mg/L)	TSS	0.2089	-0.1512	0.0508	0.4316
12	Alkalinity (mg $CaCO_3$/L)	Alk	0.436	-0.6205	0.1557	-0.1095
13	Total Hardness ($CaCO_3$/L)	T.H	0.9057	0.2044	0.0843	-0.0418
14	Sulphates (SO_4) (mg/L)	SO4	0.8236	0.4761	-0.013	0.0026
15	Chlorides (Cl) (mg/L)	Cl	0.8064	0.1893	-0.3409	-0.0064
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	-0.2116	-0.3113	-0.0706	0.5218

No.	Environmental Variables	Codes	Axis 1	Axis 2	Axis 3	Axis 4
17	Nitrate Nitrogen (NO_3-N) (mg N/L)	NO3	-0.488	-0.6876	0.1261	0.4309
18	Nitrite Nitrogen (NO_2-N) (mg N/L)	NO2	-0.2042	-0.3938	0.1505	-0.1404
19	Phosphates (PO_4-P) (mg P/L)	PO4	-0.0556	-0.2414	0.182	-0.4563
20	Chlorophyll-*a* (mg/L)	Ch-a	-0.179	0.079	-0.1274	0.6324
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	0.7447	0.5561	0.0663	-0.3001
22	Phenol (mg/L)	Ph	0	0	0	0
23	Biochemical Oxygen Demand (BOD5) at 20 °C (mg/L)	BOD	-0.5244	-0.111	0.5799	0.0278
24	Total Organic Carbon (TOC) (mg/L)	W.TOC	0.2753	0.7667	-0.5011	0.1682
25	Total plate count (colony/ml)	T.PCC	-0.5084	-0.1435	-0.1463	0.5578
26	Fecal coli form count (CFU/100ml)	FCC	-0.3117	-0.0214	0.0951	0.6683
27	E.coli (CFU/100ml)	Eco	0.1107	0.3314	0.2	0.5834
28	Cadmium (Cd) (mg/l)	Cd	0.498	0.5057	0.6994	-0.0135
29	Lead (Pb) (mg/l)	Pb	-0.3185	0.3537	0.3491	-0.5702
30	Zinc (Zn) (mg/l)	Zn	0.7254	0.2266	0.6392	-0.0178
31	Total chromium (T-Cr) (mg/l)	T.Cr	0	0	0	0
32	Arsenic (As) (mg/l)	As	0.7523	0.4513	-0.2434	0.2868
33	Selenium (Se) (mg/l)	Se	-0.7073	0.6149	-0.3085	-0.0964
34	Mercury (Hg) (mg/l)	Hg	0.3168	0.761	-0.4973	-0.0675
35	Copper (Cu) (mg/l)	Cu	0	0	0	0
36	Nickel (Ni), µg/kg	Ni	0	0	0	0
37	Iron (Fe) (mg/l)	Fe	-0.0596	-0.0382	0.0332	-0.502
38	Manganese (Mn) (mg/l)	Mn	0	0	0	0
39	Calcium (Ca) (mg/l)	Ca	0.9717	0.1588	0.0694	0.087
40	Magnesium (Mg) (mg/l)	Mg	0.5433	0.7886	0.0008	0.1694
41	Sediment Total Organic Carbon (TOC) %	S.TOC	0.4522	-0.2891	-0.4128	-0.4387
42	Sediment Cadmium (Cd) (µg/kg)	S.Cd	0.2787	-0.6557	-0.3157	0.1772

No.	Environmental Variables	Codes	Axis 1	Axis 2	Axis 3	Axis 4
43	Sediment Lead (Pb) (μg/kg)	S.Pb	0.6298	-0.6618	-0.1727	-0.1584
44	Sediment Zinc (Zn) (μg/kg)	S.Zn	0.6188	-0.6461	-0.0225	0.2091
45	Sediment Total chromium (T-Cr) (μg/kg)	S.T.Cr	0.7373	-0.5662	-0.1552	0.1486
46	Sediment Arsenic (As) (μg/kg)	S.As	0.619	-0.7068	-0.2066	-0.1008
47	Sediment Selenium (Se) (μg/kg)	S.Se	0.4197	-0.0658	-0.6144	-0.4105
48	Sediment Mercury (Hg) (μg/kg)	S.Hg	0.8948	-0.0036	-0.418	-0.077
49	Sediment Copper (Cu) (μg/kg)	S.Cu	0.4983	-0.2027	0.7125	-0.3211
50	Sediment Nickel (Ni) (μg/kg)	S.Ni	0.8238	-0.4951	-0.0308	-0.1294
51	Sediment Iron (Fe) (μg/kg)	S.Fe	0.7303	-0.6634	-0.0523	0.1106
52	Sediment Manganese (Mn) (μg/kg)	S.Mn	0.6009	-0.7482	0.1644	-0.1629
53	Sediment Calcium (Ca) (μg/kg)	S.Ca	-0.7076	0.5952	-0.3103	0.1756
54	Sediment Magnesium (Mg) (μg/kg)	S.Mg	0.8084	-0.4006	-0.0722	0.3265
55	Sediment Total HCH (μg/dry g)	S.T.HCH	-0.5931	0.5831	-0.4724	-0.2206
56	Sediment Total Chlordane (μg/dry g)	S.T.Ch	-0.672	0.5058	-0.2639	-0.1235
57	Sediment Total DDT (μg/dry g)	S.T.DDT	0.1684	-0.3329	-0.2374	0.4696
58	Sediment Total PCB (μg/dry g)	S.T.PCB	0	0	0	0
59	Sediment 2-Methylnaphthalene (μg/dry g)	S.2-Mn	-0.4849	-0.602	-0.2255	-0.4243
60	Sediment 1-Methylnaphthalene (μg/dry g)	S.1-Mn	-0.5878	-0.507	-0.1688	-0.415
61	Sediment 2,6-Dimethylnaphthalene (μg/dry g)	S.D	-0.6152	-0.4267	-0.1715	-0.4736
62	Sediment 1,6,7-Trimethylnaphthalene (μg/dry g)	S.T	-0.6036	-0.5896	0.3052	0.136
63	Sediment 1-Methylphenanthrene (μg/dry g)	S.1-Mp	-0.4292	-0.6799	0.372	-0.3498
64	Sediment C29-Hopane (μg/dry g)	S.C29	0.2304	0.452	0.8461	-0.0975
65	Sediment 18a-Oleanane (μg/dry g)	S.18a	0.1486	0.3989	0.8819	-0.1483
66	Sediment C30-Hopane (μg/dry g)	S.C30	0.1661	0.3633	0.9049	-0.0995

The characteristics of the studied sites can be visualized and illustrated in the following figures:

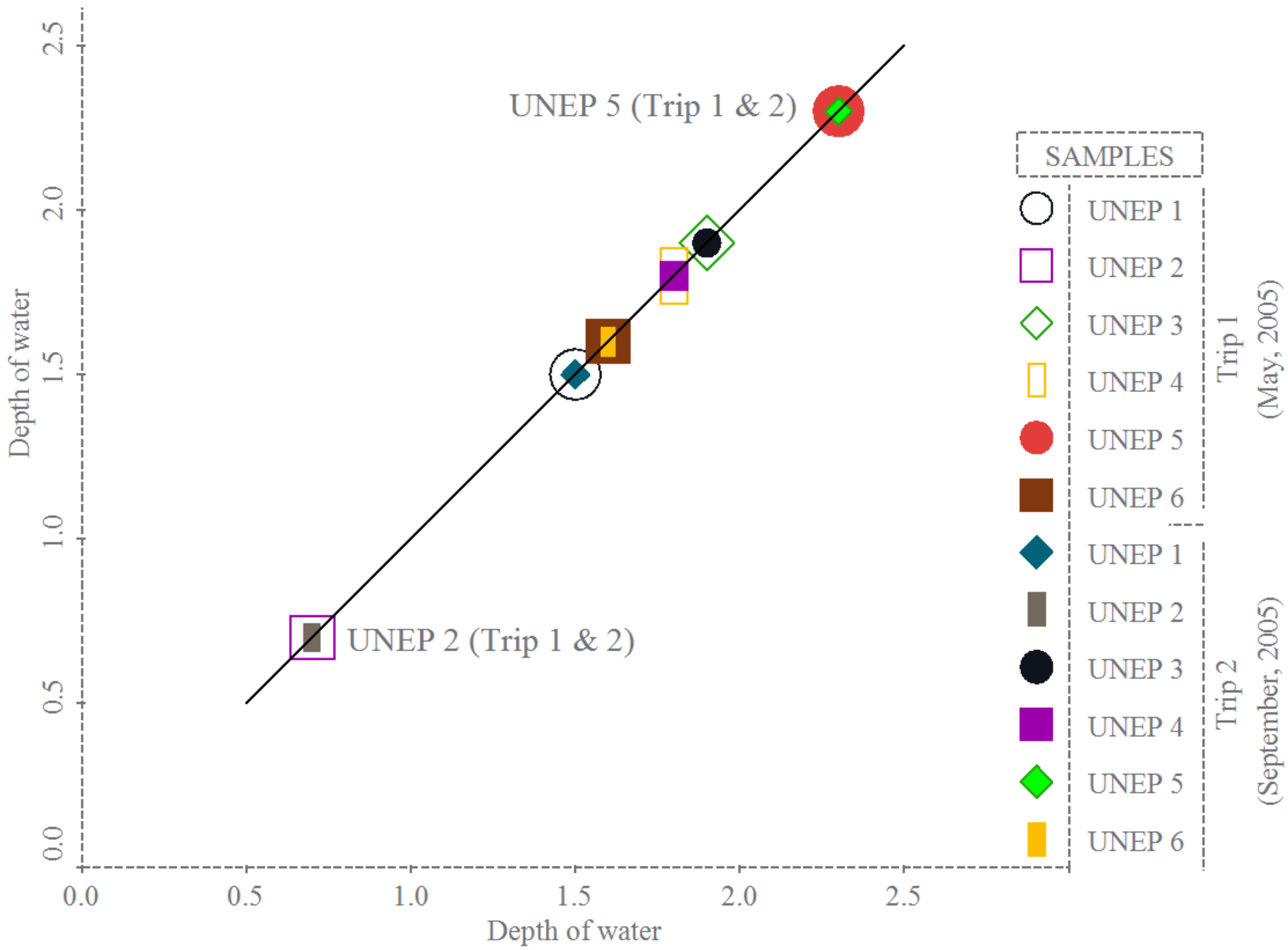


Figure 19: Ordination of UNEP sites in relation to values of Water Depth (m), (May 2005 – September 2005).

UNEP 5 had the higher depth of water in both trip one and trip two; UNEP 2 had the lowest values for water depth on both trips.

UNEP 3, 4, 6, and 1 had relatively high to moderate water depth values respectively.

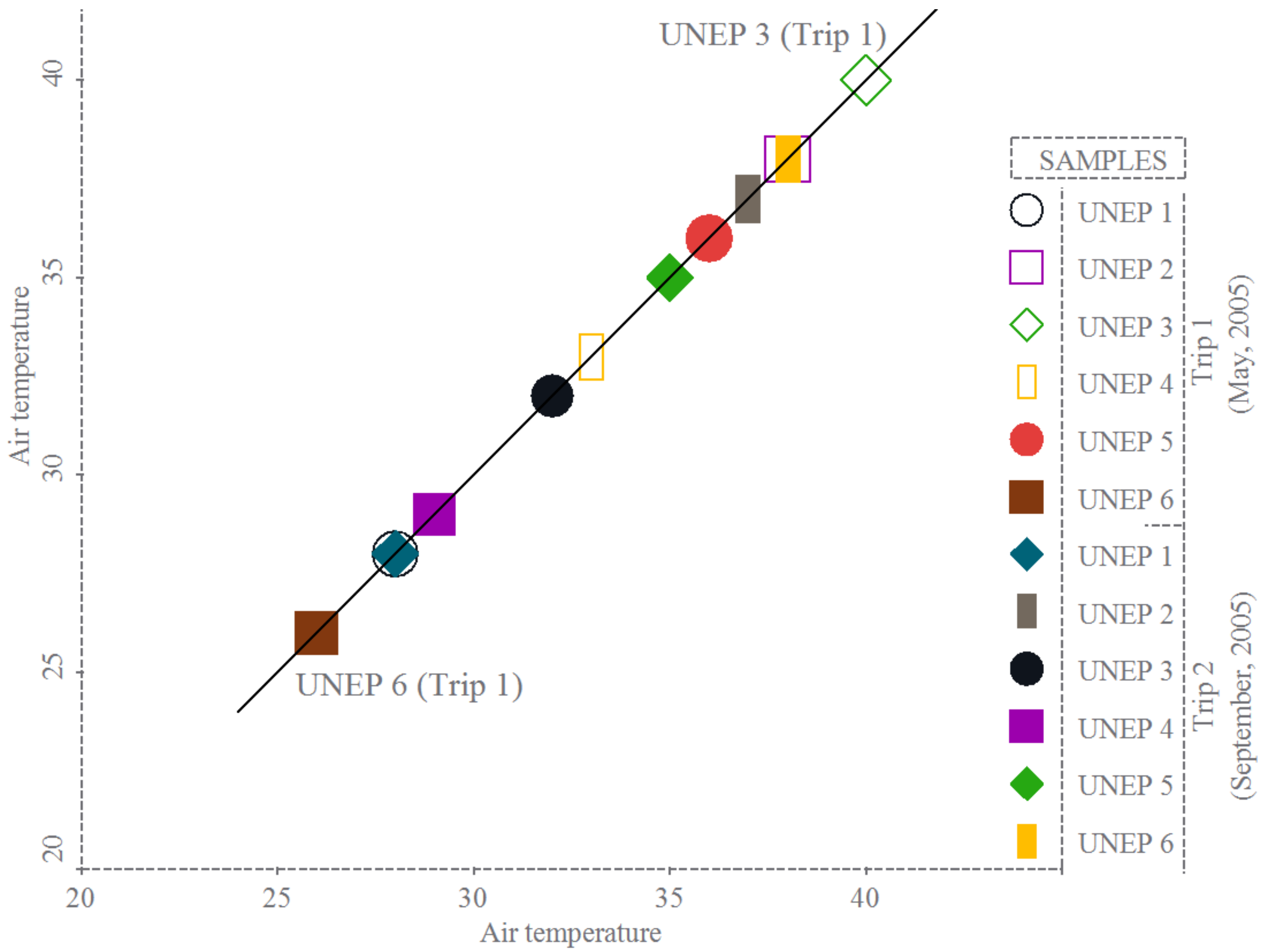


Figure 20: Ordination of UNEP sites in relation to values of Air Temperature (˚C), (May 2005 – September 2005).

The highest and lowest air temperatures were recorded in the first trip in UNEP 3 and UNEP 6 respectively.

UNEP 6 and UNEP 2 had the higher air temperatures in the second trip respectively.

UNEP 1 had the same air temperature on both trips.

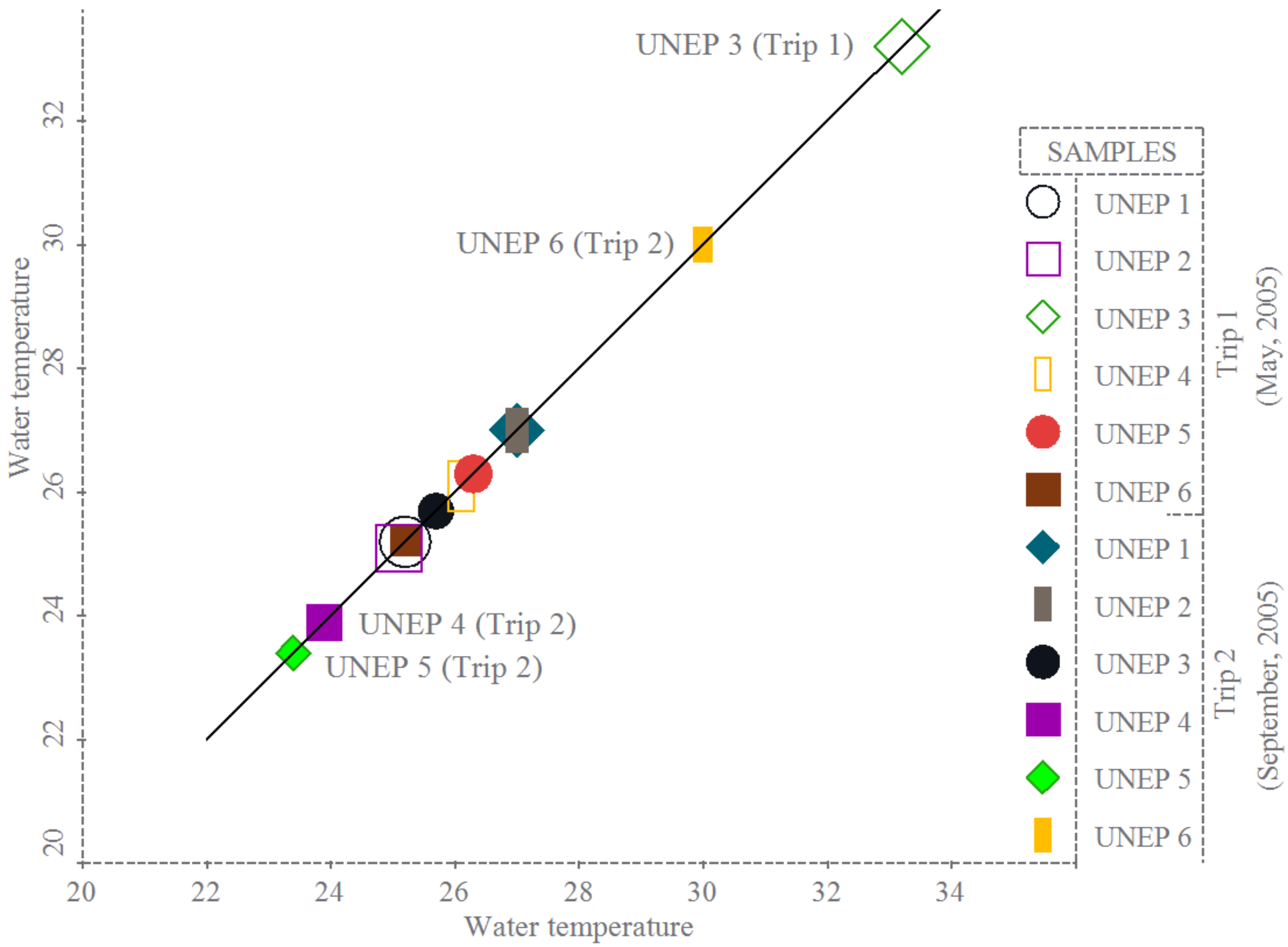


Figure 21: Ordination of UNEP sites in relation to values of Water Temperature (˚C), (May 2005 – September 2005).

The highest water temperature recorded was in the first trip, in UNEP 3. While, the higher water temperature during the second trip was in UNEP 6. The lowest water temperatures were recorded in UNEP 5 and UNEP 4 respectively, during the second trip. The remaining stations had rather similar water temperatures on both trips.

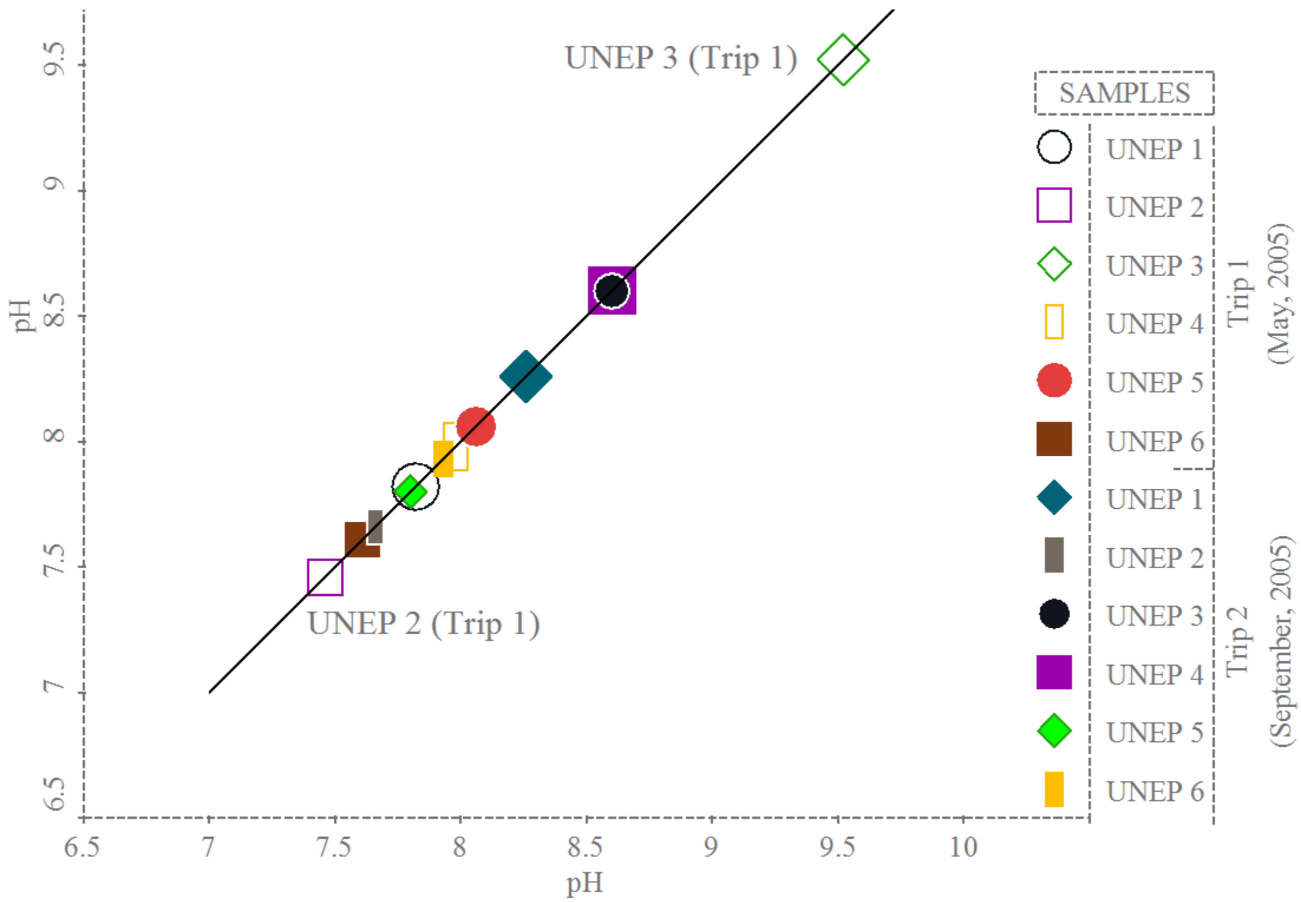


Figure 22: Ordination of UNEP sites in relation to values of pH, (May 2005 – September 2005).

UNEP 3 had the highest pH readings in trip one. The pH readings in UNEP 3 during both trips remained higher than the other stations. The lowest pH readings were in UNEP 2 during both trips.

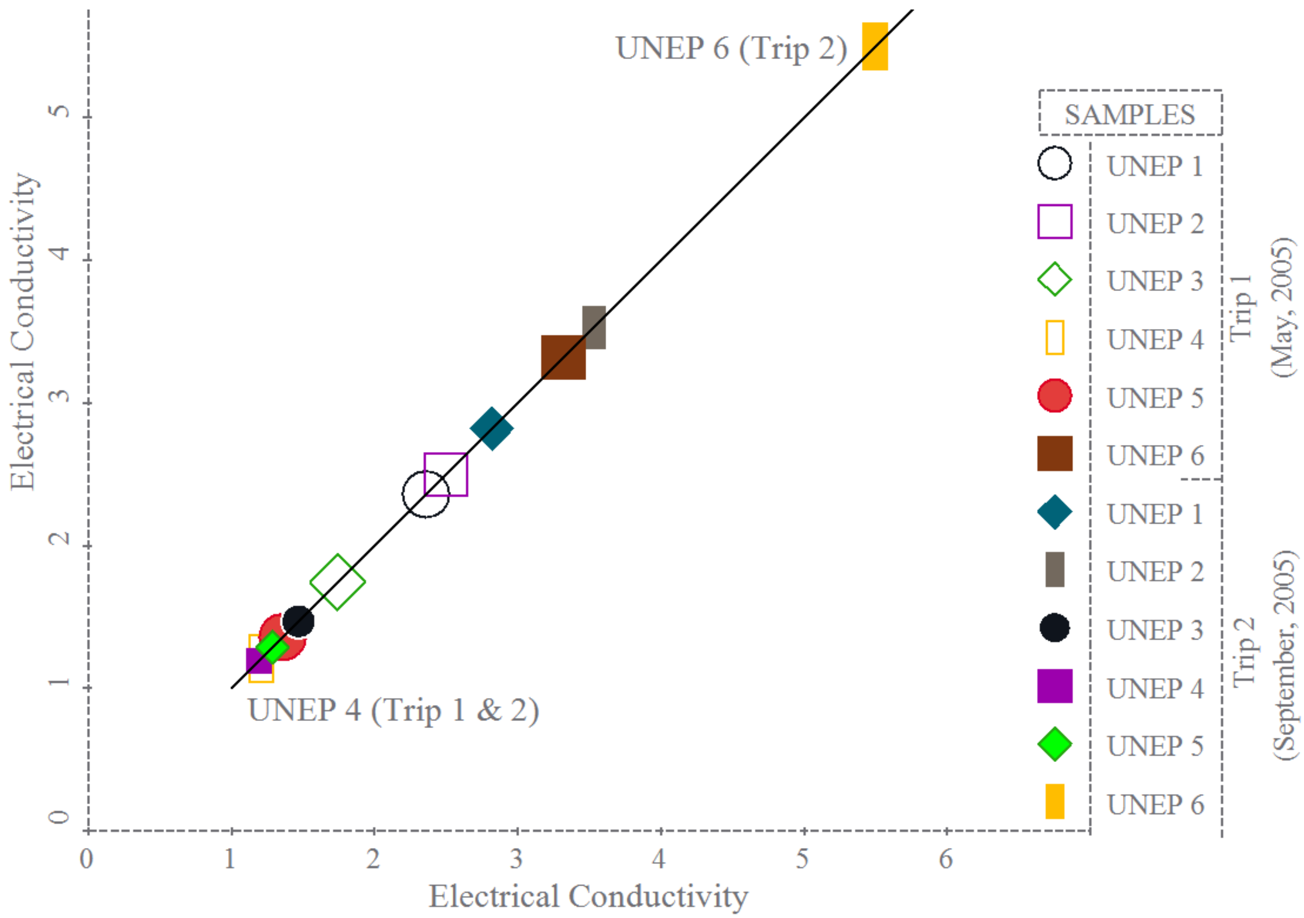


Figure 23: Ordination of UNEP sites in relation to values of Electrical Conductivity mS/cm, (May 2005 – September 2005).

On both trips UNEP 6 had the highest values especially in trip two, followed by UNEP 2, 1, 3, 5, and 4 respectively. UNEP 4 had the lowest conductivity values on both trips with the lowest values in trip two.

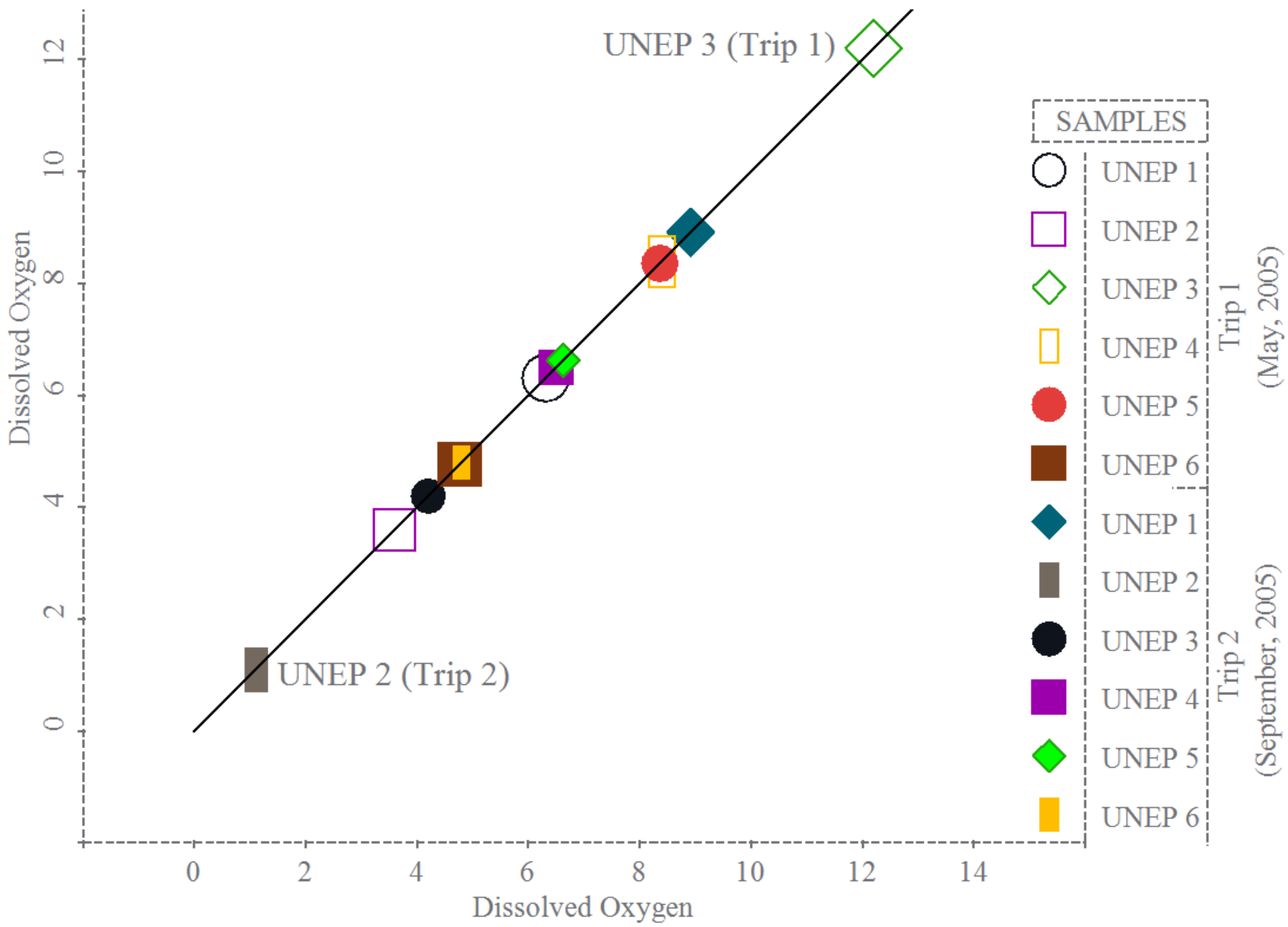


Figure 24: Ordination of UNEP sites in relation to values of Dissolved Oxygen (mg/L), (May 2005 – September 2005).

UNEP 3 had the highest dissolved oxygen concentrations in the first trip and these concentrations lowered to about half during the second trip.

On the other hand, UNEP 2 had the lowest dissolved oxygen concentrations during both trips with the lower concentrations in trip two.

UNEP 4 and UNEP 5 had similar and higher dissolved oxygen concentrations in the first trip (May 2005) than the concentrations in the second trip (September 2005).

UNEP 1 unlike UNEP 4 and 5 had higher dissolved oxygen concentrations in the second trip.

UNEP 6 on both trips had the same dissolved oxygen concentrations.

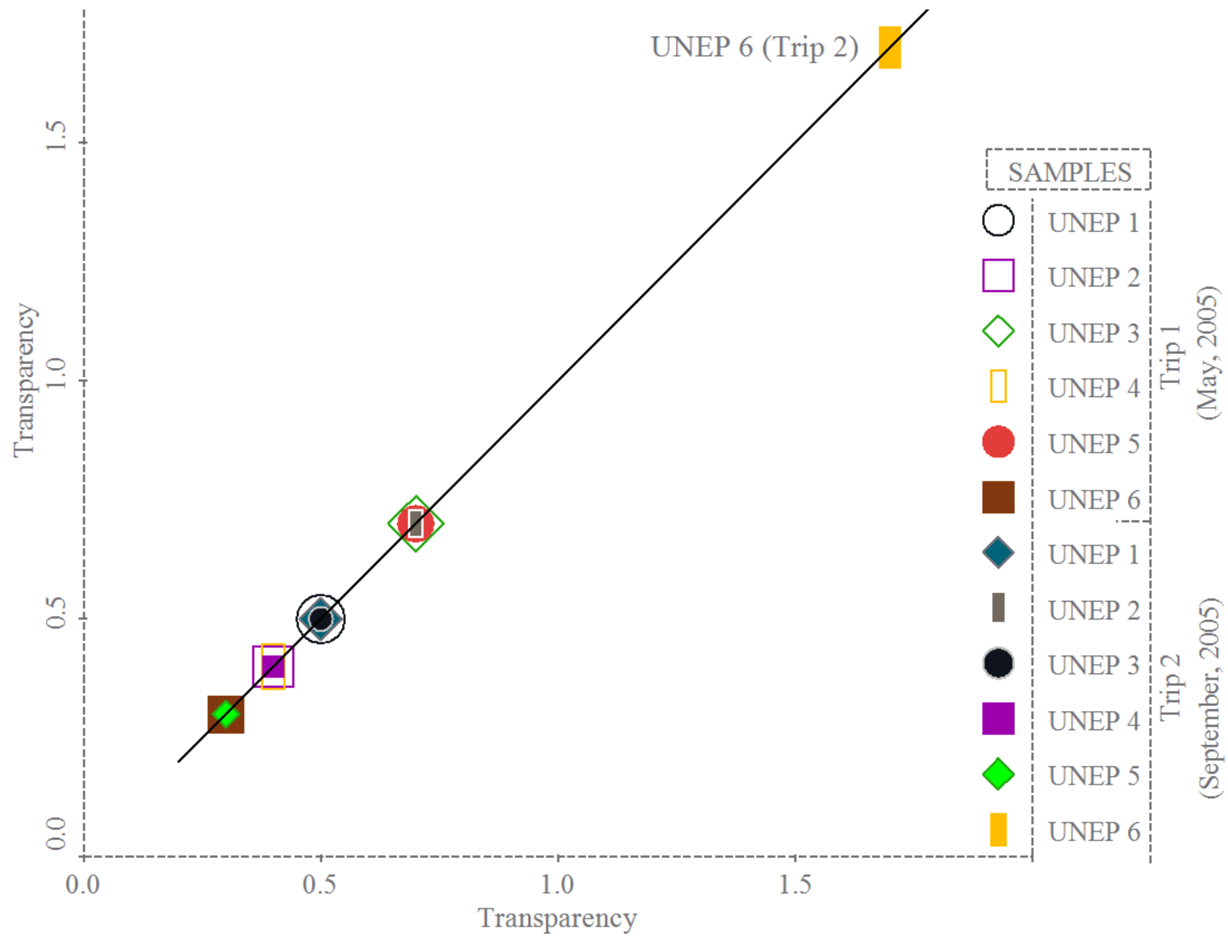


Figure 25: Ordination of UNEP sites in relation to values of Transparency (m), (May 2005 – September 2005).

The higher transparency readings were recorded in UNEP 6 during trip two (September 2005). UNEP 6 during trip one and UNEP 5 during the second trip had the same and lowest transparency readings. The remaining stations had rather similar transparency readings on both trips.

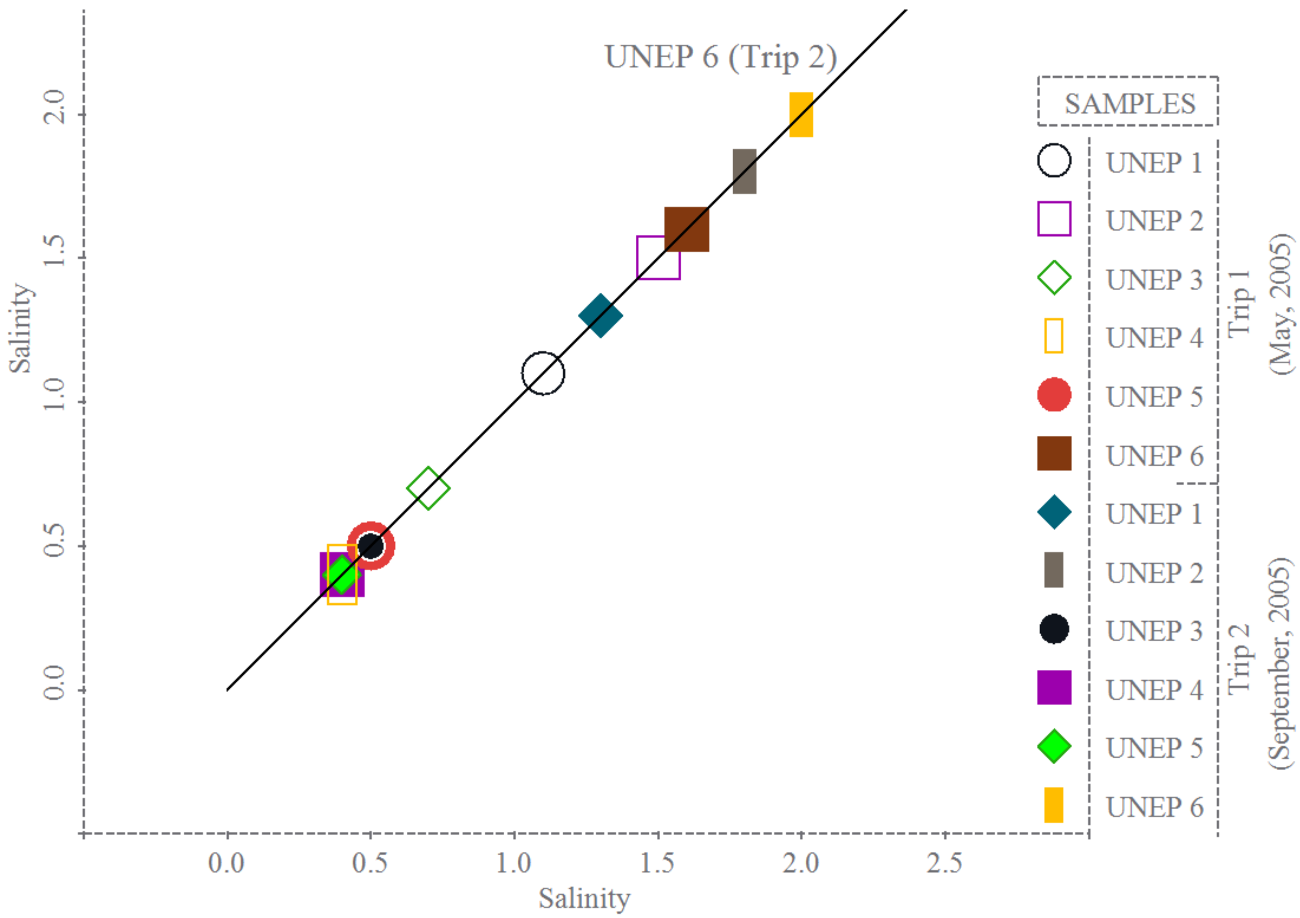


Figure 26: Ordination of UNEP sites in relation to values of Salinity (ppt), (May 2005 – September 2005).

UNEP 6 had higher salinity during both trips, especially in the second trip (September 2005), while UNEP 4 had the lowest salinity on both trips.

Generally, the salinity was slightly higher during the second trip as following, UNEP 6, 2, 1, 3, 5, and UNEP 4 respectively.

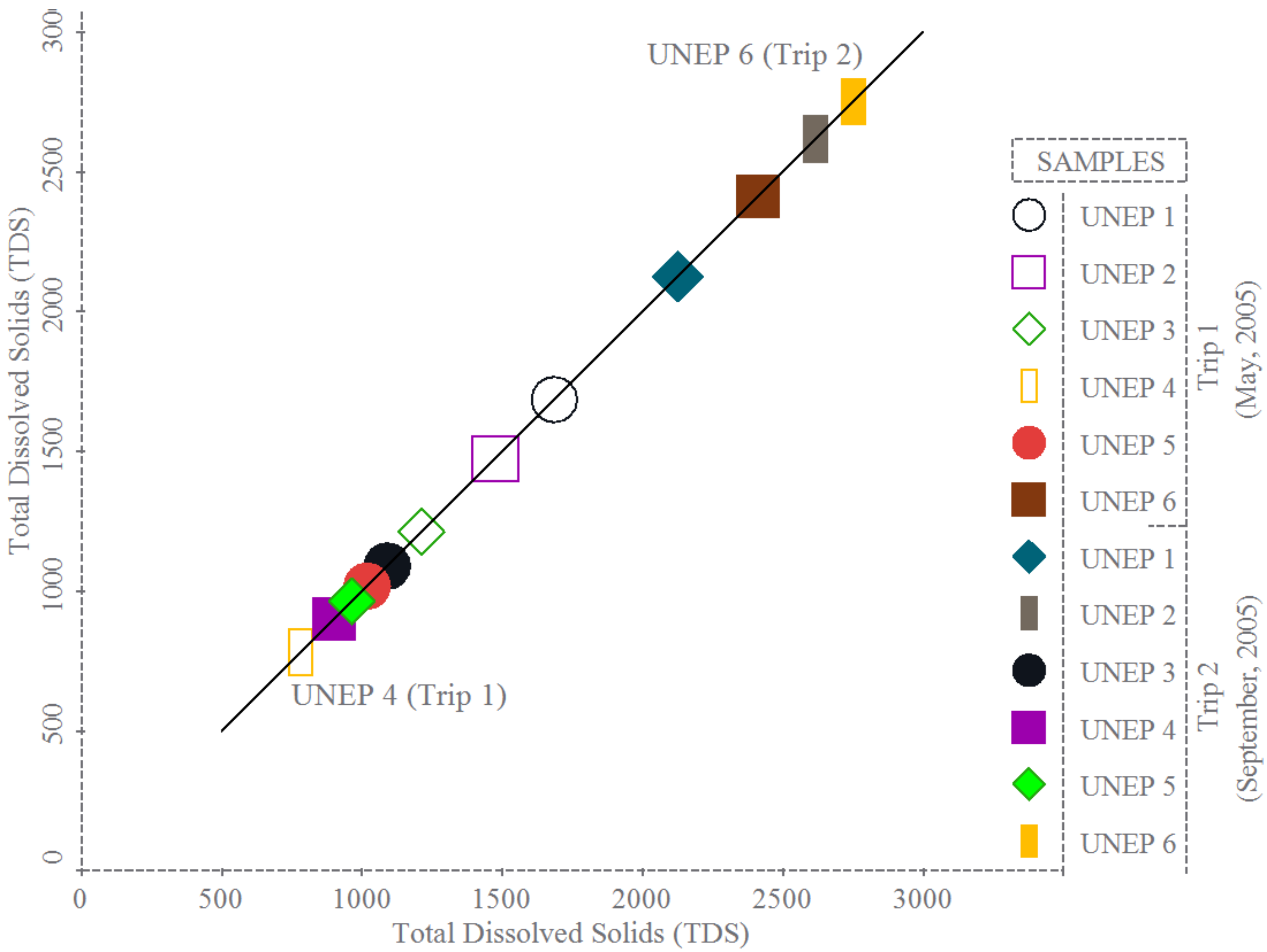


Figure 27: Ordination of UNEP sites in relation to values of Total Dissolved Solids (mg/L), (May 2005 – September 2005).

The highest Total Dissolved Solids (TDS) concentrations were recorded in UNEP 6 during the second trip (September, 2005) and the lower concentrations were recorded in UNEP 4 during the first trip (May, 2005).

UNEP 6 had higher TDS concentrations on both trips compared with the other stations especially UNEP 3, 5, and 4 that had rather similar and lower TDS concentrations for both trips.

Generally, it can be seen that the second trip had relatively higher TDS concentrations.

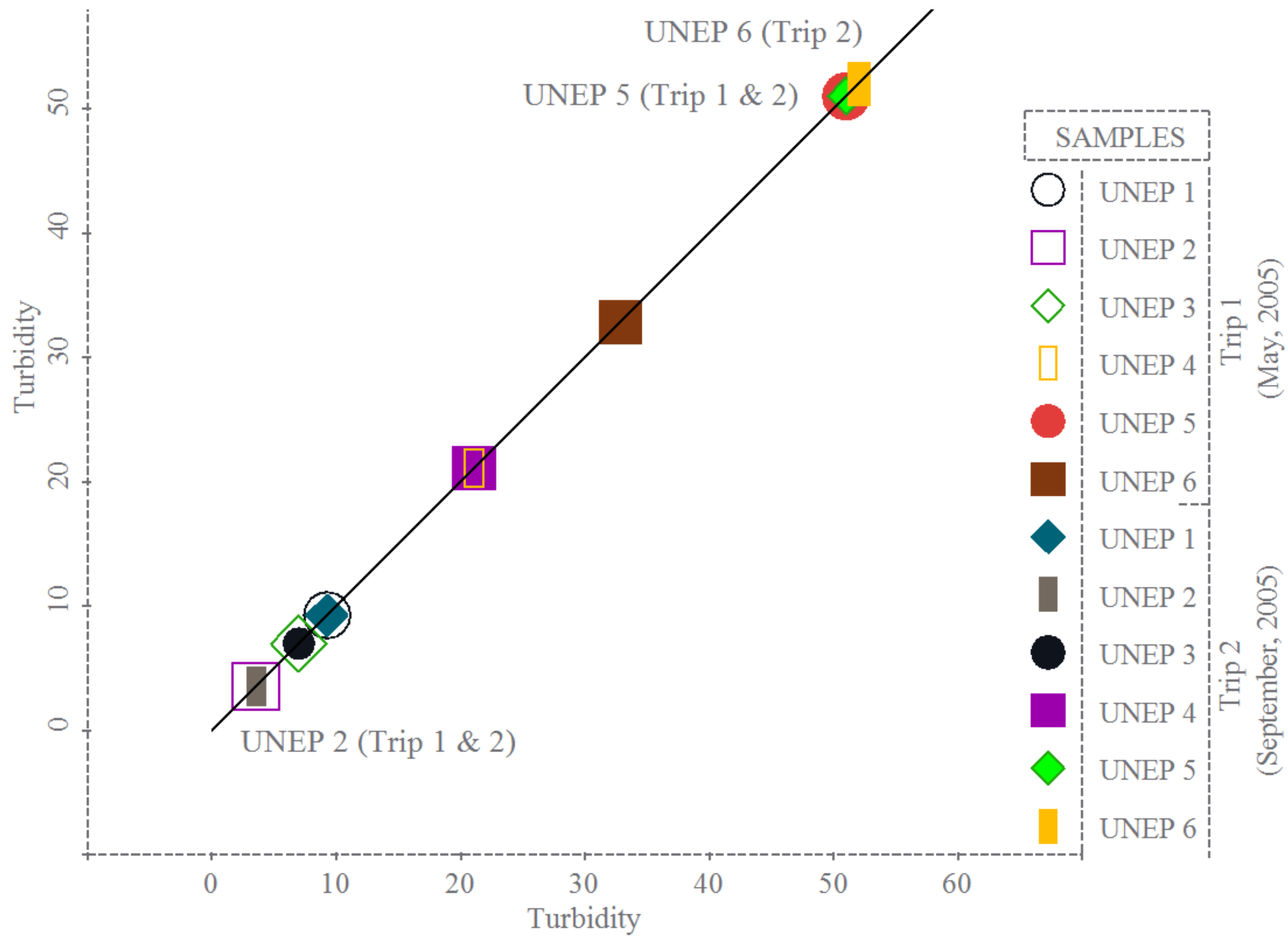


Figure 28: Ordination of UNEP sites in relation to values of Turbidity (NTU), (May 2005 – September 2005).

UNEP 6 in trip two and UNEP 5 on both trips had the highest turbidity concentrations. The other stations had rather stable turbidity concentrations during both trips with UNEP 2 having the lowerst concentrations.

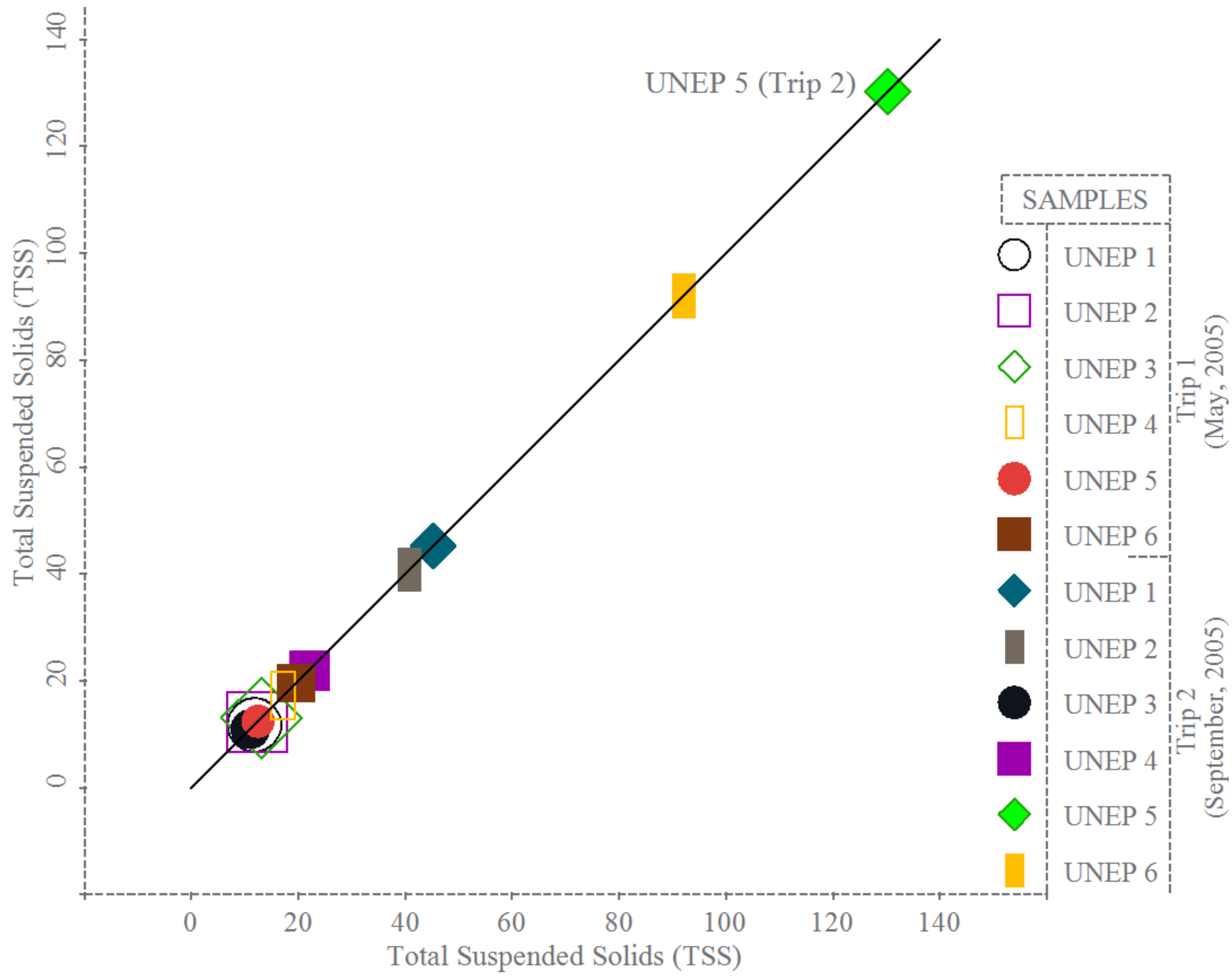


Figure 29: Ordination of UNEP sites in relation to values of Total Suspended Solids (mg/L), (May 2005 – September 2005).

UNEP 5 in the second trip had the higher Total Suspended Solid (TSS) concentrations recorded.

UNEP 3 and 4 had relatively similar TSS concentrations on both trips compared with the other UNEP stations.

Generally, higher TSS concentrations were recorded in the second trip (September, 2005) and lower concentrations recorded in the first trip (May, 2005).

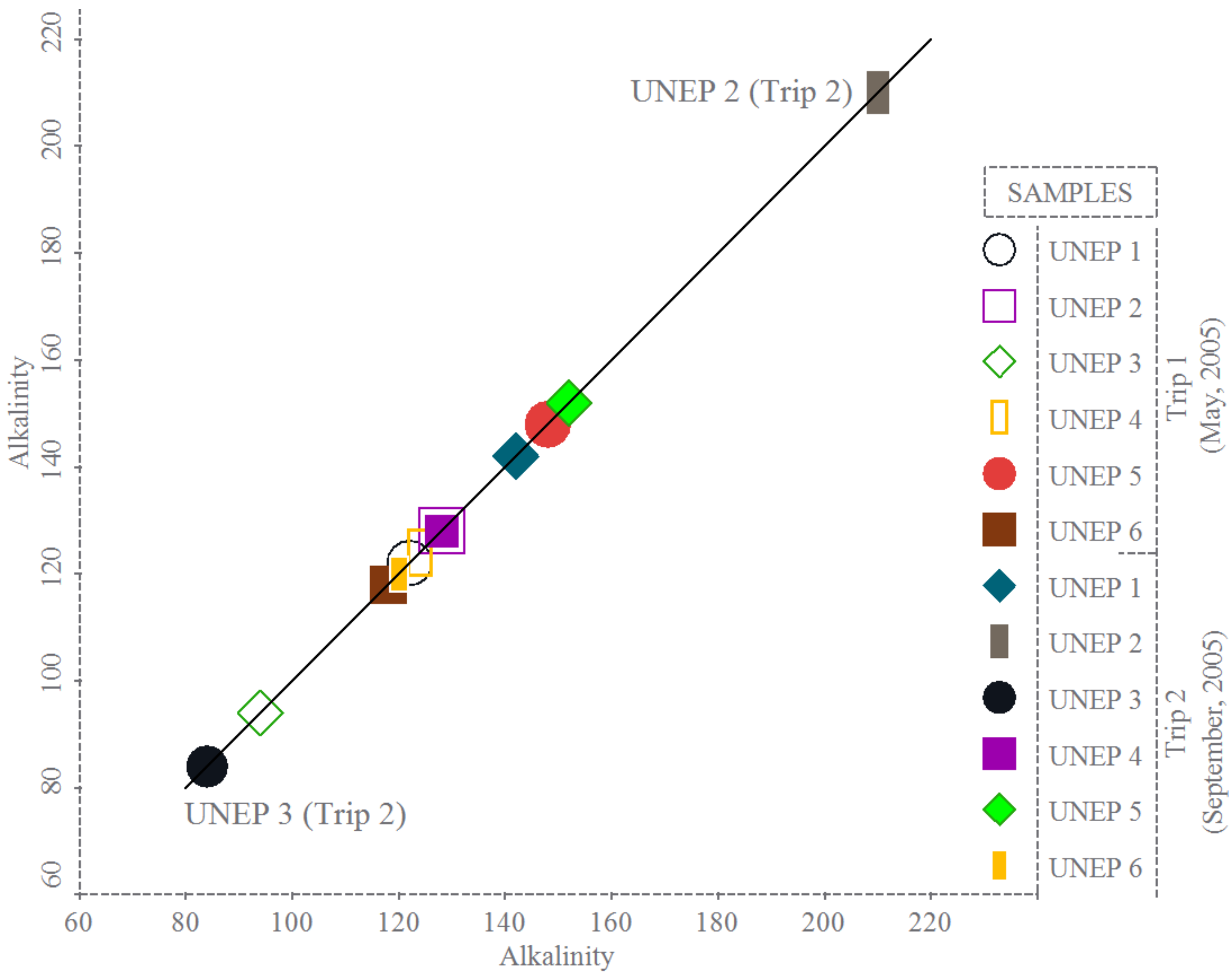


Figure 30: Ordination of UNEP sites in relation to values of Alkalinity (mg CaCO3/L), (May 2005 – September 2005).

The highest Alkalinity concentration was recorded in UNEP 2 during the second trip (September, 2005).

UNEP 3 had the lowest Alkalinity concentrations on both trips, especially in trip two.

UNEP 4, 5, and UNEP 6 each had relatively similar Alkalinity concentrations on both trips.

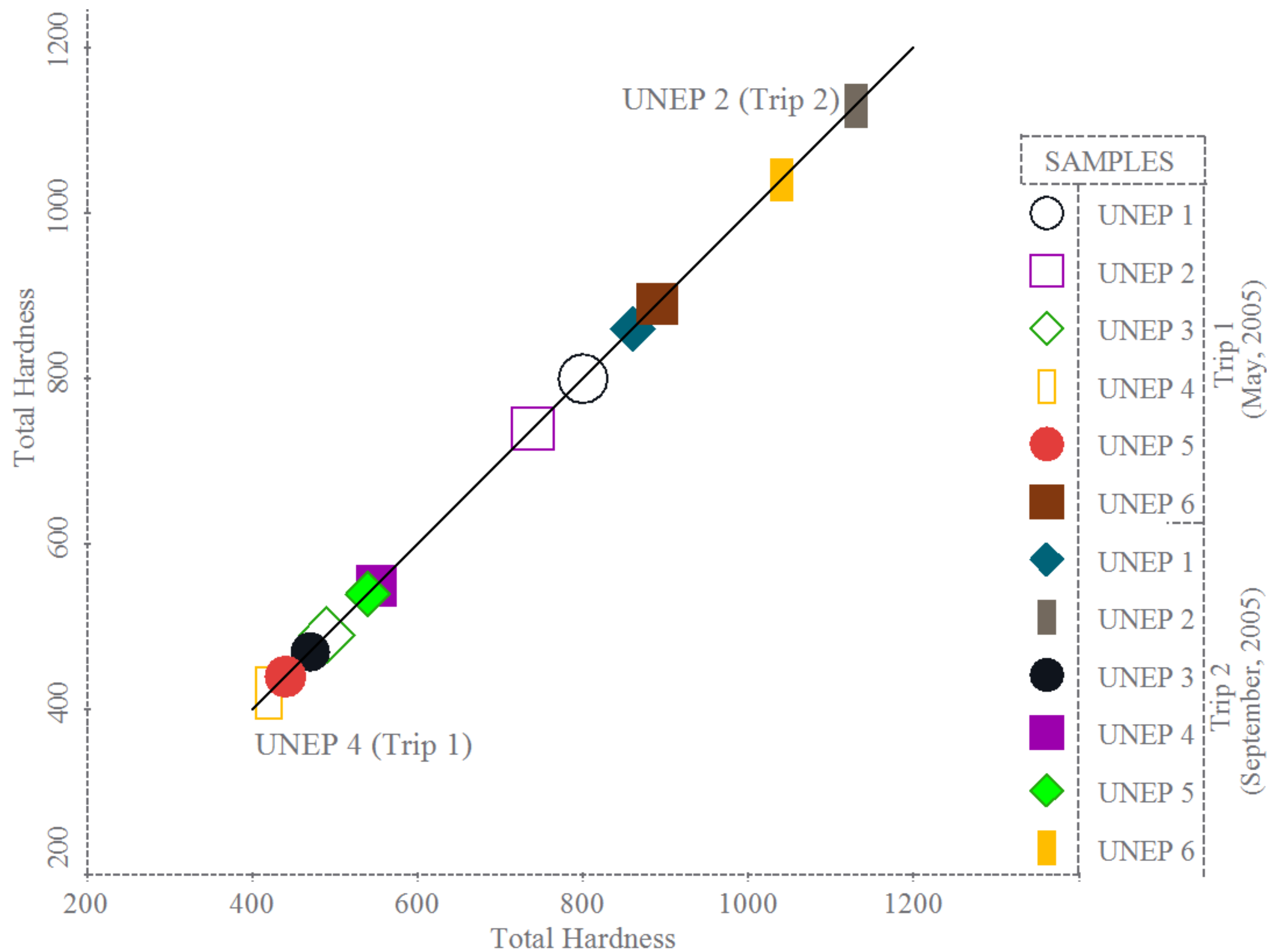


Figure 31: Ordination of UNEP sites in relation to values of Total Hardness (mg CaCO3/L), (May 2005 – September 2005).

The highest Total Hardness concentrations were recorded in UNEP 2 in the second trip (September, 2005) and the lowest concentrations were recorded in UNEP 4 in the first trip (May, 2005).

UNEP 2 unlike the other UNEP stations had a rather greater difference in the Total Hardness concentrations on both trips.

On the other hand, according to the concentrations recorded, UNEP 1 and UNEP 6 had relatively moderate to high Total Hardness concentrations respectively, whereas UNEP 3, 4, and UNEP 5 had relatively low Total Hardness concentrations on both trips when compared with the other stations.

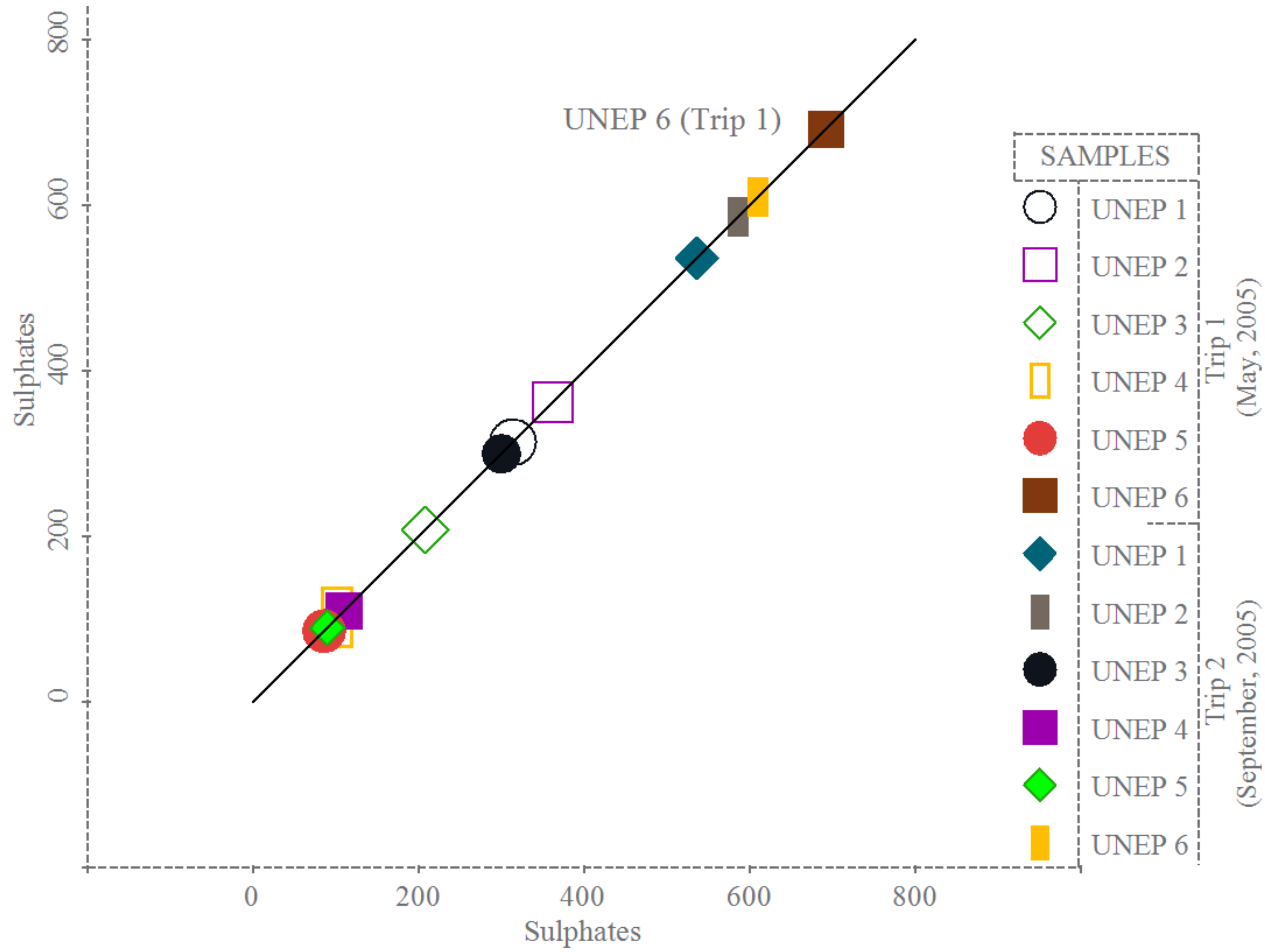


Figure 32: Ordination of UNEP sites in relation to values of Sulphates (mg/L), (May 2005 – September 2005).

The highest Sulphate concentrations were recorded in UNEP 6 during the first trip (May, 2005) while, the lowest concentrations were recorded in UNEP 5 and UNEP 4 respectively, on both trips.

According to the Sulphate concentrations recorded, UNEP 6 had relatively high levels in both trip one and trip two; whereas UNEP 1, 2, and UNEP 3 on both trips had relatively moderate to high Sulphate concentrations.

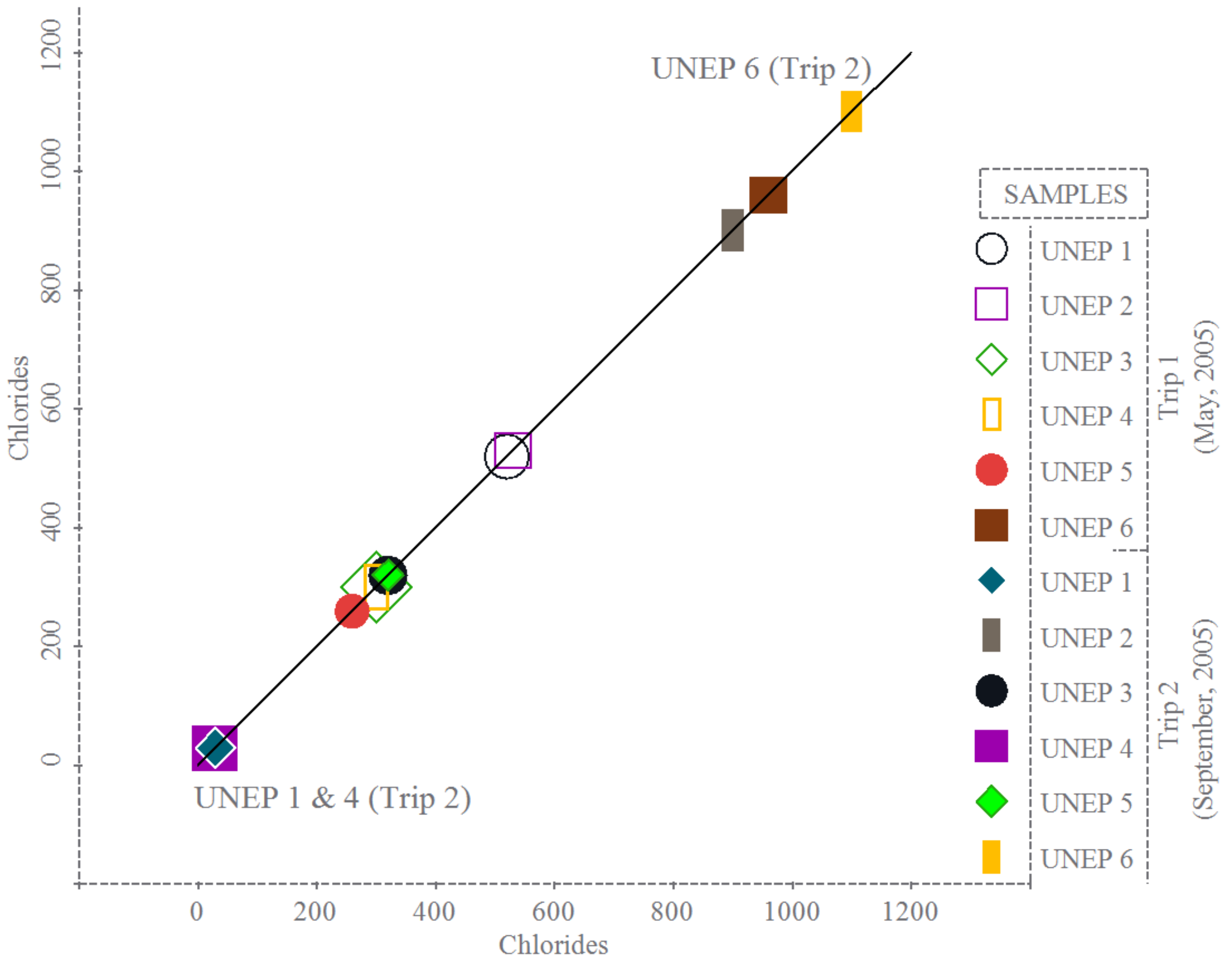


Figure 33: Ordination of UNEP sites in relation to values of Chlorides (mg/L), (May 2005 – September 2005).

UNEP 6 had the highest Chloride concentrations on both trips, especially in trip two. The lowest concentrations were recorded in UNEP 1 and UNEP 4 during trip two.

UNEP 1, 2, and 4 had rather diverse recorded Chloride concentrations on both trips, unlike UNEP 3 and UNEP 5 that had rather similar concentrations on both trips.

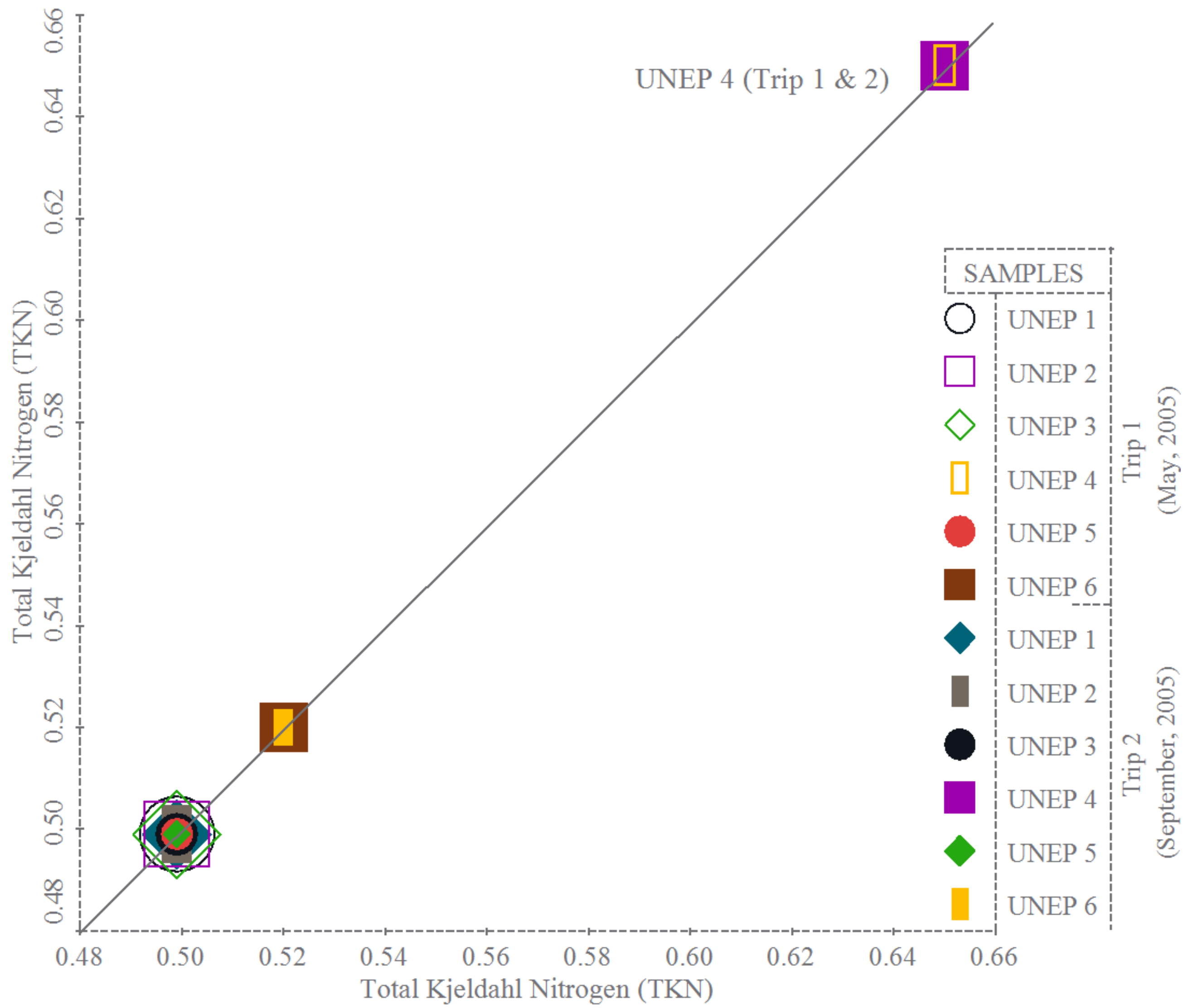


Figure 34: Ordination of UNEP sites in relation to values of Total Kjeldahl Nitrogen (mg N/L), (May 2005 – September 2005).

UNEP 4 had the highest Total Kjeldahl Nitrogen concentrations recorded in both trip one and trip two.

UNEP 1, 2, 3, and UNEP 5 had the lowest and relatively similar Total Kjeldahl Nitrogen concentrations on both trips.

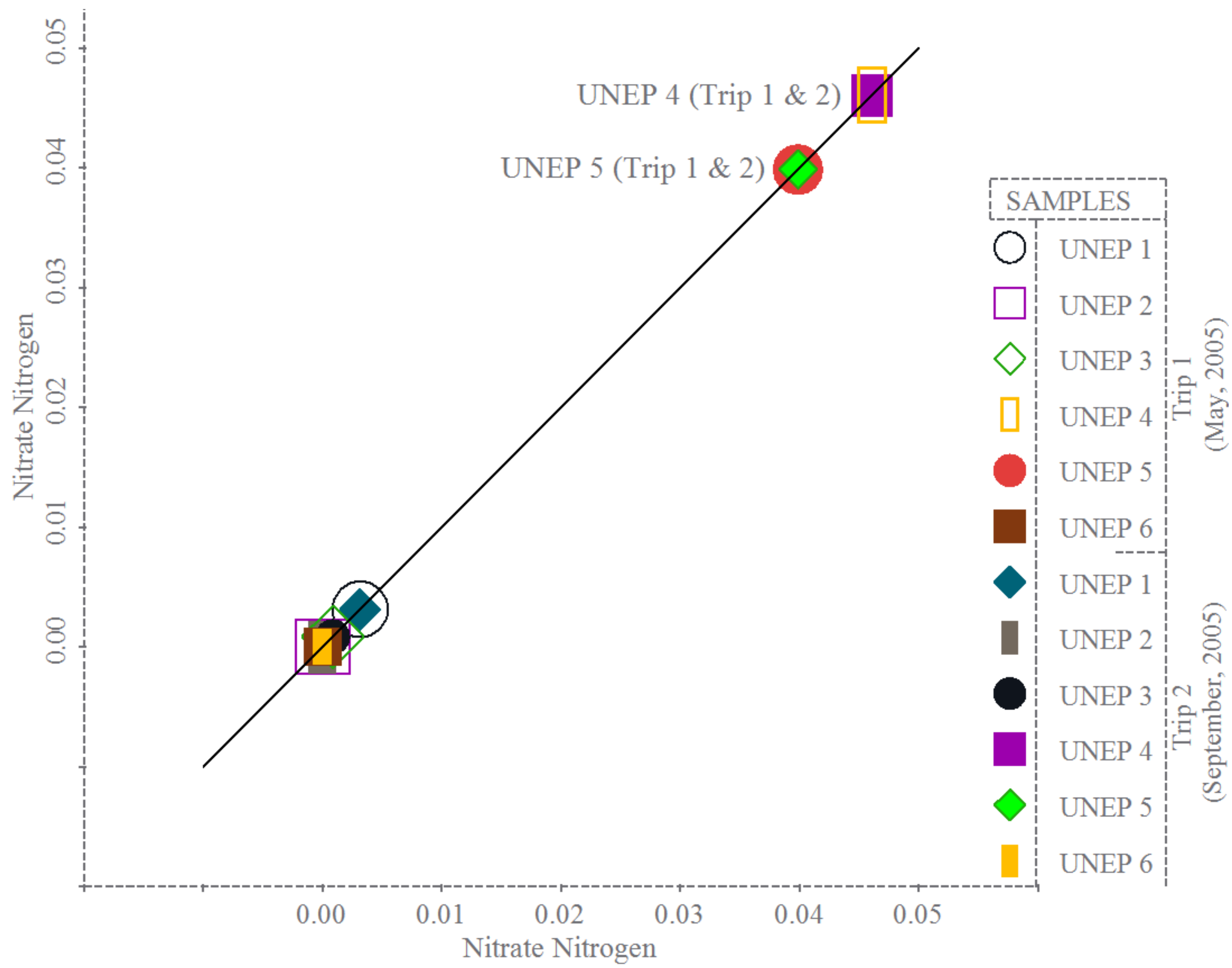


Figure 35: Ordination of UNEP sites in relation to values of Nitrate-Nitrogen (mg N/L), (May 2005 – September 2005).

The highest Nitrate-Nitrogen concentrations recorded on both trips were in UNEP 4.

UNEP 5 on both trips also had relatively high Nitrate-Nitrogen concentrations.

On the other hand, UNEP 1, 2, 3, and UNEP 6 had relatively low Nitrate-Nitrogen concentrations on both trips.

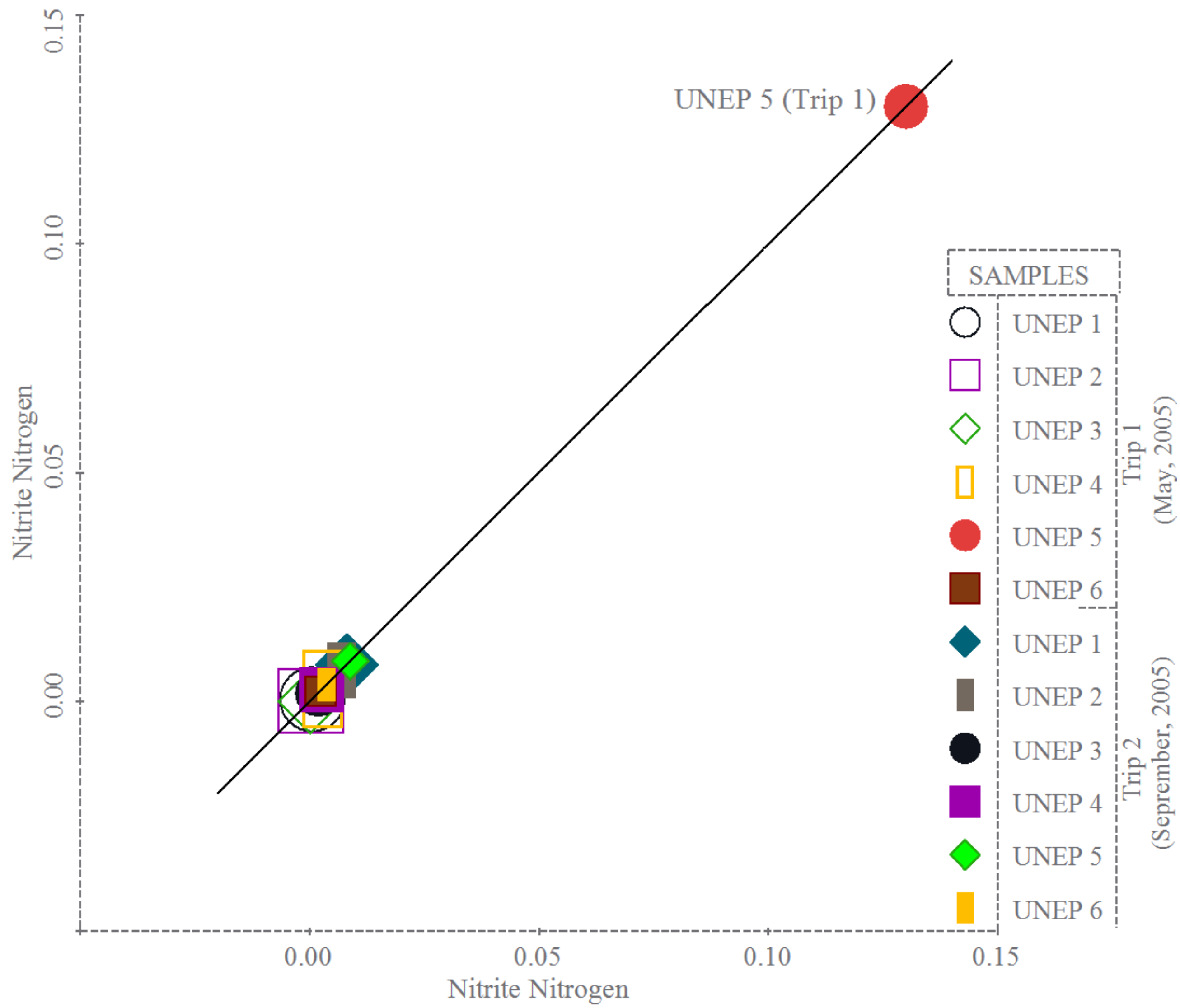


Figure 36: Ordination of UNEP sites in relation to values of Nitrite-Nitrogen (mg N/L), (May 2005 – September 2005).

UNEP 5 during the first trip (May, 2005) had the highest Nitrite-Nitrogen concentrations recorded compared with the other stations.

UNEP 1, 2, 3, 4, and UNEP 6 on both trips along with UNEP 5 during the second trip had relatively similar and low Nitrite-Nitrogen concentrations.

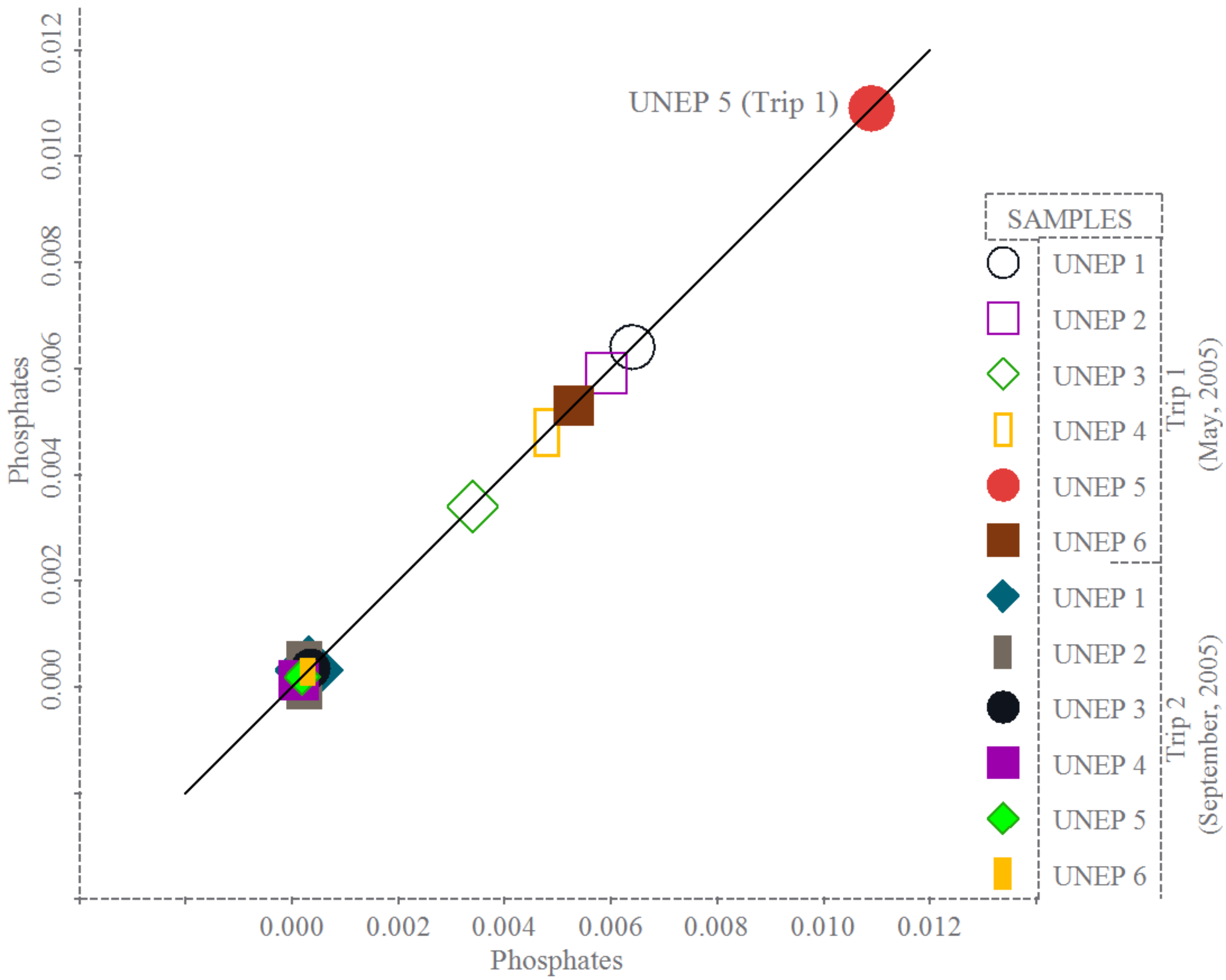


Figure 37: Ordination of UNEP sites in relation to values of Phosphates (mg P/L), (May 2005 – September 2005).

During trip one (May, 2005) UNEP 5 had the higher Phosphate concentrations recorded.

UNEP 1, 2, 3, 4, and UNEP 6 had relatively moderate Phosphate concentrations during the first trip.

All UNEP stations during the second trip (September, 2005) had relatively similar and low Phosphate concentrations.

Generally, Phosphate concentrations on trip one was higher than on trip two.

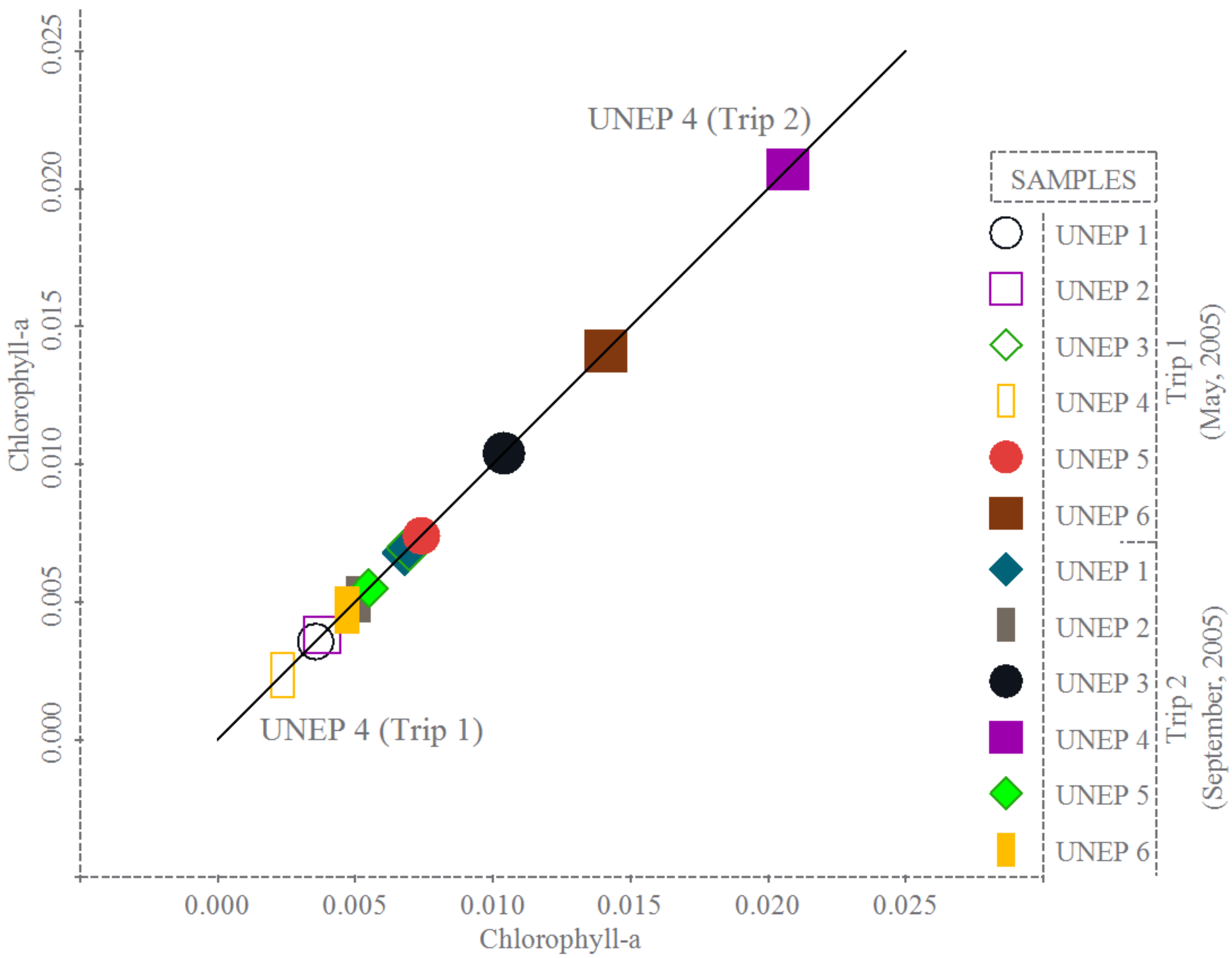


Figure 38: Ordination of UNEP sites in relation to values of Chlorophyll-a (mg/L), (May 2005 – September 2005).

The higher and lower chlorophyll-a concentrations were recorded in UNEP 4 during the second and first trip respectively.

UNEP 6 in trip one and UNEP 3 in trip two had relatively moderate chlorophyll-a concentrations in comparison to the other UNEP stations that had relatively low concentrations.

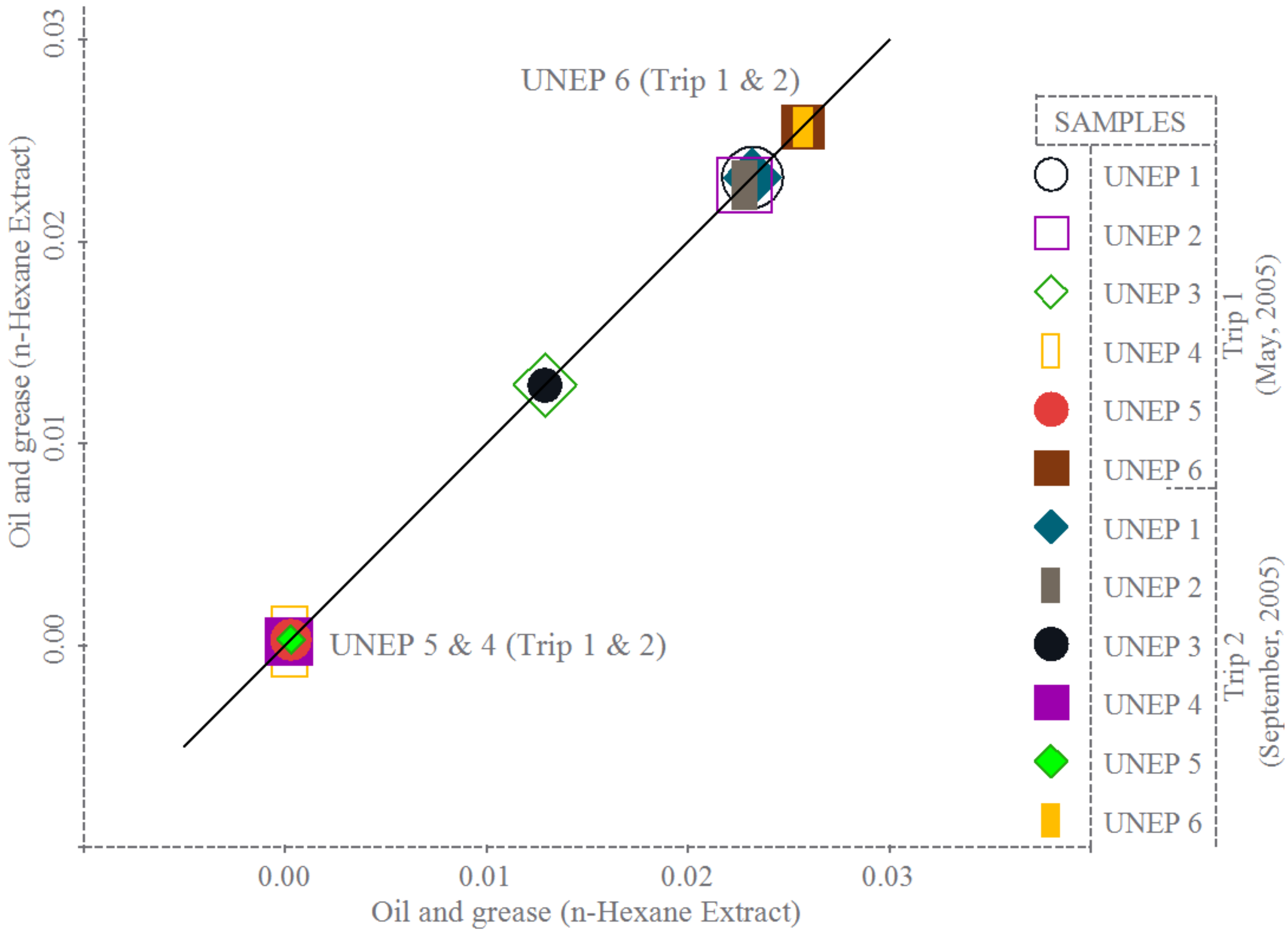


Figure 39: Ordination of UNEP sites in relation to values of Oil and grease (n-Hexane Extract), (mg/L), (May 2005 – September 2005).

UNEP 6 had the higher Oil and Grease concentrations during both trips.

UNEP 4 and UNEP 5 had the lowest Oil and Grease concentrations on both trips.

On the other hand, UNEP 1 and UNEP 2 had relatively high concentrations according to the concentrations recorded in this study. Whereas UNEP 3 had, relatively moderate Oil and Grease concentrations compared with the other stations.

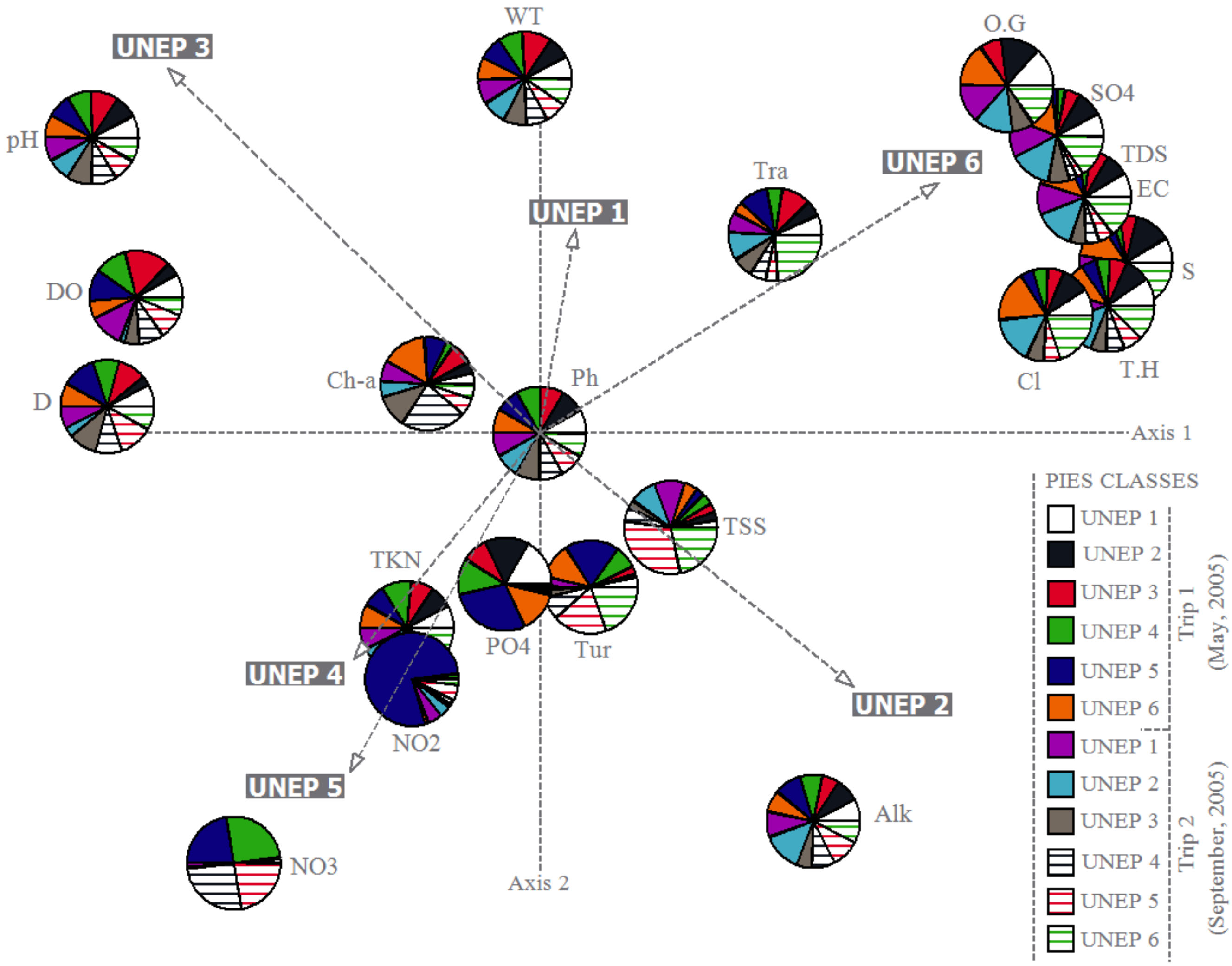


Figure 40: Ordination of UNEP sites in relation to values of Physio-chemical environmental variables, southern Iraq (May – September 2005).

The preceding physio-chemical characters of the UNEP sites can be visualized in another way; the figure above illustrated the most important physio-chemical property of each site. In addition, the Phenol pie is illustrated in the center, reflecting its constancy in all sites. (Table 5)

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of a particular site. These projections can be used to approximate the level or the concentration of individual environmental variable in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. Segmentation of these pies into slices is based on currently active classification of the UNEP sites. The relative size of a particular pie-slice corresponds to relative level or concentration of the environmental variable in a particular site (Ter Braak and Šmilauer, 2002).

For instance, Nitrate-Nitrogen is found in UNEP 4 & UNEP 5 in relatively higher concentrations than the other studied sites. Nitrite-Nitrogen is found in UNEP 5 (Trip 1) in relatively higher concentrations than the other UNEP sites.

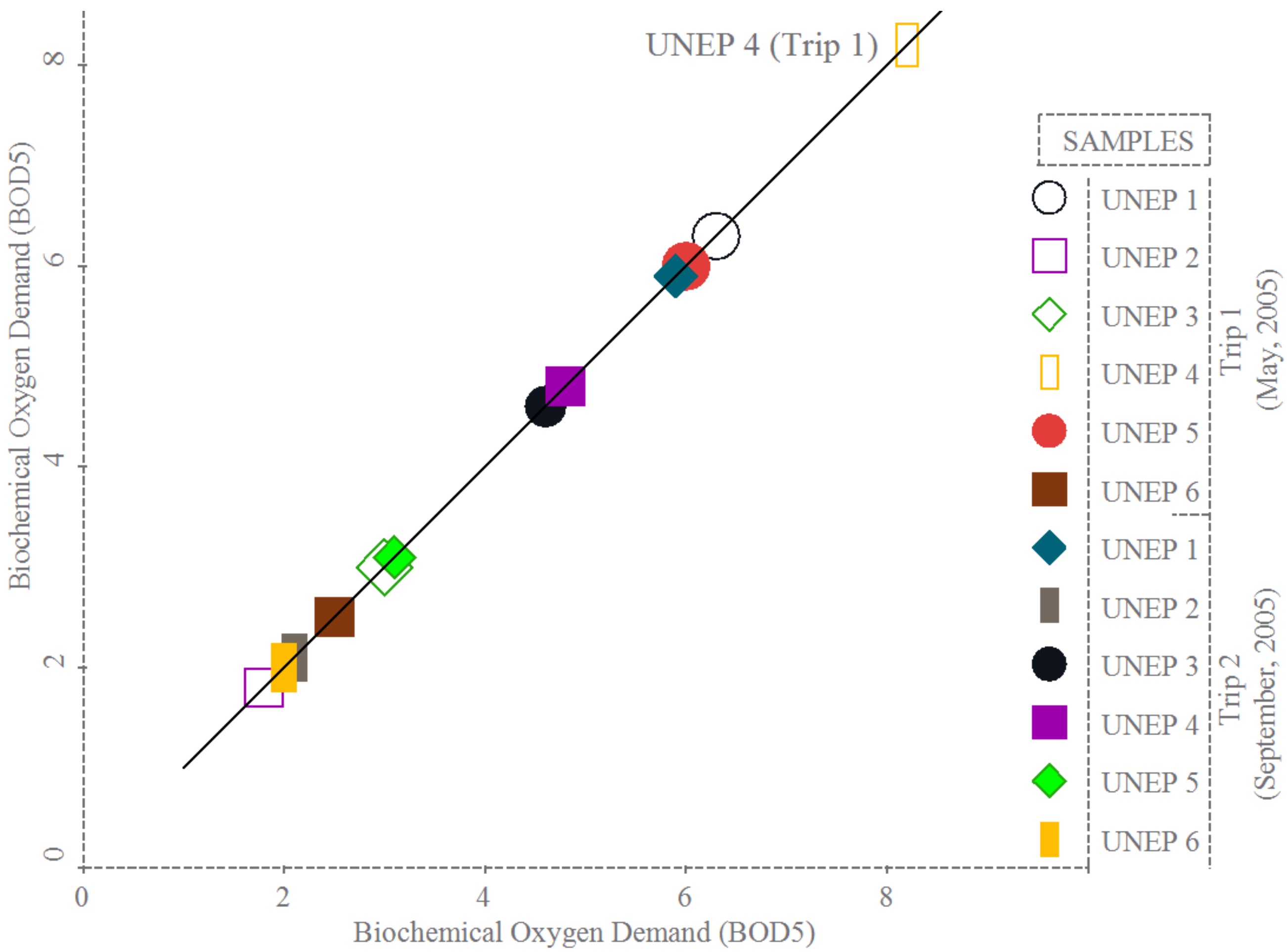


Figure 41: Ordination of UNEP sites in relation to values of Biochemical Oxygen Demand (BOD5), (mg/L), (May – September 2005).

UNEP 4 had the highest Biochemical Oxygen Demand in trip one, while UNEP 1 had the highest concentrations in trip two.

UNEP 2 and UNEP 6 during both trips had relatively similar and low Biochemical Oxygen Demand concentrations, especially UNEP 2 in trip one.

UNEP 1 on both trips, UNEP 5 in trip one, and UNEP 3 and 4 in trip two all had relatively moderate BOD concentrations.

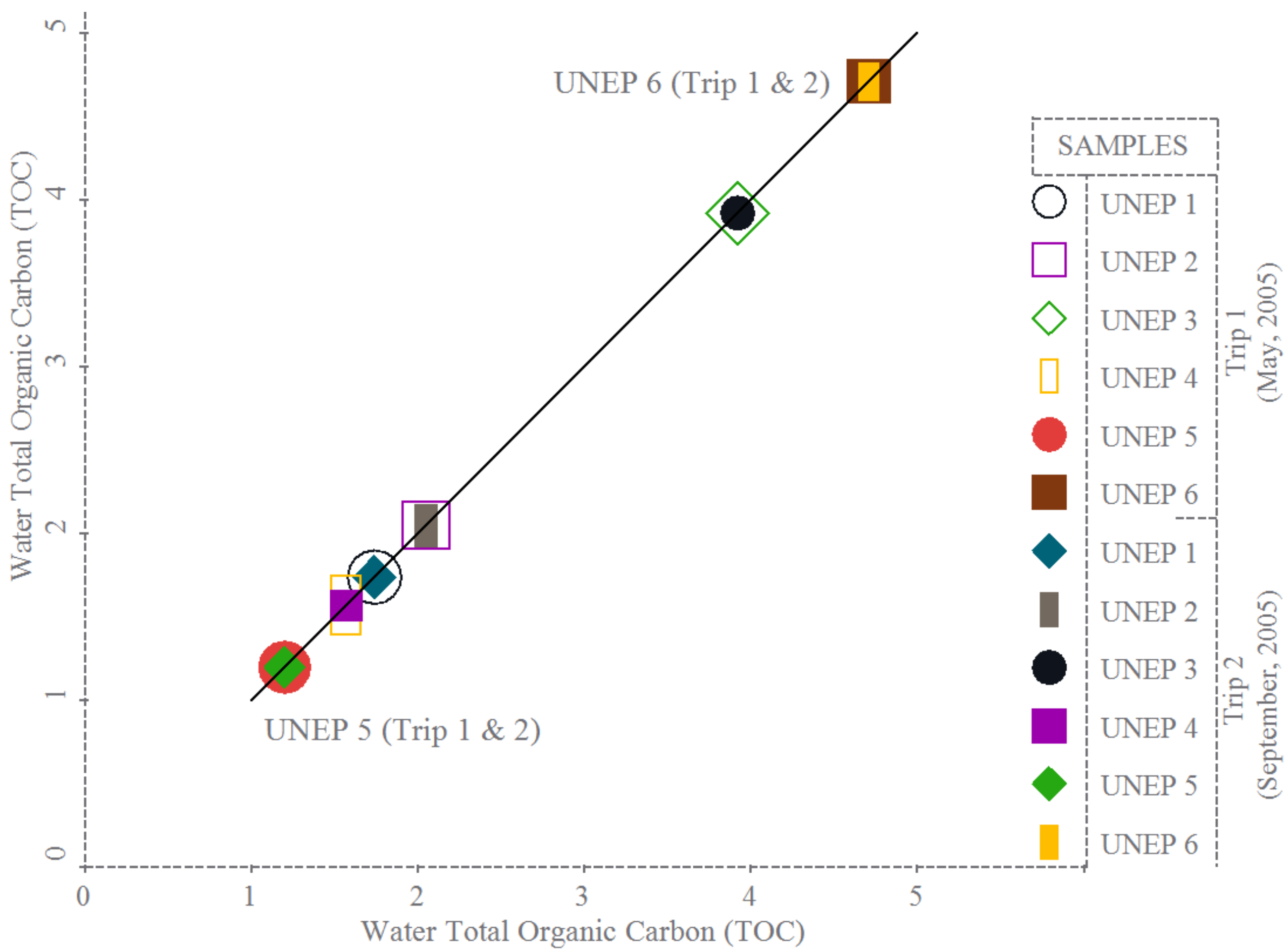


Figure 42: Ordination of UNEP sites in relation to values of Water Total Organic Carbon (mg/L), (May – September 2005).

UNEP 6 on both trips had the higher Water Total Organic Carbon concentrations, while the lower concentrations on both trips were recorded in UNEP 5.

UNEP 3 on both trips had relatively high Water Total Organic Carbon concentrations compared with UNEP 1, 2, and UNEP 4 that had relatively low concentrations.

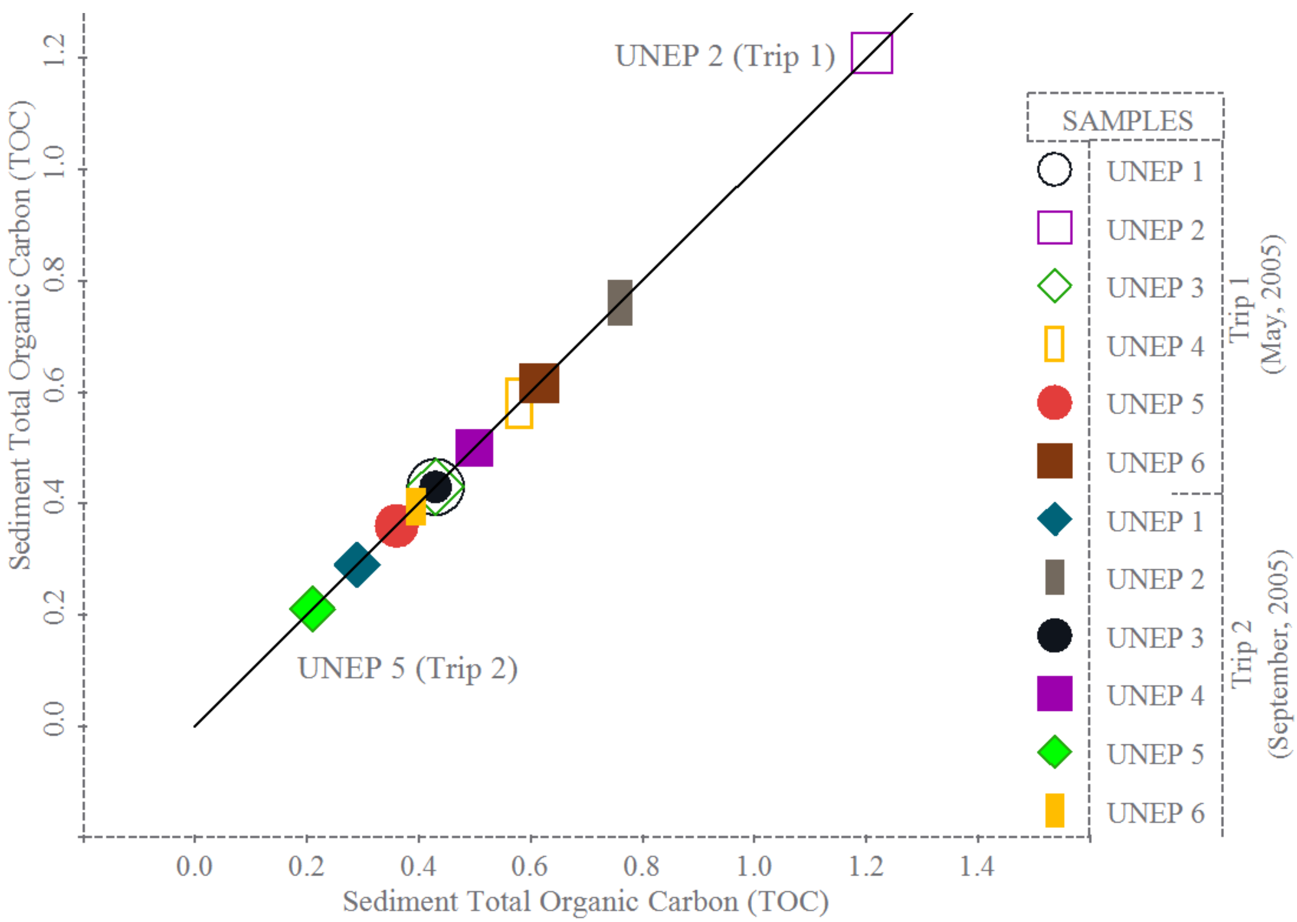


Figure 43: Ordination of UNEP sites in relation to percentage of Sediment Total Organic Carbon (May – September 2005).

UNEP 2 had the highest Sediment Total Organic Carbon concentrations on both trips particularly during trip two.

The lowest concentrations were recorded in UNEP 5 during the second trip.

The other UNEP stations had relatively moderate to low concentrations on both trips.

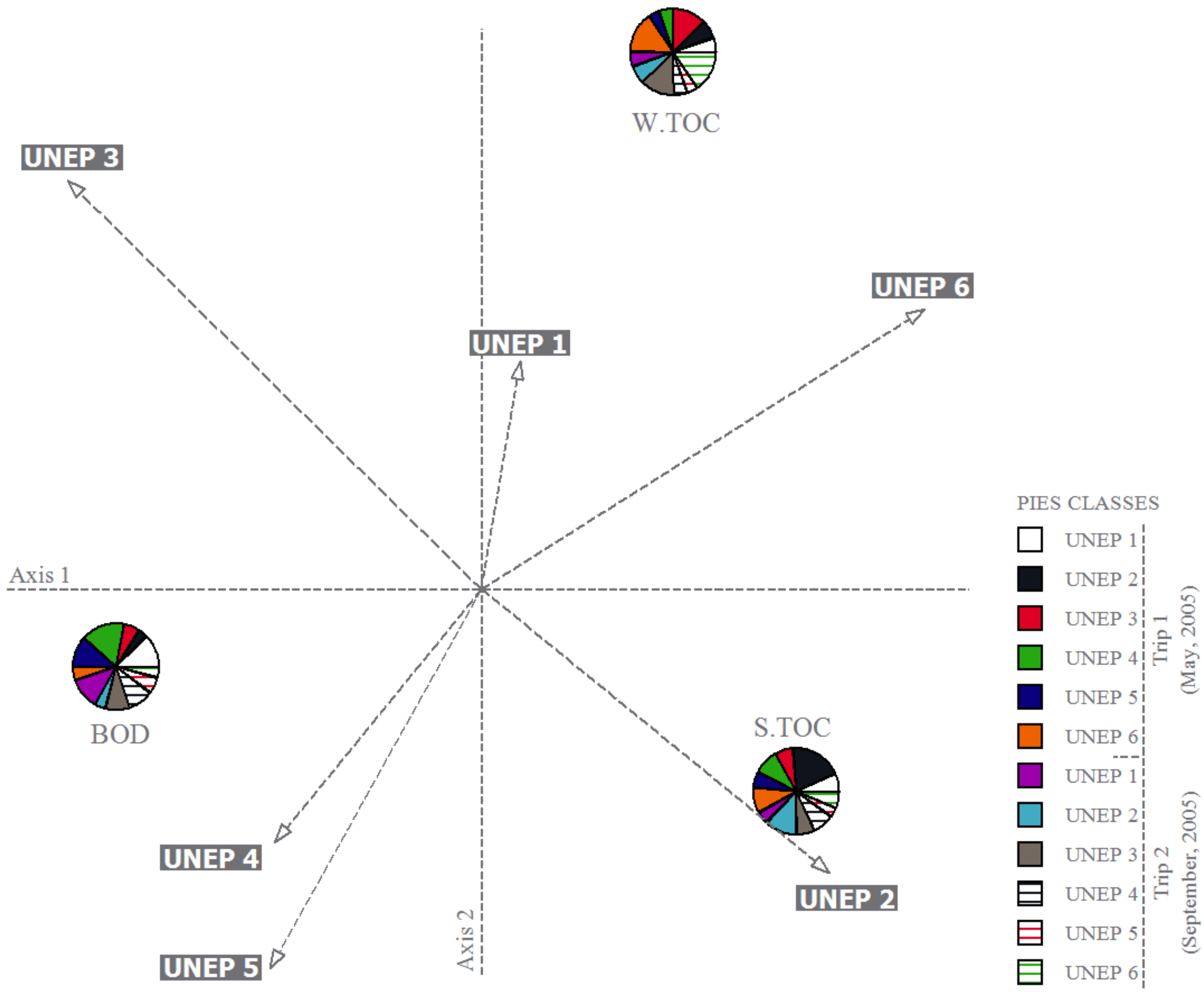


Figure 44: Ordination of UNEP sites in relation to values of biochemical & organic environmental variables (May – September 2005).

The preceding biochemical & organic characteristics of the UNEP sites can be visualized in another way; the figure above illustrated the most important biochemical & organic properties of each site.

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of particular site. These projections can be used to approximate the level or the concentration of individual environmental variable in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classification of each UNEP site. The relative size of a particular pie-slice corresponds to the relative level or concentration of the environmental variable in each particular site (Ter Braak and Šmilauer, 2002).

For instance, sediment total organic carbon is found in UNEP 2 in relatively higher percent than the other studied sites.

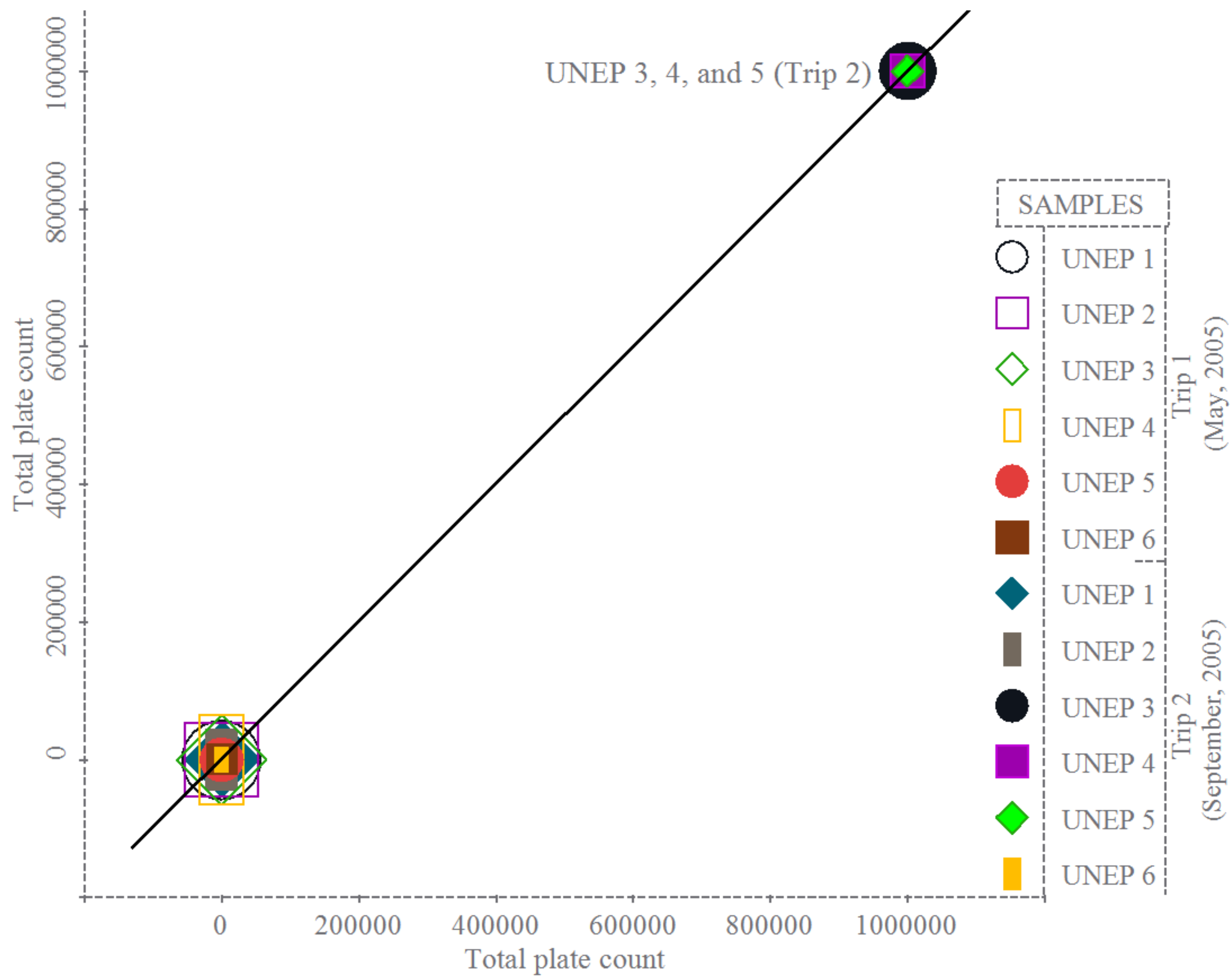


Figure 45: Ordination of UNEP sites in relation to values of Total Plate Count (colony/ml), (May – September 2005).

The highest Total Plate count was recorded in UNEP 3, 4, and UNEP 5 during the second trip (September, 2005).

The remaining stations during both trips had similar Total Plate counts.

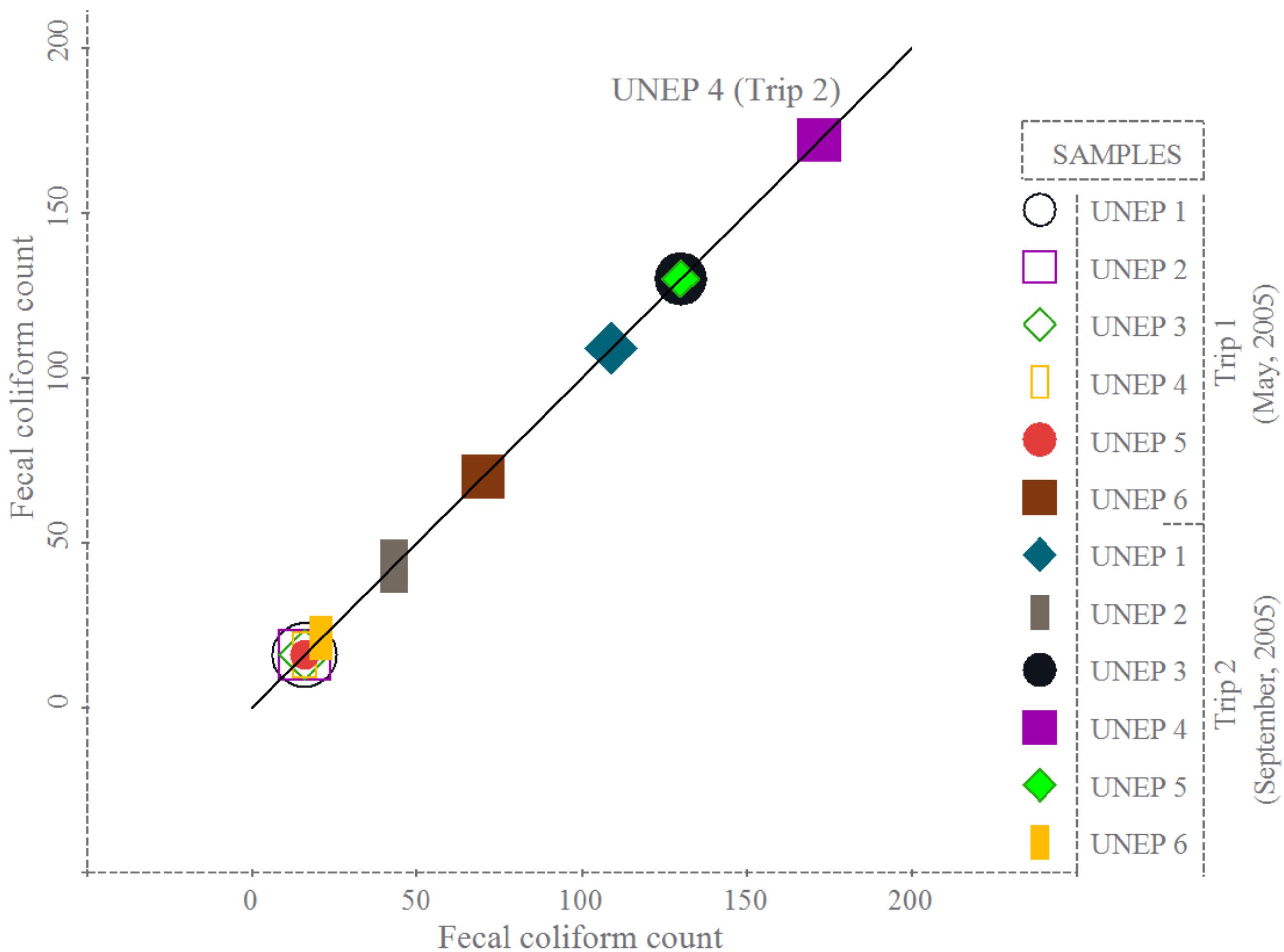


Figure 46: Ordination of UNEP sites in relation to values of Fecal Coliform Count (CFU/100ml), (May – September 2005).

UNEP 4 had the highest Fecal Coliform count in trip two (September, 2005).

UNEP 6 had the higher Fecal Coliform count in trip one (May, 2005), while the other stations had relatively similar and low Fecal Coliform count in trip one.

Generally, the Fecal Coliform count was higher in UNEP stations during the second trip.

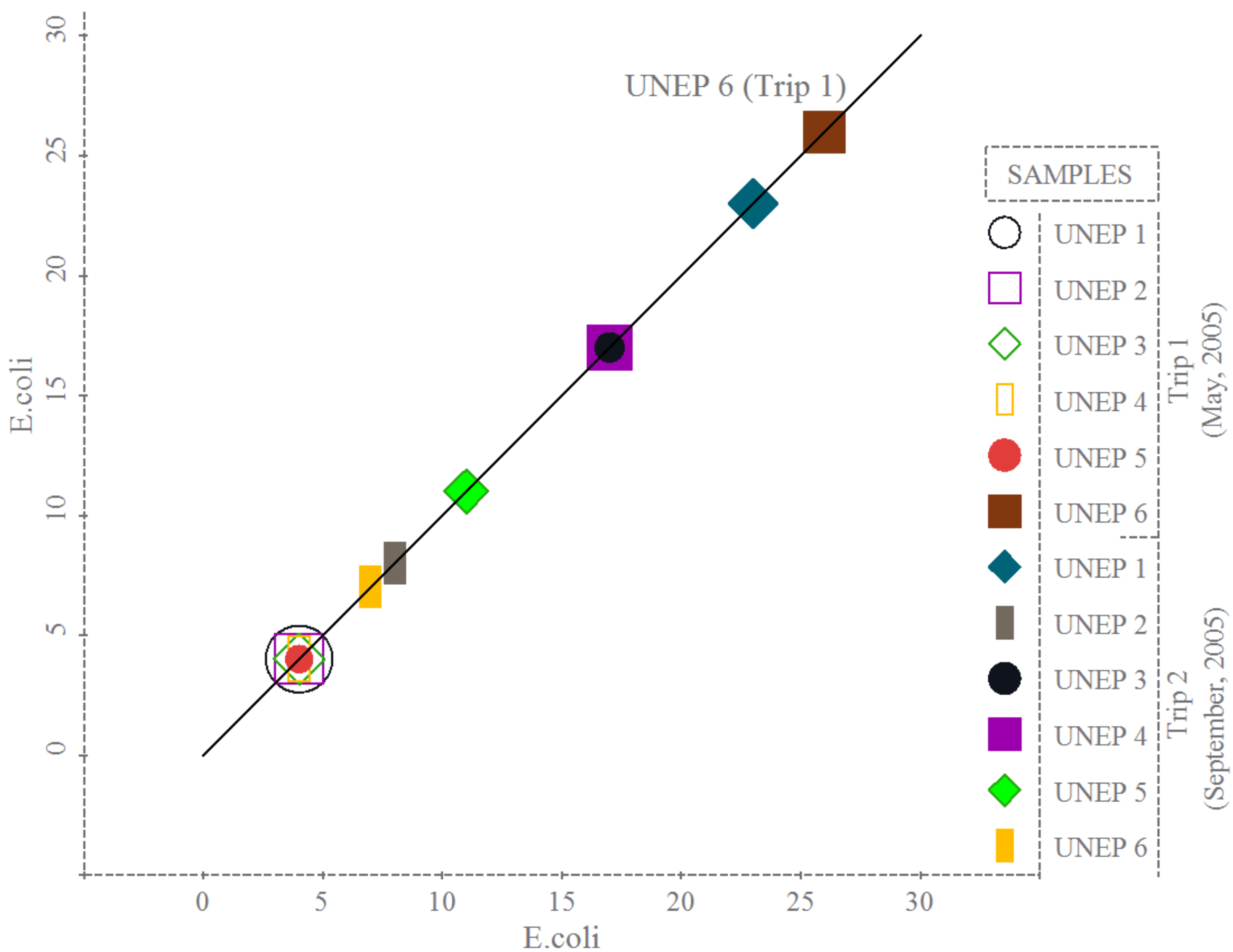


Figure 47: Ordination of UNEP sites in relation to values of *E. coli* (CFU/100ml), (May – September 2005).

UNEP 6 had the highest levels of *E. coli* during the first trip (May, 2005), while UNEP 1 had the highest levels of *E. coli* in the second trip (September, 2005).

The UNEP stations in the first trip (except UNEP 6) had rather similar and low *E. coli*.

Generally, the UNEP stations during the second trip had higher *E.coli*.

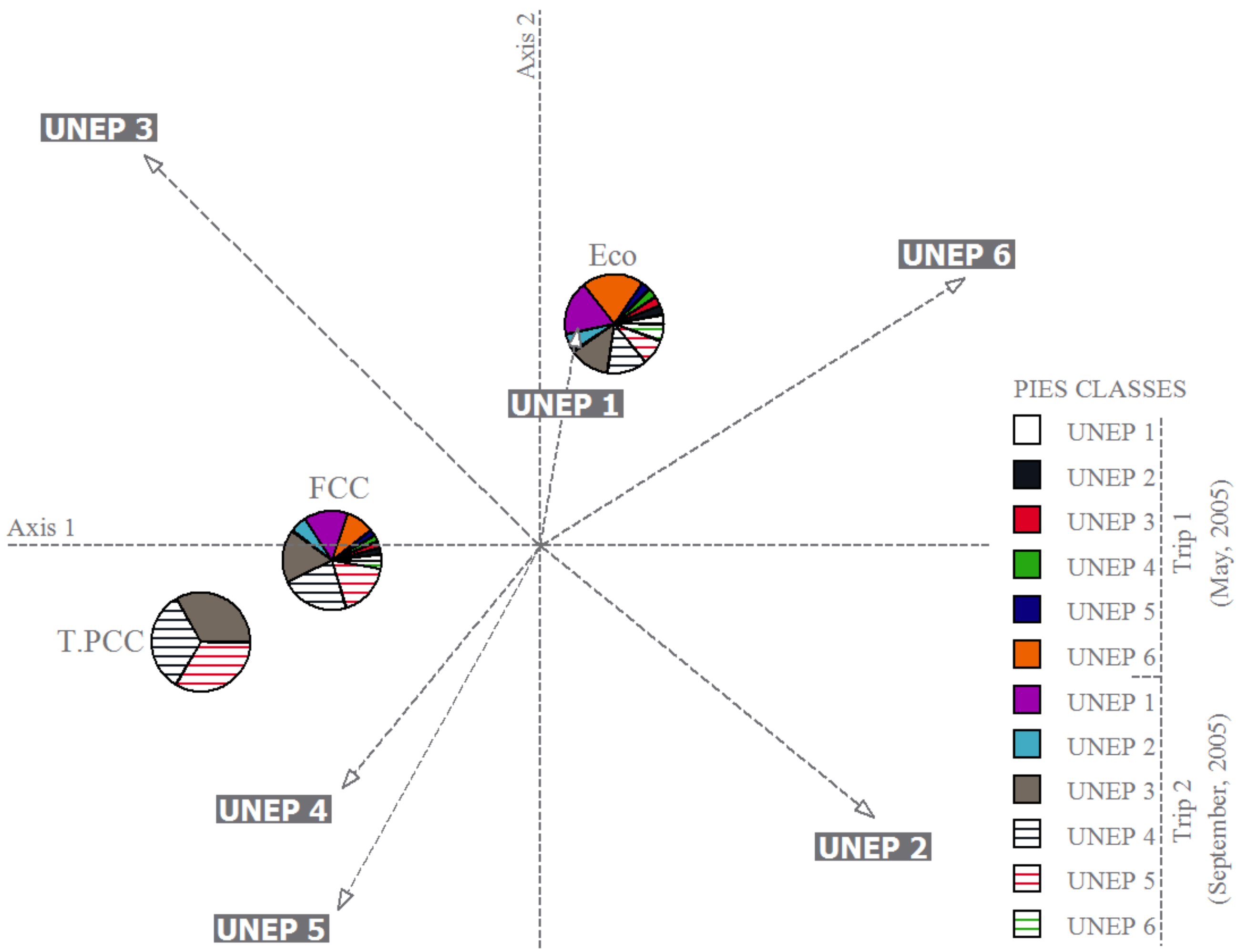


Figure 48: Ordination of UNEP sites in relation to values of Bacteriological & Biological environmental variables (May – September 2005).

The preceding Bacteriological & Biological characters of the UNEP sites can be visualized in another way; the figure above illustrated the most important Bacteriological & Biological properties of each site.

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of a particular site. These projections can be used to approximate the level or the concentration of individual environmental variables in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classification of each UNEP sites. The relative size of particular pie-slice corresponds to the relative level or concentration of the environmental variable in the particular site (Ter Braak and Šmilauer, 2002).

For instance, total plate count was found in UNEP 3, UNEP 4, & UNEP 5 in relatively higher levels than the other studied sites during the second trip.

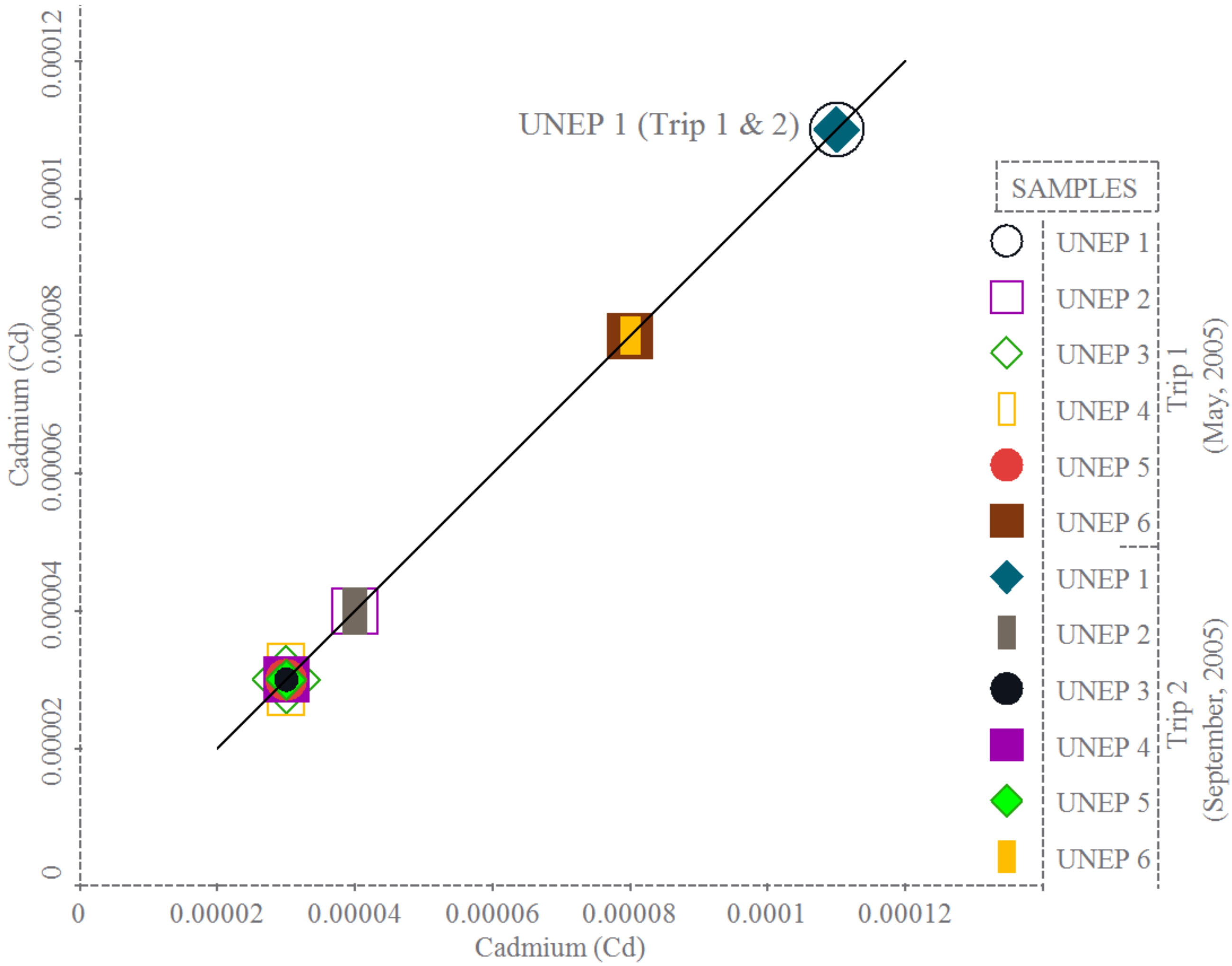


Figure 49: Ordination of UNEP sites in relation to values of Cadmium (mg/l), (May – September 2005).

During both, trip one and trip two, UNEP 1 had the higher Cadmium concentrations. UNEP 3, 4, and 5 had relatively similar and low Cadmium concentrations on both trips.

UNEP 6 had relatively moderate concentrations.

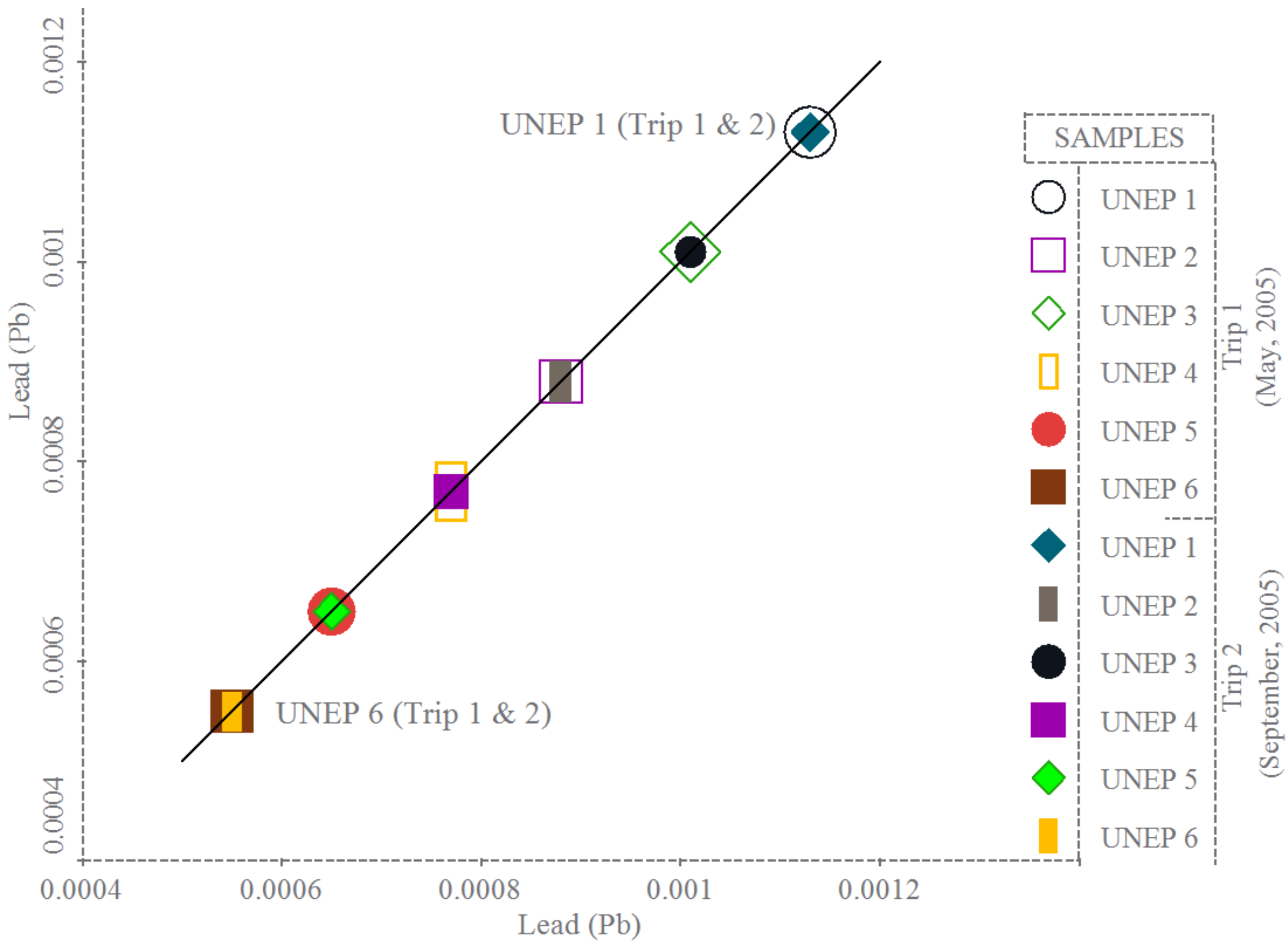


Figure 50: Ordination of UNEP sites in relation to values of Lead (mg/l), (May –September 2005).

In both trip one and trip two, UNEP 1 had the highest Lead concentrations and UNEP 6 had the lowest concentrations.

According to the other stations UNEP 1, 2, 4, and UNEP 5 respectively had the higher to lower Lead concentrations.

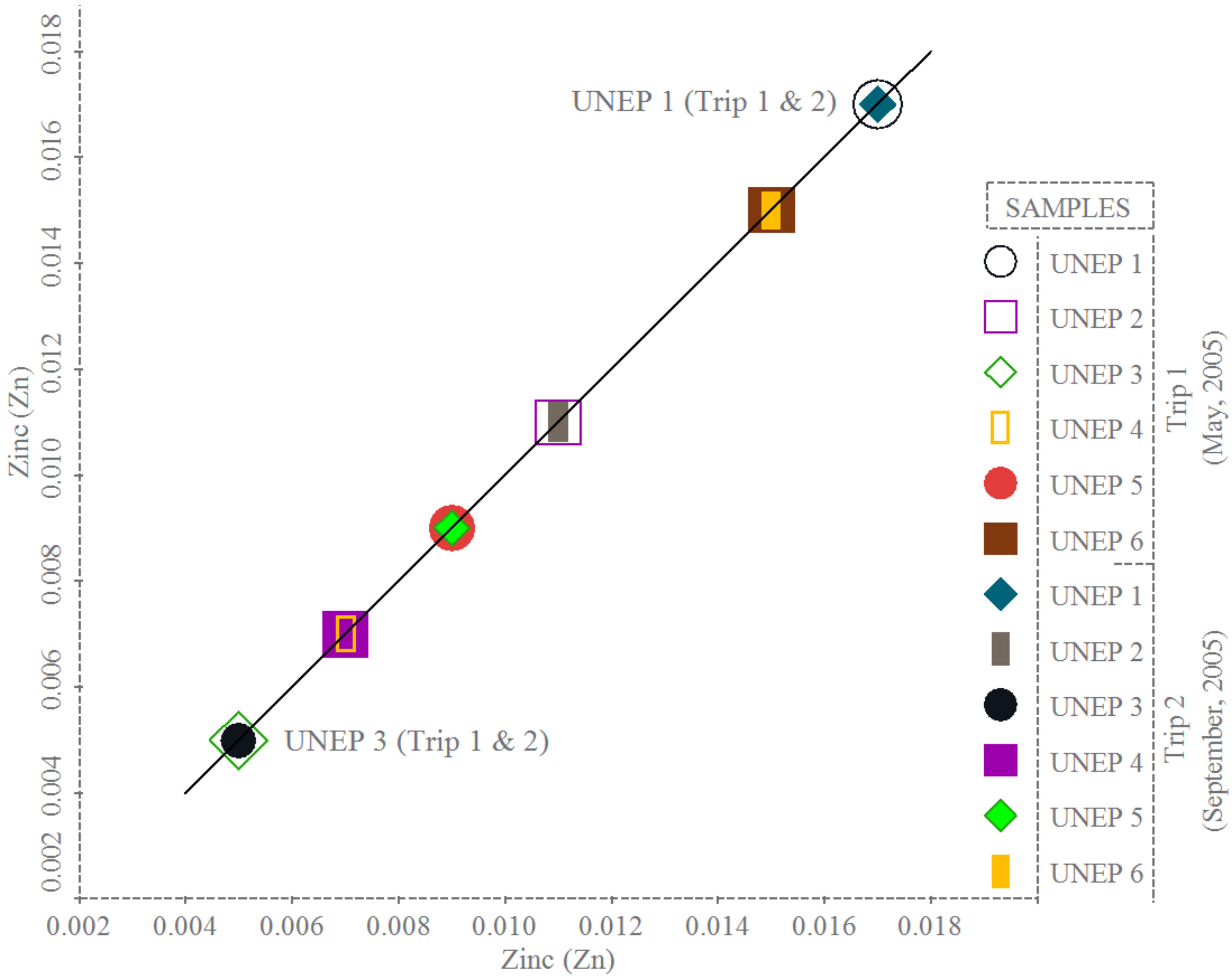


Figure 51: Ordination of UNEP sites in relation to values of Zinc (mg/l), (May – September 2005).

During both trips, UNEP 1 had the highest and UNEP 3 had the lowest Zinc concentrations.

The other stations are arranged from higher to lower concentrations as UNEP 6, 2, 5, and UNEP 4 respectively.

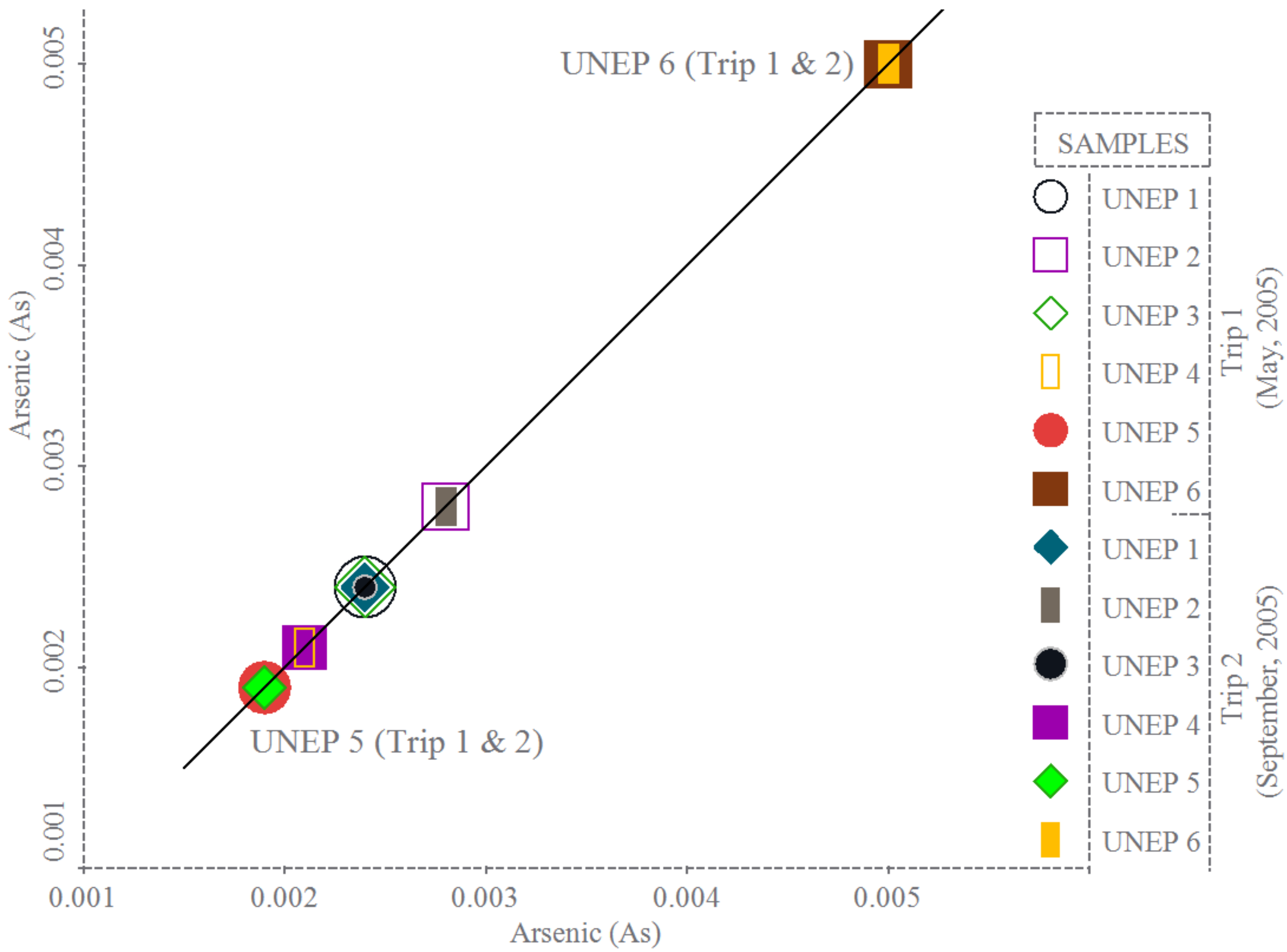


Figure 52: Ordination of UNEP sites in relation to values of Arsenic (mg/l), (May – September 2005).

UNEP 6 had the highest Arsenic concentrations during both trips and UNEP 5 had the lowest concentrations also on both trips.

UNEP 2, 1, 3, and 4 had relatively low Arsenic concentrations on both trips.

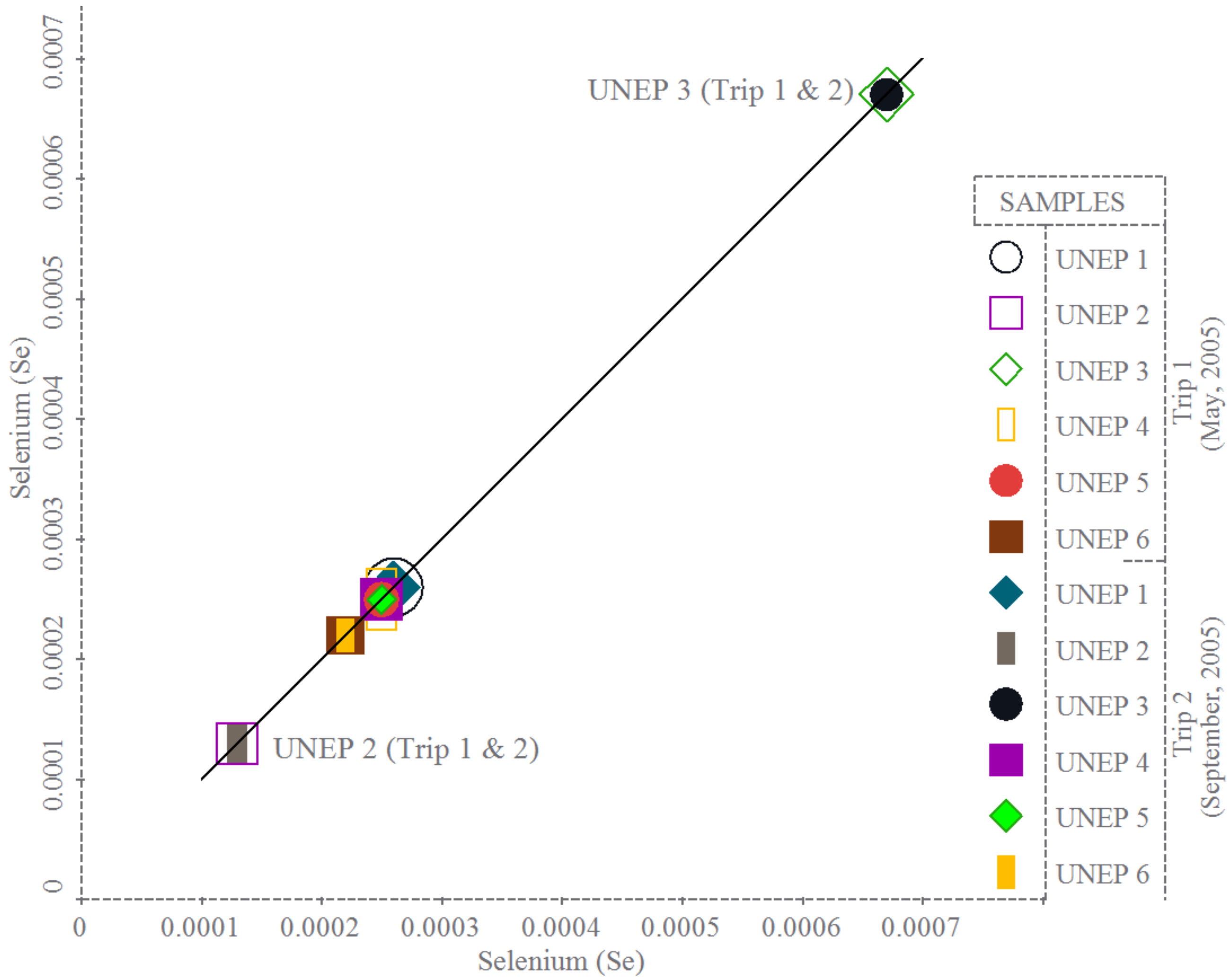


Figure 53: Ordination of UNEP sites in relation to values of Selenium (mg/l), (May – September 2005).

In both trip one and trip two UNEP 3 had the highest Selenium concentrations, whereas UNEP 2 had the lowest concentrations.

UNEP 1, 4, 5, and UNEP 6 had relatively similar and low Selenium concentrations during both trips.

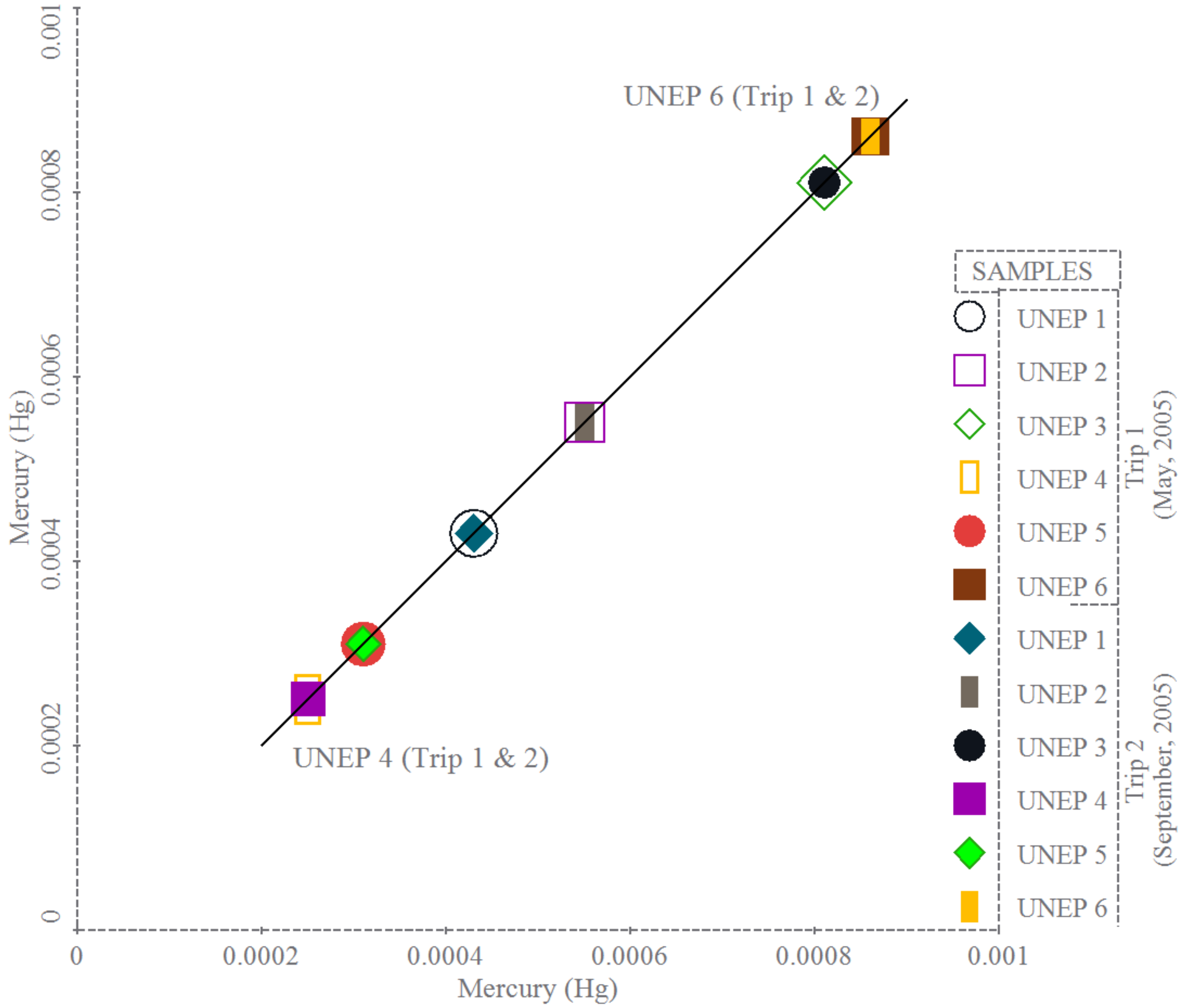


Figure 54: Ordination of UNEP sites in relation to values of Mercury (mg/l), (May – September 2005).

UNEP 6 had the highest Mercury concentrations on both trips. UNEP 4 had the lowest concentrations also on both trips.

UNEP 1 in trip one and trip two had relatively high Mercury concentrations, whereas UNEP 2, 3, and UNEP 5 had relatively moderate to low concentrations on both trips.

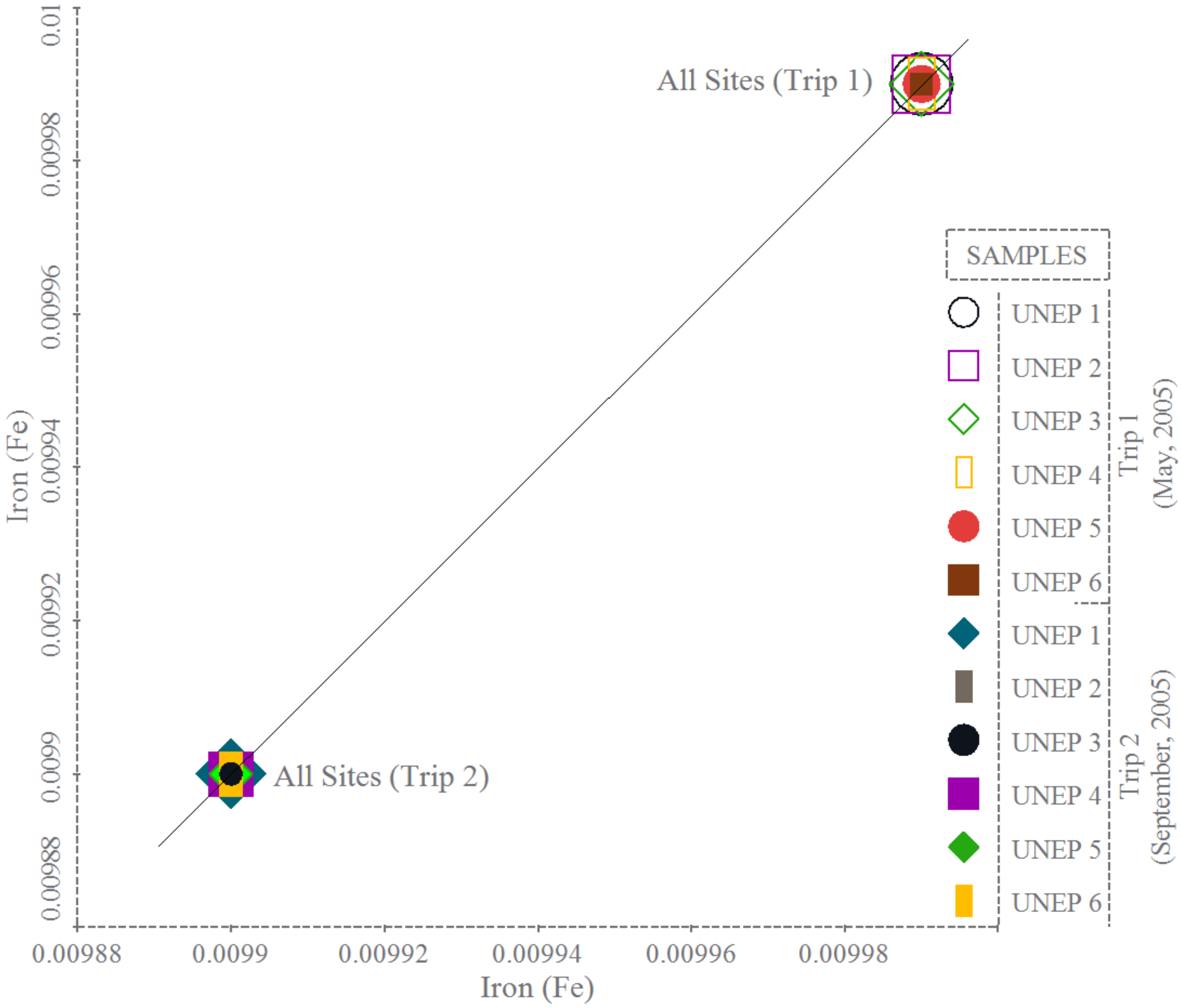


Figure 55: Ordination of UNEP sites in relation to values of Iron (mg/l), (May – September 2005).

During the first trip (May, 2005), all UNEP sites had the same and high Iron concentrations compared with the sites in the second trip (September, 2005), that had the same but lower Iron concentrations.

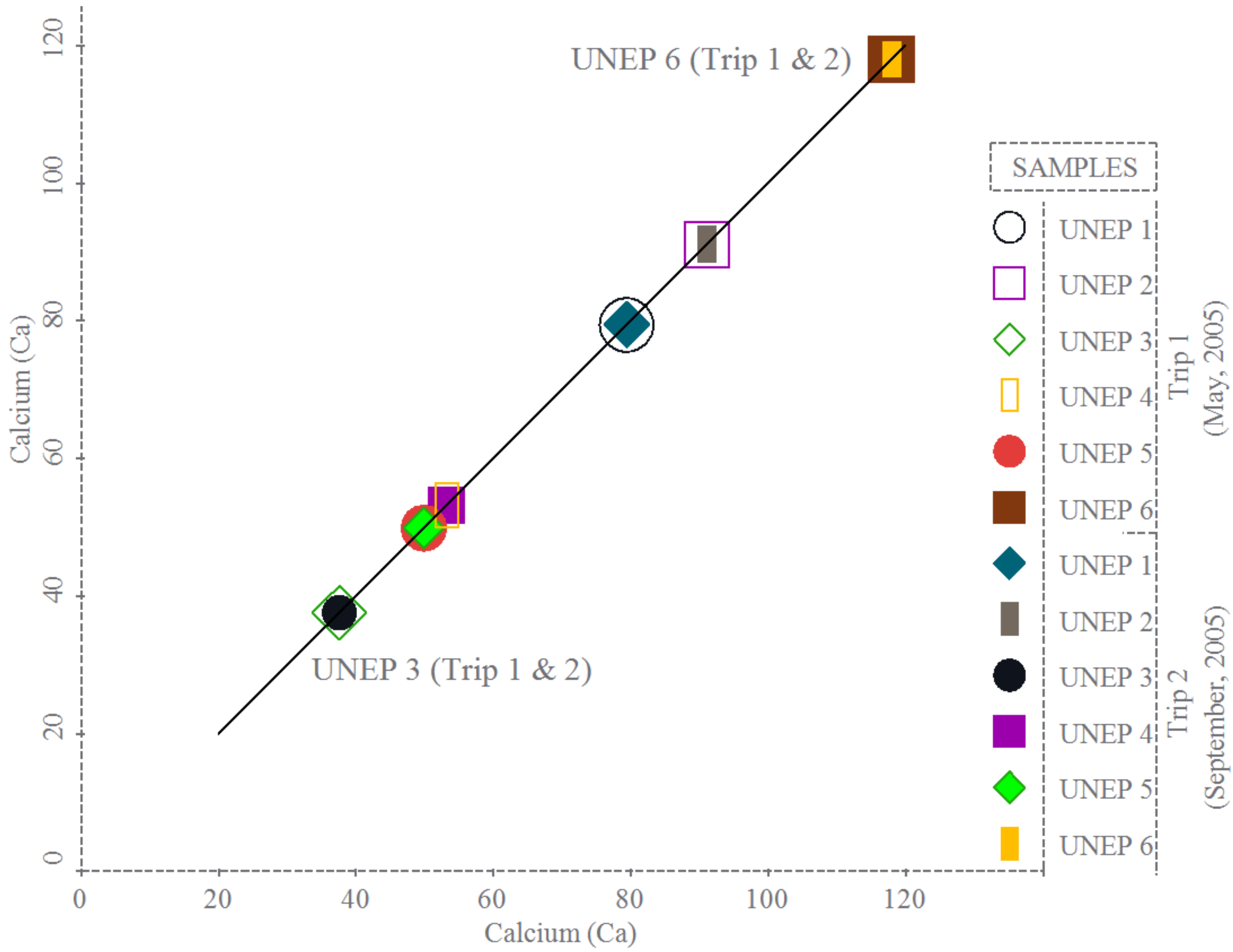


Figure 56: Ordination of UNEP sites in relation to values of Calcium (mg/l), (May – September 2005).

On both trips, UNEP 6 had the highest Calcium concentrations while, UNEP 3 had the lowerst concentrations.

UNEP 2 and UNEP 1 during both trips had relatively high to moderate Calcium concentrations respectively.

UNEP 4 and UNEP 5 had relatively similar and low Calcium concentrations on both trips.

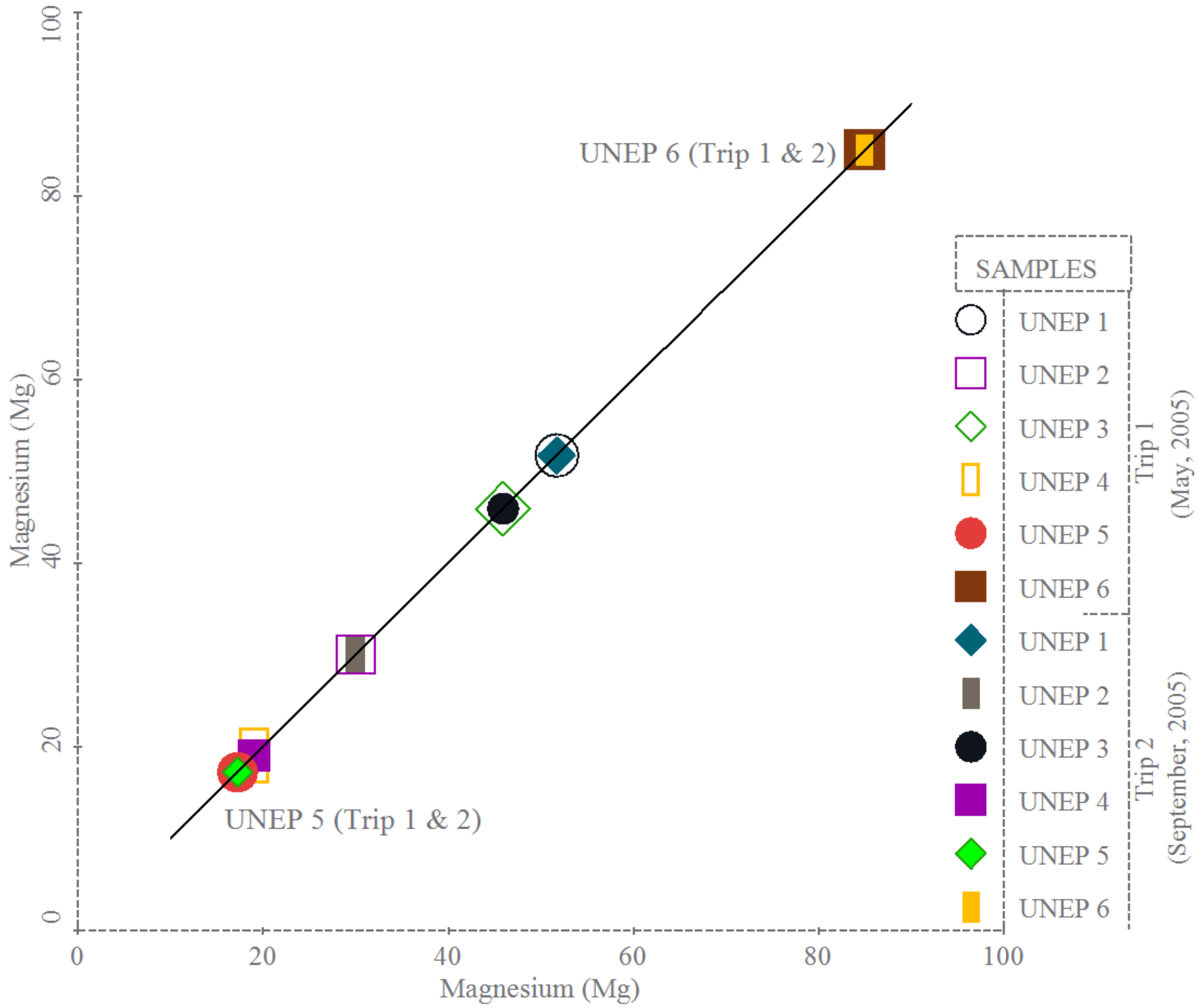


Figure 57: Ordination of UNEP sites in relation to values of Magnesium (mg/l), (May – September 2005).

In both trip one and trip two UNEP 6 had the highest Magnesium concentrations, whereas UNEP 5 and UNEP 4 had the lowest Magnesium concentrations on both trips respectively.

UNEP 1, 3, and UNEP 2 each, had the same concentrations on both trips ranging between relatively moderate to low concentrations.

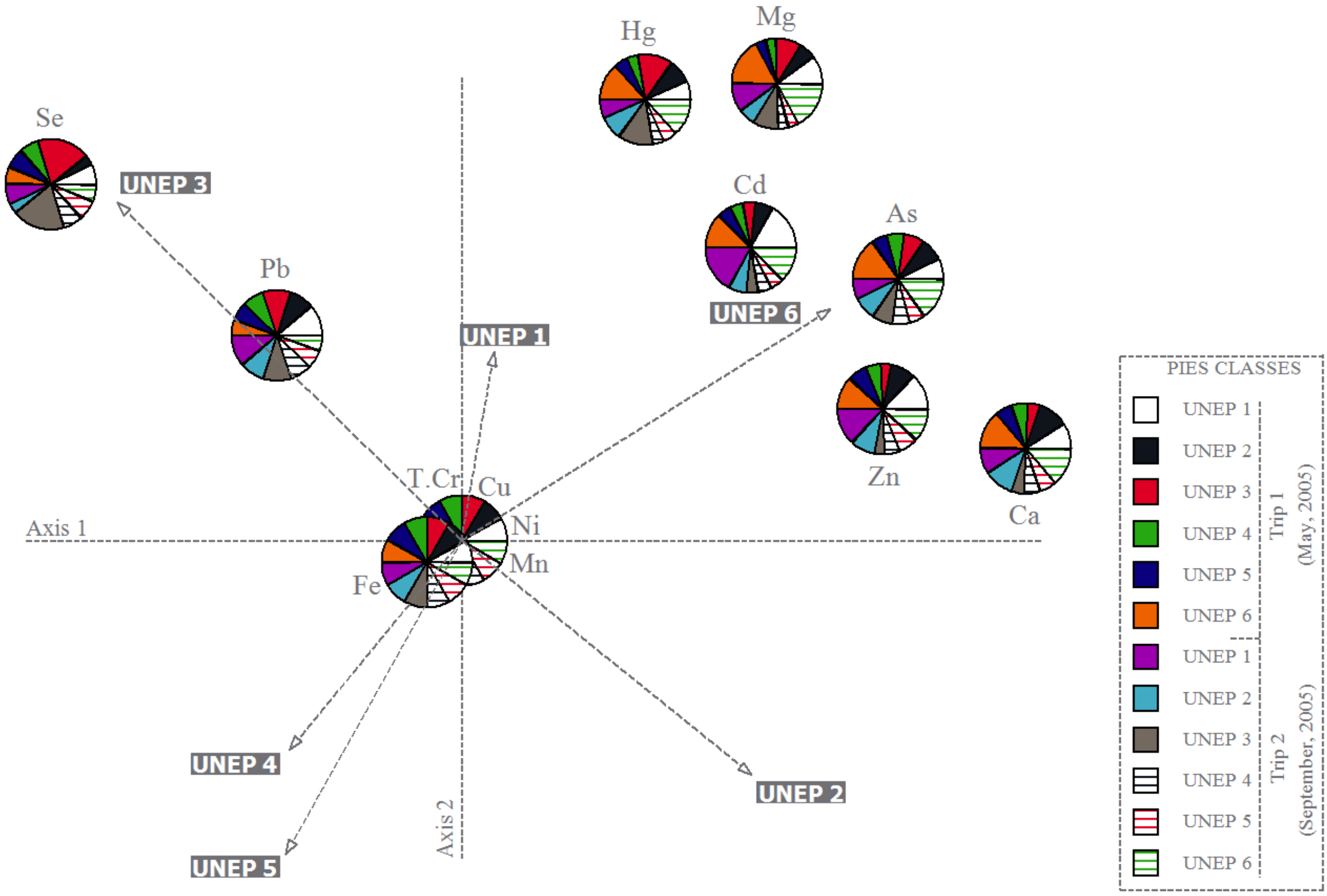


Figure 58: Ordination of UNEP sites in relation to values of Heavy metals, toxics and other environmental variables (May – September 2005).

The preceding heavy metals, toxics and other characteristics of the UNEP sites can be visualized in another way; the figure above illustrates the most important heavy metals, toxics and other property of each site. In addition, Total Chromium, Copper, Nickel, & Manganese pies are illustrated in the center, reflecting there constancy in all sites. (Table 5)

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of particular site. These projections can be used to approximate the level or concentration of individual environmental variables in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classification of the UNEP sites. The relative size of particular pie-slices corresponds to the relative level or concentration of the environmental variable in the particular site (Ter Braak and Šmilauer, 2002).

For instance, Selenium is found in UNEP 3 in relatively higher concentrations than the other studied sites.

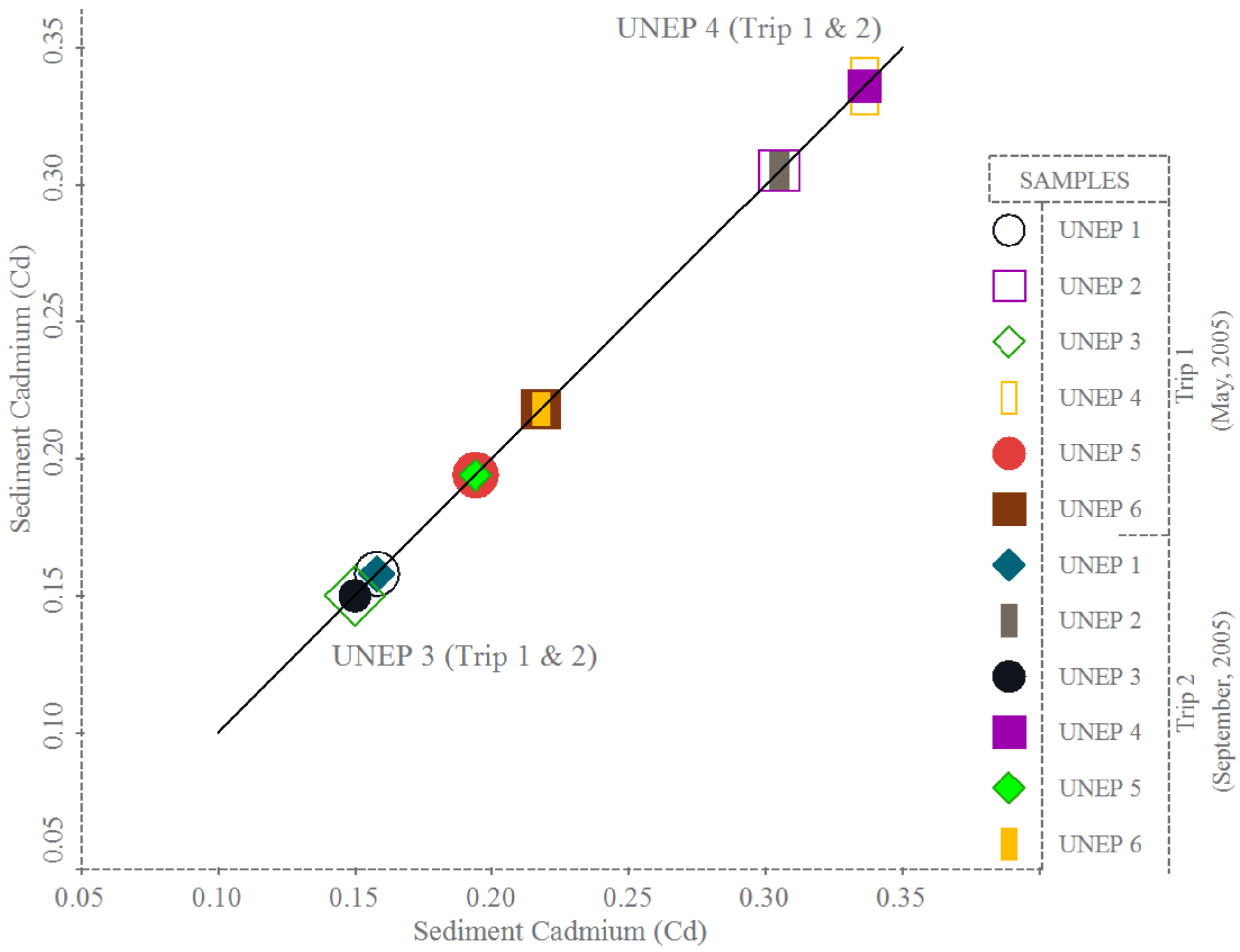


Figure 59: Ordination of UNEP sites in relation to values of Sediment Cadmium (μg/kg), (May – September 2005).

UNEP 4 on both trips had the highest Sediment Cadmium concentrations. UNEP 1 and UNEP 3 had relatively similar and the lowest Sediment Cadmium concentrations on both trips.

UNEP 2 in both trip one and trip two had relatively high concentrations, whereas UNEP 6 and UNEP 5 each, also had the same concentrations on both trips that were relatively low.

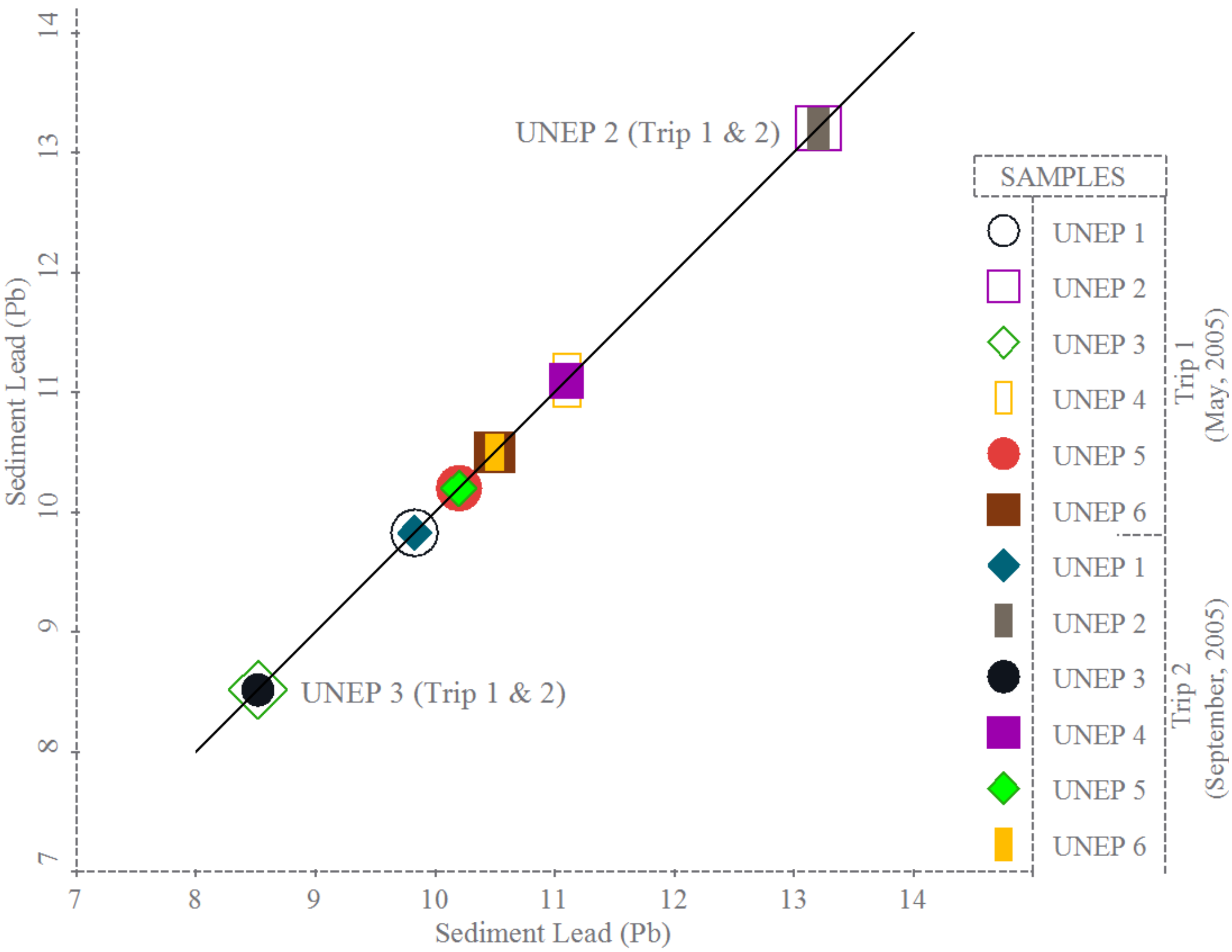


Figure 60: Ordination of UNEP sites in relation to values of Sediment Lead (µg/kg), (May – September 2005).

In both trip one and trip two, UNEP 2 had the highest Sediment Lead concentrations and UNEP 3 had the lower concentrations.

UNEP 4, 6, 5, and UNEP 1 each had the same Sediment Lead concentrations ranging between relatively moderate to low concentrations.

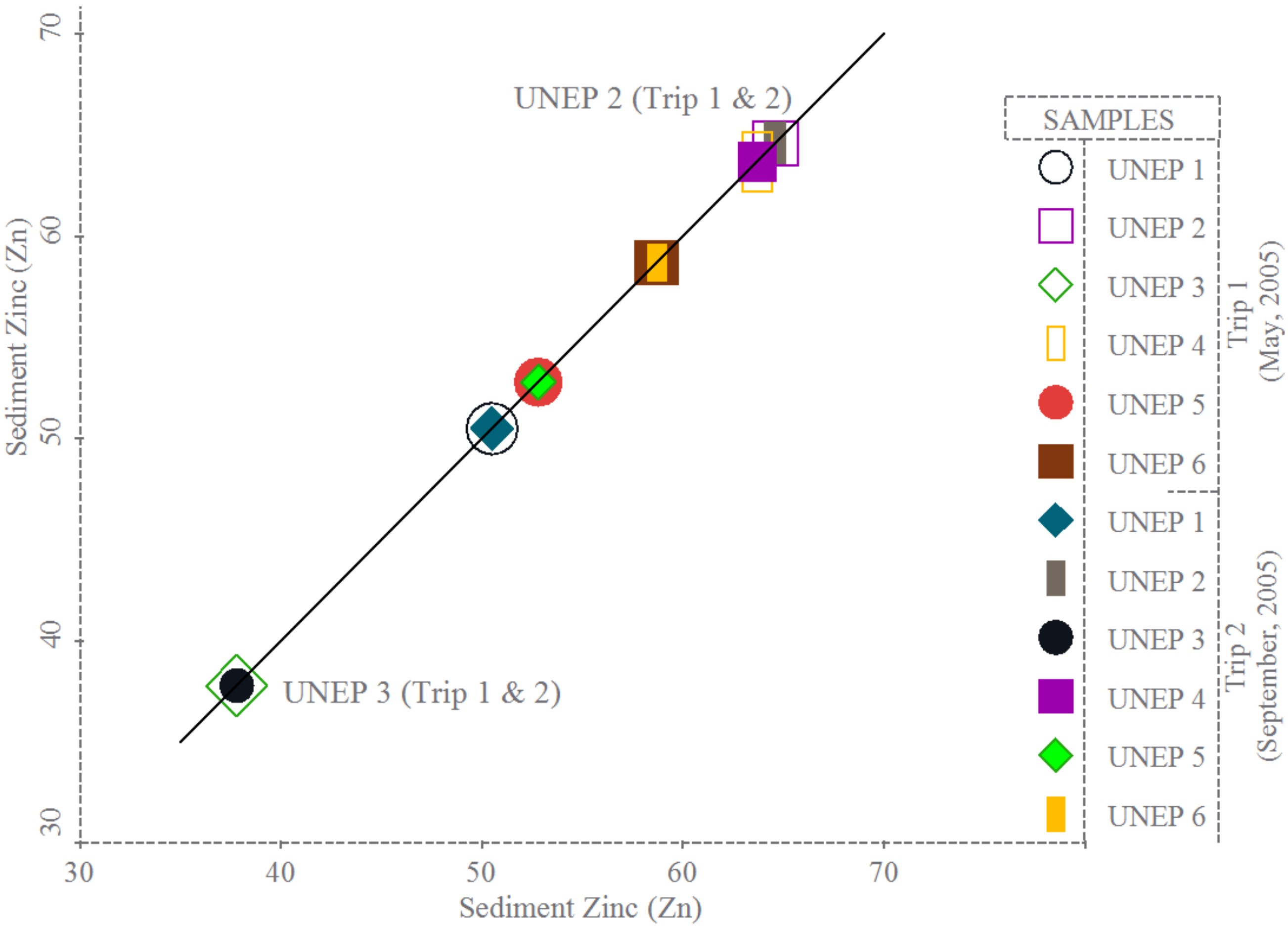


Figure 61: Ordination of UNEP sites in relation to values of Sediment Zinc (µg/kg), (May – September 2005).

All UNEP sites each had the same Sediment Zinc concentrations on both trips.

UNEP 2 and UNEP 4 had relatively similar and the highest Sediment Zinc concentrations, whereas, UNEP 3 had the lowest concentrations of all UNEP sites on both trips.

UNEP 6, 5, and UNEP 1 had relatively moderate Sediment Zinc concentrations on both trips.

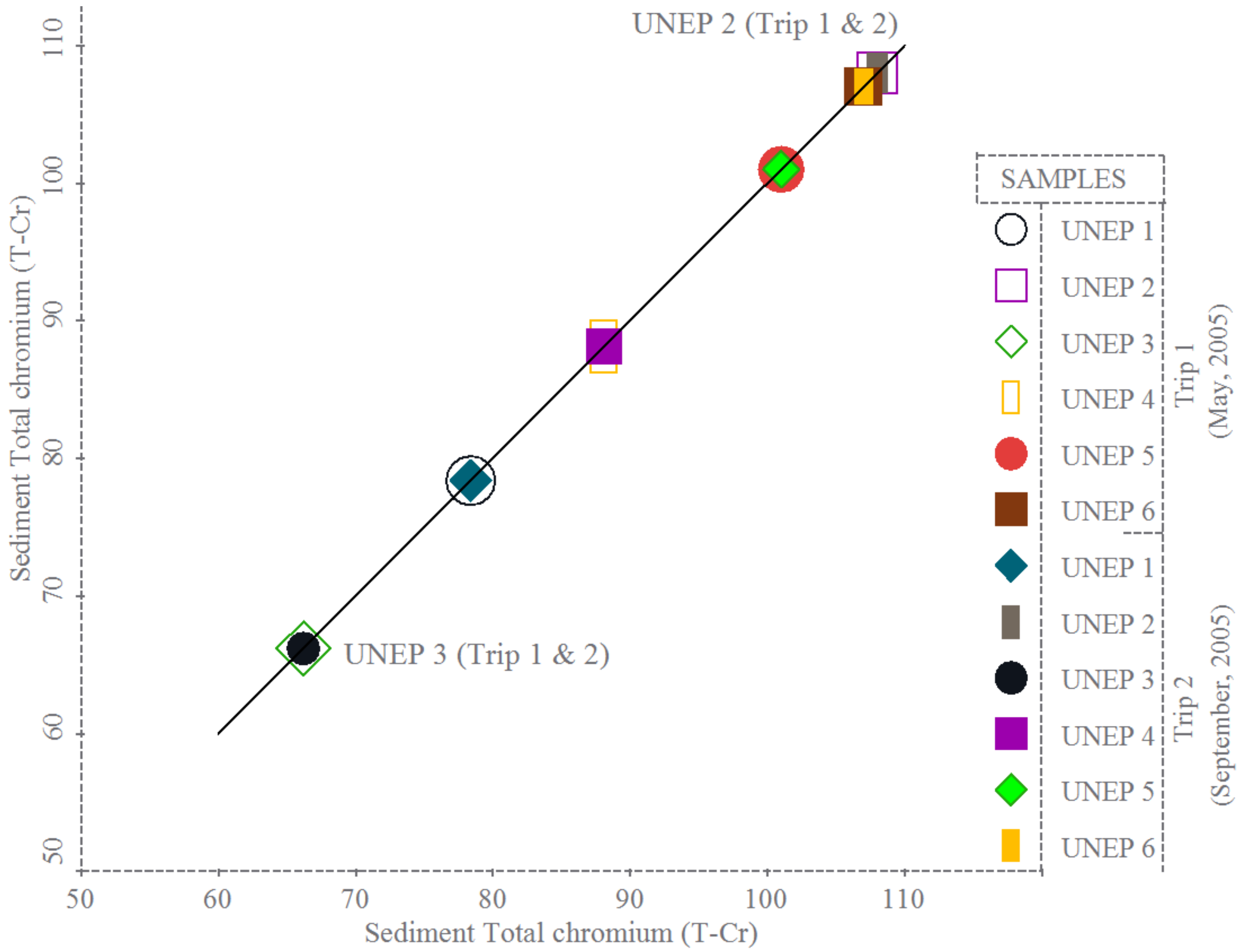


Figure 62: Ordination of UNEP sites in relation to values of Sediment Total chromium (µg/kg), (May – September 2005).

Each UNEP site had the same Sediment Total Chromium concentrations during both trips.

UNEP 2 and UNEP 6 had similar and the highest Sediment Total Chromium concentrations during both trips. UNEP 3 had the lowest concentrations.

UNEP 5, 4, and UNEP 1 had relatively high to moderate concentrations on both trips respectively.

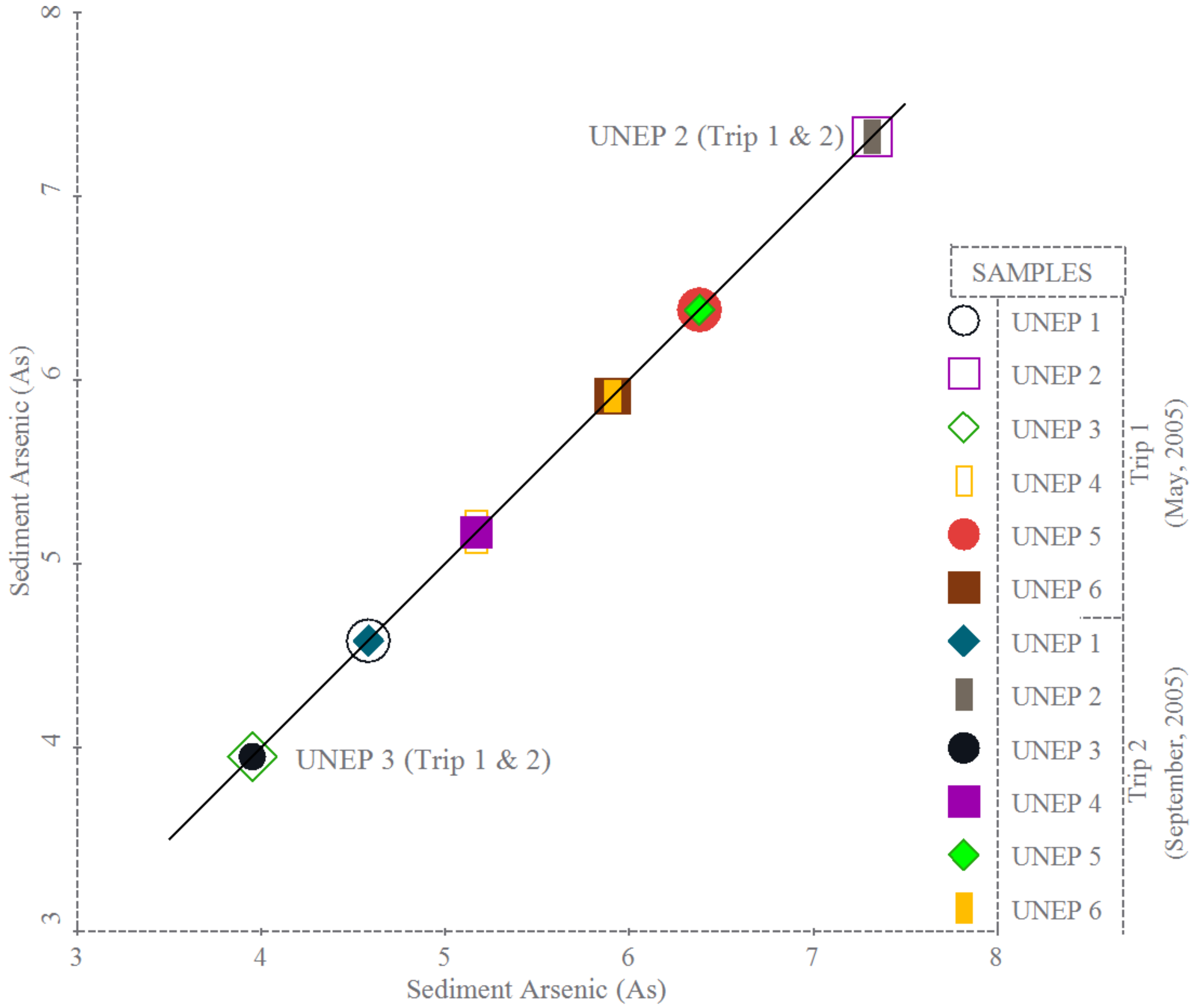


Figure 63: Ordination of UNEP sites in relation to values of Sediment Arsenic (µg/kg), (May – September 2005).

All six UNEP sites had the same Sediment Arsenic concentrations on both trips each.

In both trip one (May, 2005) and trip two (September, 2005) UNEP 2 had the highest Sediment Arsenic concentrations followed by UNEP 5, 6, 4, and 6 respectively. UNEP 3 had the lowest concentrations of all sites on both trips.

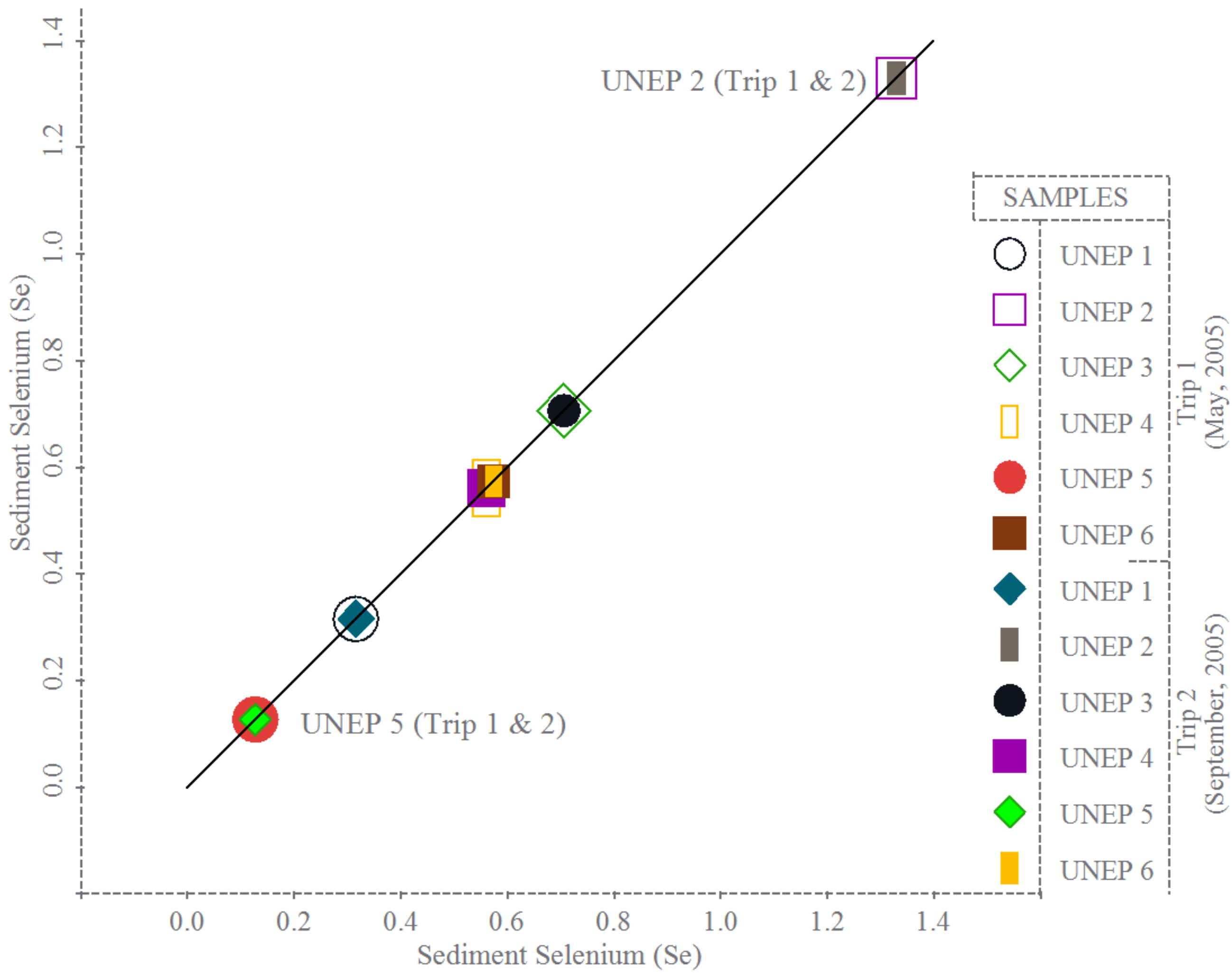


Figure 64: Ordination of UNEP sites in relation to values of Sediment Selenium (µg/kg), (May – September 2005).

Each UNEP site had the same Sediment Selenium concentrations on both trips.

UNEP 2 had the highest concentrations compared with the other sites and UNEP 5 had the lowest concentrations, on both trips.

UNEP 4 and UNEP 6 had the same Sediment Selenium concentrations on both trips. UNEP 3, 6, 4, and 1 had relatively moderate to low concentrations respectively.

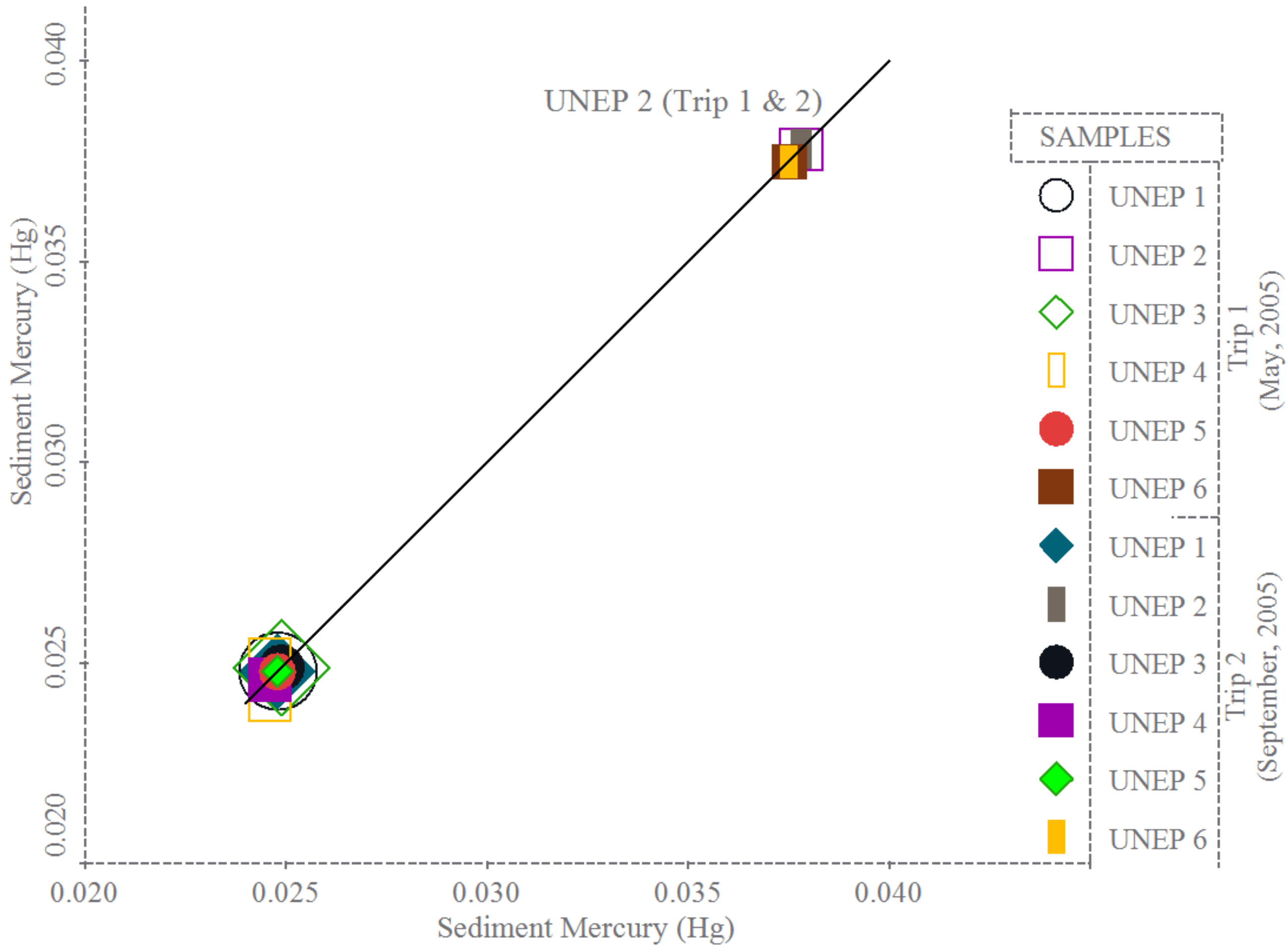


Figure 65: Ordination of UNEP sites in relation to values of Sediment Mercury (µg/kg), (May – September 2005).

Each UNEP site had the same Sediment Mercury concentrations on both trips.

On both trips, UNEP 2 and UNEP 6 had relatively the same and highest Sediment Mercury concentrations.

The other sites had similar and low concentrations on both trips.

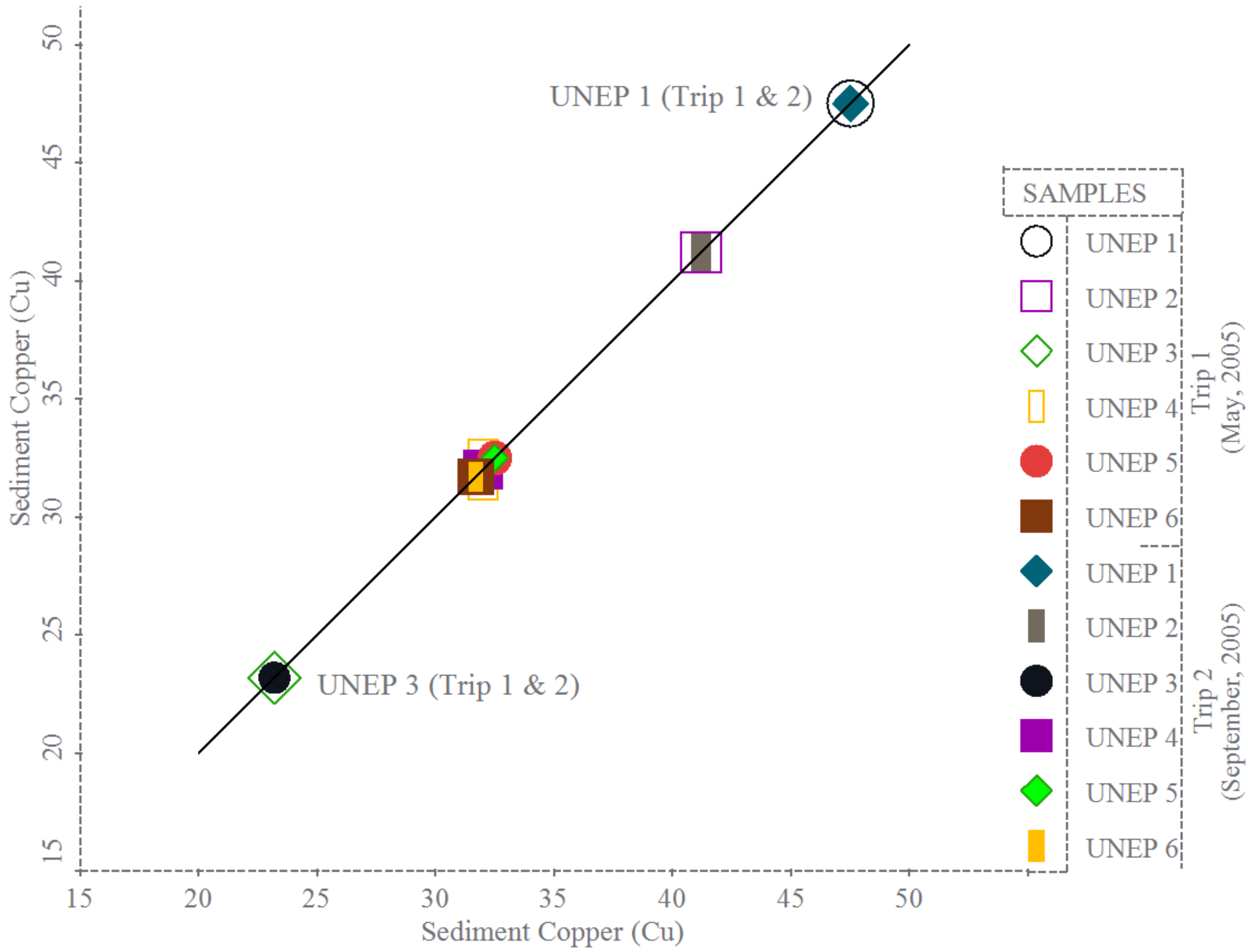


Figure 66: Ordination of UNEP sites in relation to values of Sediment Copper (µg/kg), (May – September 2005).

UNEP 1 had the same and highest Sediment Copper concentrations, whereas UNEP 3 had the same but the lowest concentrations compared with the other sites.

UNEP 2 had relatively higher concentrations compared with UNEP 4, 5 and 6, which had relatively moderate Sediment Copper concentrations.

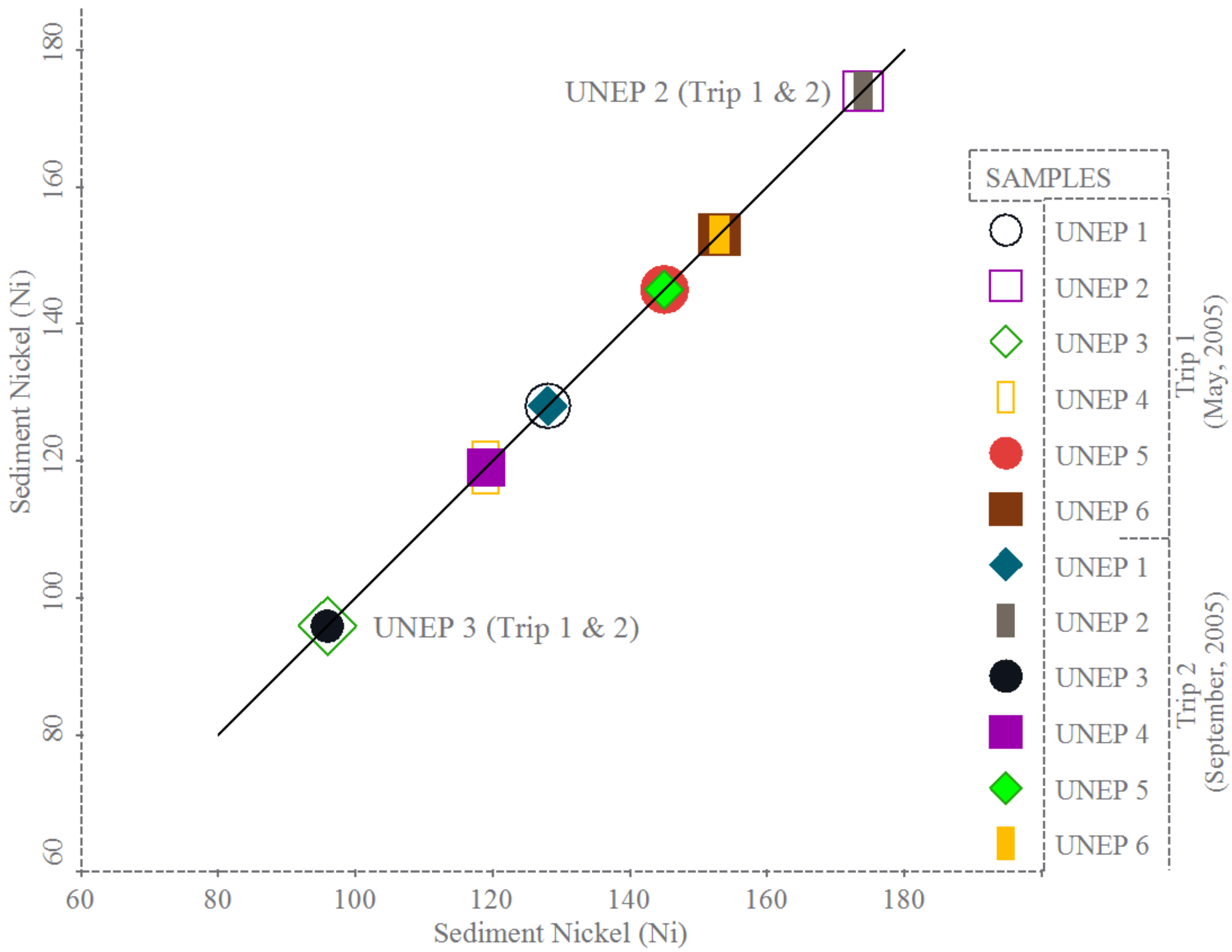


Figure 67: Ordination of UNEP sites in relation to values of Sediment Nickel (µg/kg), (May – September 2005).

Each of the six sites had the same Sediment Nickel concentrations on both trips.

UNEP 2 had the highest and UNEP 3 had the lowest concentrations on both trips compared with the other sites.

UNEP 6, 5, 1, and 4 had relatively moderate concentrations on both trips respectively.

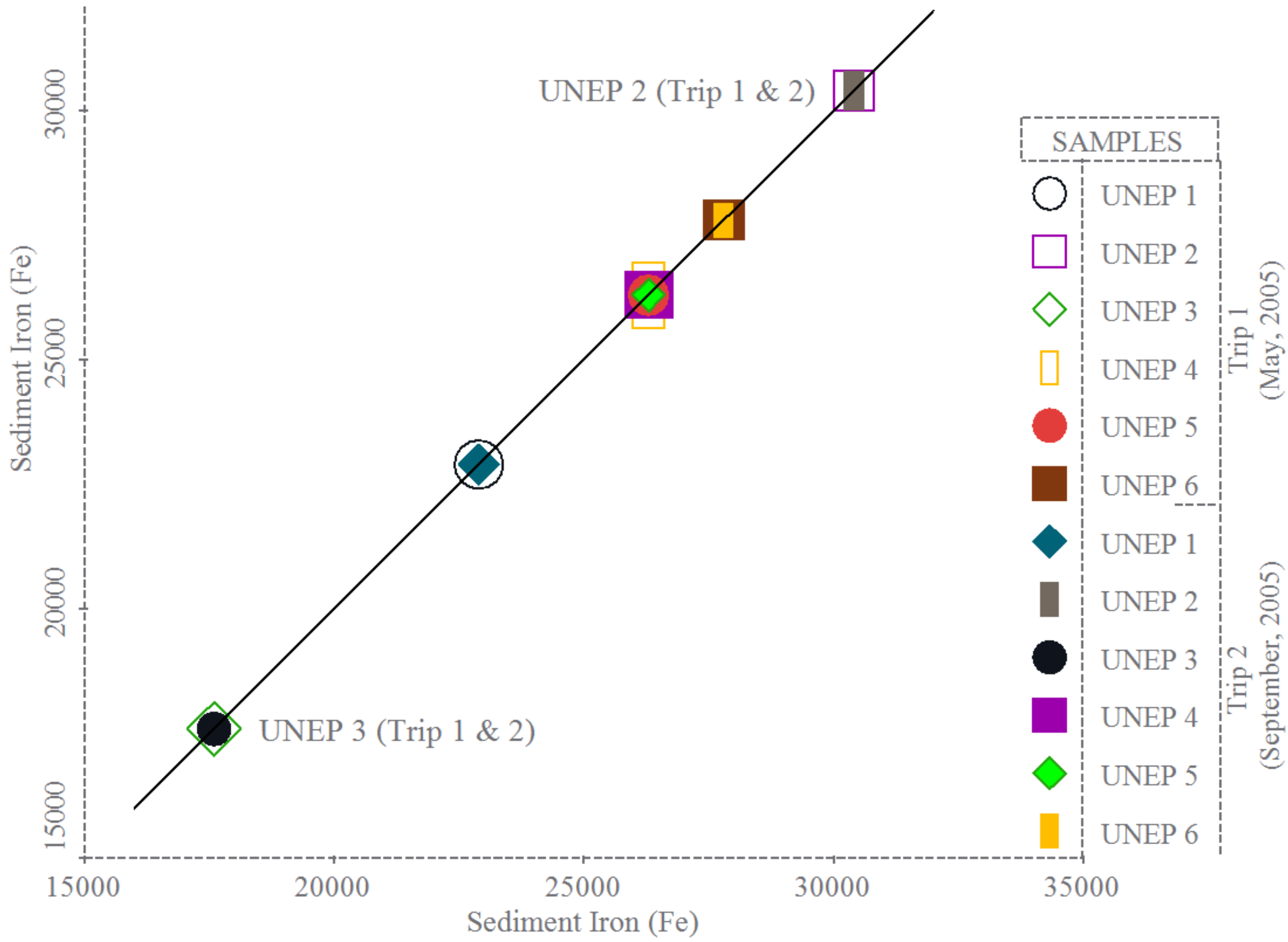


Figure 68: Ordination of UNEP sites in relation to values of Sediment Iron (µg/kg), (May – September 2005).

Each of the six sites had the same Sediment Iron concentrations on both trips.

UNEP 2 had the highest Sediment Iron concentrations on both trips, followed by UNEP 6, 4, 5, and 1 respectively. UNEP 3 had the lowest concentrations of all six sites on both trips.

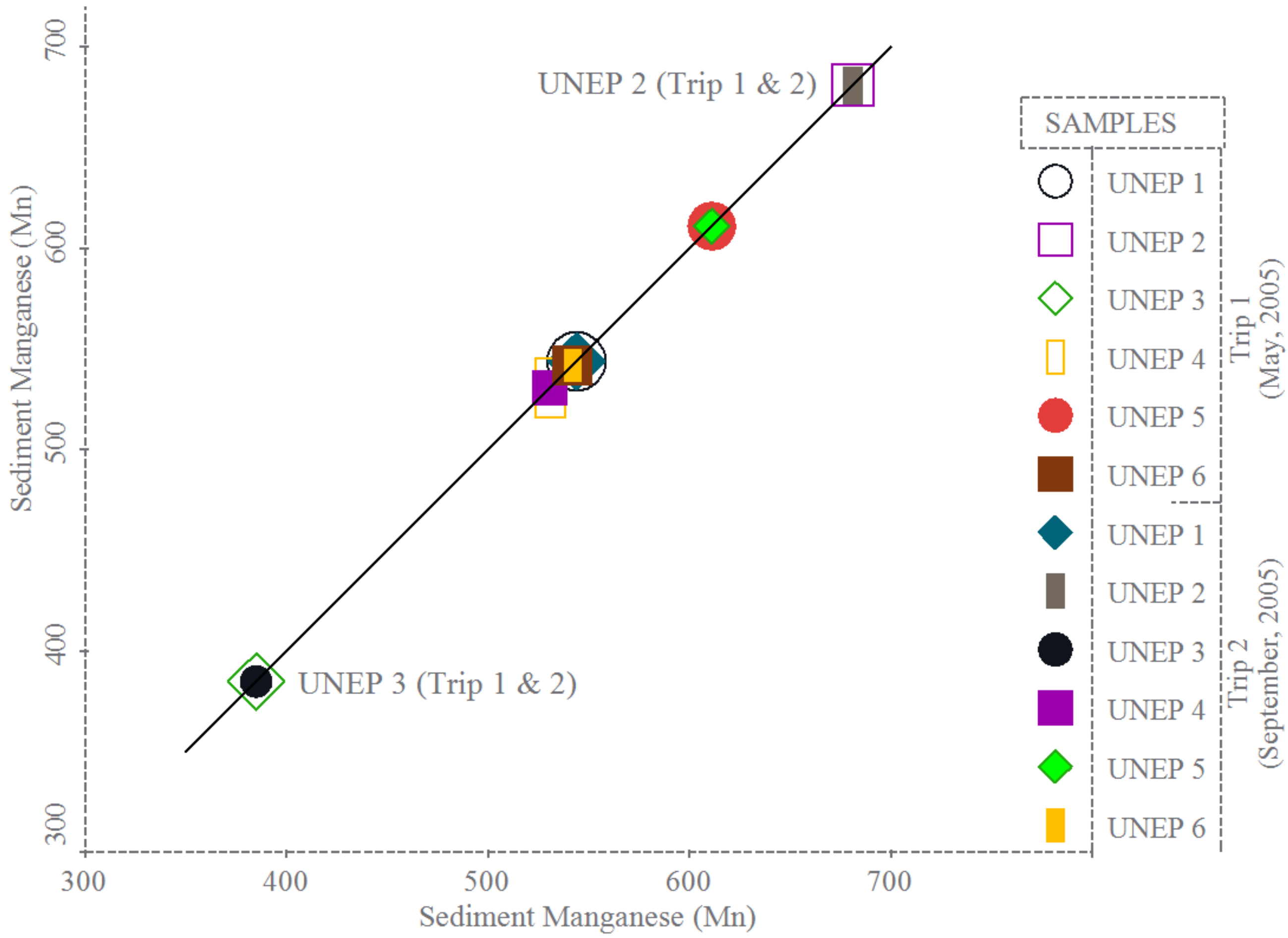


Figure 69: Ordination of UNEP sites in relation to values of Sediment Manganese (µg/kg), (May – September 2005).

Each of the six sites had the same Sediment Manganese concentrations on both trips.

UNEP 2 had the highest Sediment Manganese concentrations on both trips; UNEP 3 had the lowest concentrations of all six sites. UNEP 2 was followed by UNEP 5, 1, 6, and 4 respectively.

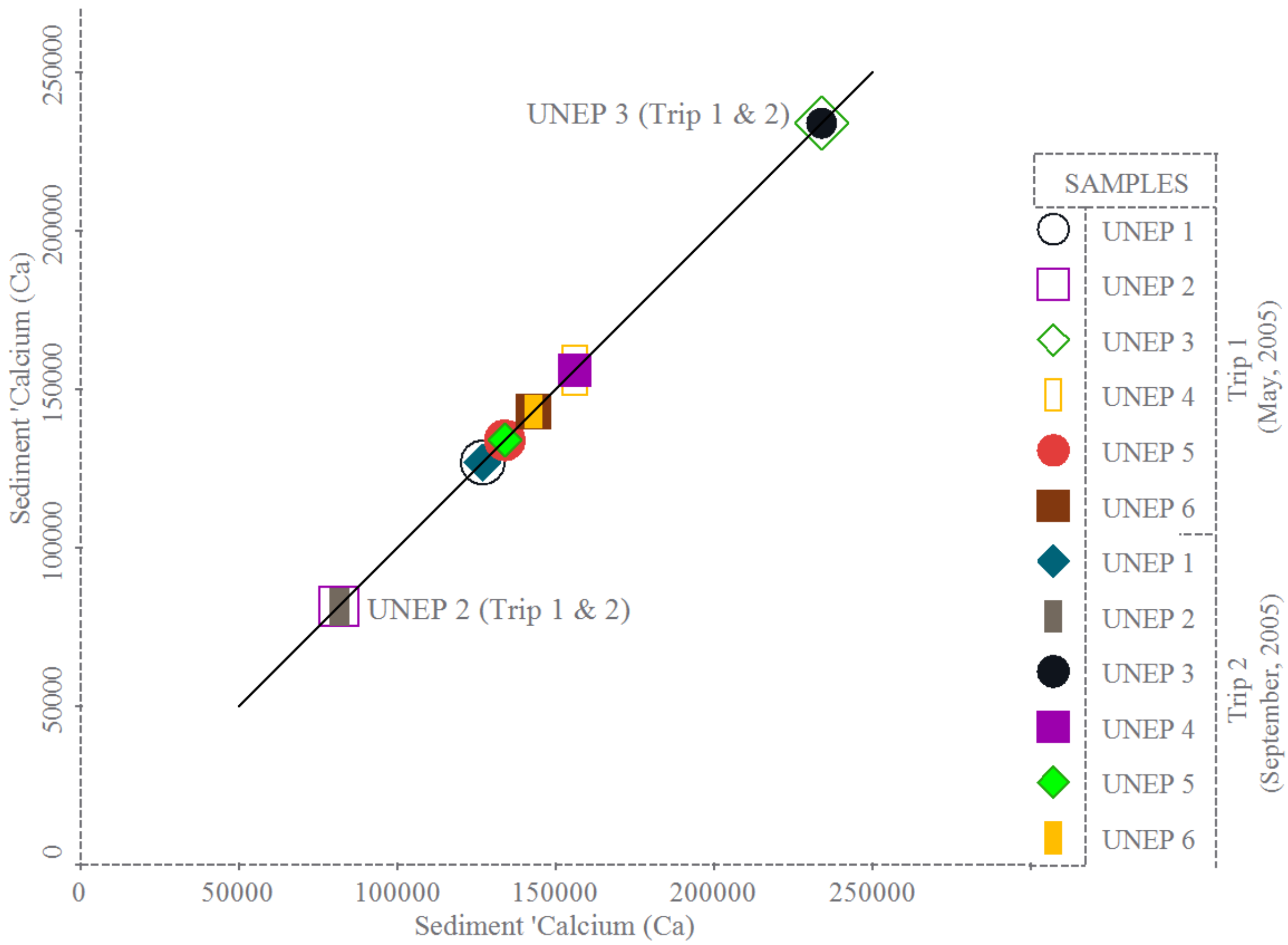


Figure 70: Ordination of UNEP sites in relation to values of Sediment Calcium (µg/kg), (May – September 2005).

Each of the six sites had the same Sediment Calcium concentrations on both trips.

UNEP 3 had the highest Sediment Calcium concentrations on both trips; UNEP 2 had the lowest concentrations on both trips.

UNEP 4, 6, 5, and 1 respectively had rather similar and relatively moderate Sediment Calcium concentrations.

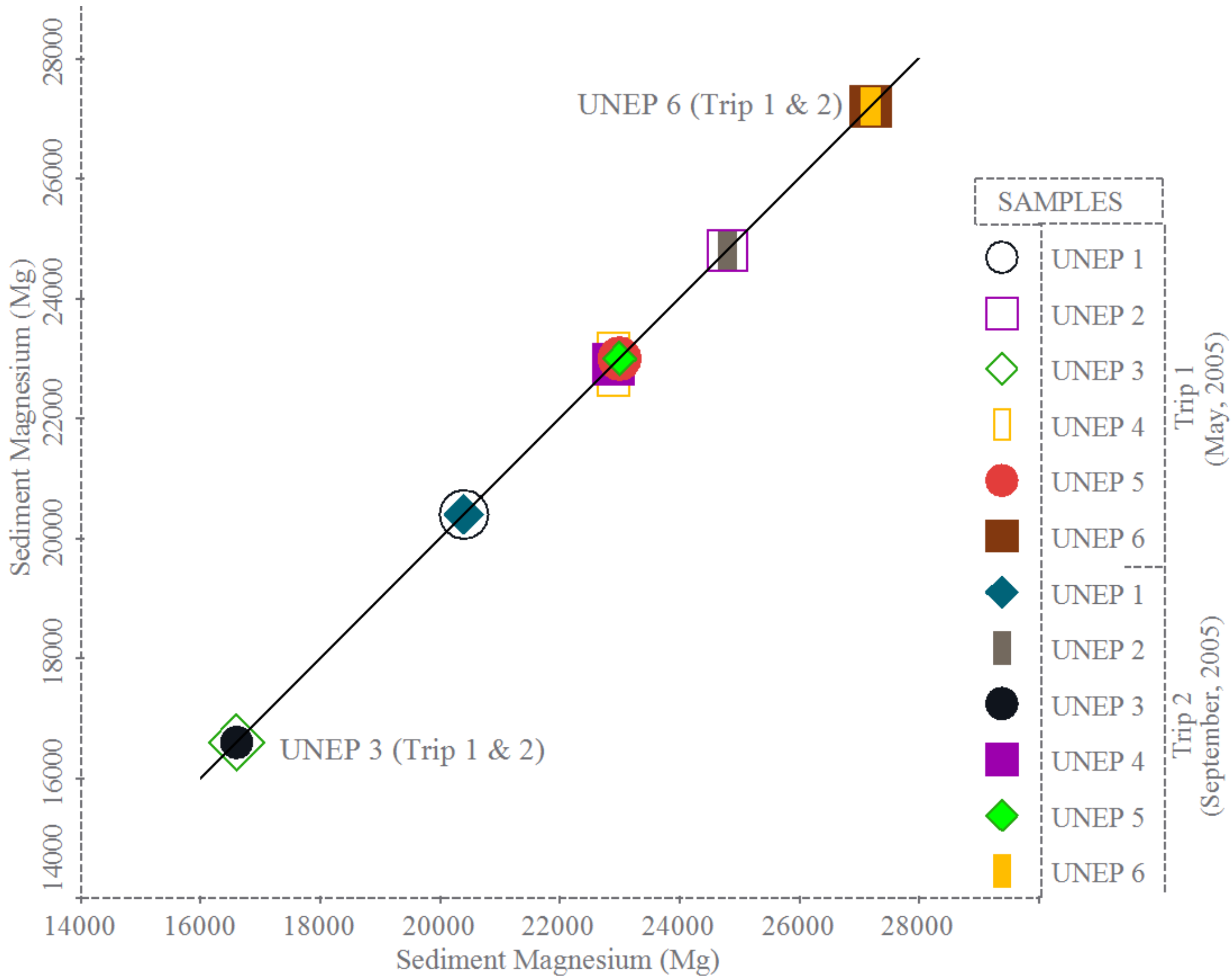


Figure 71: Ordination of UNEP sites in relation to values of Sediment Magnesium (µg/kg), (May – September 2005).

On both trips each of the UNEP sites had the same Sediment Magnesium concentrations.

UNEP 6 had the highest Sediment Magnesium concentrations on both trips and UNEP 3 had the lowest concentrations.

UNEP 6 was followed by UNEP 2, 5, 4 and 1 that had relatively high to moderate Sediment Magnesium concentrations according to the recorded concentrations.

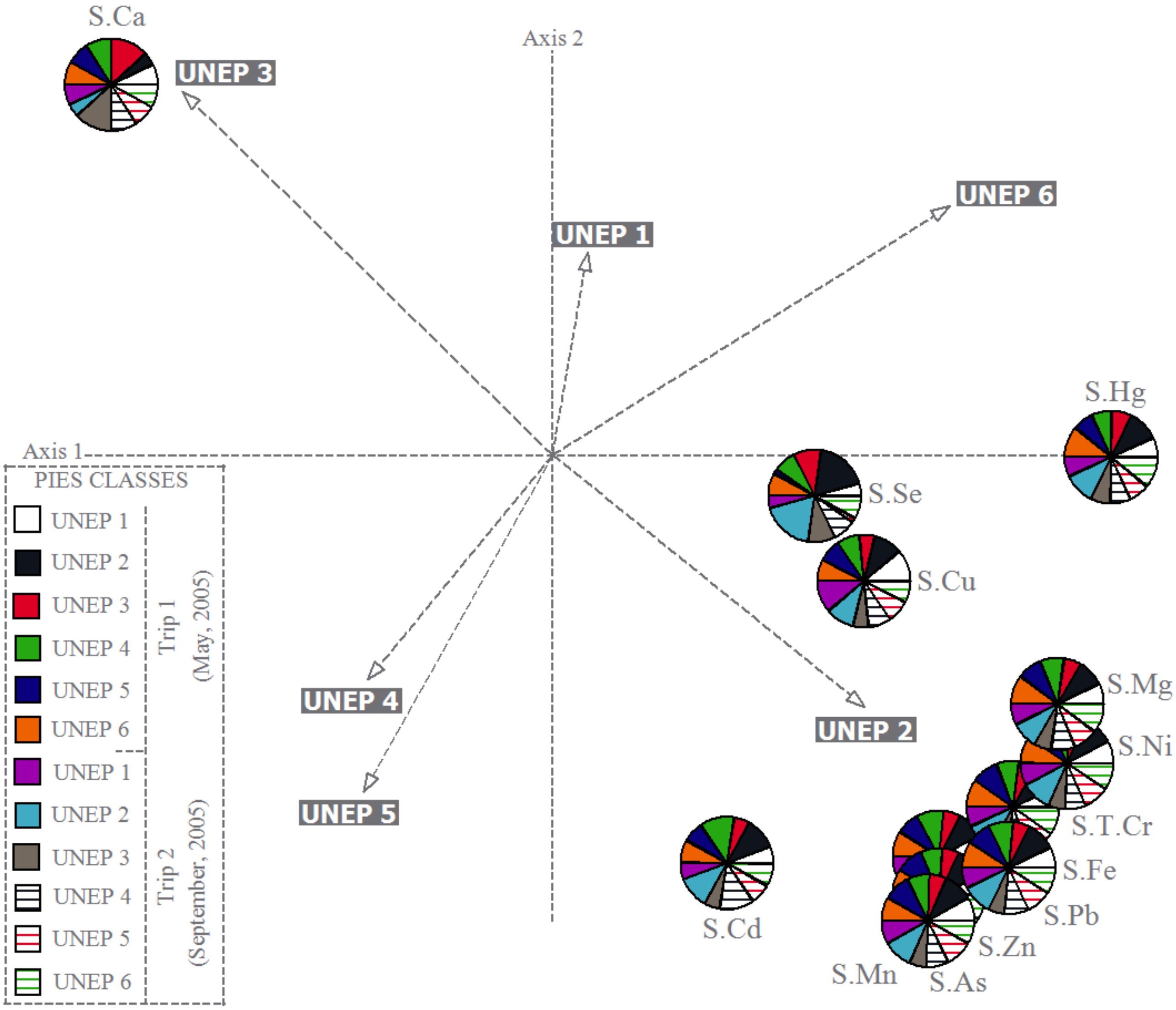


Figure 72: Ordination of UNEP sites in relation to values of Sediment Heavy metals, toxics and other environmental variables, (May – September 2005).

The preceding sediment heavy metals, toxics and other characteristics of the UNEP sites can be visualized in another way; the figure above illustrated the most important sediment Heavy metals, toxics and other property of each site.

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of particular site. These projections can be used to approximate the level or concentration of an individual environmental variable in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classifications of the UNEP sites. The relative size of a particular pie-slice corresponds to the relative level or the concentration of the current environmental variable in the particular site. (Ter Braak and Šmilauer, 2002)

For instance, sediment Calcium is found in UNEP 3 in relatively higher concentrations than the other studied sites.

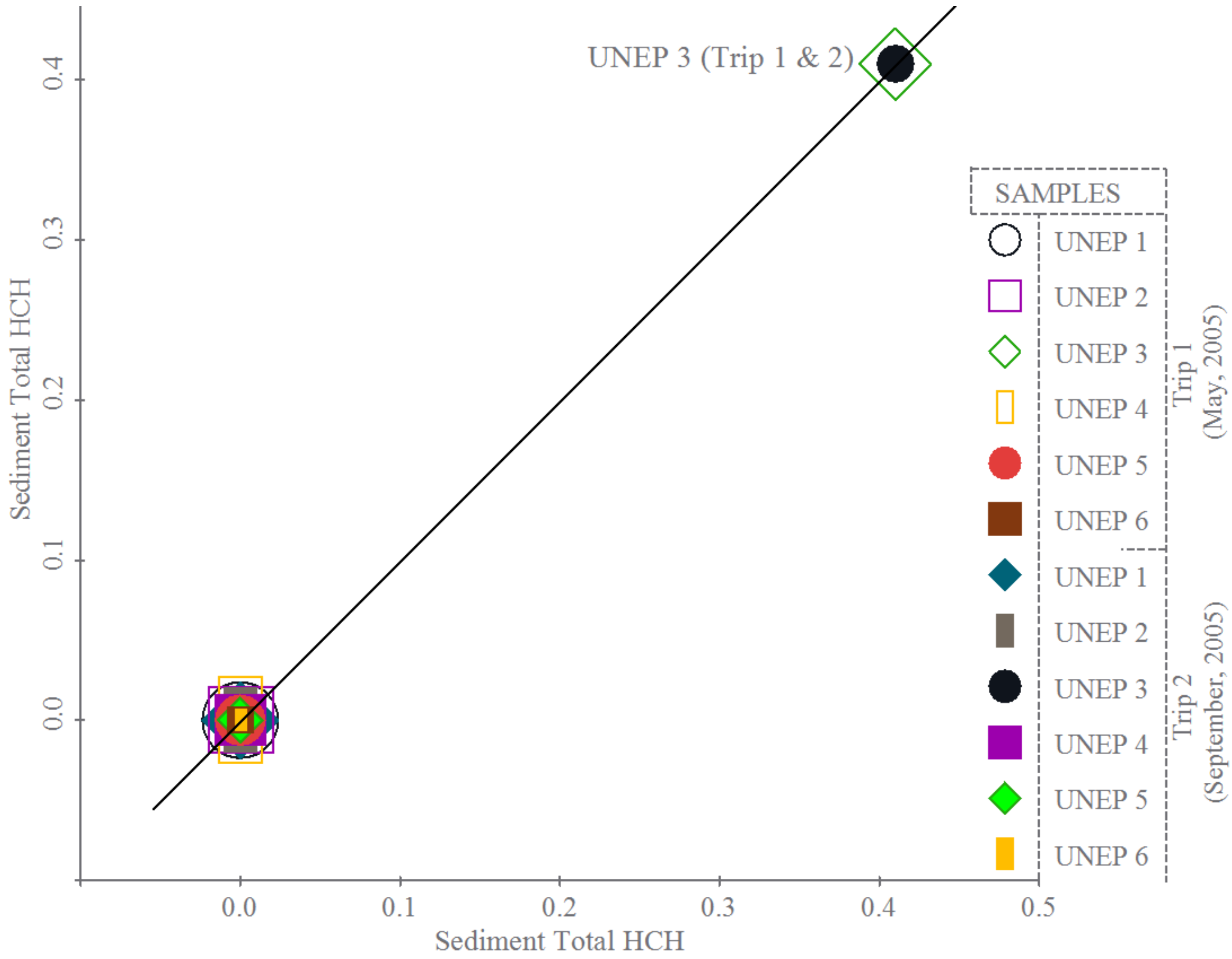


Figure 73: Ordination of UNEP sites in relation to values of Sediment HCH (µg/dry g), (May – September 2005).

On both trips each of the UNEP sites had the same Sediment Total HCH concentrations.

UNEP 3 had the highest concentrations, whereas the other sites during both trips had the same Sediment Total HCH concentrations.

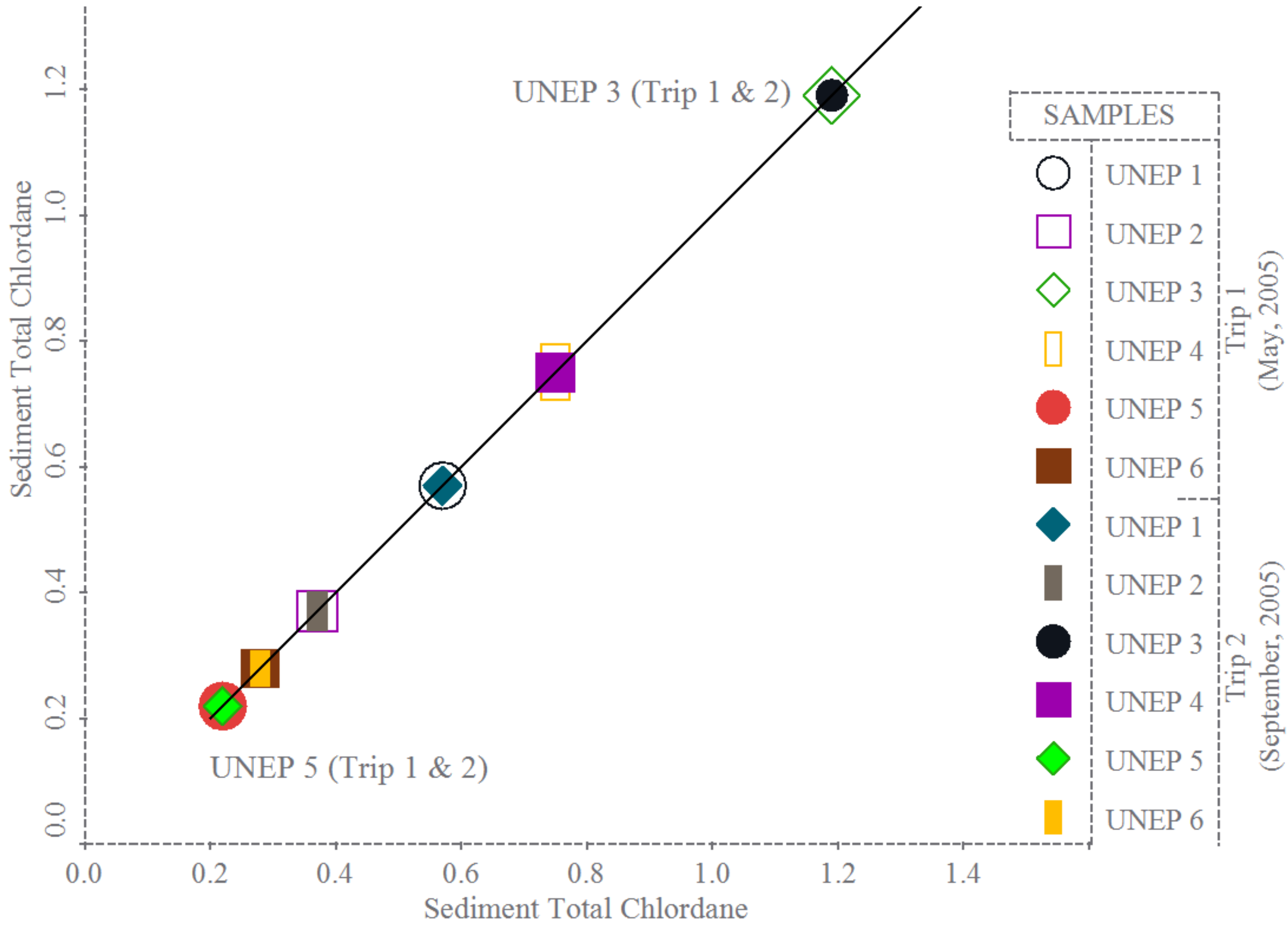


Figure 74: Ordination of UNEP sites in relation to values of Sediment Chlordane (µg/dry g), (May – September 2005).

On both trips each of the UNEP sites had the same Sediment Total Chlordane concentrations.

UNEP 3 had the highest Sediment Total Chlordane concentrations on both trips, followed by UNEP 4 and 1 that had relatively moderate concentrations respectively.

UNEP 5, 6, and 2 had the lowest Sediment Total Chlordane concentrations respectively.

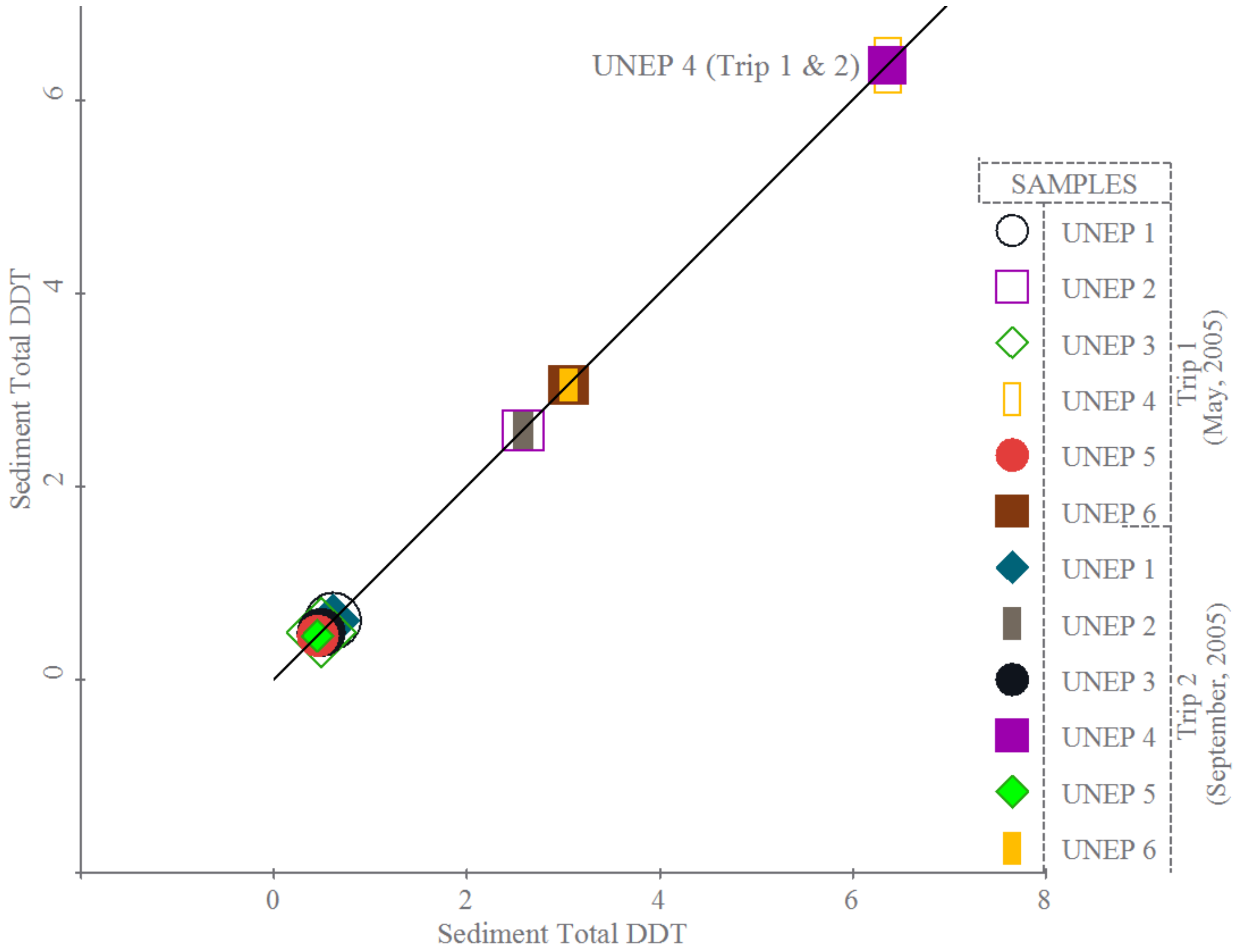


Figure 75: Ordination of UNEP sites in relation to values of Sediment Total DDT (µg/dry g), (May – September 2005).

Each of the six sites had the same Sediment Total DDT concentrations on both trips.

On both trips UNEP 4 had the highest Sediment Total DDT concentrations. UNEP 6 and UNEP 2 had relatively moderate concentrations. Whereas, the other sites had relatively the same and lower Sediment Total DDT concentrations.

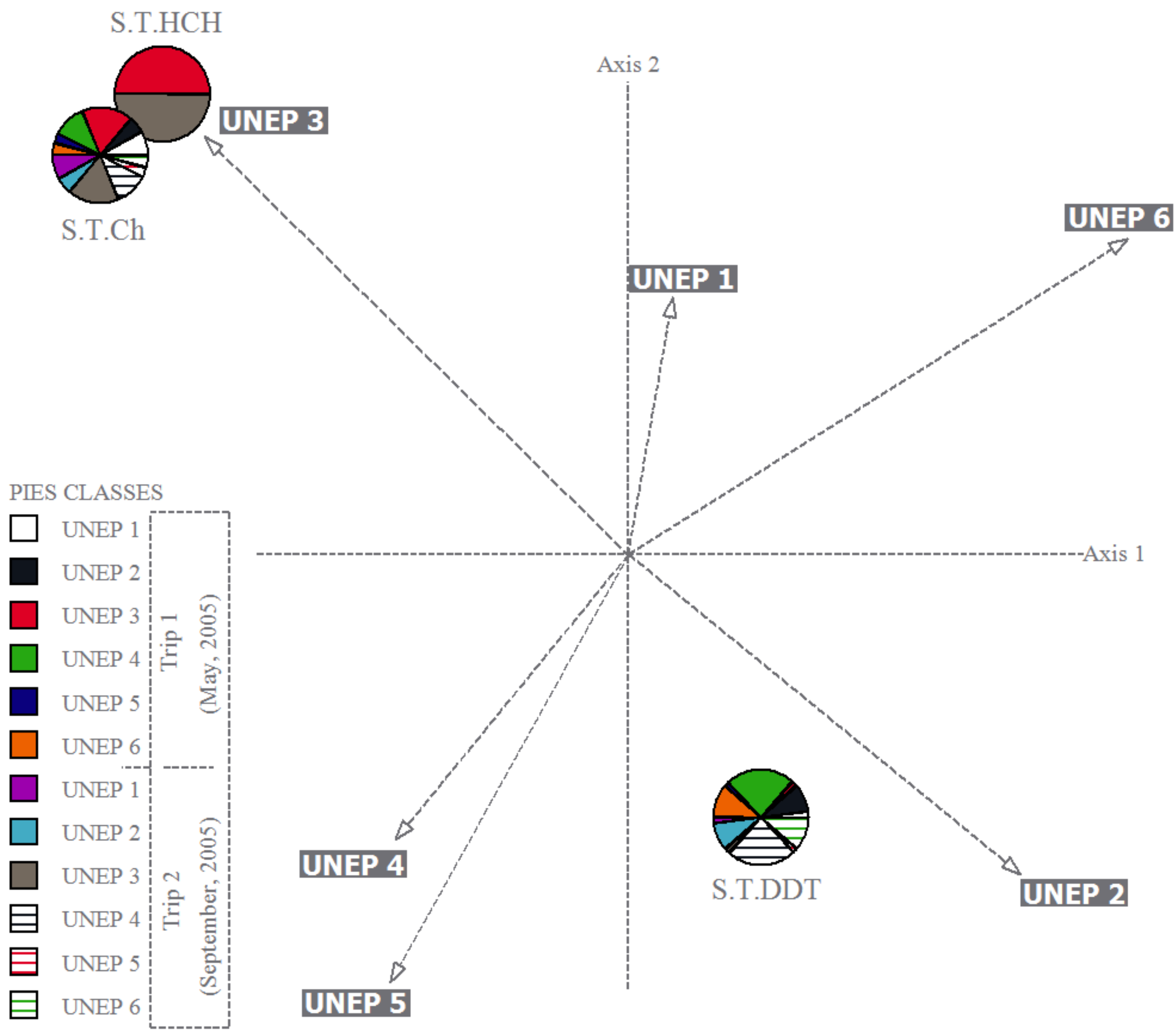


Figure 76: Ordination of UNEP sites in relation to values of Sediment Pesticides and PCBs (May – September 2005).

The preceding sediment Pesticides and PCBs of the UNEP sites can be visualized in another way; the figure above illustrated the most important sediment Pesticides and PCBs of each site.

In the figure above, environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of particular site. These projections can be used to approximate the level or concentration of individual environmental variables in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classification of UNEP sites. The relative size of particular pie-slices corresponds to the relative level or concentration of the environmental variable in the particular site (Ter Braak and Šmilauer, 2002).

For instance, sediment total HCH is found exclusively in UNEP 3.

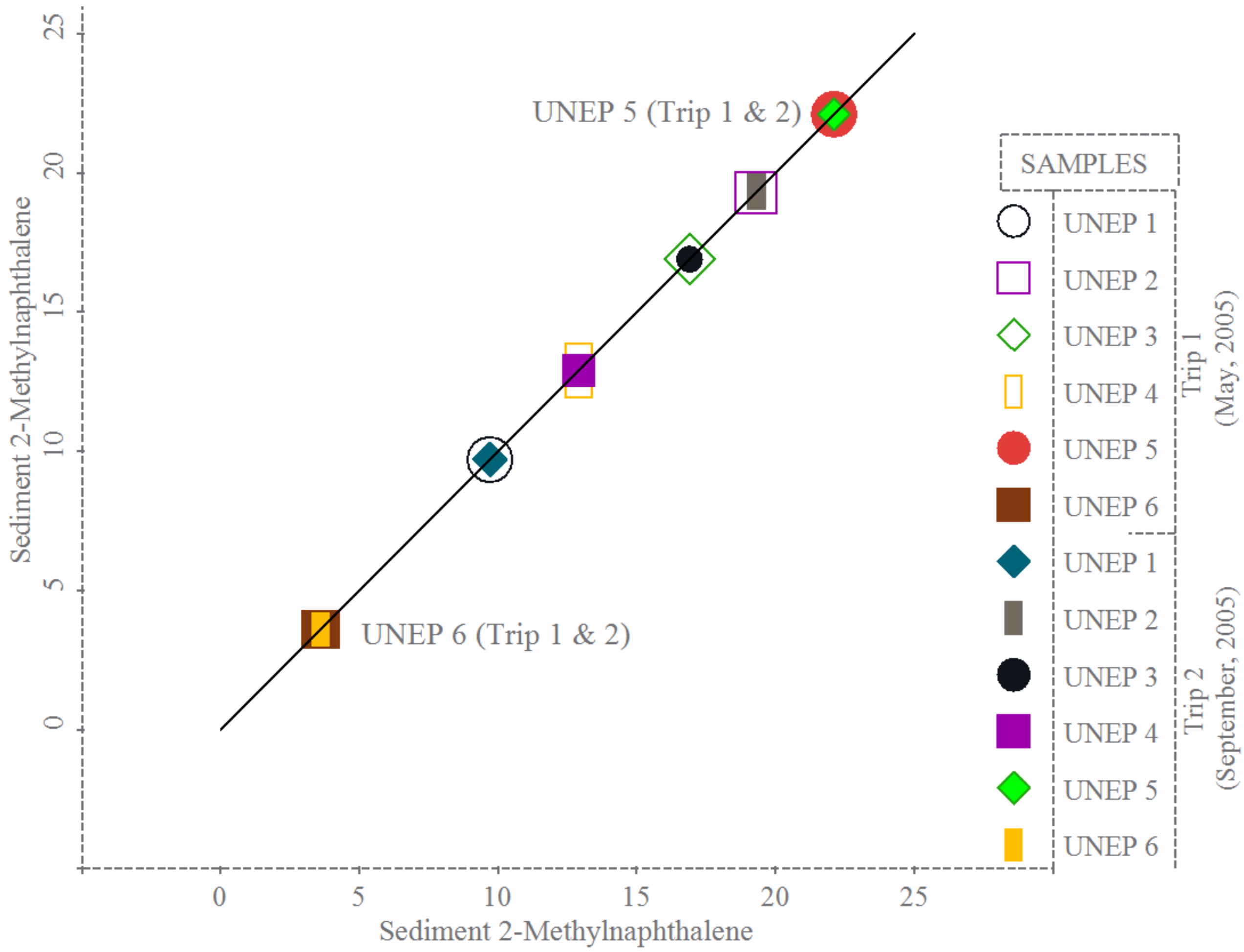


Figure 77: Ordination of UNEP sites in relation to values of Sediment 2-Methylnaphthalene (µg/dry g), (May – September 2005).

Each of the six sites had the same Sediment 2-Methylnaphthalene concentrations on both trips.

UNEP 5 had the highest concentrations on both trips followed by UNEP 2, 3, 4, and 1 that had relatively high to moderate concentrations, respectively.

UNEP 6 had the lowest Sediment 2-Methylnaphthalene concentrations compared with the other sites.

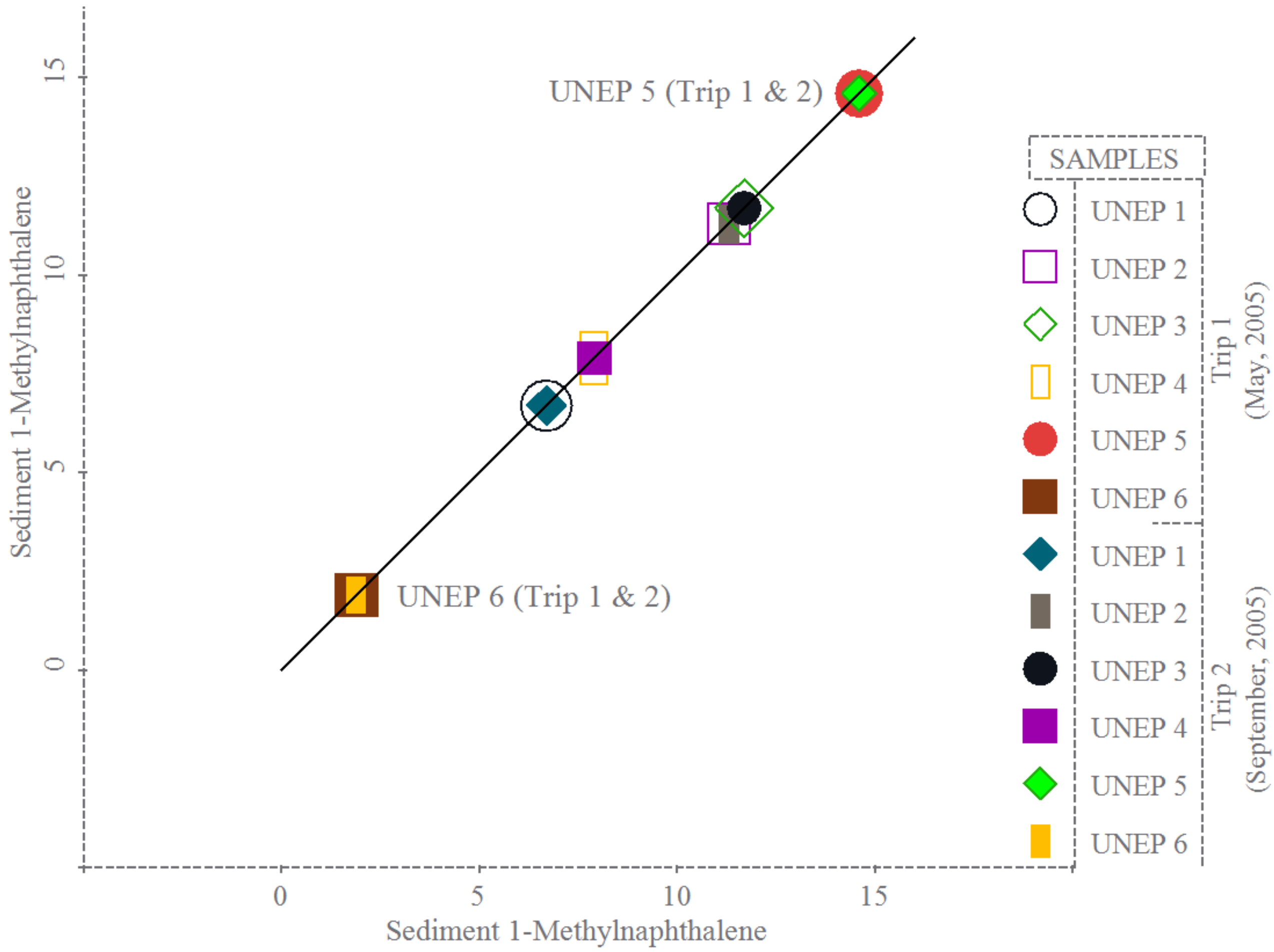


Figure 78: Ordination of UNEP sites in relation to values of Sediment 1-Methylnaphthalene (µg/dry g), (May – September 2005).

Each of the six sites had the same Sediment 1-Methylnaphthalene concentrations on both trips.

UNEP 5 had the highest concentrations on both trips followed by UNEP 3, 2, 4, and 1 that had relatively high to moderate concentrations, respectively.

UNEP 6 had the lowest Sediment 1-Methylnaphthalene concentrations compared with the other sites.

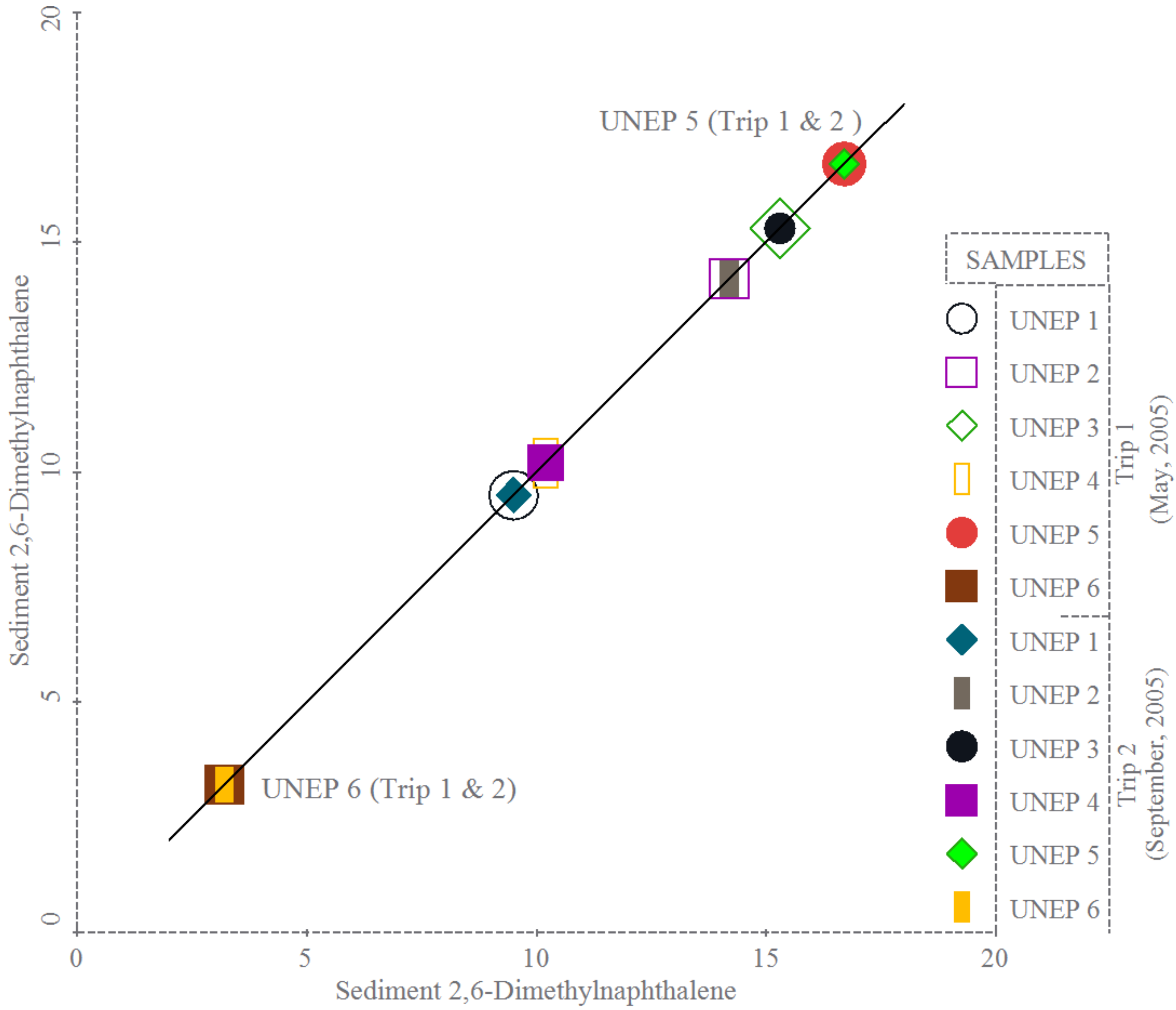


Figure 79: Ordination of UNEP sites in relation to values of Sediment 2, 6-Dimethylnaphthalene (µg/dry g), (May – September 2005).

Each of the six sites had the same Sediment 2, 6-Dimethylnaphthalene concentrations on both trips.

UNEP 5 had the highest concentrations on both trips followed by UNEP 3, and 2 that had relatively high concentrations, respectively.

UNEP 4 and 1 had relatively moderate concentrations of Sediment 2, 6-Dimethylnaphthalene on both trips.

UNEP 6 had the lowest concentrations compared to the other sites.

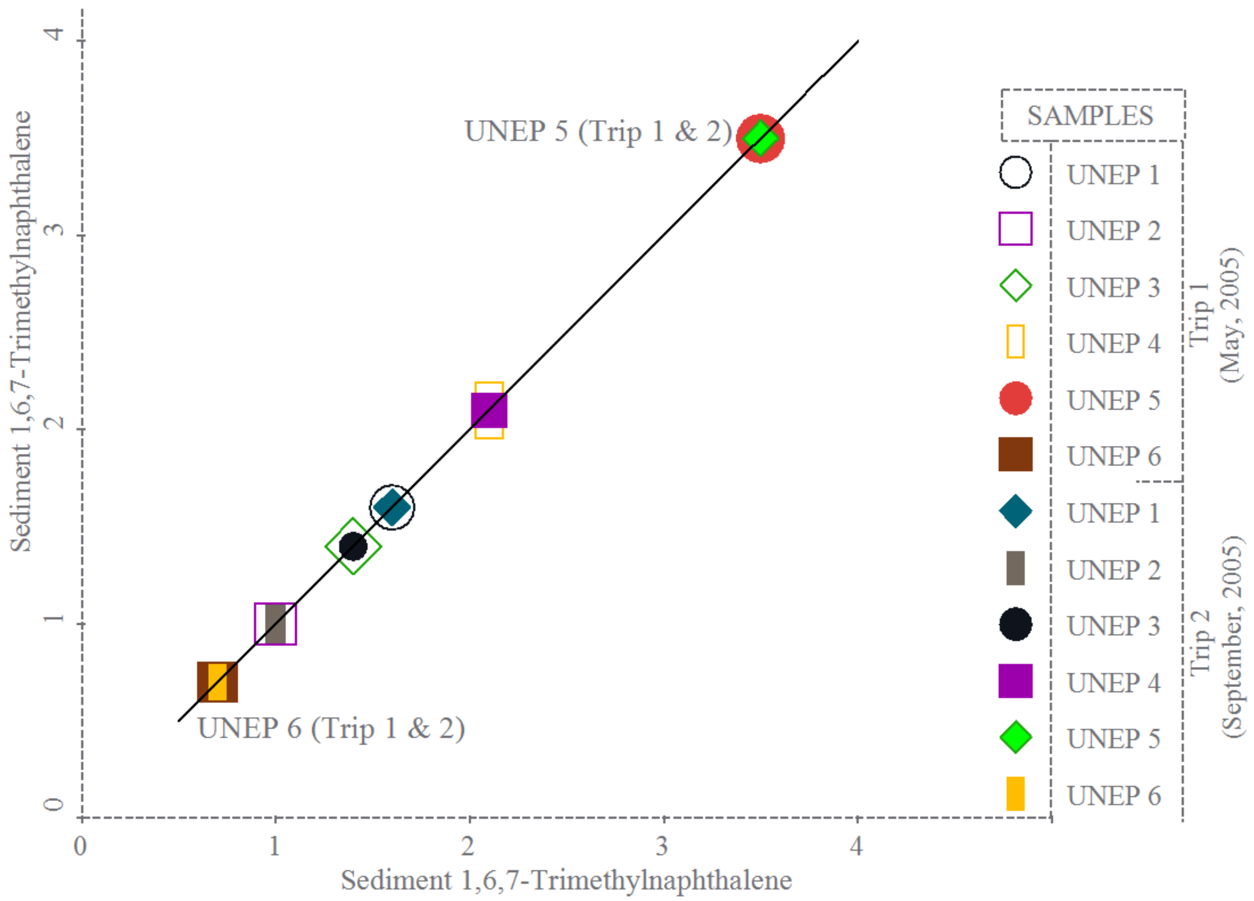


Figure 80: Ordination of UNEP sites in relation to values of Sediment 1,6,7-Trimethylnaphthalene (µg/dry g), (May – September 2005).

Each of the six sites had the same Sediment 1,6,7-Trimethylnaphthalene concentrations on both trips.

On both trips, UNEP 5 had the highest concentrations followed by UNEP 4, 1, 3, and 2 that had relatively low Sediment 1,6,7-Trimethylnaphthalene concentrations on both trips.

Compared with the other sites, UNEP 6 had the lowest concentrations.

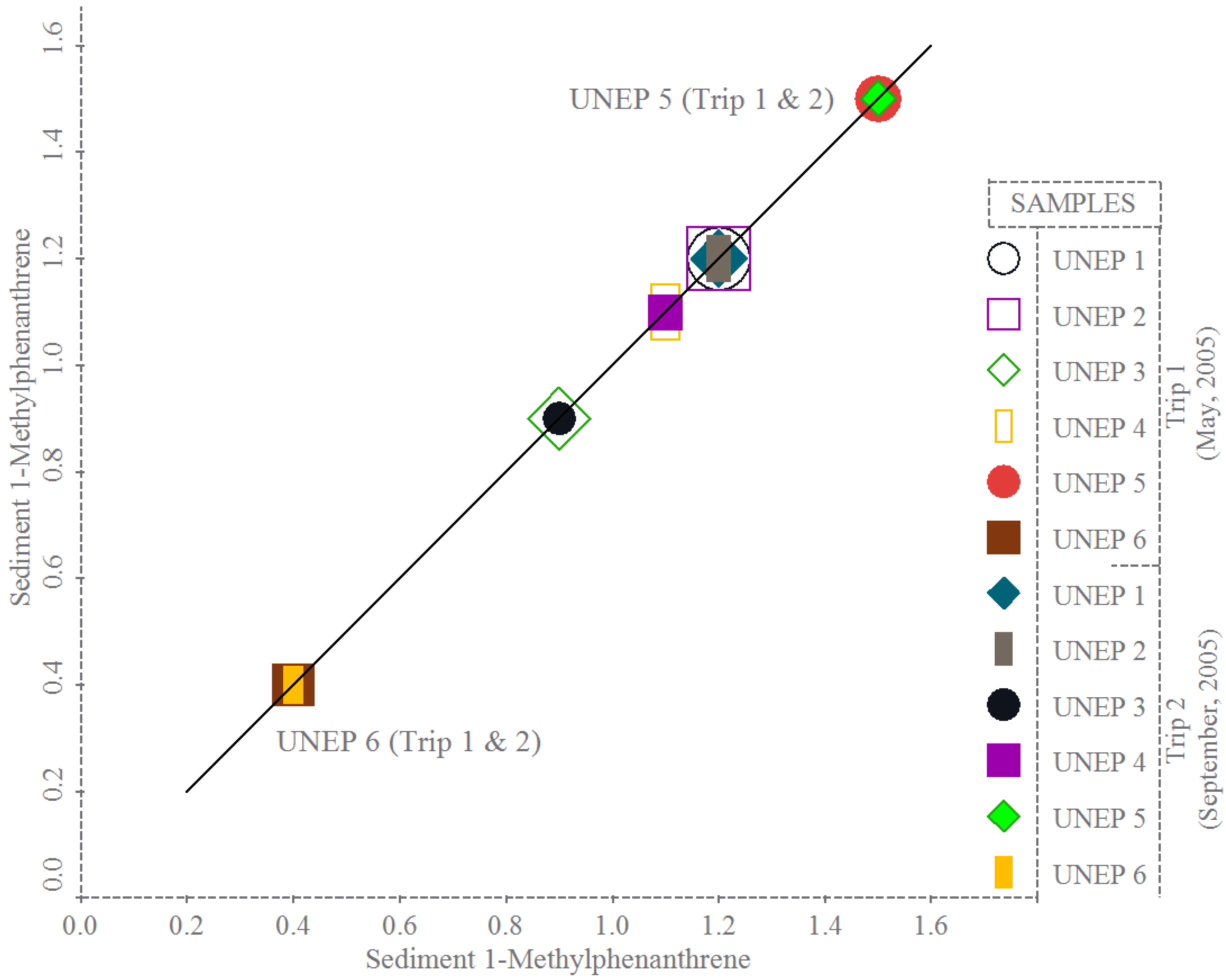


Figure 81: Ordination of UNEP sites in relation to values of Sediment 1-Methylphenanthrene (μg/dry g), (May – September 2005).

Each of the six sites had the same Sediment 1-Methylphenanthrene concentrations on both trips.

UNEP 5 had the highest concentrations on both trips followed by UNEP 1, 2, 4, and 3 that had relatively high to moderate concentrations, respectively.

Compared with the other sites, UNEP 6 had the lowest concentrations.

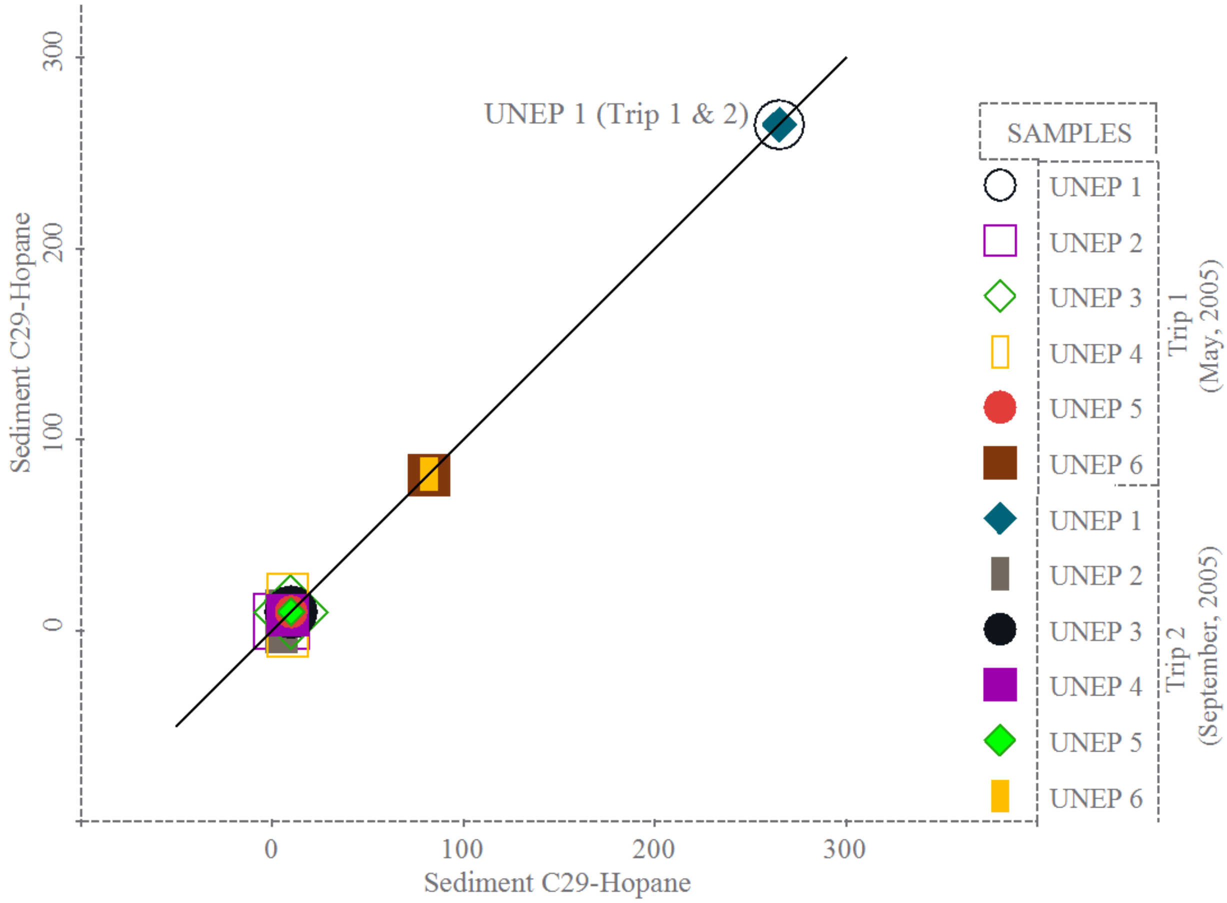


Figure 82: Ordination of UNEP sites in relation to values of Sediment C29-Hopane (µg/dry g), (May – September 2005).

All six UNEP sites each, had the same Sediment C29-Hopane concentrations on both trips.

On both trips, UNEP 1 had the highest Sediment C29-Hopane concentrations.

UNEP 6 had relatively low concentrations. UNEP 5, 2, 3, and 4 had the same and lowest Sediment C29-Hopane concentrations on both trips.

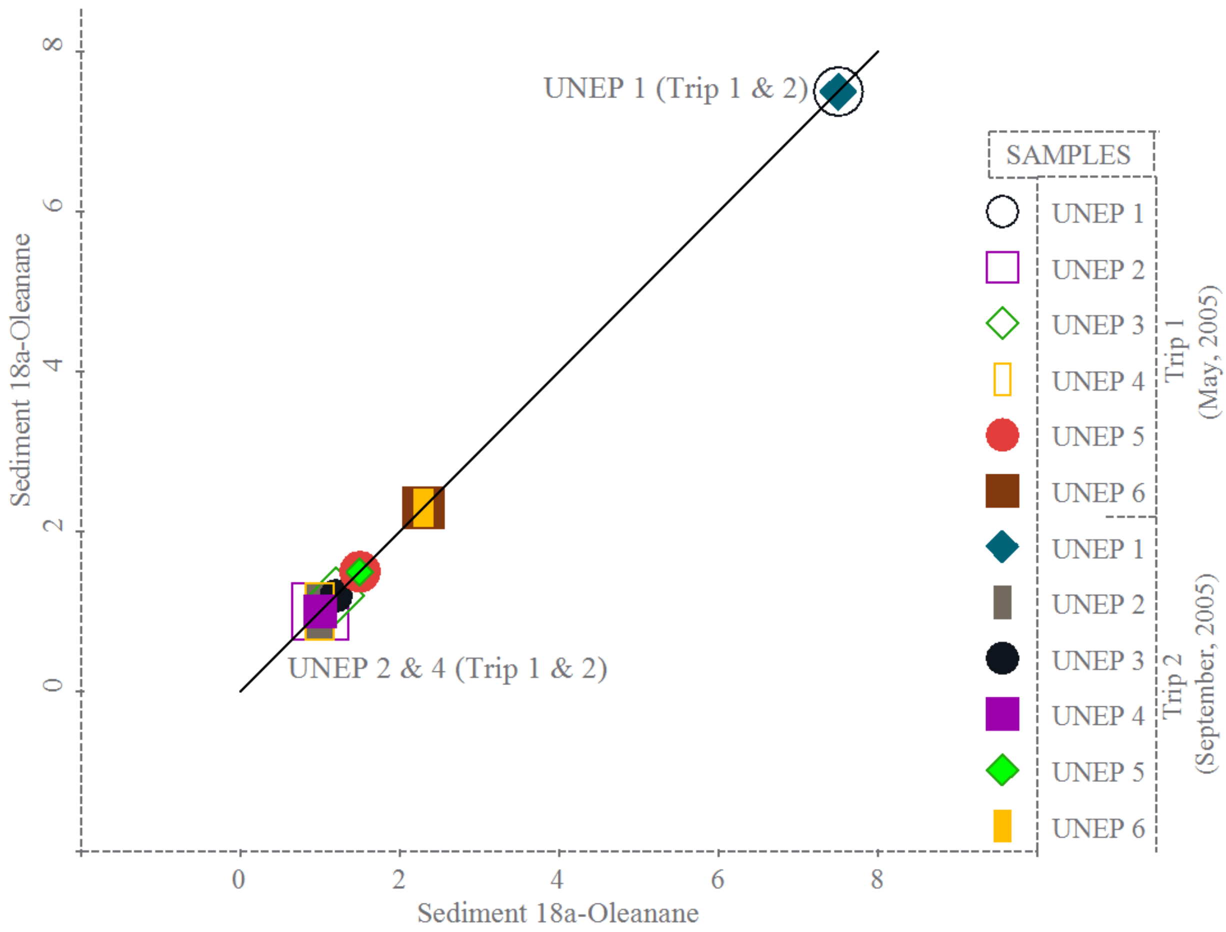


Figure 83: Ordination of UNEP sites in relation to values of Sediment 18a-Oleanane (µg/dry g), (May – September 2005).

All six UNEP sites had the same Sediment 18a-Oleanane concentrations on both trips.

On both trips, UNEP 1 had the highest Sediment 18a-Oleanane concentrations.

UNEP 6 had relatively low concentrations. UNEP 5, 3, 2, and 4 had the same and lower Sediment 18a-Oleanane concentrations on both trips.

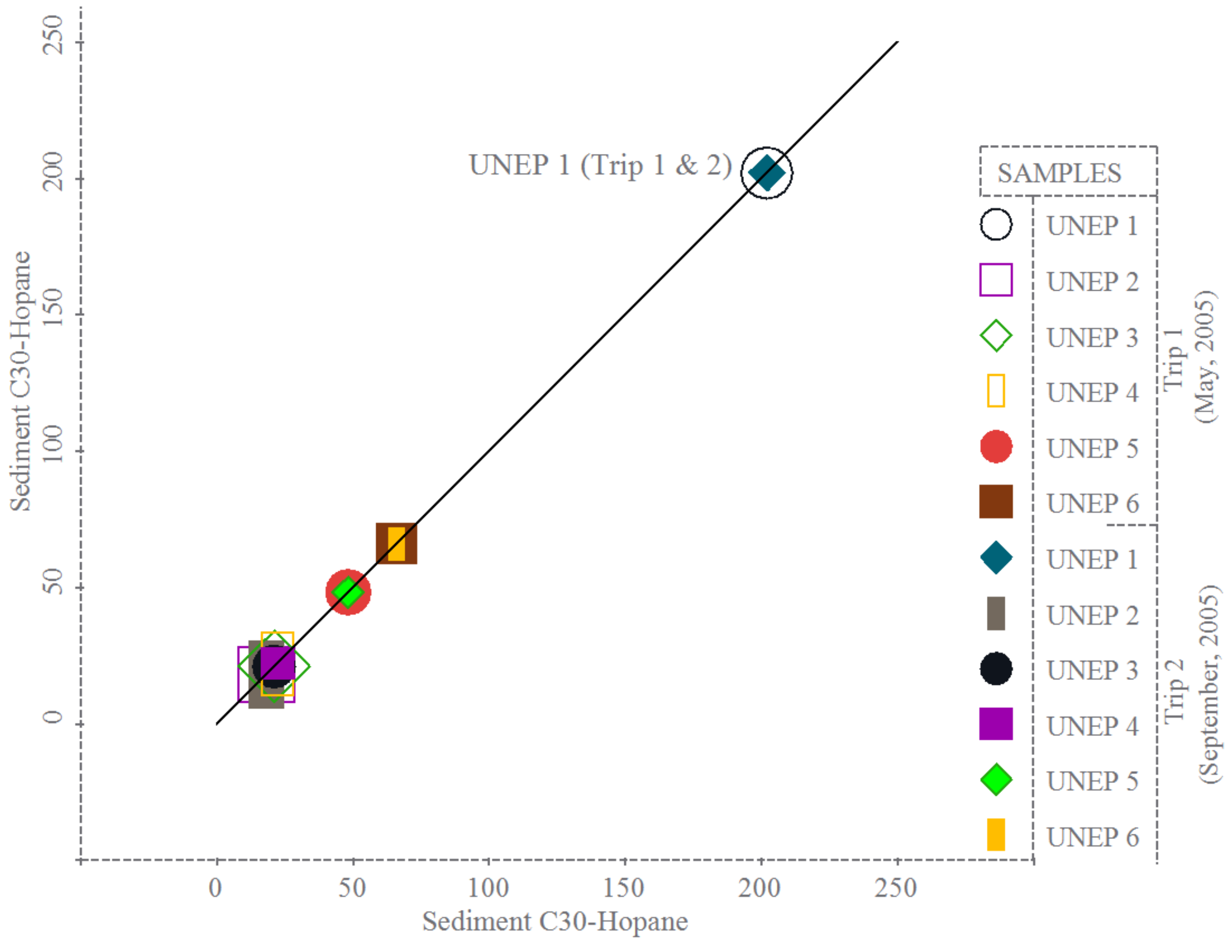


Figure 84: Ordination of UNEP sites in relation to values of Sediment C30-Hopane (µg/dry g), (May – September 2005).

All six UNEP sites had the same Sediment C30-Hopane concentrations on both trips.

UNEP 1 had the highest Sediment C30-Hopane concentrations on both trips.

UNEP 6 and UNEP 5 had relatively low concentrations. UNEP 3, 2, and 4 had the same and lowest Sediment C30-Hopane concentrations on both trip one and trip two.

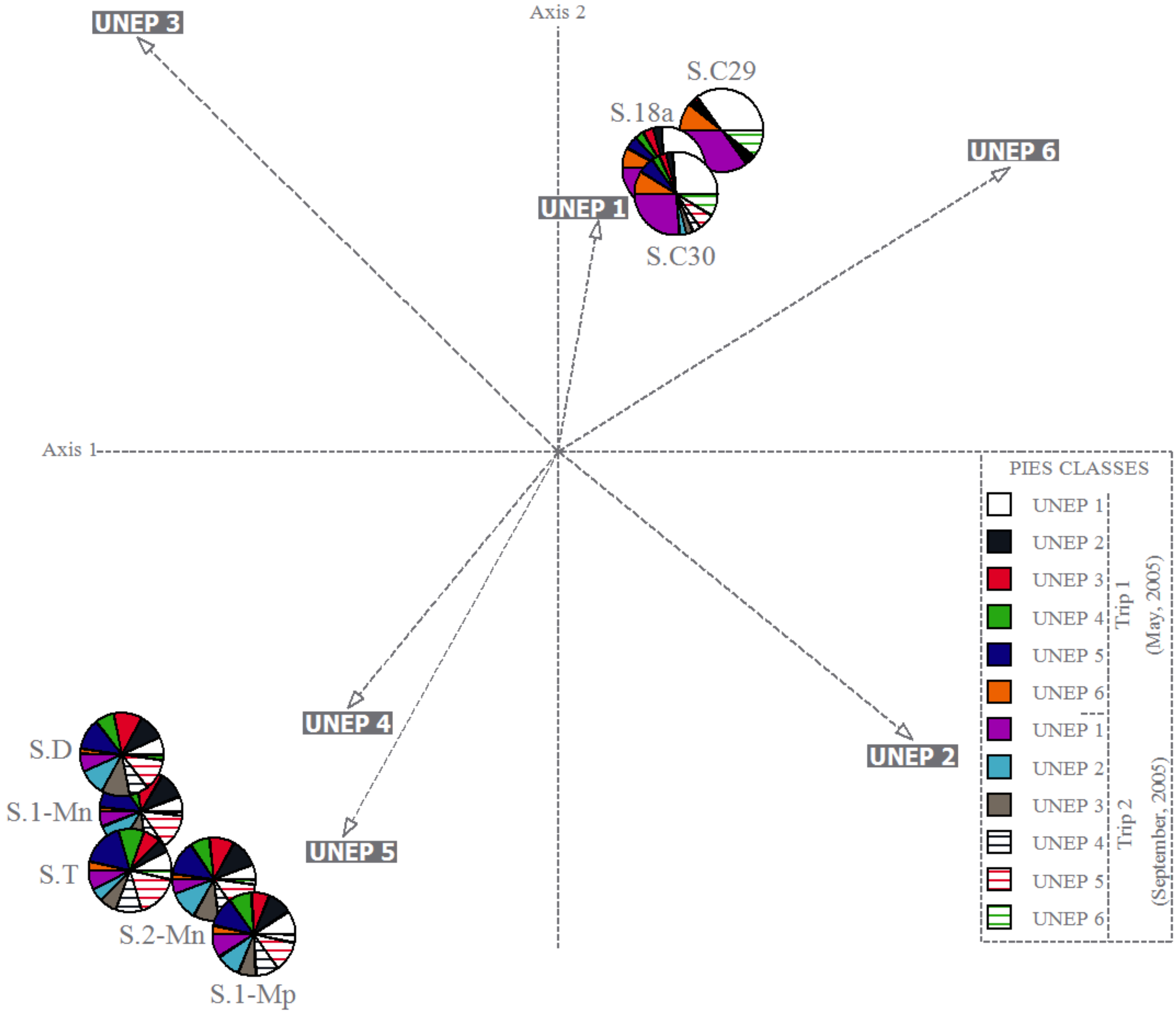


Figure 85: Ordination of UNEP sites in relation to values of Sediment Polynuclear Aromatic Hydrocarbons (PAHs), (May – September 2005).

The preceding sediment Polynuclear Aromatic Hydrocarbons (PAHs) of the UNEP sites can be visualized in another way; the figure above illustrated the most important sediment Polynuclear Aromatic Hydrocarbons (PAHs) of each site.

In the figure above, the environmental variable symbols can be projected perpendicularly onto the line overlaying the arrow of a particular site. These projections can be used to approximate the level or concentration of individual environmental variables in respect to that site.

Environmental variable symbols are replaced by environmental variable pies. The segmentation of these pies into slices is based on the classification of the UNEP sites. Relative size of particular pie-slice corresponds to relative level or concentration of the environmental variable at a particular site (Ter Braak and Šmilauer, 2002).

For instance, sediment C29 is found in UNEP 1 in higher concentrations than the other sites.

B. MACROPHYTES

Aquatic macrophytes exert a large number of indirect effects on wetland and lake ecosystems. They exert their influence by transforming organic and inorganic compounds in the water. Many macrophytes are adapted to live in waterlogged, anoxic sediments by having aerenchymatous tissues in their stems and roots. This tissue carries oxygen taken in from stomata in the aerial parts of the plant and transports it to lower parts where it is released to the anaerobic root zone. In addition, soil micro-organisms, both aerobic and anaerobic, are able to perform biogeochemical reactions that may be toxic to the plants and to other organisms in the ecosystem.

Traditionally the functioning of wetland and lake ecosystems near the mouths of river systems is driven to a large extent by depth and turbidity of the water. Many ecosystem models show that macrophytes can be considered as keystone species in the functioning of shallow lake and wetland ecosystems.

MACROPHYTES COMMUNITY ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (this shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.282 and 0.073 respectively. In addition, the lengths of the gradient showed a clear linear response (Table 6), which implies the use of the Principal Components Analysis (PCA) method in the next step to analyze the relations with the explanatory variables.

Table 1: Eigenvalues and Lengths of gradient for the four axes of Macrophytes community derived from the detrended correspondence analysis (DCA) method.

Axes	1	2	3	4
Eigenvalues	0.282	0.073	0.017	0.006
Lengths of gradient	2.437	1.26	0.882	0.886

The diagram obtained from the DCA (Figure 68) shows that in UNEP 1 and UNEP 5 were exclusively dominated by the submerged plants during the first and second trip. UNEP 2 and UNEP 4 remained in the same position with the same abundance of plant groups during the two trips. In UNEP 3 the submerged plants were the dominant group in both trip one and trip two, this was similar in UNEP 6 with the presence of the floating plants on trip two.

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 occurances or by its quantity) of the species belonging to a particular class in the corresponding sample. (Ter Braak and Šmilauer, 2002)

Furthermore, macrophytes diversity and richness across the studying period reflect the differences between the studied sites and demonstrate the recovery in these sites from May 2005 until September 2005, best seen in UNEP 6.

In addition, it can be concluded that UNEP 5 during both trip one and trip two had the lowest diversity and richness values (0).

UNEP 1 on both trips along with UNEP 6 in the first trip had the same values of diversity and richness (1.09).

UNEP 4 on both trips along with UNEP 6 in trip two also had the same values (1.6). While, UNEP 3 had lower values during trip one than trip two (2.19 and 2.3 respectively). On the other hand, the highest diversity and richness values were recorded in UNEP 2 during the two trips (2.39). (Figure 69) (Table 5)

Higest Overall Macrophytes diversity is in UNEP 2 and there after UNEP 3, although UNEP 4 has a relative high one. (Figure)

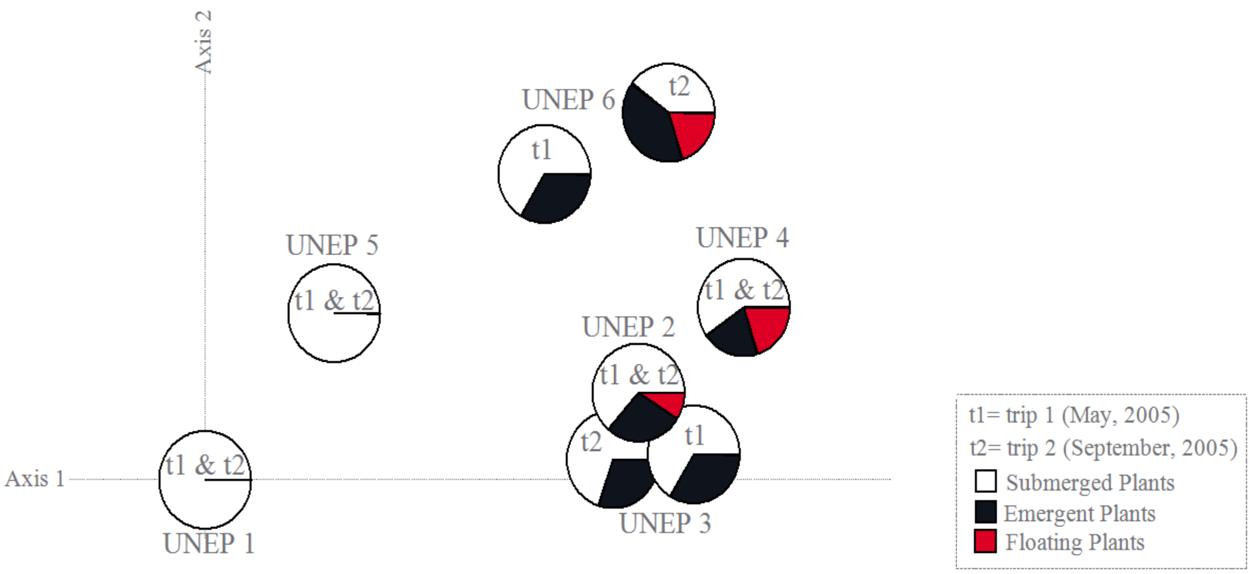


Figure 86: Ordination diagram [Axis 1 x Axis 2] with Macrophytes' samples pies classes, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

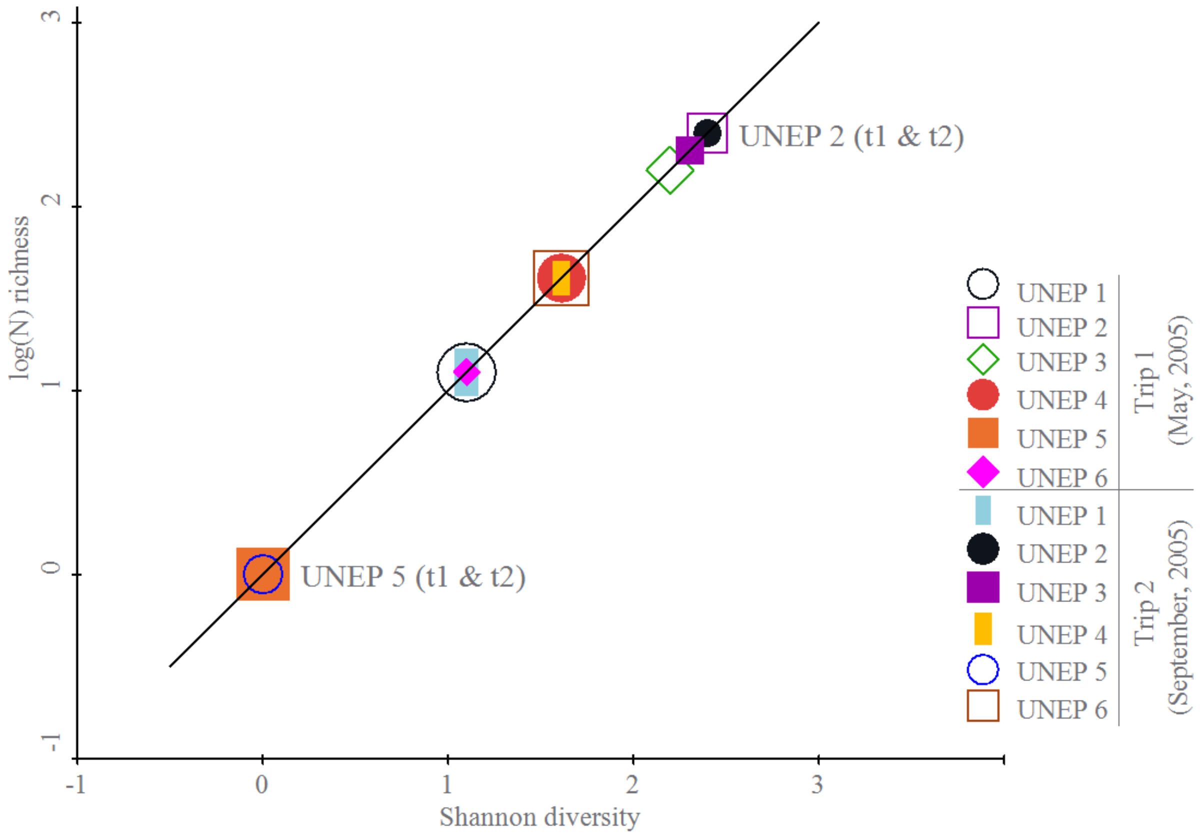


Figure 87: Macrophytes diversity & richness, southern Iraq (May - September 2005) obtained from the detrended correspondence analysis (DCA) method.

MACROPHYTES COMMUNITY ORDINATION AND ENVIRONMENTAL VARIABLES:

Due to the minimal information provided by the third and forth axes regarding variation in community structure (Eigenvalues = 0.117, and 0.094, respectively); (Table 7), these axes are not considered further. Moreover, the variables, which exhibited associations with the third and fourth axes, imply less ecological significance than the variables that exhibited associations with the first and second axes (Lepš and Šmilauer, 2003). Therefore, our discussion will focus mainly on the variables associated with the first and second axes of the PCA. (Figure 70 through Figure 75)

The results obtained from the PCA showed that Macrophytes-environment correlations are related to the first and second axes of the PCA ($r = 0.997$ and 0.998 respectively). The four canonical axes derived from the PCA accounted for 82.1% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 59.6% (Table 7).

Table 2: Eigenvalues and Macrophytes-environment correlations for the four axes derived from the Principal Components Analysis (PCA) method.

Axes	1	2	3	4
Eigenvalues	0.302	0.196	0.117	0.094
Macrophytes-environment correlations	0.997	0.998	0.999	0.862
Cumulative percentage variance				
of Macrophytes data	30.2	49.8	61.6	71
of Macrophytes-environment relation	36.1	59.6	73.7	82.1

The results obtained from the PCA showed that the most important environmental variables to explain the variance in the community structure was Water Depth, Turbidity, Total Kjeldahl Nitrogen, Nitrate Nitrogen, Lead (Pb), Sediment Total Organic Carbon, Sediment Cadmium, Sediment Zinc, Sediment Selenium, Sediment Total HCH, Sediment Total Chlordane, Sediment Total DDT, Sediment 1,6,7-Trimethylnaphthalene, Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane, based on there moderate to strong correlations with the first and second axes of the PCA, while the other parameters were less correlated with these axes (Table 8).

Furthermore, weaker correlations with the first and second axes did not reflect significant correlations with the Macrophytes community structure. Therefore, weakly correlated variables are not representing in the diagrams.

Table 3: Inter-set correlations of environmental variables with axes, used to know the most important explanatory environmental variables for Macrophytes community.

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
1	Depth of water (m)	D	-0.5889	0.1287	0.1088	0.6455
2	Air temperature (˚C)	AT	0.4896	0.1474	0.2511	0.0502
3	Water temperature (˚C)	WT	0.3456	-0.0084	0.436	0.1382
4	pH	pH	0.2313	0.0136	-0.0329	0.6531
5	Electrical Conductivity (mS/cm)	EC	0.0863	-0.0008	0.6085	-0.7325
6	Dissolved Oxygen (mg/L)	DO	-0.3427	-0.0144	-0.1115	0.6062
7	Transparency (m)	Tra	0.0665	0.1712	0.5324	-0.4629
8	Salinity (ppt)	S	0.216	-0.1316	0.4872	-0.741
9	Total Dissolved Solids (TDS) (mg/L)	TDS	0.0796	-0.1707	0.5289	-0.6603
10	Turbidity (NTU)	Tur	-0.6802	0.3619	0.4627	0.0047
11	Total Suspended Solids (TSS) (mg/L)	TSS	-0.3514	0.0735	0.3031	-0.2291
12	Alkalinity (mg $CaCO_3$/L)	Alk	-0.0776	-0.0383	-0.2182	-0.388
13	Total Hardness ($CaCO_3$/L)	T.H	0.1113	-0.1683	0.3414	-0.7662
14	Sulphates (SO4) (mg/L)	SO4	0.1753	-0.1992	0.5254	-0.5798
15	Chlorides (Cl) (mg/L)	Cl	0.1813	0.1364	0.6854	-0.5023
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	-0.1245	0.7928	-0.5227	0.0312
17	Nitrate Nitrogen (NO3-N) (mg N/L)	NO3	-0.4941	0.5294	-0.4924	0.3116
18	Nitrite Nitrogen (NO2-N) (mg N/L)	NO2	-0.3891	-0.0647	0.0497	0.2119
19	Phosphates (PO4-P) (mg P/L)	PO4	-0.2528	-0.0856	0.0127	0.188
20	Chlorophyll-a (mg/L)	Ch-a	-0.0796	0.3254	-0.0107	0.2878
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	0.2808	-0.4215	0.4364	-0.5828

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
23	Biochemical Oxygen Demand (BOD5) at 20°C (mg/L)	BOD	-0.4471	-0.0262	-0.6457	0.1853
24	Water Total Organic Carbon (TOC) (mg/L)	W.TOC	0.3189	0.1099	0.8015	0.0155
25	Total plate count (colony/mL)	T.PCC	-0.0195	0.1258	-0.2016	0.3307
26	Fecal coliform count (CFU/100mL)	FCC	-0.1441	0.0384	-0.2314	0.1936
27	E. coli (CFU/100ml)	Eco	-0.209	-0.0823	0.1404	0.0441
28	Cadmium (Cd) (mg/l)	Cd	-0.3965	-0.4731	0.1551	-0.5304
29	Lead (Pb) (mg/l)	Pb	0.3323	-0.6814	-0.496	0.0609
30	Zinc (Zn) (mg/l)	Zn	-0.4277	-0.3796	0.2113	-0.6886
31	Total chromium (T-Cr) (mg/l)	T.Cr	0.0253	0.077	0.0384	-0.368
32	Arsenic (As) (mg/l)	As	0.0145	0.2226	0.7744	-0.4398
33	Selenium (Se) (mg/l)	Se	0.3365	-0.205	0.1557	0.6927
34	Mercury (Hg) (mg/l)	Hg	0.4533	-0.1196	0.806	-0.015
37	Iron (Fe) (mg/l)	Fe	-0.0501	0.008	0.0299	0.2849
39	Calcium (Ca) (mg/l)	Ca	-0.065	0.0453	0.4689	-0.7561
40	Magnesium (Mg) (mg/l)	Mg	-0.0356	-0.1209	0.7318	-0.3168
41	Sediment Total Organic Carbon (TOC) %	S.TOC	0.6293	0.1545	-0.1137	-0.3314
42	Sediment Cadmium (Cd) (µg/kg)	S.Cd	0.2246	0.7216	-0.4301	-0.3214
43	Sediment Lead (Pb) (µg/kg)	S.Pb	0.2636	0.2929	-0.2451	-0.587
44	Sediment Zinc (Zn) (µg/kg)	S.Zn	-0.0809	0.5558	-0.2409	-0.6037
45	Sediment Total chromium (T-Cr) (µg/kg)	S.T.Cr	-0.1514	0.3525	0.2942	-0.5124
46	Sediment Arsenic (As) (µg/kg)	S.As	0.0465	0.2056	0.1155	-0.4416
47	Sediment Selenium (Se) (µg/kg)	S.Se	0.8867	0.1112	-0.0197	-0.3085
48	Sediment Mercury (Hg) (µg/kg)	S.Hg	0.3655	0.1733	0.5219	-0.5914
49	Sediment Copper (Cu) (µg/kg)	S.Cu	-0.2321	-0.4615	-0.3894	-0.6548
50	Sediment Nickel (Ni) (µg/kg)	S.Ni	-0.017	0.0446	0.214	-0.6343

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
51	Sediment Iron (Fe) (μg/kg)	S.Fe	-0.1084	0.3929	0.0006	-0.6129
52	Sediment Manganese (Mn) (μg/kg)	S.Mn	-0.1377	0.0274	-0.1556	-0.5588
53	Sediment Calcium (Ca) (μg/kg)	S.Ca	0.1625	0.0574	0.1827	0.6973
54	Sediment Magnesium (Mg) (μg/kg)	S.Mg	-0.2477	0.4727	0.3027	-0.6043
55	Sediment Total HCH (μg/dry g)	S.T.HCH	0.5501	-0.2105	0.1983	0.6271
56	Sediment Total Chlordane (μg/dry g)	S.T.Ch	0.4925	-0.0521	-0.2485	0.5209
57	Sediment Total DDT (μg/dry g)	S.T.DDT	0.0467	0.862	-0.344	-0.2342
59	Sediment 2-Methylnaphthalene (μg/dry g)	S.2-Mn	0.2665	-0.1752	-0.3401	0.4184
60	Sediment 1-Methylnaphthalene (μg/dry g)	S.1-Mn	0.2117	-0.2477	-0.32	0.5056
61	Sediment 2,6-Dimethylnaphthalene (μg/dry g)	S.D	0.2919	-0.3034	-0.3542	0.5133
62	Sediment 1,6,7-Trimethylnaphthalene (μg/dry g)	S.T	-0.5653	0.0067	-0.3392	0.4519
63	Sediment 1-Methylphenanthrene (μg/dry g)	S.1-Mp	-0.173	-0.3181	-0.6645	0.1877
64	Sediment C29-Hopane (μg/dry g)	S.C29	-0.4405	-0.5993	-0.089	-0.3797
65	Sediment 18a-Oleanane (μg/dry g)	S.18a	-0.4519	-0.6579	-0.154	-0.3252
66	Sediment C30-Hopane (μg/dry g)	S.C30	-0.532	-0.6342	-0.1152	-0.3283

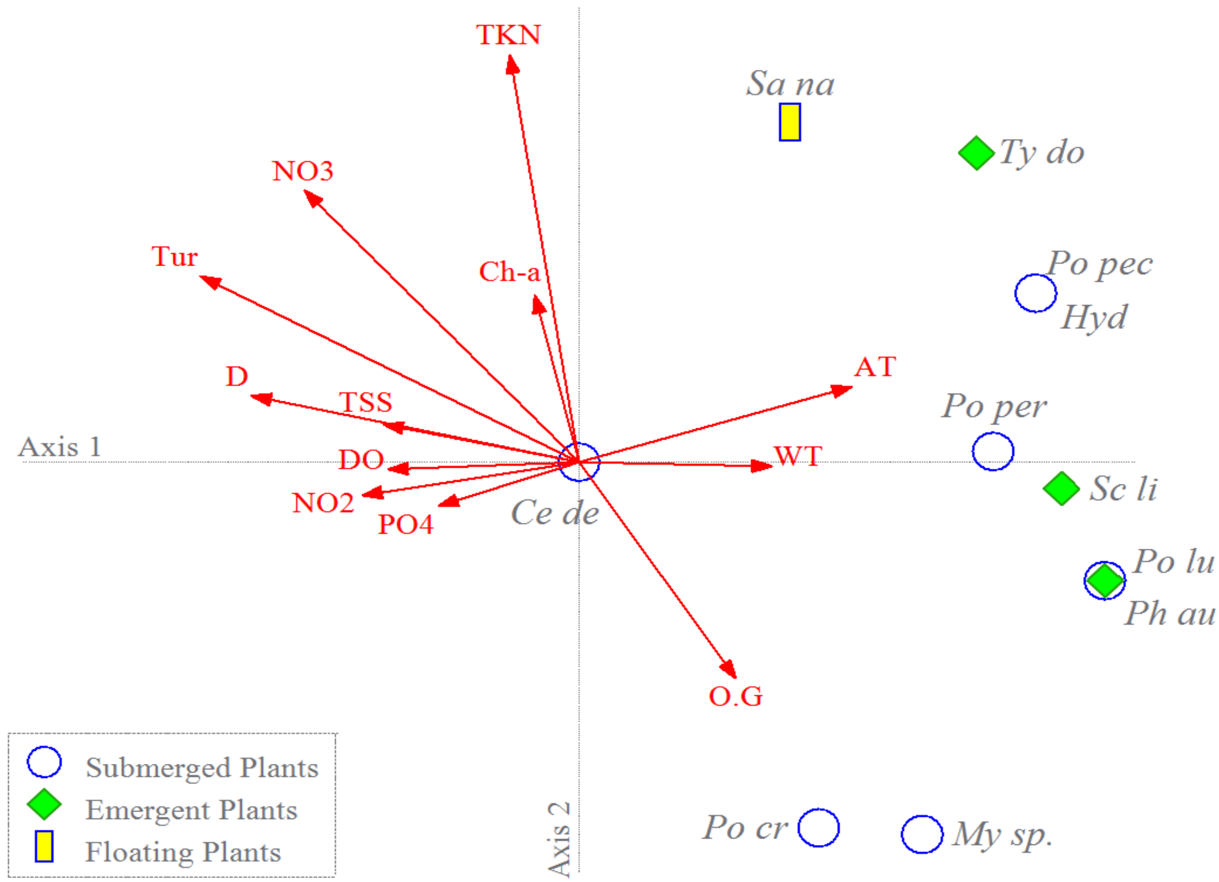


Figure 88: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

According to the diagram above, the distance between the symbols in the diagram approximates the dissimilarity of distribution of relative abundance of those species across the samples, measured by their Chi-square distance. Points in proximity correspond to species that often occur together.

Each arrow points in the expected direction of the steepest increase in values of environmental variable. The angles between arrows indicate correlations between individual environmental variables. More precisely, we can read the approximated correlations of one environmental variable with the others by projecting their arrowheads onto the imaginary axis running in the direction of that variable's arrow.

The species symbols can be projected perpendicularly onto the line overlaying approximate the optima of individual species in respect to values of that environmental variable. Species projection points are in the order of the predicted increase of optimum value for that variable. Therefore, one can infer that most plant species prefer relatively warmer air and water temperatures compared with the other environmental variables, and relatively lower Turbidity, Total Suspended Solids, Water Depth, Dissolved Oxygen, Nitrite Nitrogen, and Phosphate. The two species *Potamogeton crispus* and *Myriophyllum sp.* seem to favor higher oil and grease values compared with the other species. *Salvinia natans, Typha domingensis, Potamogeton pectinatus*, and *Hydrilla* seem to favor relatively high to moderate Total Kjeldahl Nitrogen, chlorophyll-a, and nitrate concentrations when compared with the other species.

Furthermore, it can be noticed that *Ceratophyllum demersum* is located in this figure and all the following figures in the centre; meaning that this species was found in all environmental conditions.

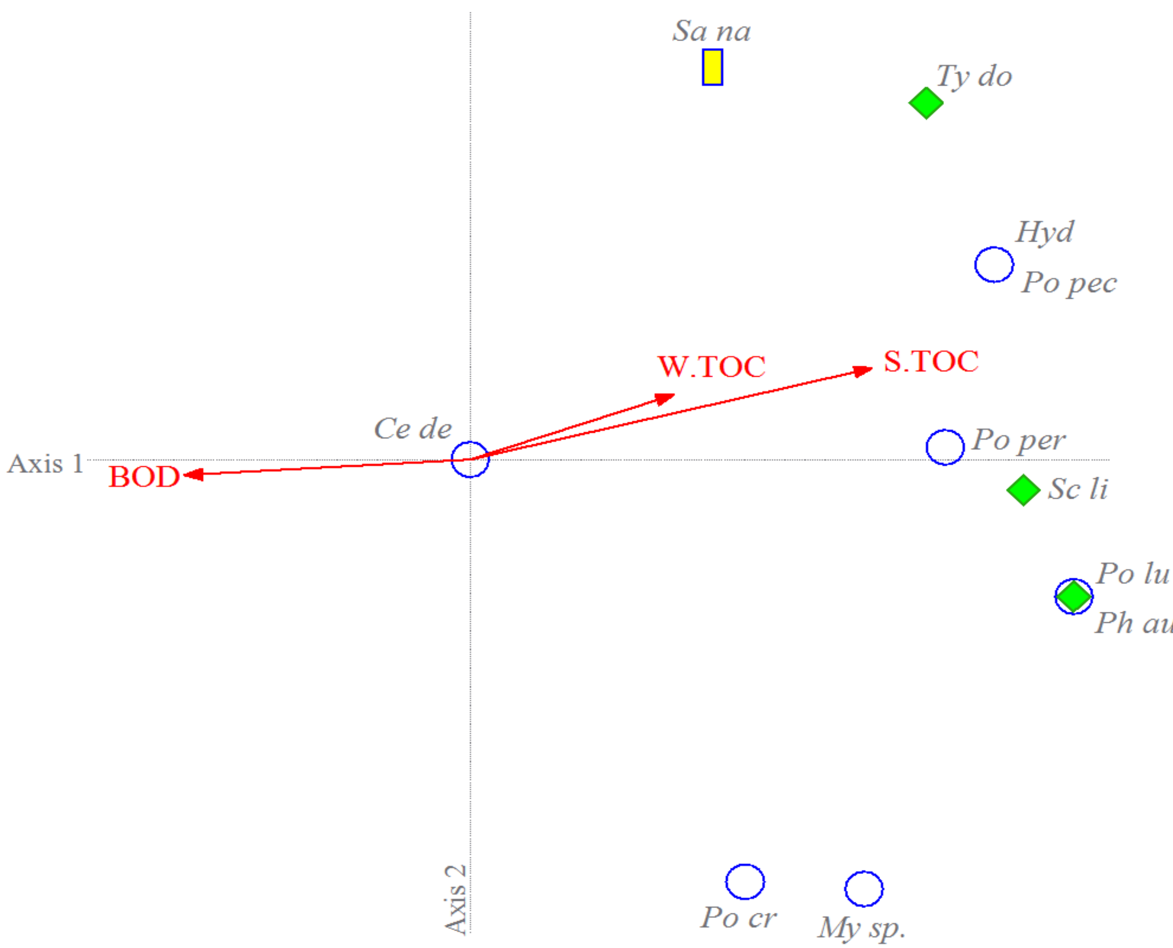


Figure 89: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

From the above figure, it is clear that all the indicated plant species are present in low Biochemical Oxygen Demand levels, and favor higher sediment and water total organic carbon, respectively with the exception of *Potamogeton crispus* and *Myriophyllum sp.*

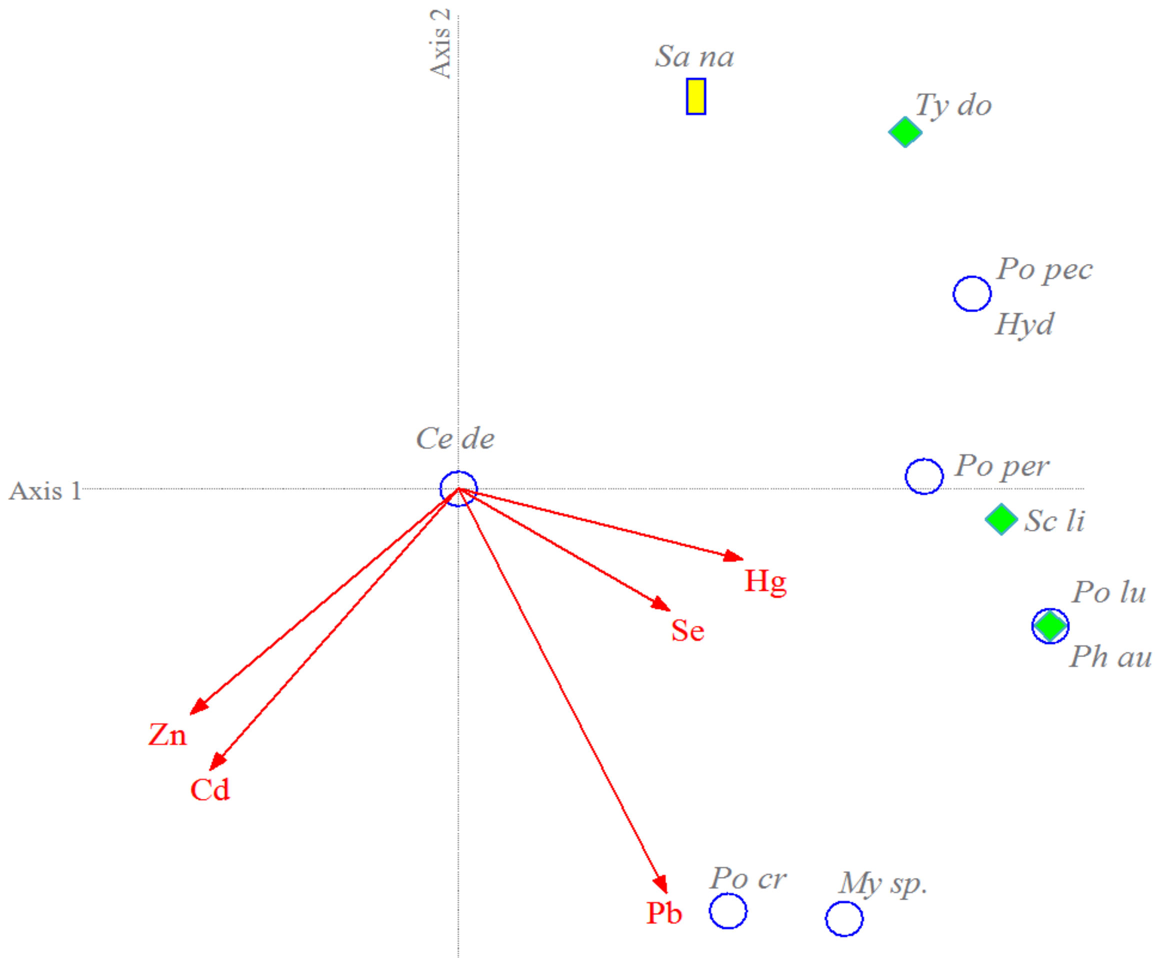


Figure 90: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

From the above figure, it can be seen that most species do not favor the presence of both Zinc and Cadmium, while *Potamogeton crispu*s and *Myriophyllum sp.* seem to tolerate higher Lead concentrations than the other species. *Salvinia natans* and *Typha domingensis* seem to favor conditions with generally low water heavy metals.

The remaining species seem to tolerate relatively high Mercury, Selenium, and low to moderate Lead concentrations.

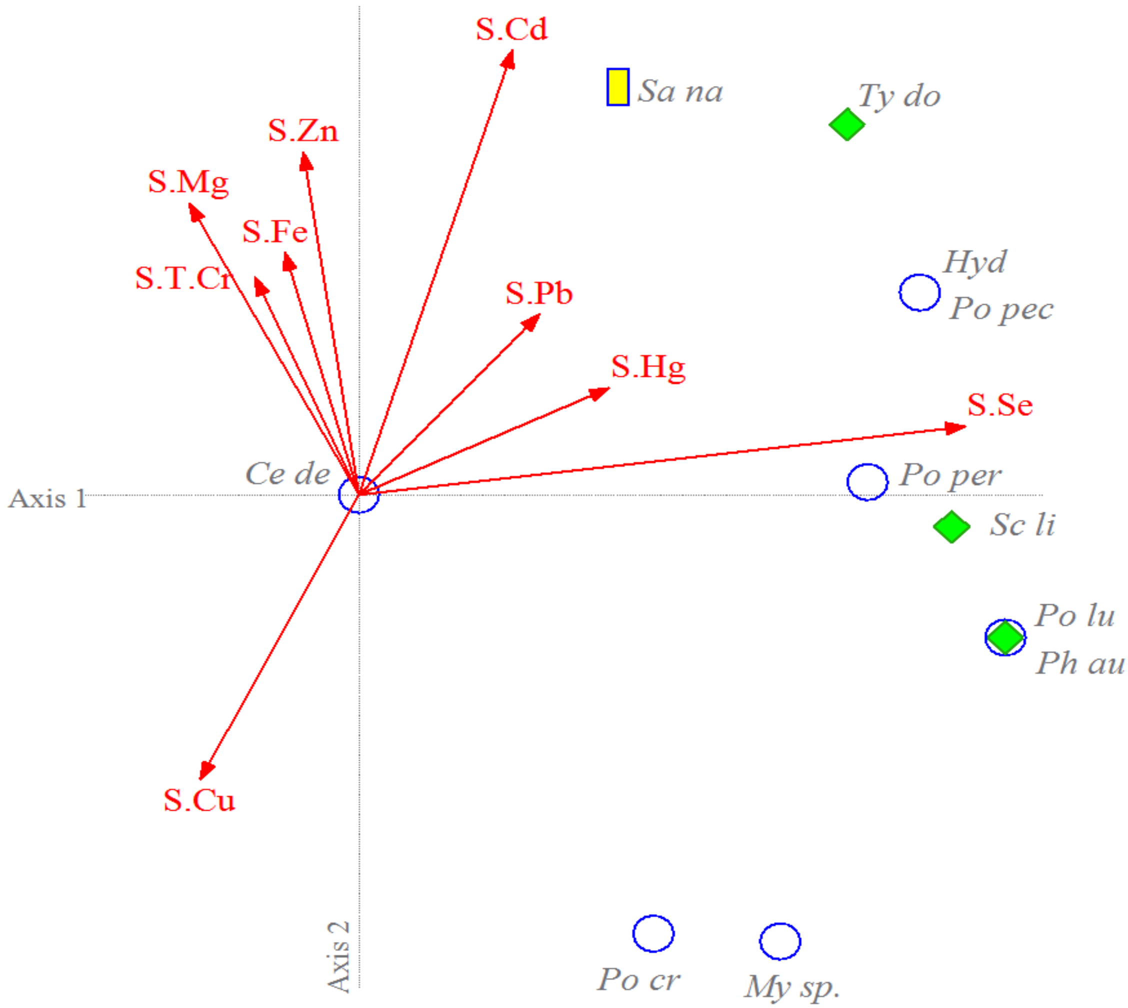


Figure 91: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Generally, from the above figure, it can be seen that most plant species prefer low Zinc, Iron, Magnesium, and Total Chromium present in sediment, except *Salvinia natans* and *Typha domingensis* that can tolerate high sediment Cadmium, Lead, and Mercury and moderate sediment Selenium compared to the other plant species. On the other hand, *Potamogeton crispus* and *Myriophyllum sp.* tolerate high sediment Copper and moderate sediment Selenium.

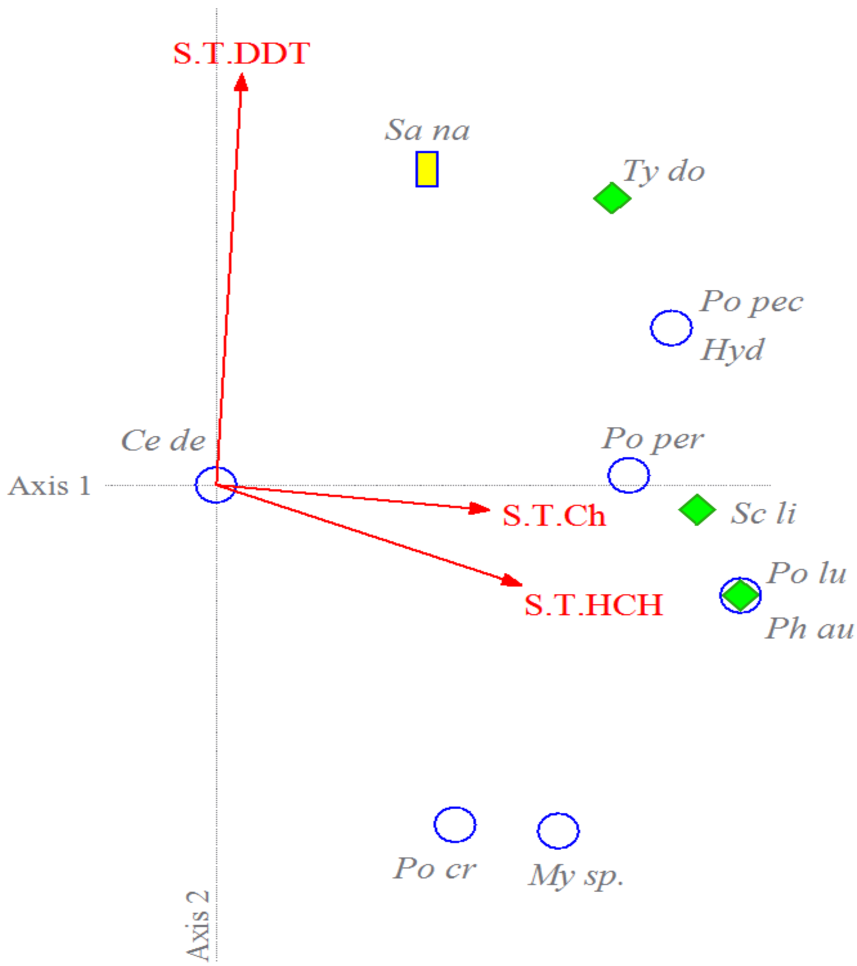


Figure 92: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

As shown in the above figure that the two species *Salvinia natans* and *Typha domingensis* can tolerate relatively high concentrations of Sediment Total DDT, with *Potamogeton pectinatus* and *Hydrilla* tolerating moderate concentrations. The remaining species shown in the figure tolerate relatively high concentrations of Sediment Total Chlordane and Sediment Total HCH compared to their toleration to Sediment Total DDT.

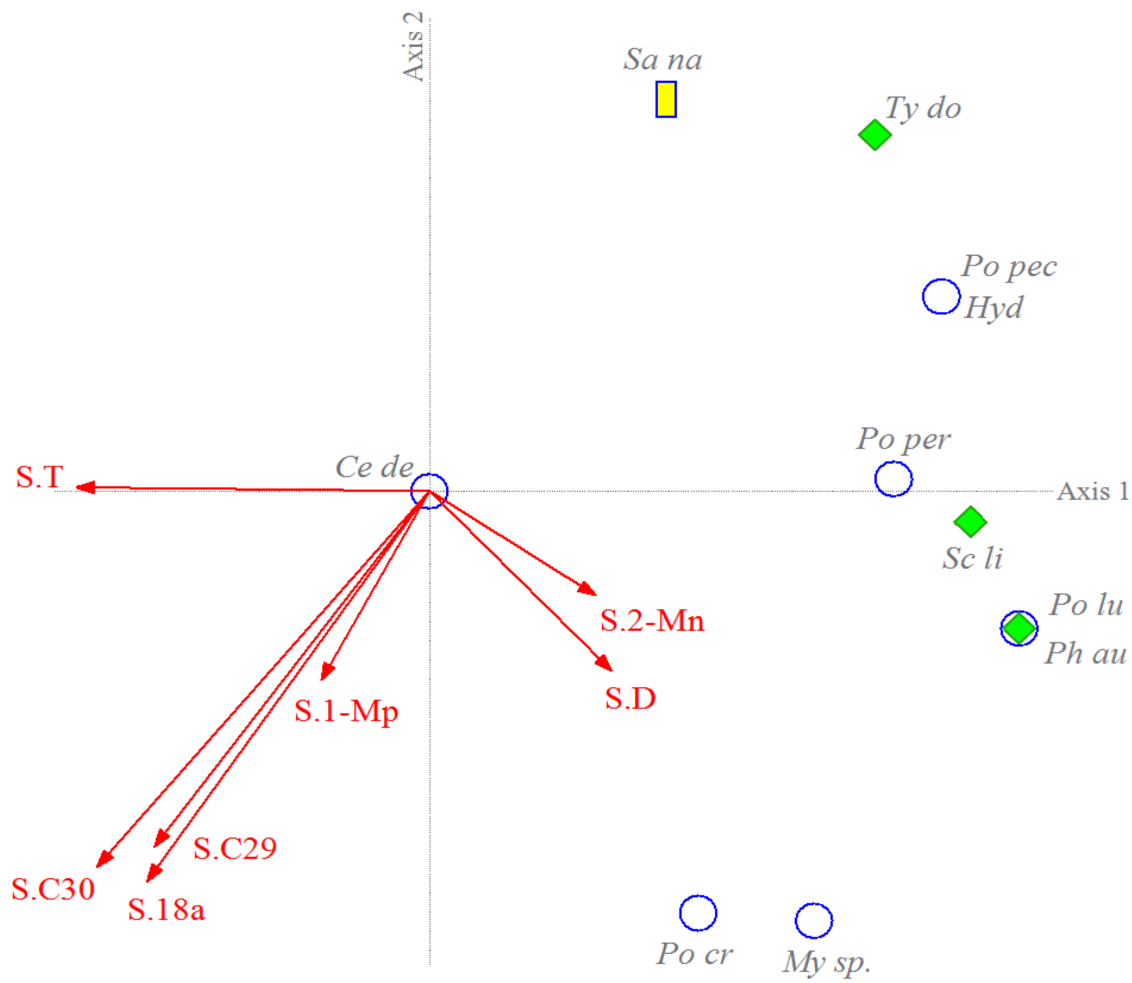


Figure 93: Ordination of Macrophytes communities in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

From the above figure it can be noticed that generally, all the plant species indicated prefer conditions with low Sediment 1,6,7-Trimethylnaphthalene in addition to the species *Salvinia natans, Typha domingensis, Potamogeton pectinatus*, and *Hydrilla* that prefer low concentrations of the remaining sediment Polynuclear Aromatic Hydrocarbons. On the other hand the species *Schoenoplectus litoralis, Potamogeton lucens,* and *Phragmites australis* tolerate conditions with relatively higher concentrations of Sediment 2-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, and their preferences to low concentrations of Sediment 1-Methylphenanthrene, Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane. While both species *(Potamogeton crispus* and *Myriophyllum sp.*) unlike the other species tolerates relatively high concentrations of Sediment 2-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, Sediment 1-Methylphenanthrene, Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane.

MACROPHYTES COMMUNITY ORDINATION AND HABITATS:

The results obtained from PCA showed that eigenvalues for the first and second axes were 0.517 and 0.183 respectively. In addition, Macrophytes-Habitats correlations was strongly related to the first and second axes of the PCA (r = 0.995 and 0.985 respectively). The four canonical axes derived from the PCA accounted for 94.8% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 72.9% (Table 9).

Table 4: Eigenvalues and Macrophytes-habitats correlations for the four axes derived from the Principal Components Analysis (PCA).

Axes	1	2	3	4
Eigenvalues	0.517	0.183	0.134	0.078
Macrophytes-habitats correlations	0.995	0.985	0.995	0.98
Cumulative percentage variance				
of Macrophytes data	51.7	70.1	83.5	91.3
of Macrophytes-Habitat relation	54.1	72.9	86.9	94.8

The diagram obtained from the PCA (Figure 76) can show the dissimilarity of distribution of relative abundance of Macrophytes' species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Each arrow points in the expected direction of the steepest increase of values of the habitat. Each arrow shows the marginal effect of the particular habitat upon the sample scores in the ordination diagram.

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. Therefore, one can infer that UNEP 5 and UNEP 6 are the deficient stations; UNEP 2 and UNEP 3 are the richest stations, with the occurrence of emergent and floating plants and most submerged plants.

In addition, Figure 77 is 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 are replaced by pie symbols. 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 occurances or its quantity) of the current species in the particular class of habitats (Ter Braak and Šmilauer, 2002).

Ceratophyllum demersum is the dominant species; appearing in all stations and on both trips during May and September 2005, whereas the other species vary in their distribution and abundance in the different stations as shown in the figures below. For instance, *Phragmites australis* and *Potamogeton lucens* occurred only in UNEP 2 and UNEP 3 on both trips.

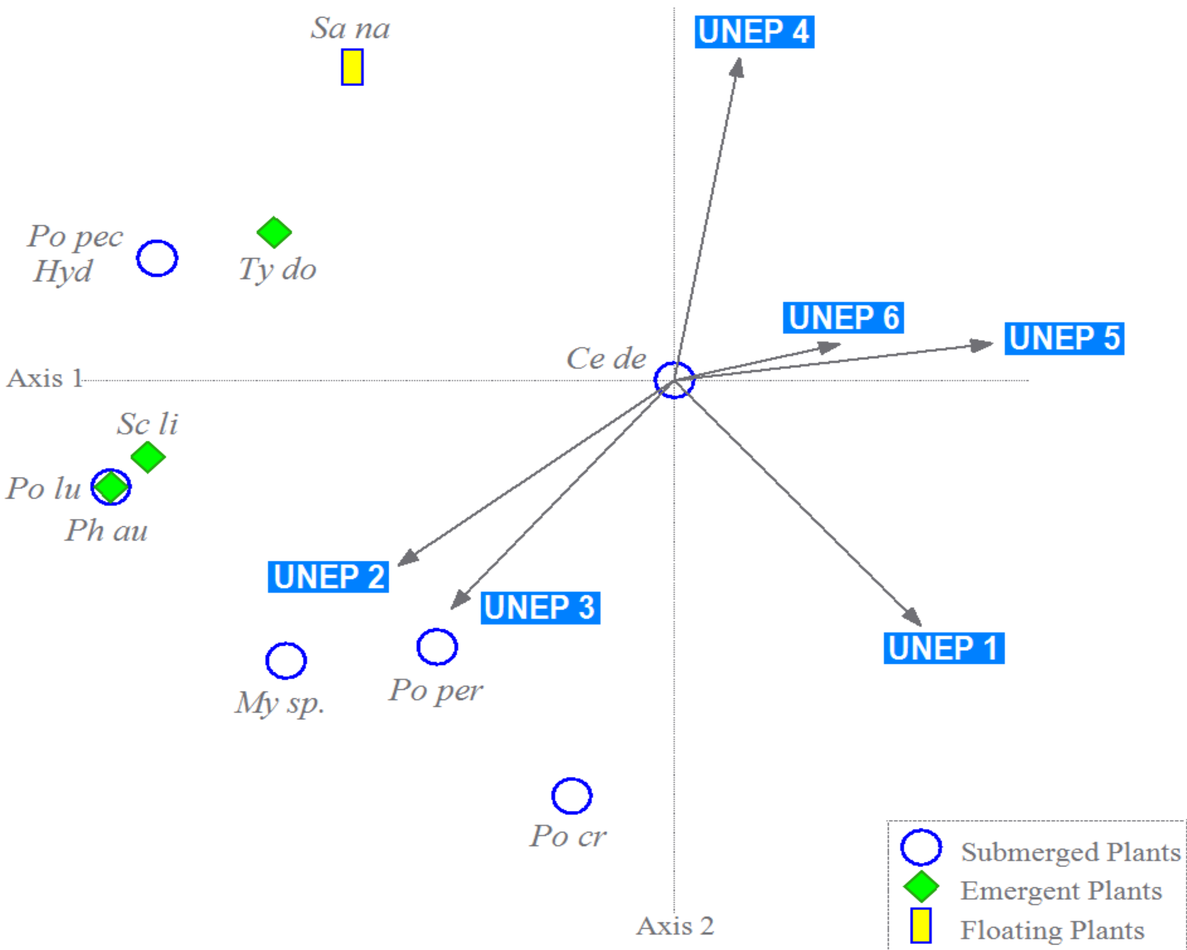


Figure 94: Ordination of Macrophytes communities in relation to preferred habitats, southern Iraq (May – September 2005).

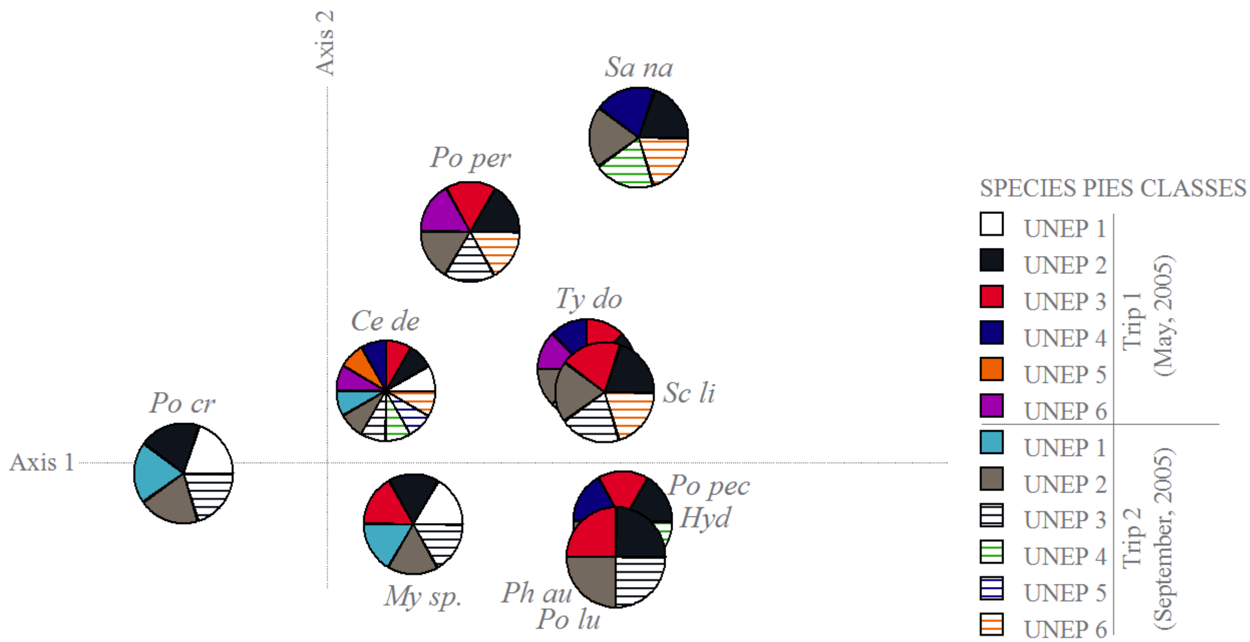


Figure 95: Ordination of Macrophytes pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

C. PHYTOPLANKTON

Phytoplanktons (algae) are the most important living components of any aquatic ecosystem. Along with aquatic plants, they represent the primary autotrophic organism and thus are the primary food source for the higher trophic levels. They are involved in the biogeochemical cycle, the oxygenation of the water column, nitrogen-fixation, water-chemistry regulation and they also offer a refuge for other organism.

PHYTOPLANKTON COMMUNITY ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (this shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.649 and 0.21 respectively. In addition, the lengths of the gradient showed a linear response (Table 10), which implies the use of the Principal Components Analysis (PCA) method in the next step to analyze the relations with the explanatory variables.

Table 5: Eigenvalues and Lengths of gradient for the four axes of Phytoplankton community derived from the detrended correspondence analysis (DCA) method.

Axes	1	2	3	4
Eigenvalues	0.649	0.21	0.075	0.047
Lengths of gradient	3.359	2.357	1.589	0.975

The diagram obtained from the DCA (Figure 78) shows that Bacillariophyceae-Pennales are the dominant genera, however, UNEP sites differ by the abundance of other Families and generally it appears that the community was changing and trying to establish itself from May until September 2005.

For instance, UNEP 1 was characterized by the occurrence of Bacillariophyceae-Centrales, Chlorophyceae, & Cyanophyceae beside the dominant genera: Bacillariophyceae-Pennales (Figure 78). This formula 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.

The distance between the symbols in the diagram approximates the dissimilarity of their species composition, measured by their Chi-square distance. The sample symbols are replaced by pie symbols. The segmentation of these symbols into slices is based on the classification of species. The relative size of particular pie-slice corresponds to the relative importance (measured either by its number of occurances or by its quantity) of the species belonging to a particular class in the corresponding sample (Ter Braak and Šmilauer, 2002).

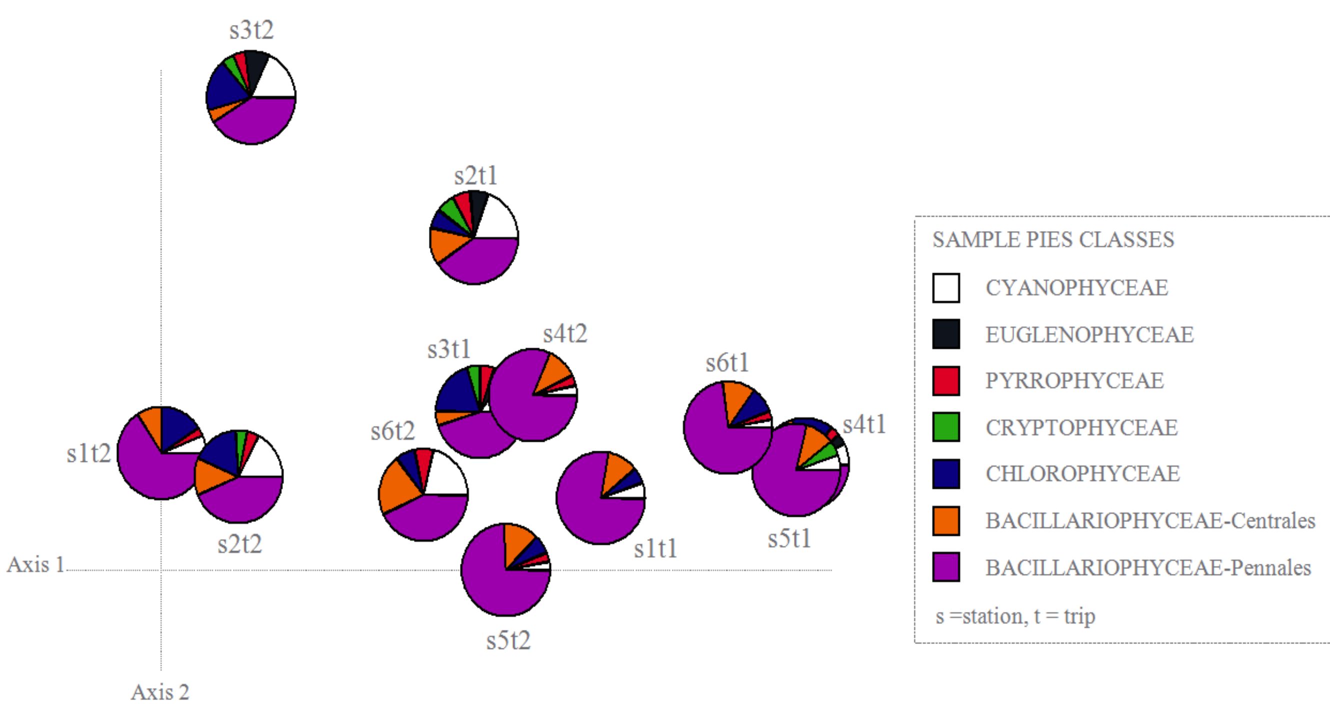


Figure 96: Ordination diagram [Axis 1 x Axis 2] with Phytoplankton' samples pies classes, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

Furthermore, Phytoplankton diversity and richness across the period of study differed between the studied sites and demonstrated the recovery in these sites from May 2005 until September 2005, best seen in UNEP 4 & UNEP 5. In addition, most of the studied sites were developing from a relatively low diversity to quite diverse communities during September 2005. (Figure 79)

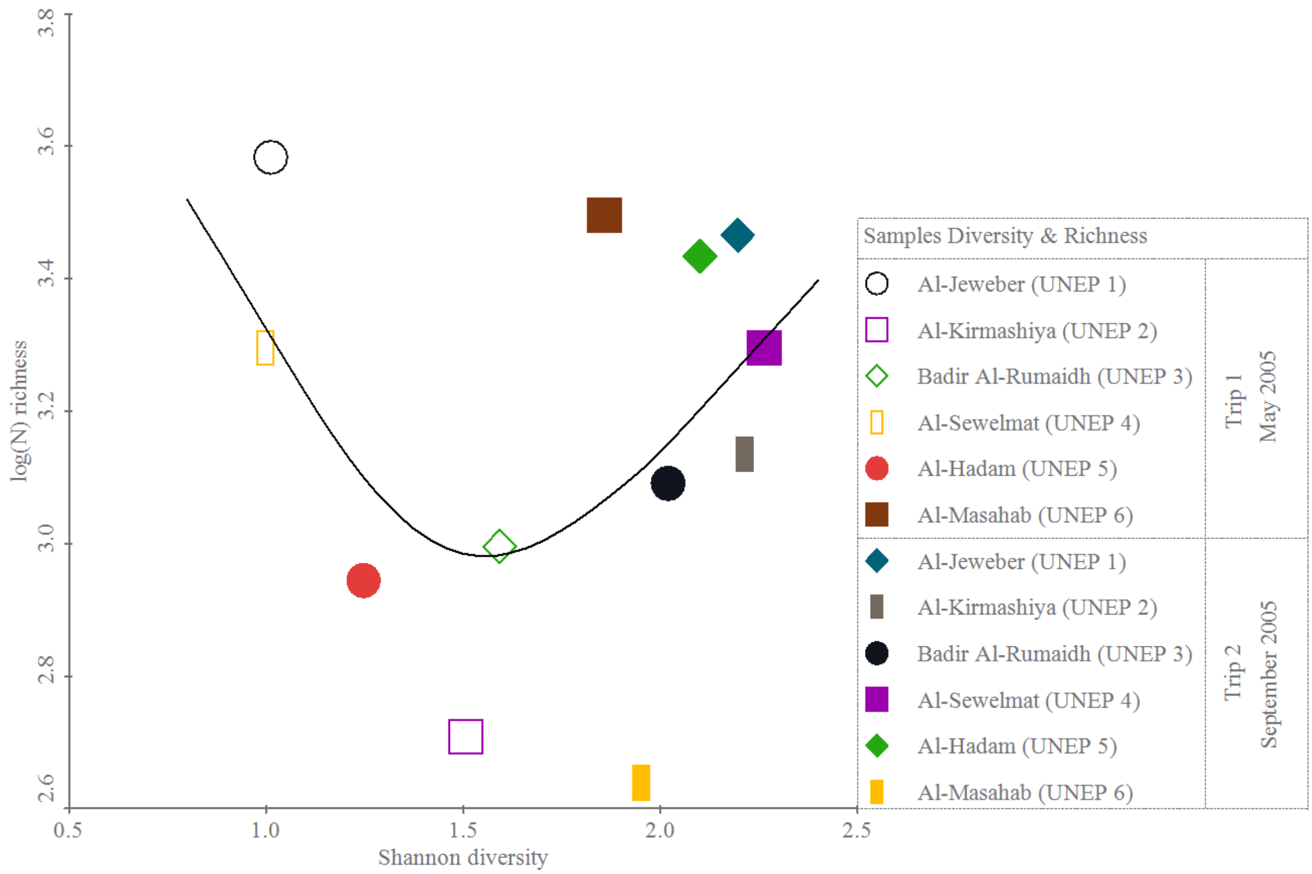


Figure 97: Phytoplankton diversity & richness, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

It can be concluded from the above figure that phytoplankton diversity values were relatively higher during the second trip in UNEP 1, 2, 3, 4, and UNEP 5 when compared with the diversity values in these stations during the first trip. Although, UNEP 6 had rather similar diversity values in both trip one and trip two (1.85 and 1.95 respectively) (Table 5). Highest Overall Phytoplankton Biodiversity was found in UNEP 3 and 2, although one month proved to be the highest in UNEP 4. (Figure)

According to the richness values, the higher values were recorded in UNEP 1 and UNEP 6 during the first trip (3.58 and 3.49 respectively). While, during the second trip the higher values were recorded in UNEP 1 and UNEP 5 (3.46 and 3.43 respectively).

The lower richness values recorded were in UNEP 2 on trip one and UNEP 6 on trip two (2.7 and 2.63 respectively).

The richness values in UNEP 3 during both trips along with UNEP 2 during the second trip and UNEP 5 during the first trip were relatively similar.

On the other hand, UNEP 4 on both trips had the same richness values (3.29). (Table 5)

PHYTOPLANKTON COMMUNITY ORDINATION AND ENVIRONMENTAL VARIABLES:

Due to the minimal information provided by the third and forth axes regarding variation in community structure (Eigenvalues = 0.008, and 0.0, respectively); (Table 11), these axes are not considered further. Moreover, the variables, which exhibited associations with the third and fourth axes, imply less ecological significance than the variables that exhibited associations with the first and second axes (Lepš and Šmilauer, 2003). Therefore, our discussion will focus mainly on the variables associated with the first and second axes of the PCA (Figure 80 through Figure 114).

The results obtained from the PCA showed that Phytoplankton-environment correlations are related to the first and second axes of the PCA (r = 0.67 and 0.51 respectively). The four canonical axes derived from the PCA accounted for 100% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 97.5% (Table 11).

Table 6: Eigenvalues and Phytoplankton-environment correlations for the four axes derived from the Principal Components Analysis (PCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.751	0.241	0.008	0
Phytoplankton-environment correlations	0.67	0.51	0	0
Cumulative percentage variance				
of Phytoplankton data	75.1	99.2	100	100
of Phytoplankton-environment relation	33.9	97.5	100	100

The results obtained from the PCA showed that the most important environmental variables to explain the variance in the community structure were: Air temperature, Phosphates, Water Total Organic Carbon, E. coli, Cadmium, Lead, Zinc, Arsenic, Iron, Sediment Mercury, Sediment Magnesium, Sediment 2,6-Dimethylnaphthalene, Sediment 1-Methylphenanthrene, Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane, based on there moderate to strong correlations with the first and second axes of the PCA, while the other parameters were less correlated with these axes. (Table 12)

Furthermore, weaker correlations with the first and second axes did not reflect significant correlations with the Phytoplankton community structure. Therefore, weakly correlated variables are not representing in the diagrams.

Table 7: Inter-set correlations of environmental variables with axes, used to know the most important explanatory environmental variables for Phytoplankton community.

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
1	Depth of water (m)	D	0.0133	0.0138	-0.0014	0.5256
2	Air temperature (˚C)	AT	-0.5513	-0.237	-0.3878	0.2208
3	Water temperature (˚C)	WT	-0.2995	-0.1023	0.0206	-0.1496
4	pH	pH	-0.3368	-0.2381	0.0543	0.1142
5	Electrical Conductivity (mS/cm)	EC	0.0194	0.1766	0.2045	-0.2448
6	Dissolved Oxygen (mg/L)	DO	-0.0125	-0.1682	0.2891	0.1635
7	Transparency (m)	Tra	-0.2116	-0.1817	-0.0192	0.0489
8	Salinity (ppt)	S	0.0779	0.2113	0.235	-0.3551
9	Total Dissolved Solids (TDS) (mg/L)	TDS	0.0966	0.219	0.3024	-0.3352
10	Turbidity (NTU)	Tur	0.0202	0.2561	0.0529	0.6446
11	Total Suspended Solids (TSS) (mg/L)	TSS	-0.2107	-0.0577	0.1112	0.3772
12	Alkalinity (mg $CaCO_3$/L)	Alk	-0.081	-0.1593	0.0643	0.0835

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
13	Total Hardness ($CaCO_3$/L)	T.H	0.1372	0.0917	0.2648	-0.3021
14	Sulphates (SO4) (mg/L)	SO4	0.0652	0.3767	0.317	-0.4808
15	Chlorides (Cl) (mg/L)	Cl	0.1795	0.4229	-0.2652	-0.1147
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	-0.0601	0.1226	-0.194	0.0613
17	Nitrate Nitrogen (NO3-N) (mg N/L)	NO3	-0.0703	-0.0719	-0.1501	0.5277
18	Nitrite Nitrogen (NO2-N) (mg N/L)	NO2	-0.0159	-0.0947	0.0892	0.4038
19	Phosphates (PO4-P) (mg P/L)	PO4	0.4678	0.1211	-0.0898	0.1075
20	Chlorophyll-a (mg/L)	Ch-a	-0.0624	0.3563	0.2651	0.3739
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	0.2281	0.1361	0.2801	-0.5363
23	Biochemical Oxygen Demand (BOD5) at 20°C (mg/L)	BOD	0.2859	-0.3198	-0.0108	-0.2306
24	Water Total Organic Carbon (TOC) (mg/L)	W.TOC	-0.0906	0.5256	-0.0688	-0.1843
25	Total plate count (colony/mL)	T.PCC	-0.2424	-0.0926	-0.1562	0.4243
26	Fecal coliform count (CFU/100mL)	FCC	-0.2464	0.0358	0.2829	0.2332
27	E. coli (CFU/100mL)	Eco	-0.0493	0.4972	0.5501	-0.15
28	Cadmium (Cd) (mg/L)	Cd	0.5725	-0.061	0.5829	-0.4019
29	Lead (Pb) (mg/L)	Pb	0.1112	-0.6177	0.1486	-0.5387
30	Zinc (Zn) (mg/L)	Zn	0.5398	0.0313	0.5547	-0.2755
31	Total chromium (T-Cr) (mg/L)	T.Cr	-0.4499	-0.2392	0.131	0.1496
32	Arsenic (As) (mg/L)	As	0.1181	0.6284	0.1165	-0.1349
33	Selenium (Se) (mg/L)	Se	-0.2336	-0.1081	-0.1974	-0.069
34	Mercury (Hg) (mg/L)	Hg	-0.1133	0.4118	-0.0562	-0.2497
37	Iron (Fe) (mg/L)	Fe	0.4809	0.2574	-0.1808	-0.0625
39	Calcium (Ca) (mg/L)	Ca	0.2668	0.4082	0.2669	-0.2385
40	Magnesium (Mg) (mg/L)	Mg	0.252	0.4175	0.2713	-0.2988
41	Sediment Total Organic Carbon (TOC) %	S.TOC	-0.0757	0.2328	-0.2426	-0.2901

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
42	Sediment Cadmium (Cd) (μg/kg)	S.Cd	-0.2035	0.1802	-0.2941	0.0207
43	Sediment Lead (Pb) (μg/kg)	S.Pb	-0.0992	0.0945	-0.1236	-0.0658
44	Sediment Zinc (Zn) (μg/kg)	S.Zn	0.0372	0.2367	-0.0368	0.0399
45	Sediment Total chromium (T-Cr) (μg/kg)	S.T.Cr	-0.0093	0.4015	-0.0145	0.278
46	Sediment Arsenic (As) (μg/kg)	S.As	-0.1178	0.2112	-0.1005	0.2484
47	Sediment Selenium (Se) (μg/kg)	S.Se	-0.336	0.1079	-0.3204	-0.3818
48	Sediment Mercury (Hg) (μg/kg)	S.Hg	-0.0737	0.4745	-0.0522	-0.1606
49	Sediment Copper (Cu) (μg/kg)	S.Cu	0.4284	-0.3576	0.4372	-0.3318
50	Sediment Nickel (Ni) (μg/kg)	S.Ni	0.0512	0.2197	0.0762	0.0807
51	Sediment Iron (Fe) (μg/kg)	S.Fe	0.0269	0.2789	-0.0047	0.148
52	Sediment Manganese (Mn) (μg/kg)	S.Mn	0.0749	-0.0133	0.0827	0.1414
53	Sediment Calcium (Ca) (μg/kg)	S.Ca	-0.2004	0.0427	-0.2018	0.0264
54	Sediment Magnesium (Mg) (μg/kg)	S.Mg	0.1013	0.4927	0.0639	0.1762
55	Sediment Total HCH (μg/dry g)	S.T.HCH	-0.3267	-0.0763	-0.2771	-0.1289
56	Sediment Total Chlordane (μg/dry g)	S.T.Ch	-0.2233	-0.2169	-0.2348	-0.3017
57	Sediment Total DDT (μg/dry g)	S.T.DDT	-0.0911	0.3004	-0.2177	-0.0259
59	Sediment 2-Methylnaphthalene (μg/dry g)	S.2-Mn	-0.3738	-0.3718	-0.319	0.3197
60	Sediment 1-Methylnaphthalene (μg/dry g)	S.1-Mn	-0.3457	-0.4103	-0.2854	0.3273
61	Sediment 2,6-Dimethylnaphthalene (μg/dry g)	S.D	-0.3486	-0.4547	-0.2856	0.241
62	Sediment 1,6,7-Trimethylnaphthalene (μg/dry g)	S.T	-0.0149	-0.289	-0.0181	0.5926
63	Sediment 1-Methylphenanthrene (μg/dry g)	S.1-Mp	-0.0242	-0.5918	-0.0001	0.2348
64	Sediment C29-Hopane (μg/dry g)	S.C29	0.5837	-0.2872	0.5948	-0.3974
65	Sediment 18a-Oleanane (μg/dry g)	S.18a	0.573	-0.3651	0.5905	-0.368
66	Sediment C30-Hopane (μg/dry g)	S.C30	0.591	-0.334	0.6078	-0.306

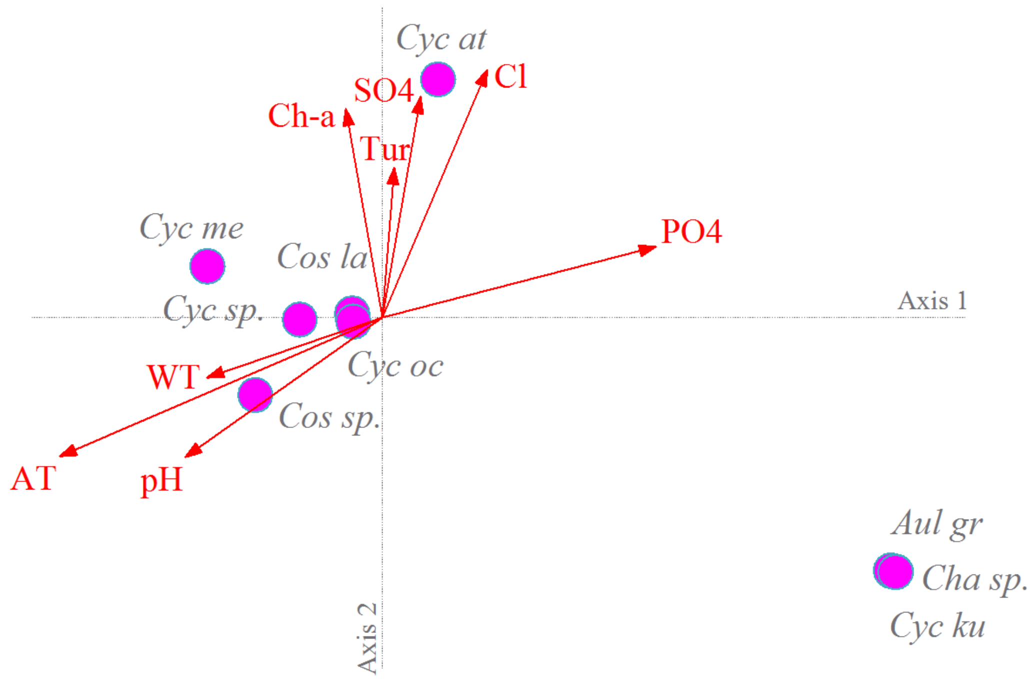


Figure 98: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

From the diagram above, the distance between the symbols approximates the dissimilarity of distribution of relative abundance of those species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together.

Each arrow points in the expected direction of the steepest increase in values of environmental variable. The angles between arrows indicate correlations between individual environmental variables. More precisely, we can read the approximated correlations of one environmental variable with the others by projecting their arrowheads onto the imaginary axis running in the direction of that variable's arrow.

The species symbols can be projected perpendicularly onto the line overlaying approximate the optima of individual species in respect to values of that environmental variable. Species projection points are in the order of the predicted increase of optimum value for that variable. Therefore, one can infer that most of Bacillariophyceae-Centrales genera prefer relatively low to moderate Air Temperature, Water Temperature, pH, Orthophosphate, Chloride, Sulphate, & Turbidity. In addition, there occurrence is reflected by low chlorophyll-a concentrations.

However, *Cyclotella atomus* favors relatively high Chloride, Sulphate, Turbidity, & chlorophyll-a, and moderate Orthophosphate. *Aulacoseira granulata, Chaetoceros sp.,* & *Cyclotella kuetzingiana* favor relatively high Orthophosphate and occur in similar conditions.

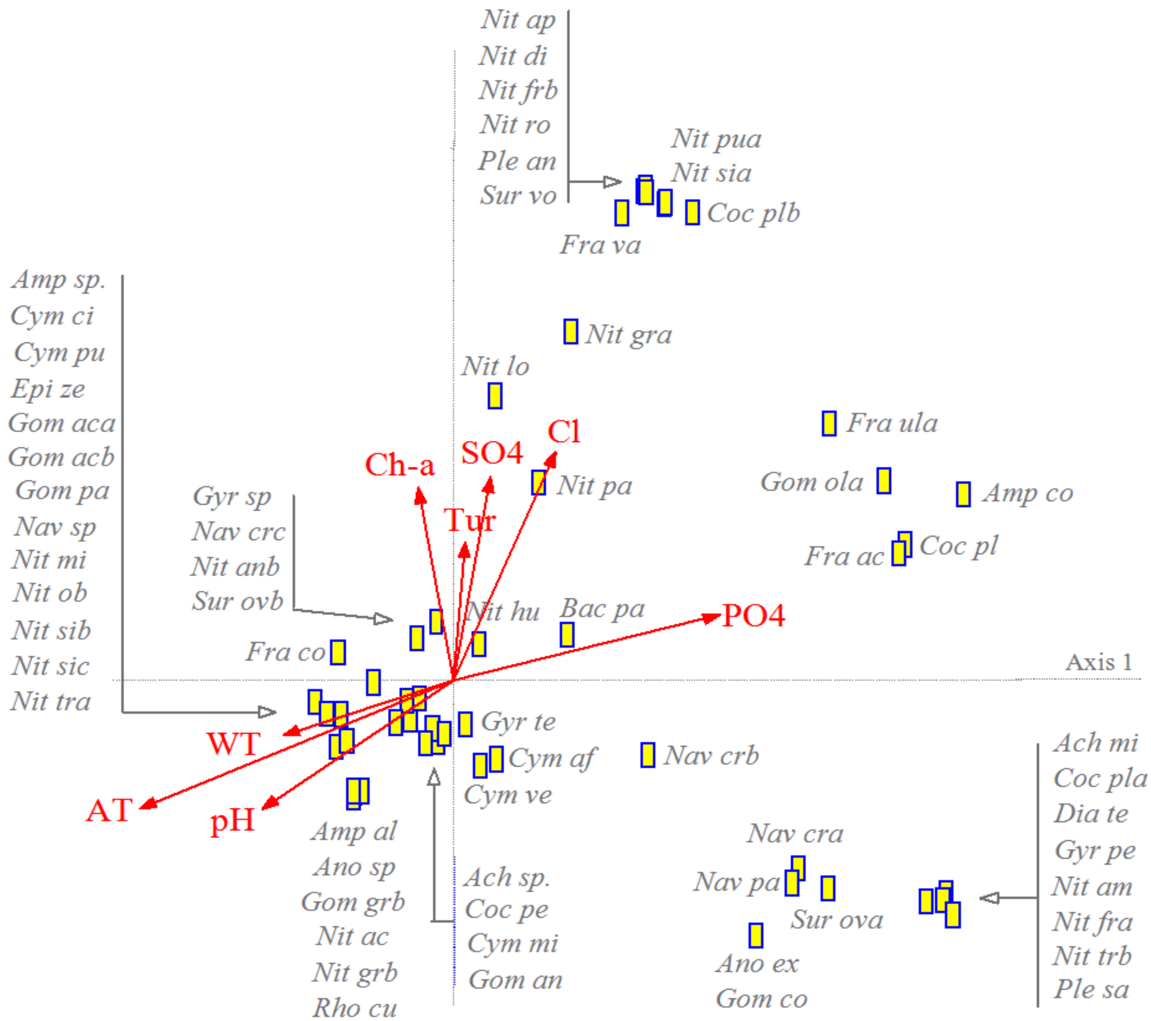


Figure 99: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

Figure 81 shows that most of Bacillariophyceae-Pennales genera prefer relatively low to moderate Air Temperature, Water Temperature, pH, Orthophosphate, Chloride, Sulphate, & Turbidity. In addition, there occurrence is reflected by low chlorophyll-a concentrations.

However, *Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum, Surirella augusta, Nitzschia punctata, Nitzschia sigma, Cocconeis placentula var. lineata, Fragilaria vaucheriae, Nitzschia gracilis, Nitzschia longissima, Nitzschia palea, Synedra ulna, Gomphonema olivaceum, Amphora coffeaeformis, Fragilaria acus,* & *Cocconeis placentula* favor relatively moderate to high

Chloride, Sulphate, Turbidity, & chlorophyll-a, and Orthophosphate. In addition, *Navicula cryptocephala, Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis* and *Pleurosigma salinarum* favor relatively moderate to high Orthophosphate (Figure 81).

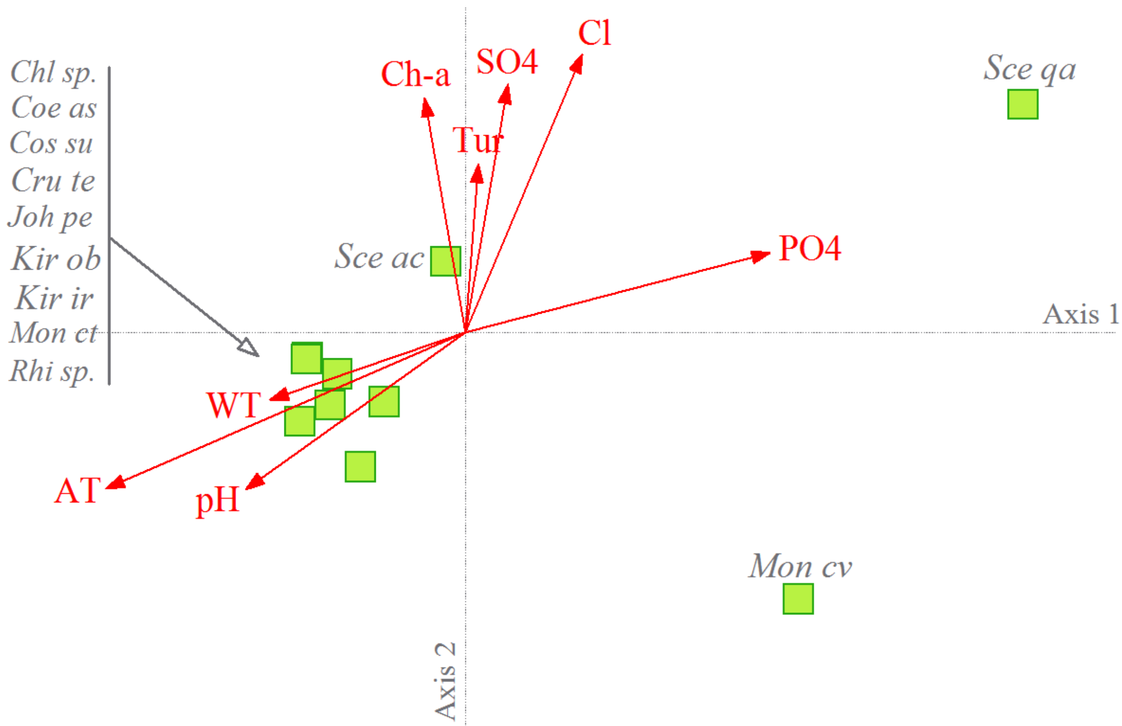


Figure 100: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

Most of Chlorophyceae genera prefer relatively low to moderate Air Temperature, Water Temperature, pH, Orthophosphate, Chloride, Sulphate, & Turbidity and chlorophyll-a. The exception is demonstrated by *Scenedesmus quadricauda*, which seems to prefer relatively high Orthophosphate, Chloride, Sulphate, & Turbidity and chlorophyll-a. In addition, *Monoraphidium convolutum* prefers relatively high Orthophosphate.

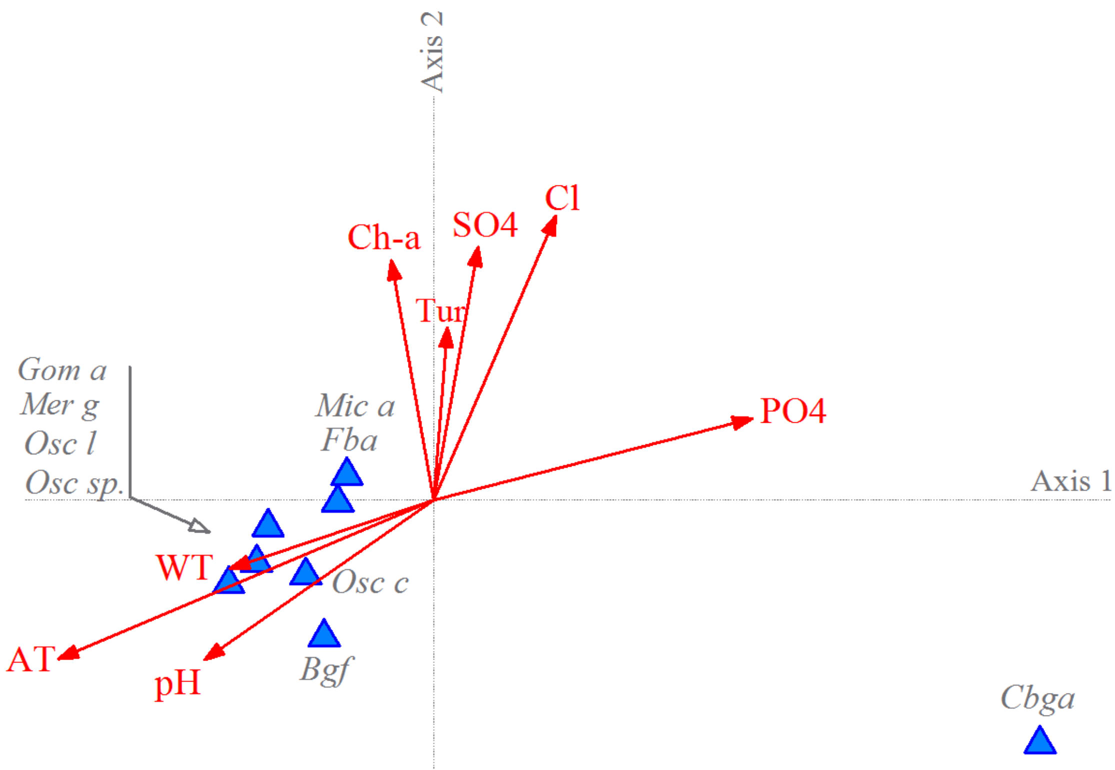


Figure 101: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

Most of Cyanophyceae genera prefer relatively low to moderate Air Temperature, Water Temperature, pH, Orthophosphate, Chloride, Sulphate, & Turbidity and chlorophyll-a. Only the Coccoid blue – green algae prefer relatively high Orthophosphate.

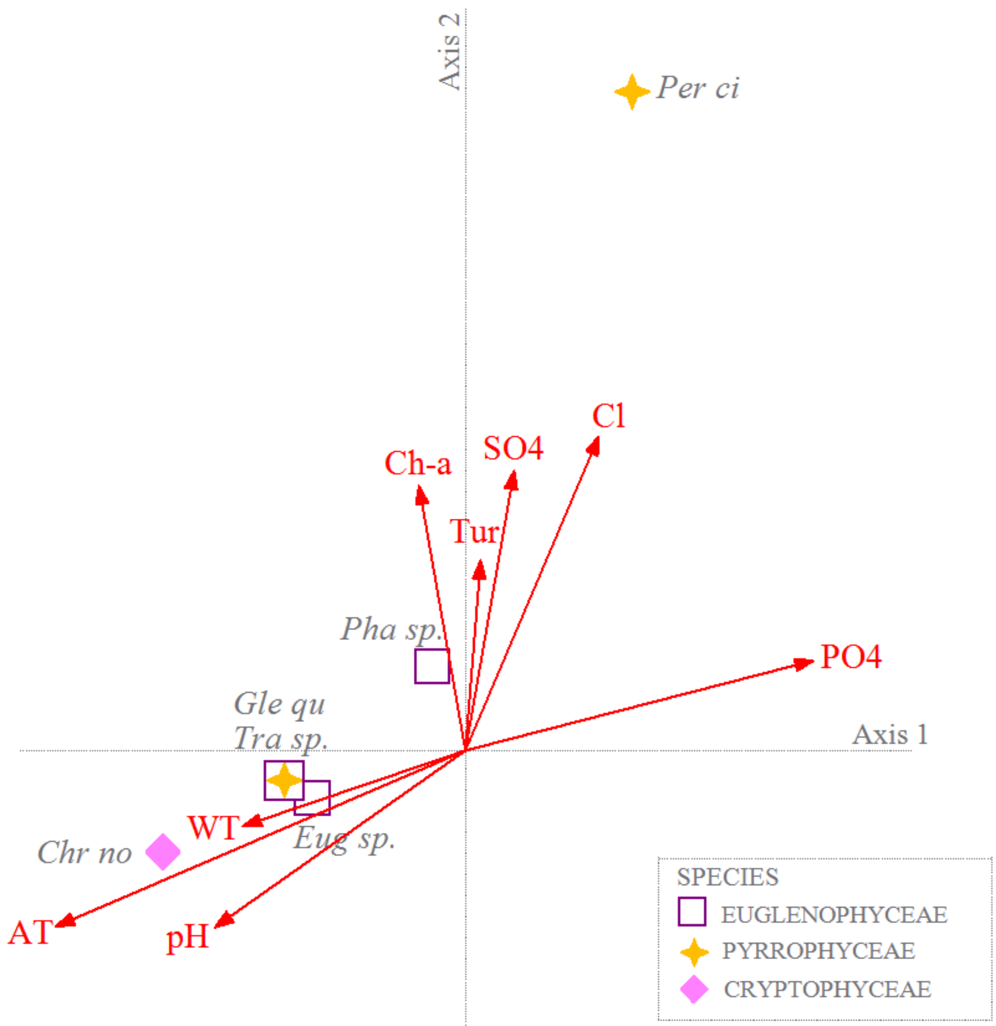


Figure 102: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera prefer relatively low to moderate Air Temperature, Water Temperature, pH, Orthophosphate, Chloride, Sulphate, & Turbidity and chlorophyll-a, except *Chroomonas nordstedtii*, which seems to prefer relatively high Air Temperature, Water Temperature, & pH.

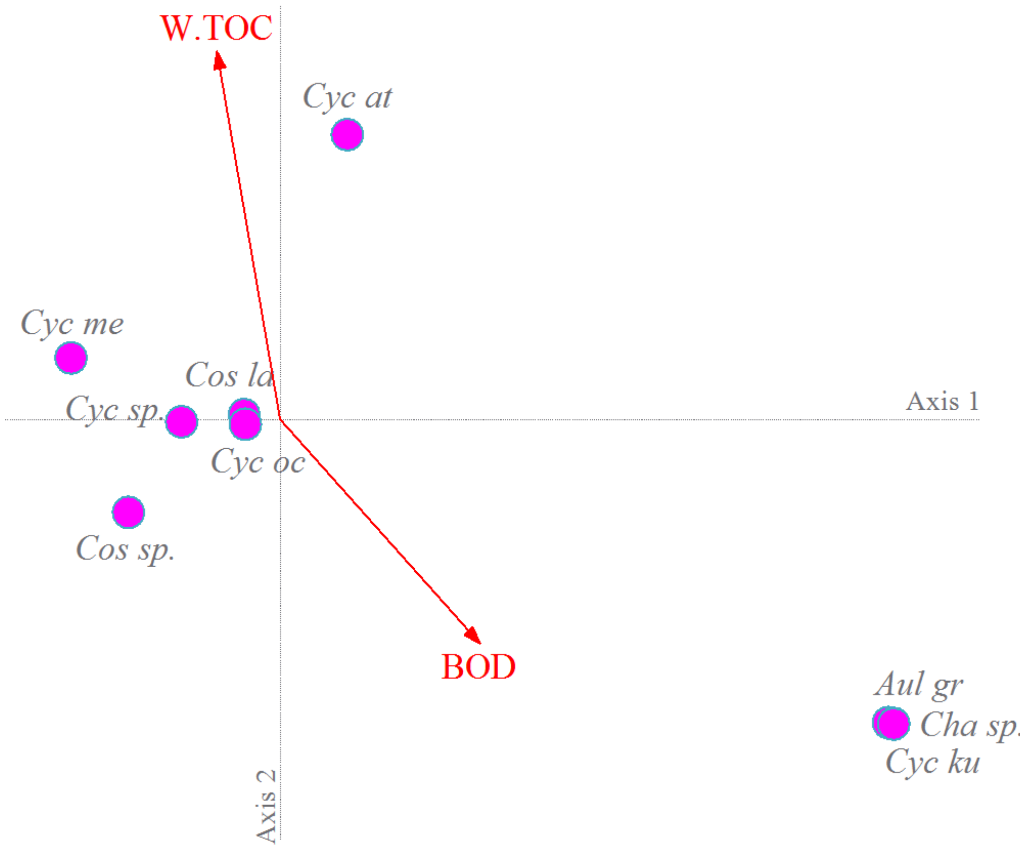


Figure 103: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Most of Bacillariophyceae-Centrales genera prefer relatively low to moderate Water Total Organic Carbon and Biochemical Oxygen Demand. However, *Aulacoseira granulata, Chaetoceros sp.,* & *Cyclotella kuetzingiana* can occur in conditions with relatively high Biochemical Oxygen Demand. In addition, *Cyclotella atomus* can tolerate relatively high Water Total Organic Carbon.

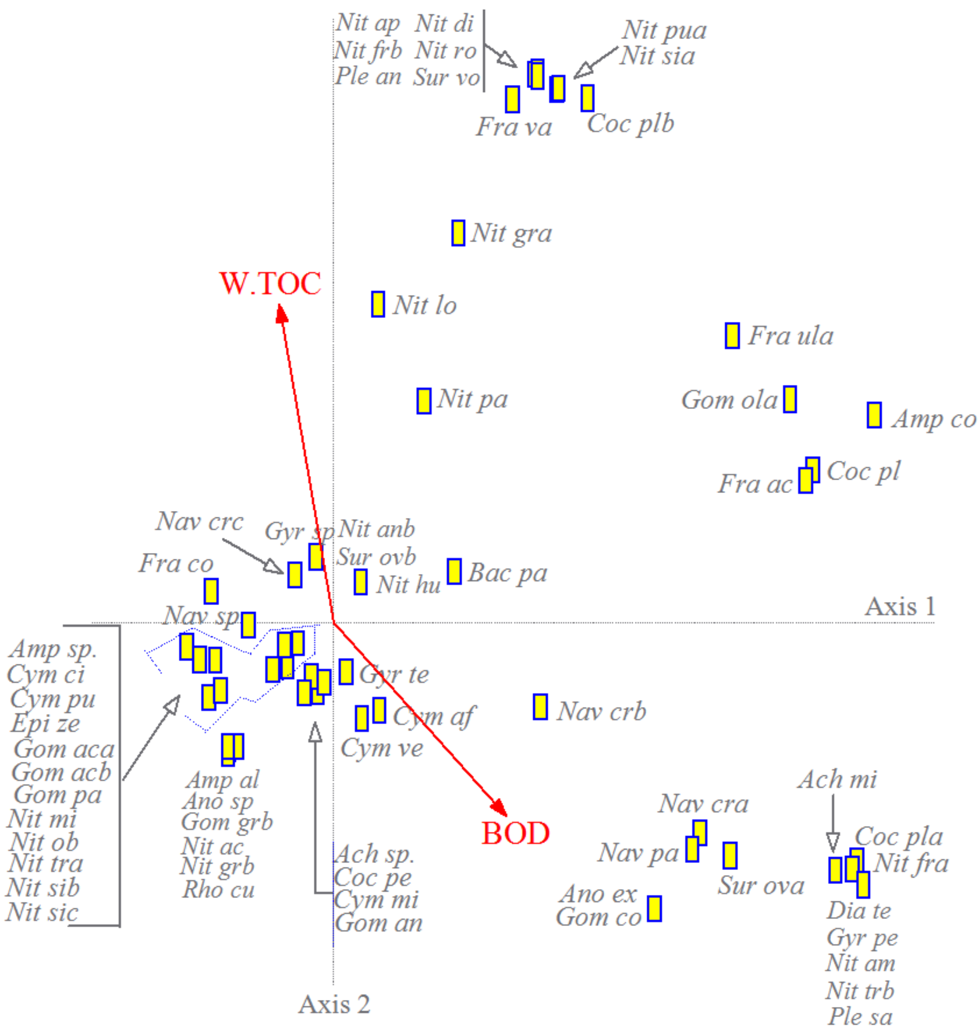


Figure 104: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Most of Bacillariophyceae-Pennales genera prefer relatively low to moderate Water Total Organic Carbon and Biochemical Oxygen Demand. However, *Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis,* & *Pleurosigma salinarum*, can occur in conditions with relatively high Biochemical Oxygen Demand. In addition, *Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum, Surirella augusta, Nitzschia punctata, Nitzschia sigma, Cocconeis placentula var. lineata, Fragilaria vaucheriae, Nitzschia gracilis,* & *Nitzschia longissima* can tolerate relatively high Water Total Organic Carbon (Figure 86).

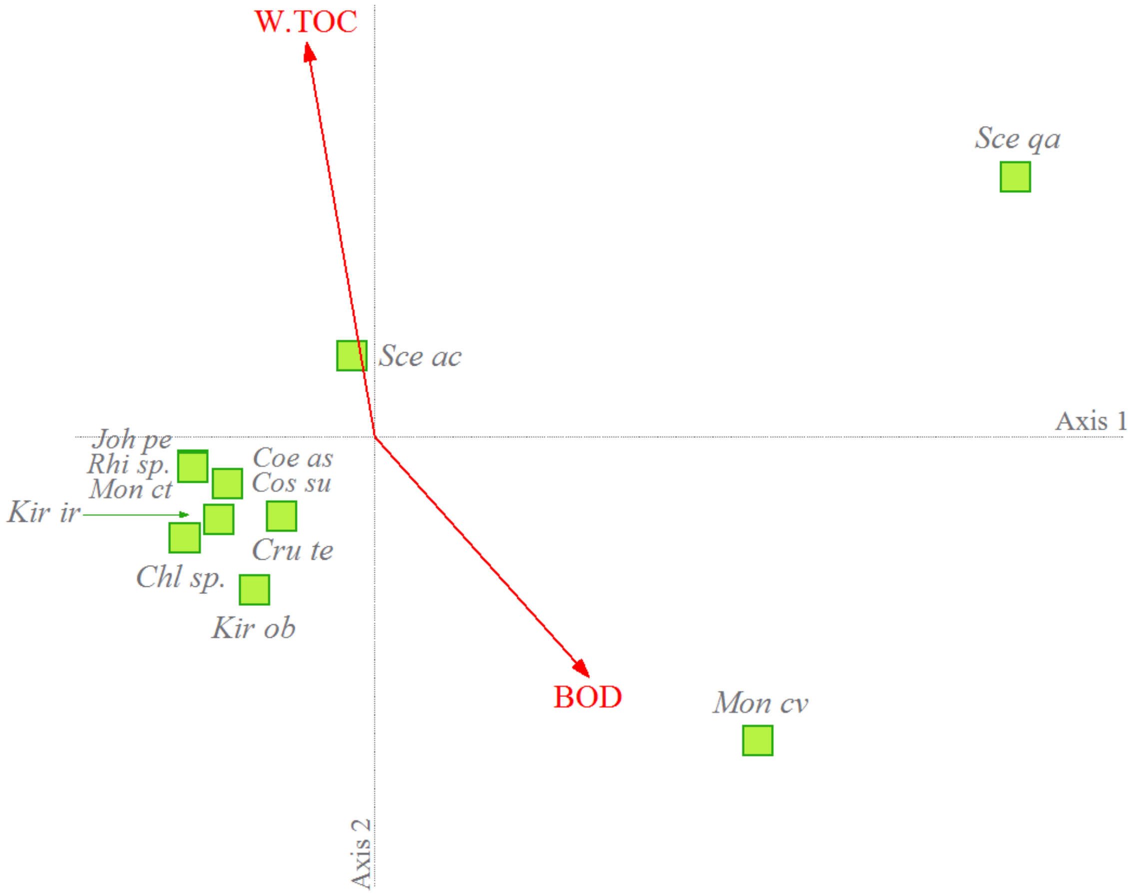


Figure 105: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Most of Chlorophyceae genera prefer relatively low Water Total Organic Carbon and low to moderate Biochemical Oxygen Demand, except *Monoraphidium convolutum*, which seems to tolerate relatively high Biochemical Oxygen Demand conditions and *Scenedesmus quadricauda*, which can tolerate higher Water Total Organic Carbon when compared with the others.

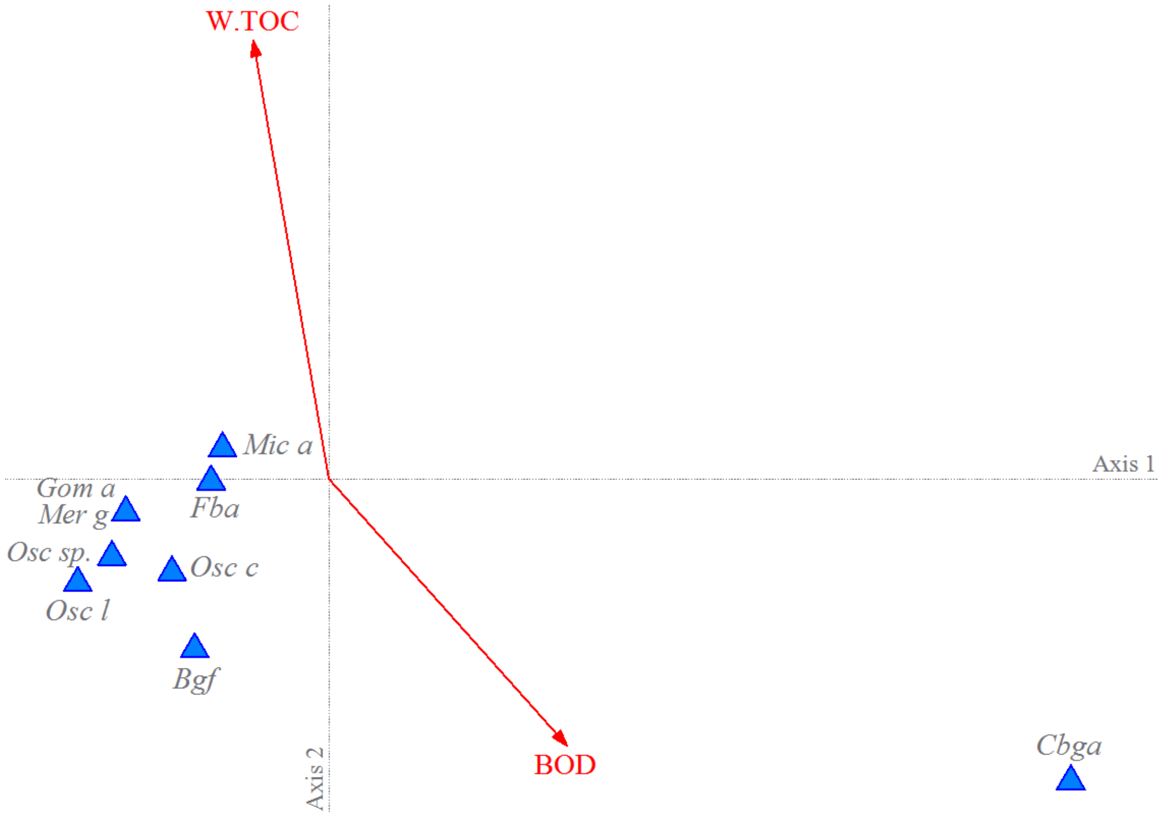


Figure 106: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Most of Cyanophyceae genera prefer relatively low Water Total Organic Carbon and low to moderate Biochemical Oxygen Demand, except Coccoid blue – green algae which seem to tolerate high Biochemical Oxygen Demand conditions.

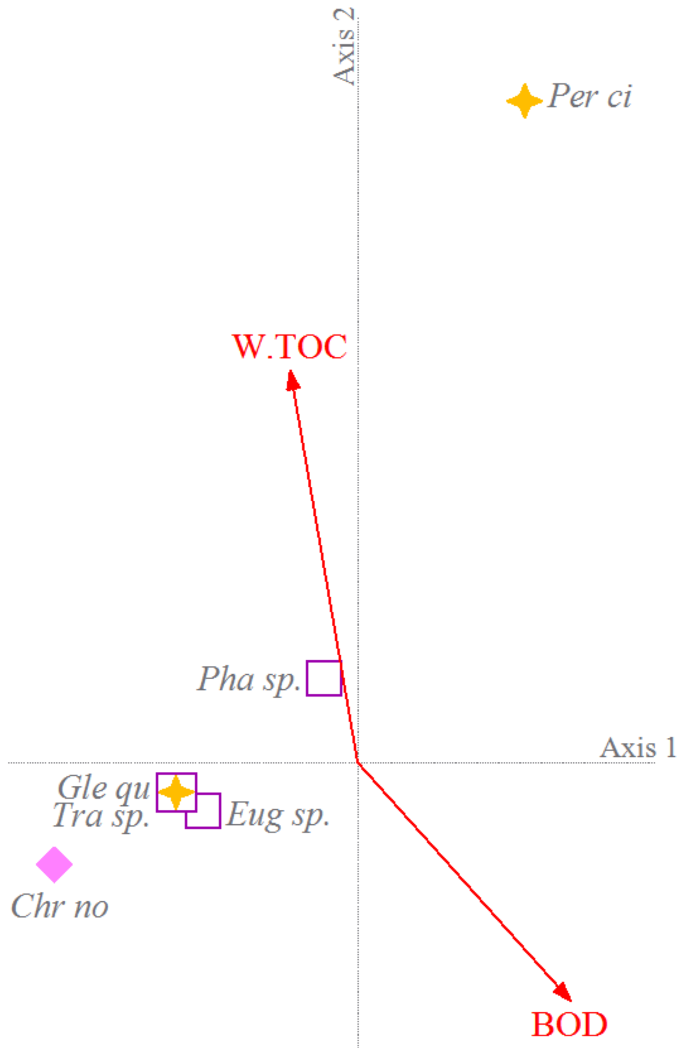


Figure 107: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera prefer relatively low Water Total Organic Carbon and Biochemical Oxygen Demand, except *Peridinium cinctum*, which seem to tolerate high Water Total Organic Carbon conditions.

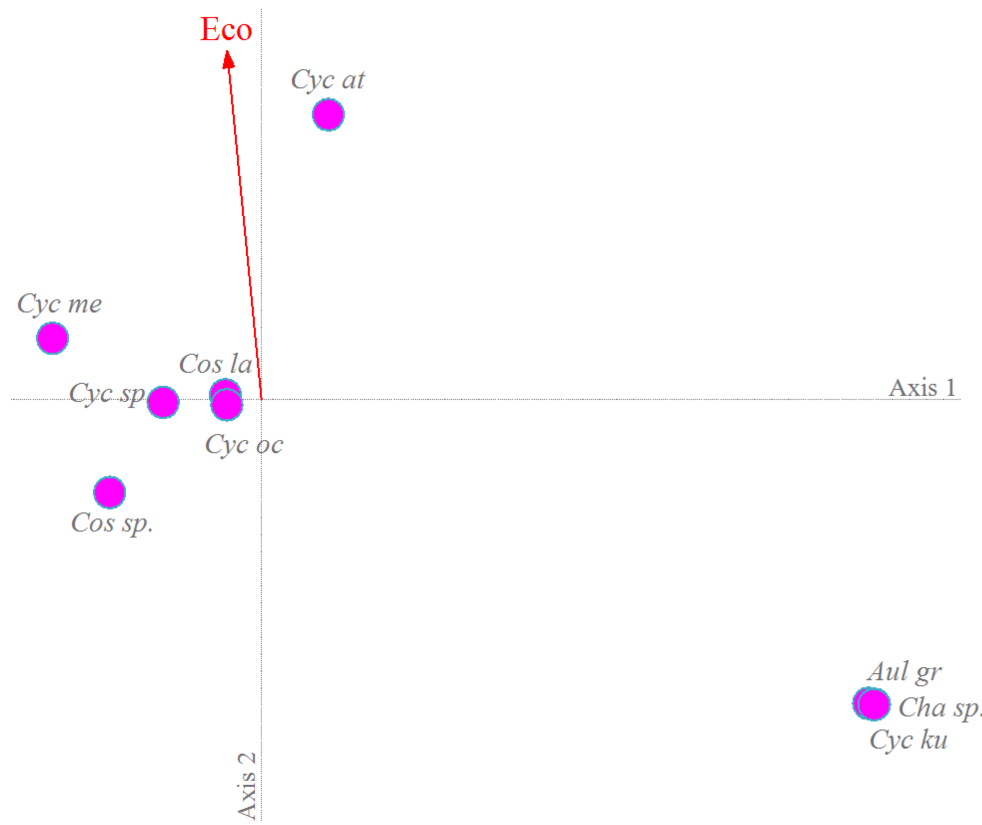


Figure 108: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

Most of Bacillariophyceae-Centrales genera prefer relatively low *E. coli* conditions, except *Cyclotella atomus*, which seem to tolerate the occurrence of *E. coli* at relatively high levels.

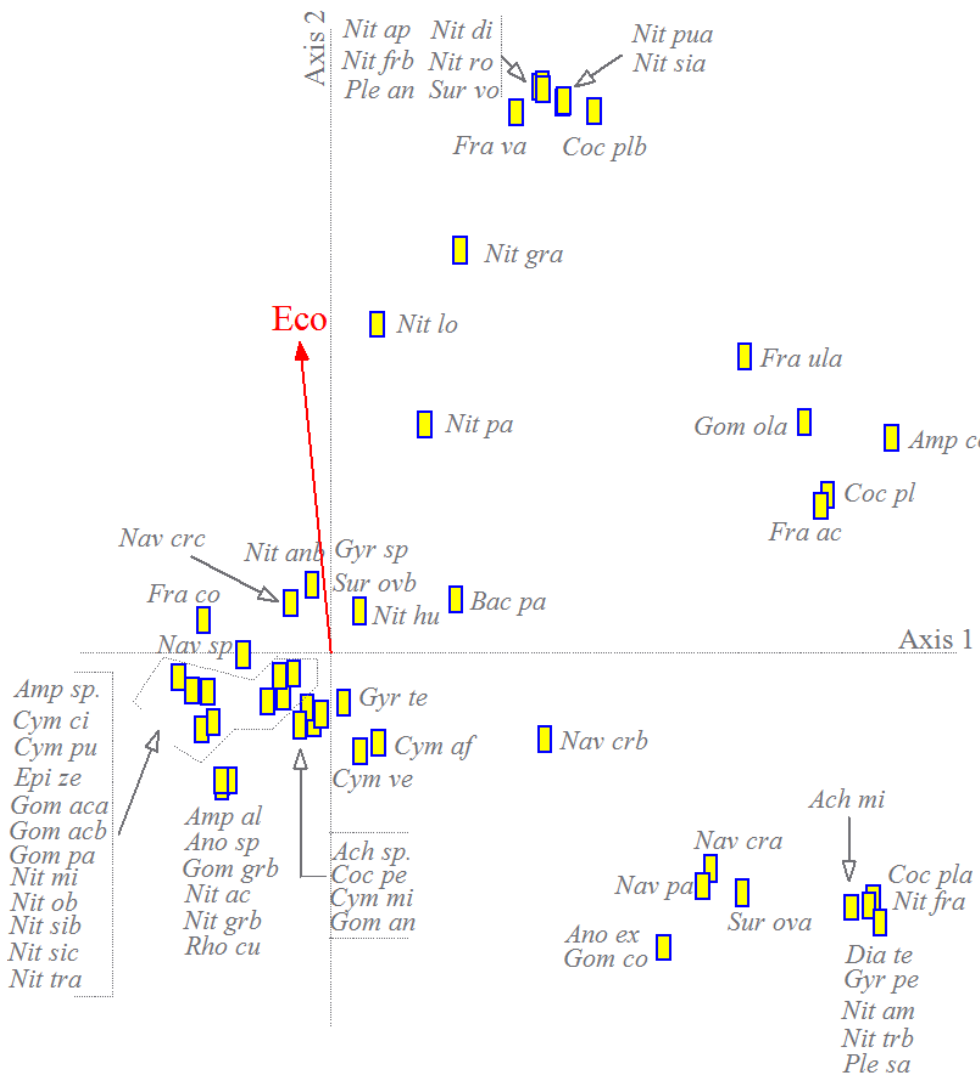


Figure 109: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

Most of Bacillariophyceae-Pennales genera prefer relatively low *E. coli* conditions, except *Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum, Surirella augusta, Nitzschia punctata, Nitzschia sigma, Cocconeis placentula var. lineata, Fragilaria vaucheriae, Nitzschia gracilis, Nitzschia longissima, Synedra ulna,* & *Nitzschia palea*, which seem to tolerate relatively high *E. coli* levels.

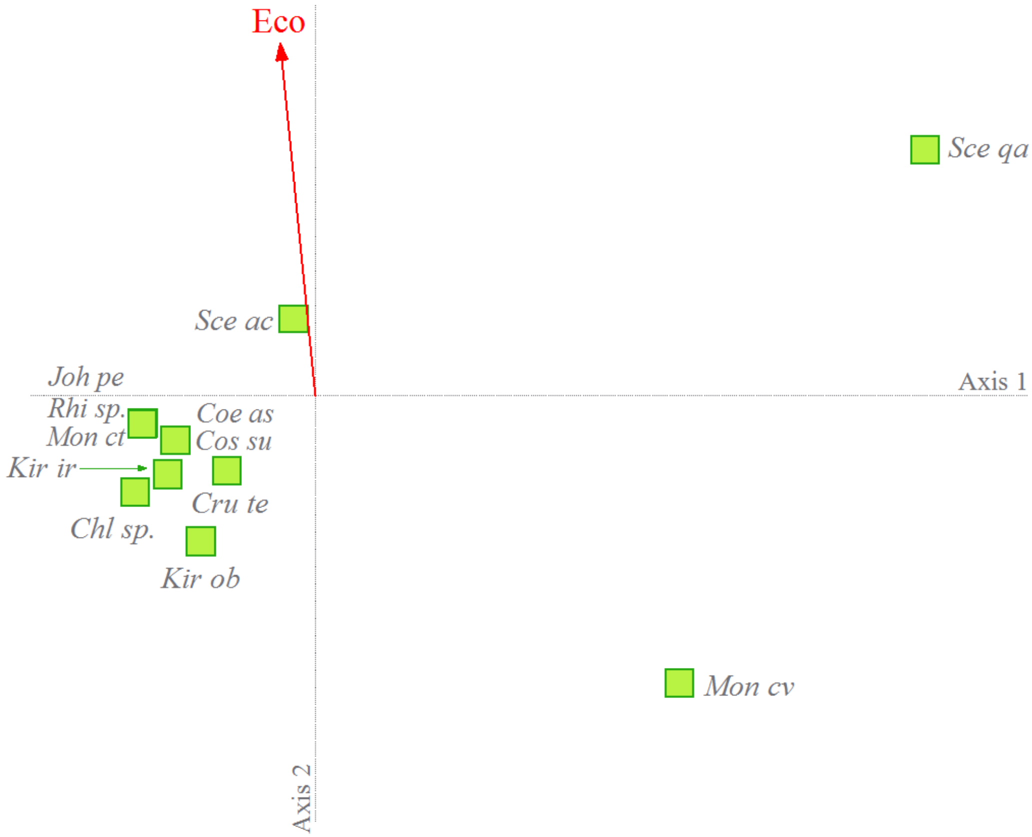


Figure 110: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

Most of Chlorophyceae genera prefer relatively low *E. coli* conditions, except *Scenedesmus quadricauda*, which seem to tolerate conditions with relatively moderate *E. coli* presence.

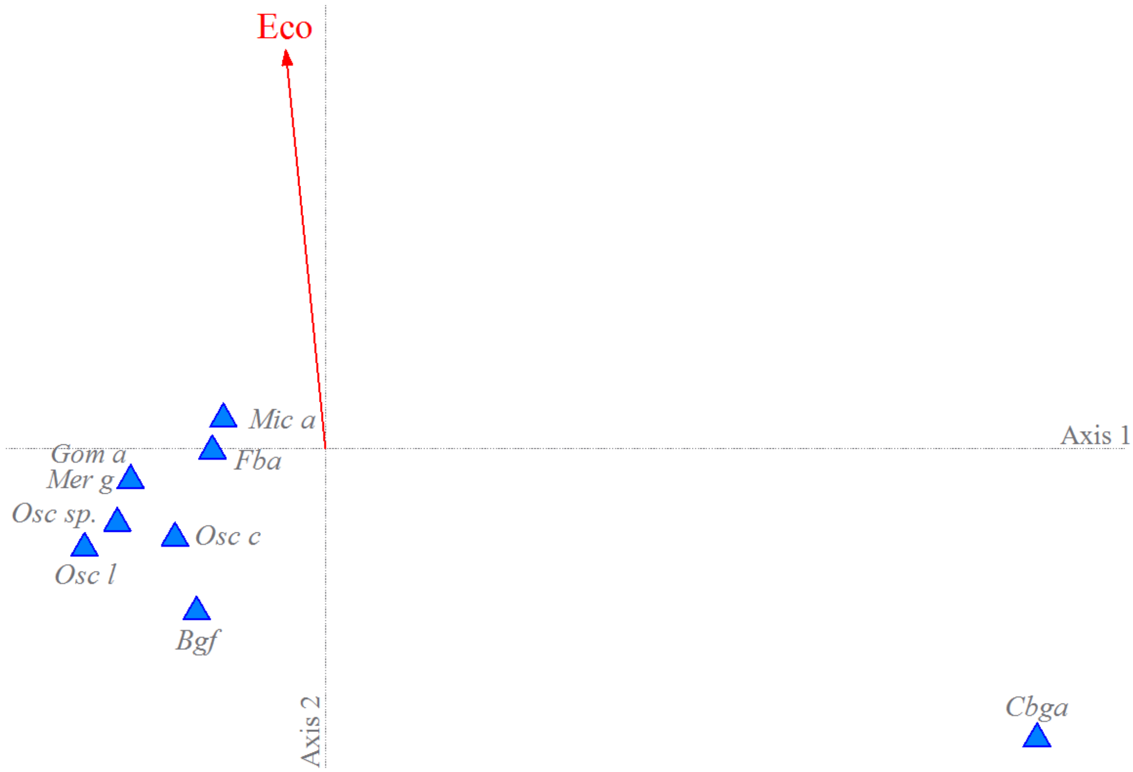


Figure 111: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

From the figure above, it can be distinguished that Cyanophyceae genera prefer low *E. coli* levels and correlated negatively with it.

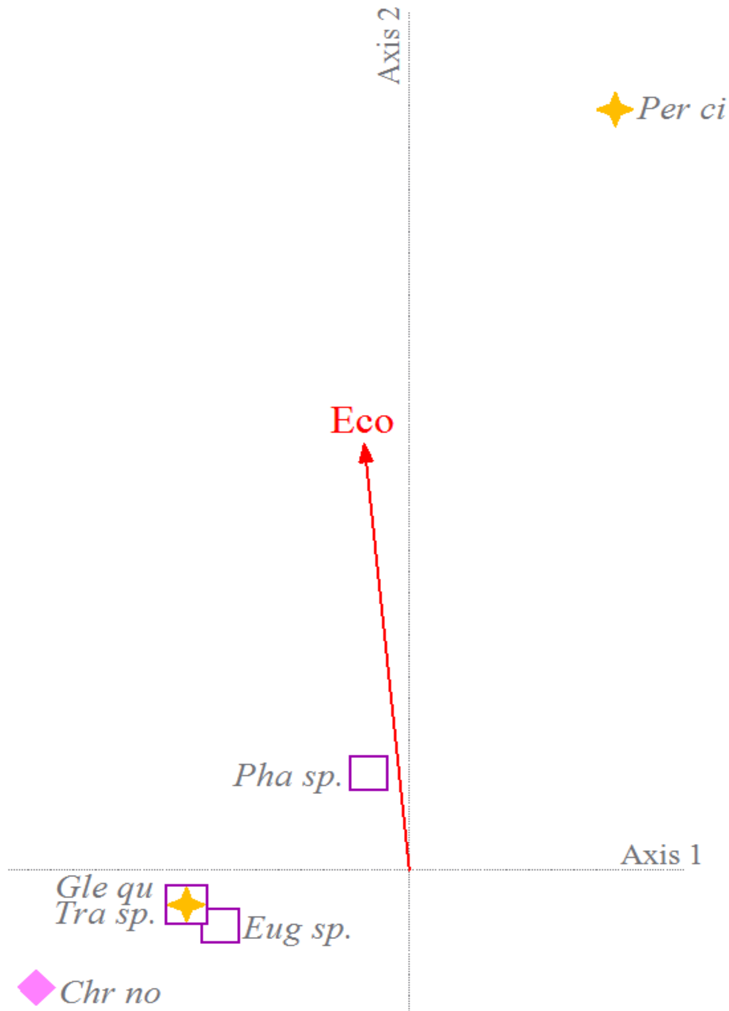


Figure 112: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

From the other hand, Figure 94 can demonstrate the negative correlations between most Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera and *E. coli* presence. However, *Peridinium cinctum* is the only species tolerating high *E. coli* conditions.

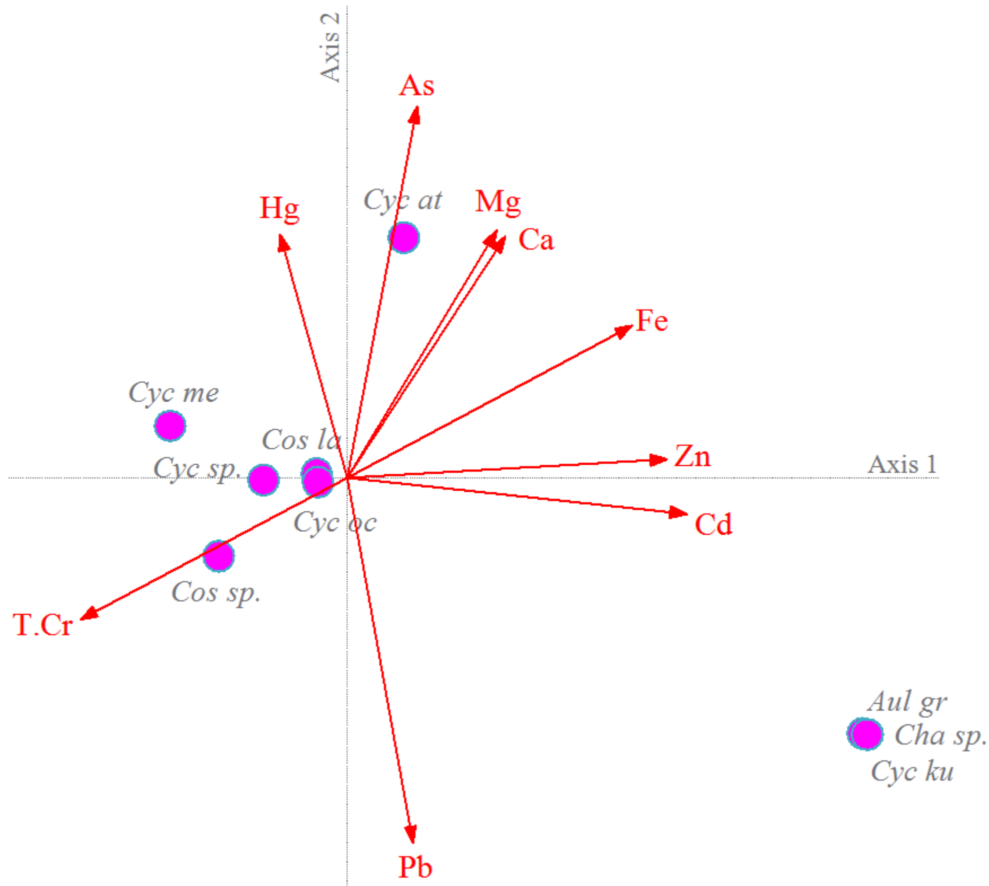


Figure 113: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

When investigating the relationship between Bacillariophyceae-Centrales and the important heavy metals, it can be seen that *Aulacoseira granulata, Chaetoceros sp.*, & *Cyclotella kuetzingiana* can tolerate relatively high concentrations of Lead, Cadmium, Zinc, & Iron, and prefer relatively low concentrations of the other heavy metals.

Cyclotella atomus can tolerate relatively high concentrations of Mercury, Arsenic, Magnesium, & Calcium, moderate Iron, and prefers relatively low concentrations of the other heavy metals.

Cyclotella meneghiniana, Cyclotella sp., & *Coscinodiscus sp.* can be distinguished by their tolerance to relatively moderate Total Chromium concentrations. In addition, they prefer relatively low concentrations of the other heavy metals.

Coscinodiscus lacustris and *Cyclotella ocellata* are the Bacillariophyceae-Centrales genera, which prefer low Heavy metals concentrations.

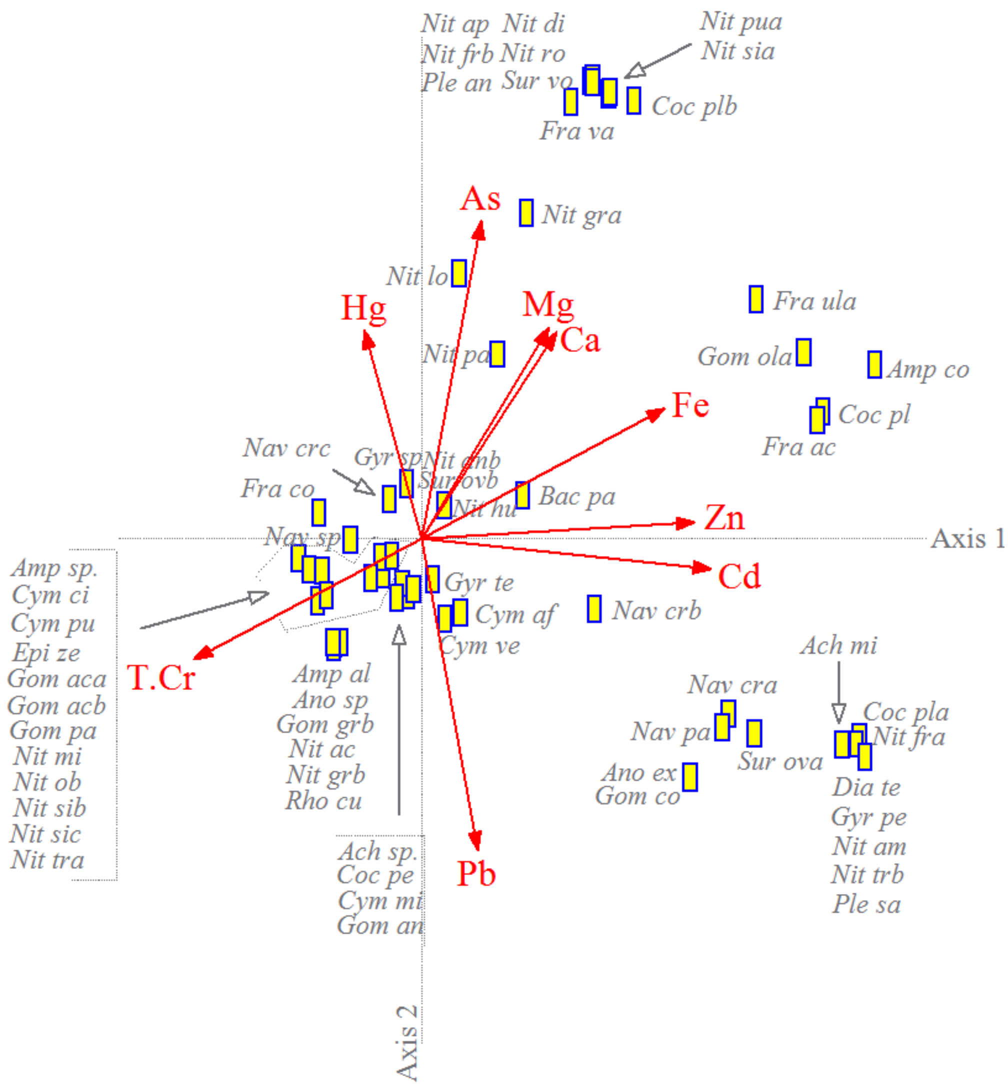


Figure 114: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

When plotting Bacillariophyceae-Pennales with the important heavy metals, it can be seen that most of them prefer relatively low to moderate heavy metals concentrations.

However, *Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis,* & *Pleurosigma salinarum*, can tolerate relatively high concentrations of Lead, Cadmium, Zinc, & Iron, and prefer relatively low concentrations of the other heavy metals.

Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum, Surirella augusta, Nitzschia punctata, Nitzschia sigma, Cocconeis placentula var. lineata, Fragilaria *vaucheriae, Nitzschia gracilis, Nitzschia longissima,* & *Synedra ulna* can tolerate relatively high concentrations of Magnesium, & Calcium, Iron, and prefer relatively low concentrations of the other heavy metals.

Synedra ulna, Gomphonema olivaceum, Amphora coffeaeformis, Cocconeis placentula, & *Fragilaria acus* can tolerate relatively high concentrations of Magnesium, Calcium, Iron, Cadmium, & Zinc and prefer relatively low concentrations of the other heavy metals.

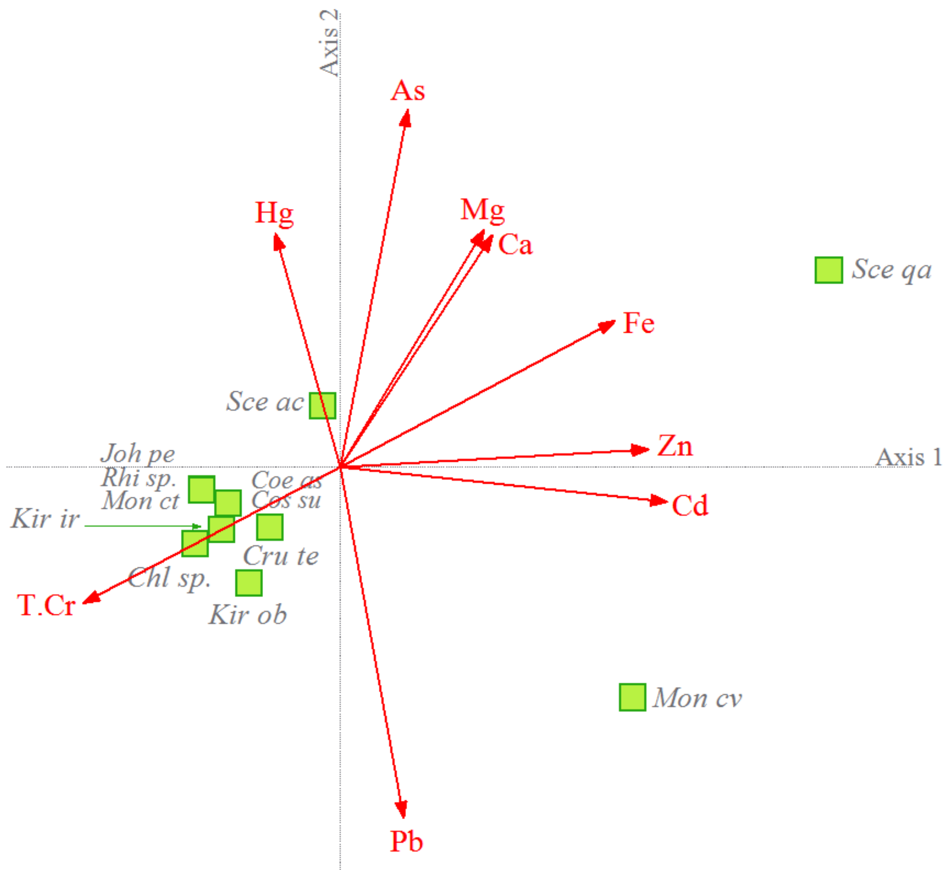


Figure 115: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of Chlorophyceae genera respond to the important heavy metals by preferring relatively low to moderate concentrations. Moreover, they seem to prefer moderate concentrations of Total Chromium upon the other heavy metals.

However, *Monoraphidium convolutum* can tolerate relatively high Lead, Cadmium, & Zinc concentrations. *Scenedesmus quadricauda* can tolerate relatively high Cadmium, Zinc, Iron, Magnesium, & Calcium.

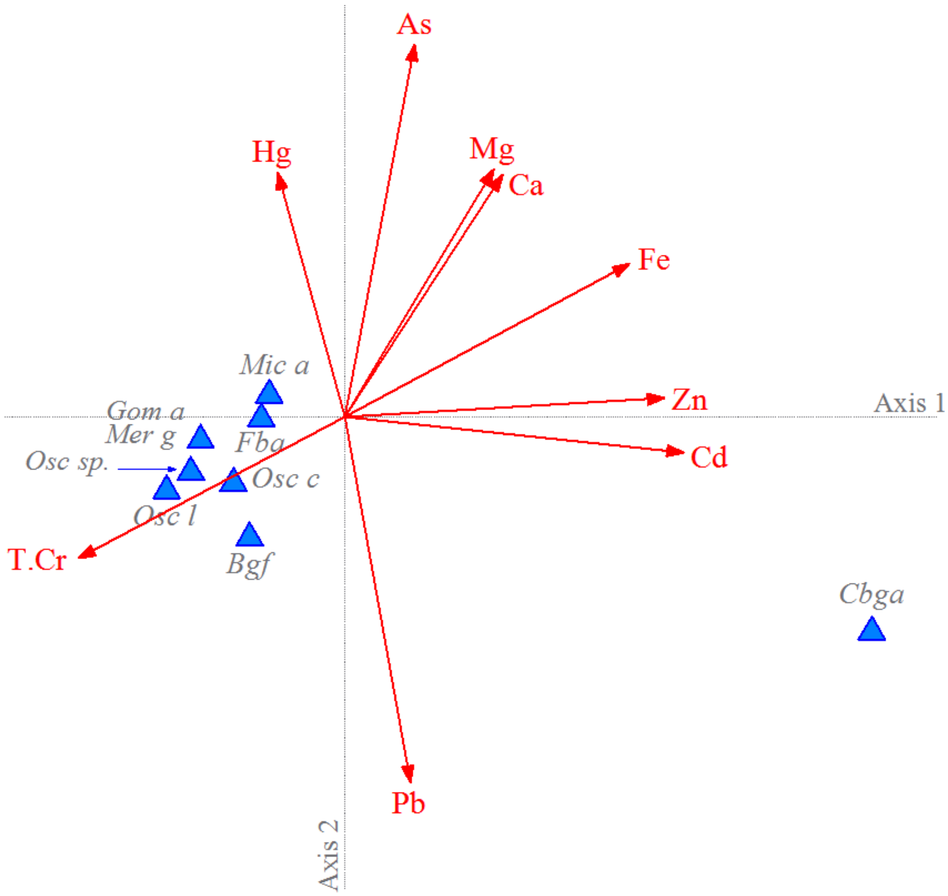


Figure 116: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Relatively, most of Cyanophyceae genera respond negatively when elevating heavy metals, but they seem to prefer moderate concentrations of Total Chromium.

However, Coccoid blue – green algae can tolerate relatively high concentrations of Lead, Cadmium, & Zinc, & Iron.

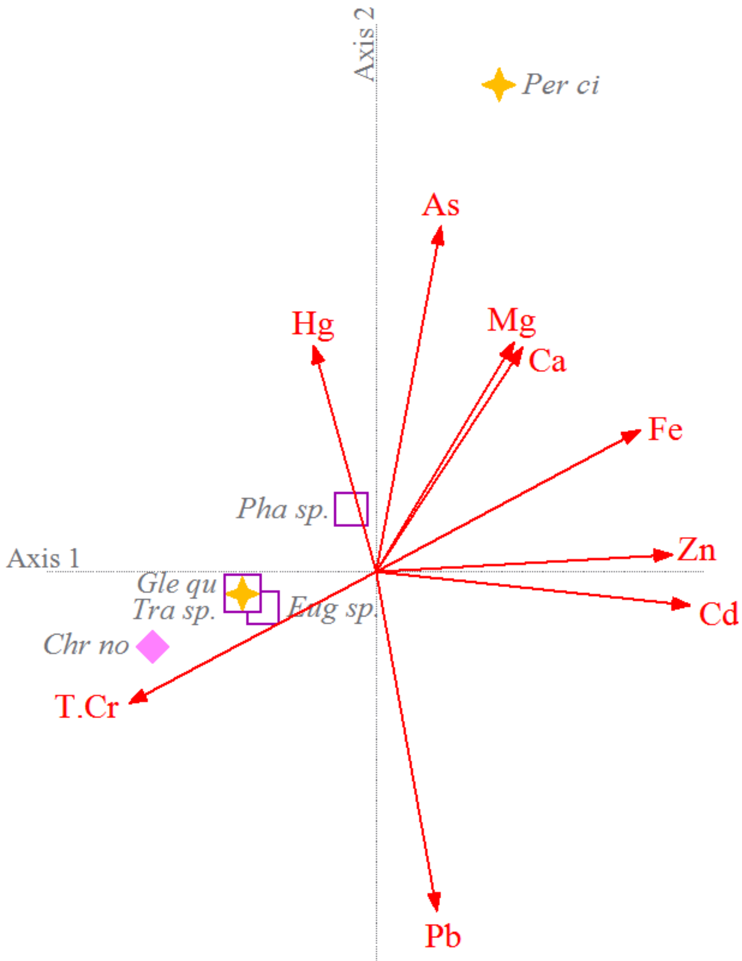


Figure 117: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera prefer relatively low heavy metals, but they seem to prefer moderate concentrations of Total Chromium. In addition, *Chroomonas nordstedtii* seems to tolerate relatively high Total Chromium concentrations.

However, *Peridinium cinctum* can tolerate relatively high concentrations of Mercury, Arsenic, Magnesium, & Calcium, & Iron.

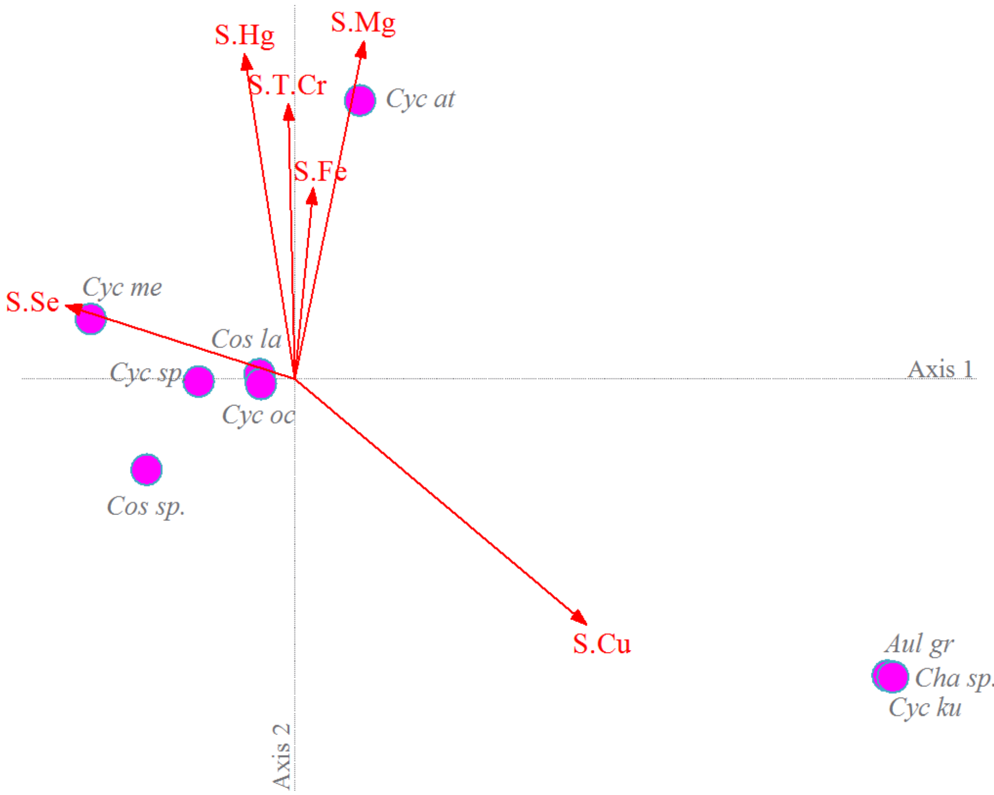


Figure 118: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important Sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Aulacoseira granulata, Chaetoceros sp., and *Cyclotella kuetzingiana* seem to tolerate relatively higher Sediment Copper more than the other species.

Whereas *Cyclotella atomus* seems to tolerate relatively high to moderate concentrations of Sediment Magnesium, Sediment Total chromium, Sediment Mercury, and Sediment Iron with low concentrations of Sediment Selenium and Sediment Copper.

The remaining species seem to tolerate relatively higher Sediment Selenium concentrations than the other sediment heavy metals, when compared with the other species.

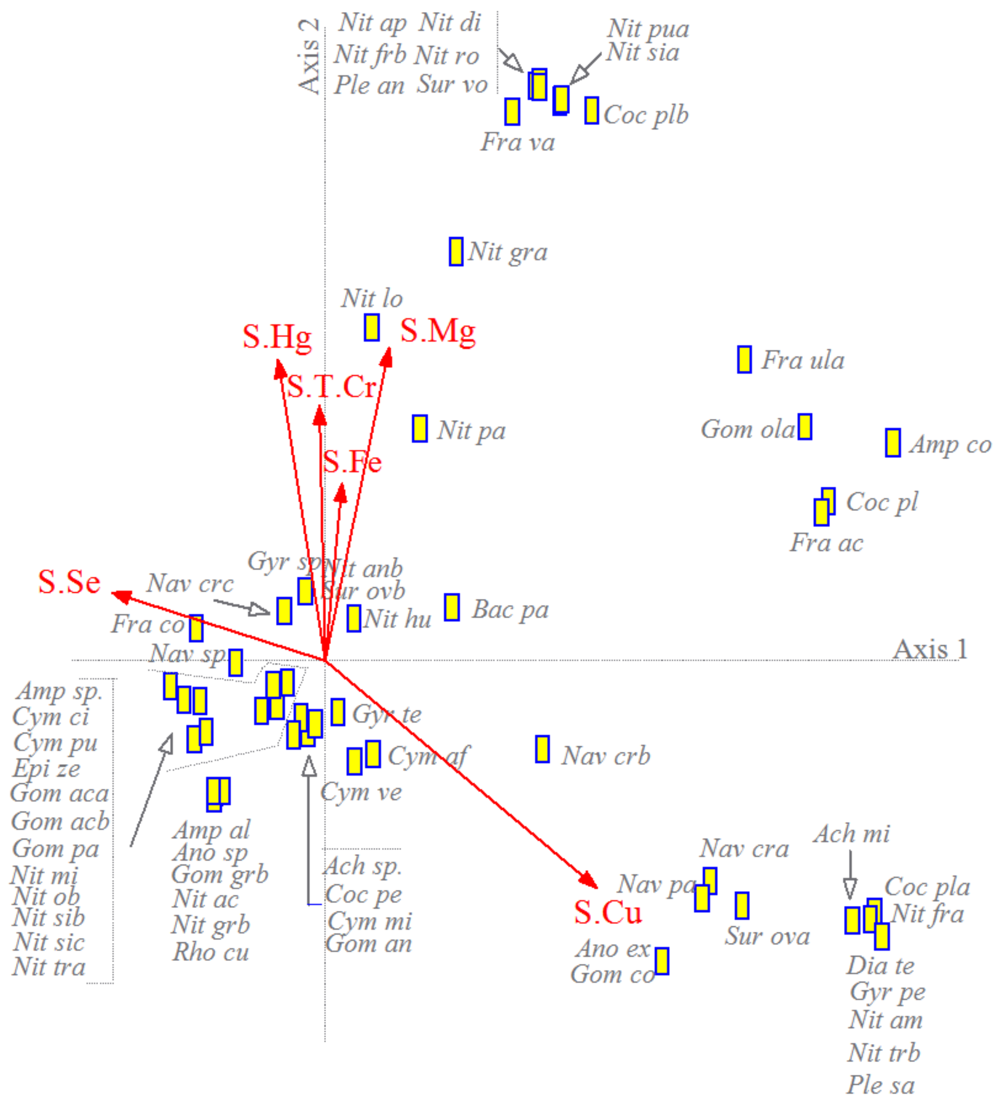


Figure 119: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important Sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of the Bacillariophyceae-Pennales species seem to tolerate conditions with relatively low to moderate concentrations of sediment heavy metals. However, *Navicula crucicula, Navicula parva, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Surirella ovalis, Achnanthes minutissima, Cocconeis placentula var. euglypta, Nitzschia frustulum, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Tryblionella debilis,* and *Pleurosigma salinarum* seem to tolerate relatively higher concentrations of Sediment Copper than the other species.

On the other hand, the species *Fragilaria acus, Cocconeis placentula, Amphora coffeaeformis, Gomphonema olivaceum, Synedra ulna, Nitzschia palea, Nitzschia longissima, Nitzschia gracilis, Fragilaria vaucheriae, Cocconeis placentula var. lineata, Nitzschia sigma, Nitzschia punctata, Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum,* and *Surirella augusta* seem to tolerate conditions with relatively moderate to high concentrations of Sediment Magnesium, Sediment Total chromium, Sediment Mercury, and Sediment Iron, than the other species.

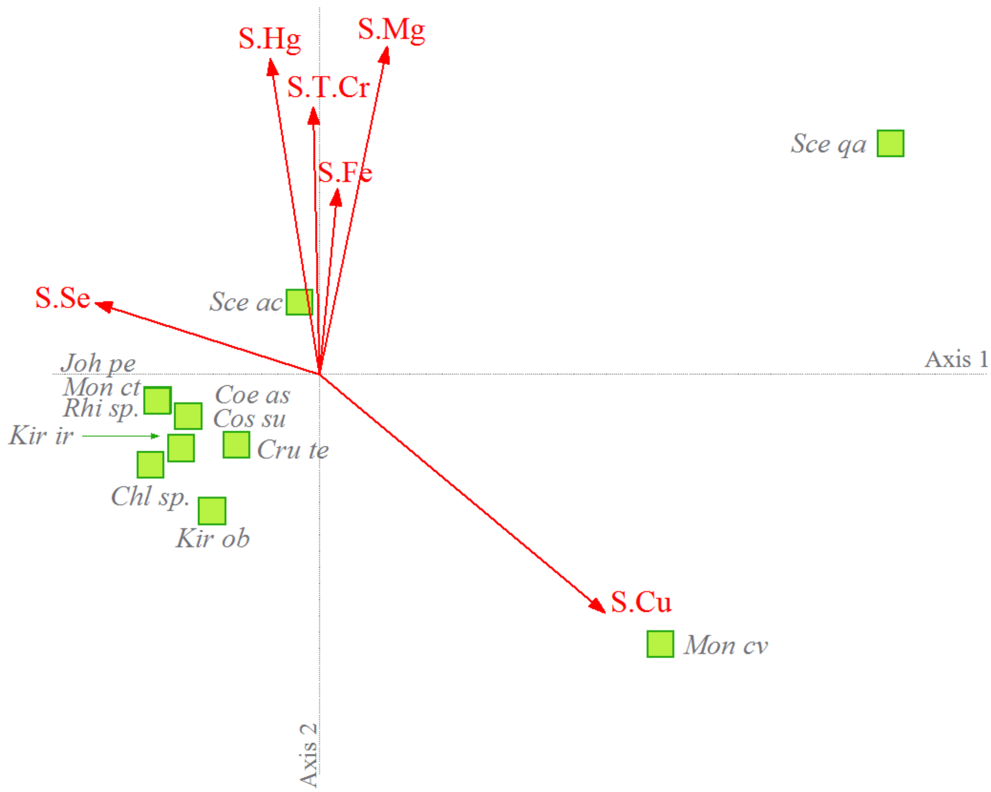


Figure 120: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important Sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of Chlorophyceae genera prefer relatively low concentrations of most sediment heavy metals. However, they seem to prefer moderate concentrations of sediment Selenium.

In addition, *Scenedesmus quadricauda* seems to prefer moderate concentrations of sediment Mercury, sediment Magnesium, sediment total Chromium, & sediment Iron.

Furthermore, *Monoraphidium convolutum* appears to prefer relatively high concentrations of sediment Copper.

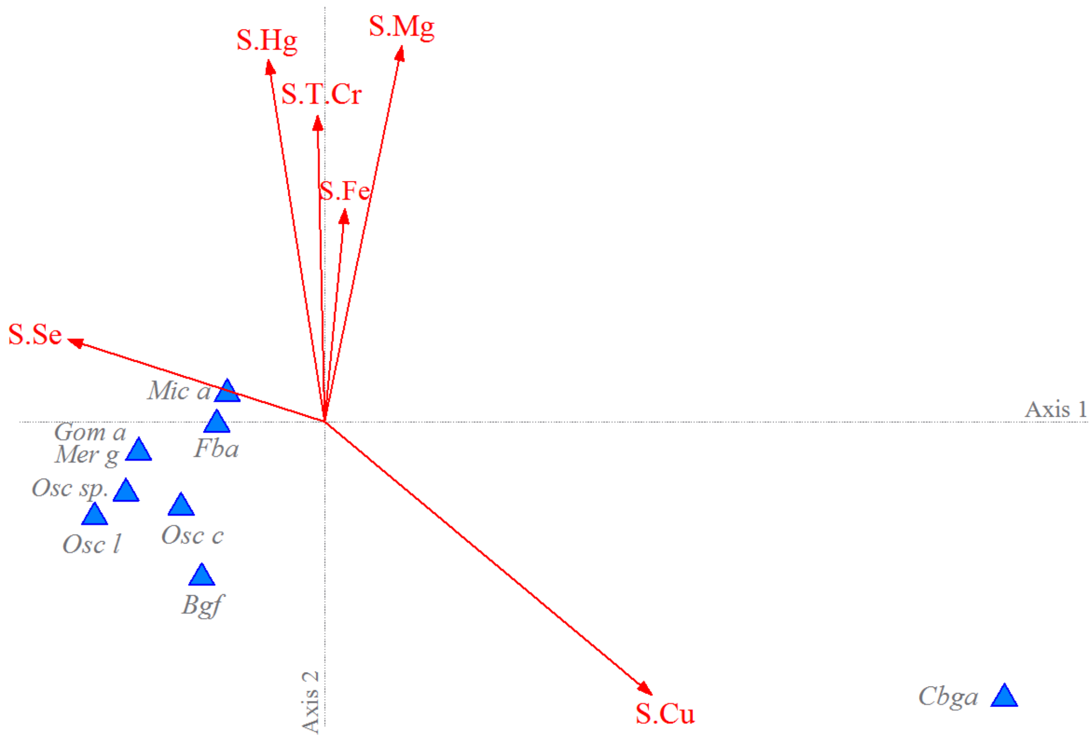


Figure 121: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important Sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of Cyanophyceae genera prefer relatively low concentrations of most sediment heavy metals. However, they seem to prefer moderate concentrations of sediment Selenium.

In addition, Coccoid blue – green algae seem to prefer relatively high concentrations of sediment Copper.

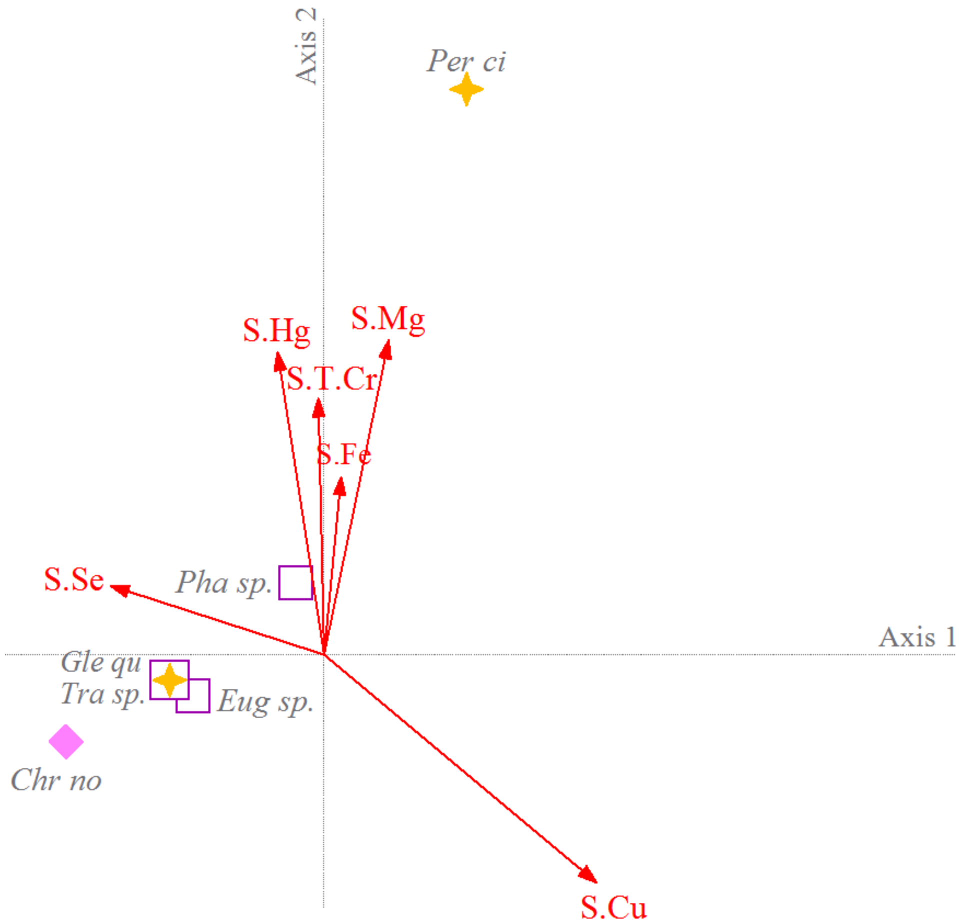


Figure 122: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important Sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera prefer relatively low concentrations of most sediment heavy metals. However, they seem to prefer moderate concentrations of sediment Selenium.

In addition, *Chroomonas nordstedtii* appears to prefer relatively high concentrations of sediment Selenium.

Furthermore, *Peridinium cinctum* seems to prefer relatively high concentrations of sediment Mercury, sediment Magnesium, sediment total Chromium, & sediment Iron.

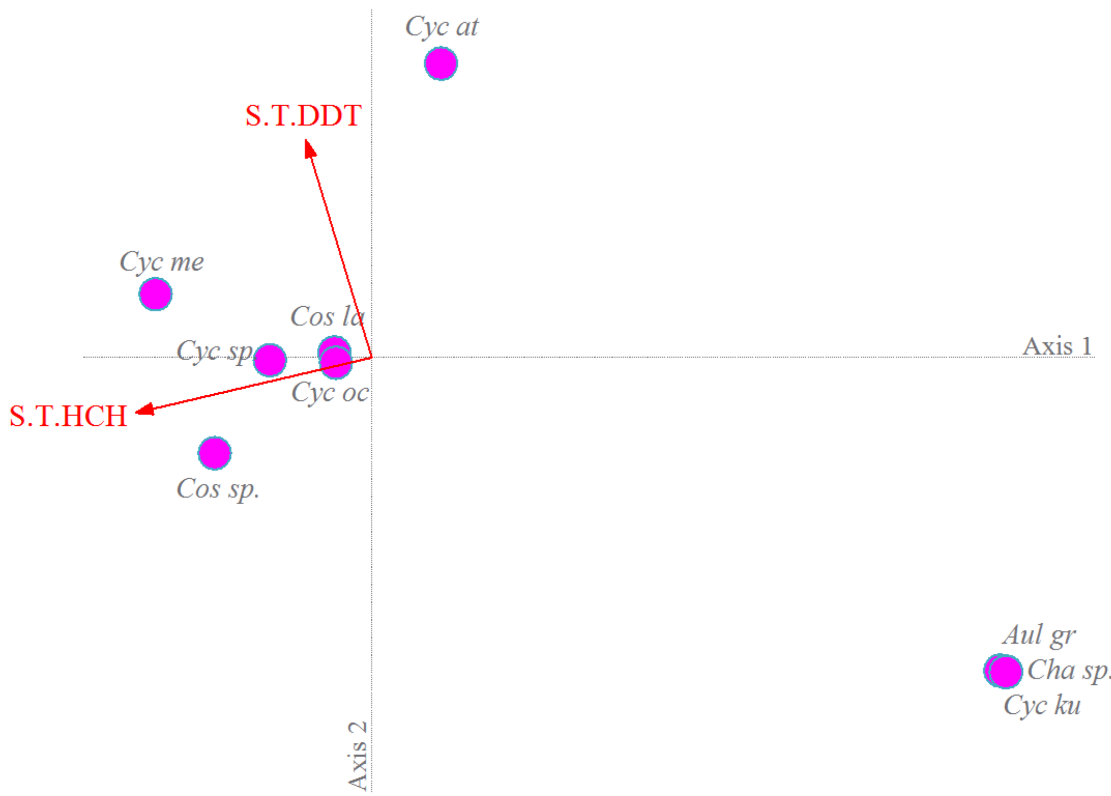


Figure 123: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Most of Bacillariophyceae-Centrales genera seem to prefer relatively low sediment total DDT, except *Cyclotella atomus*, which seems to prefer relatively high concentrations and *Cyclotella meneghiniana*, which seems to prefer relatively moderate concentrations of sediment total DDT.

Most of Bacillariophyceae-Centrales genera seem to prefer relatively low to moderate concentrations of sediment total HCH. In addition, *Cyclotella meneghiniana* and *Coscinodiscus sp.* can tolerate relatively high concentrations of sediment total HCH.

On the other hand, *Aulacoseira granulata, Chaetoceros sp.*, & *Cyclotella kuetzingiana* prefer lower pesticides concentrations in their environment.

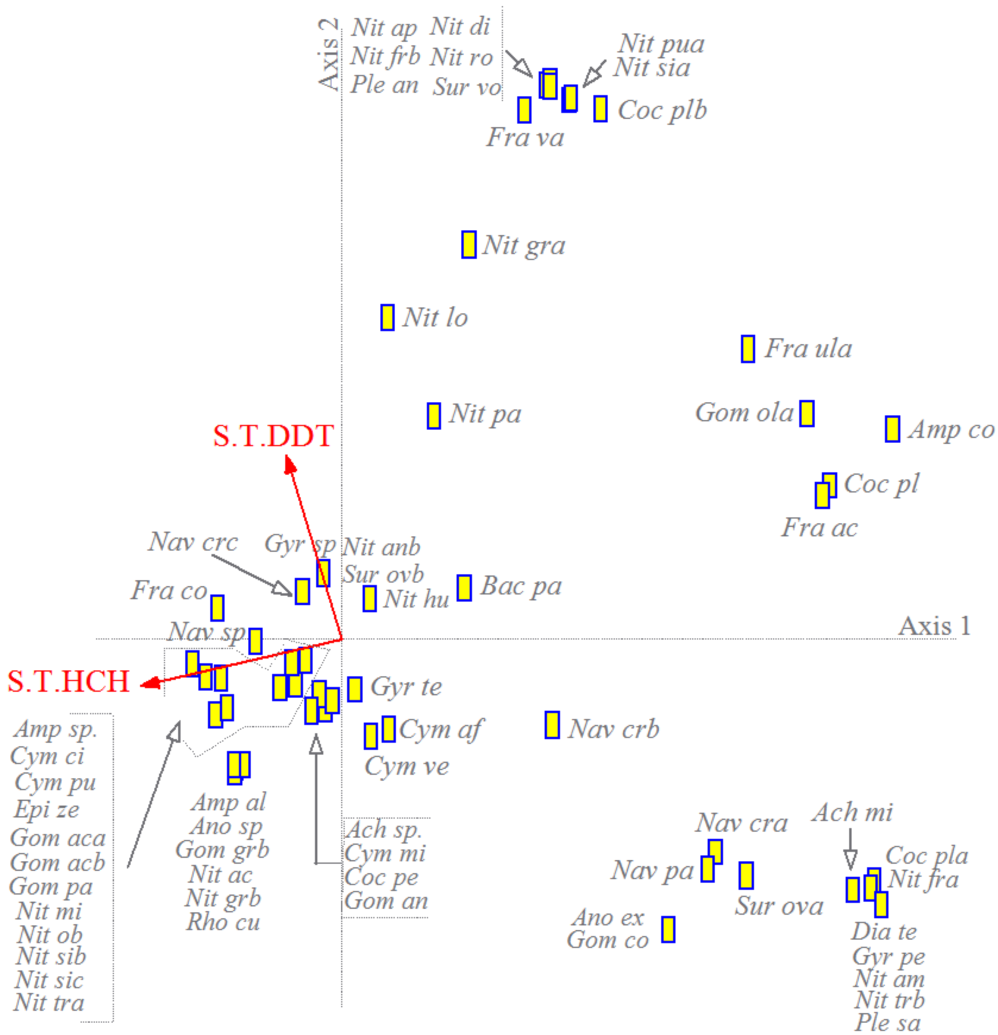


Figure 124: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Most of Bacillariophyceae-Pennales genera seem to prefer relatively low sediment total DDT, except *Nitzschia apiculata, Nitzschia dissipata, Nitzschia frustulum var. perminuta, Nitzschia romana, Pleurosigma angulatum, Surirella augusta, Nitzschia punctata, Nitzschia sigma, Cocconeis placentula var. lineata, Fragilaria vaucheriae, Nitzschia gracilis, Nitzschia longissima, Nitzschia palea,* & *Synedra ulna*, which seem to prefer relatively high concentrations and *Gomphonema olivaceum* and *Amphora coffeaeformis*, which seem to prefer relatively moderate concentrations of sediment total DDT.

Most of Bacillariophyceae-Pennales genera seem to prefer relatively low concentrations of sediment total HCH, except the species demonstrated in the left side of the diagram above, which seem to tolerate relatively moderate to high concentrations of sediment total HCH.

On the other hand, *Navicula cryptocephala, Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma* *tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis,* & *Pleurosigma salinarum* prefer lower pesticides concentrations in their environment.

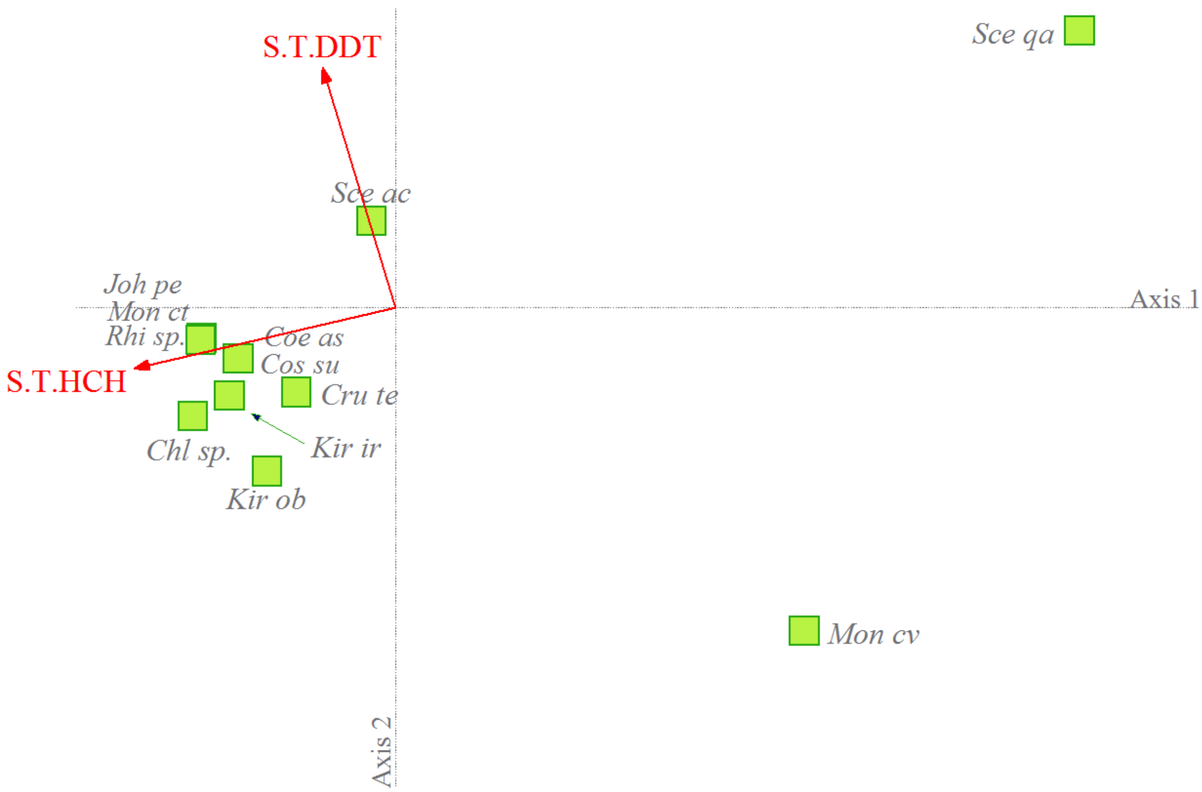


Figure 125: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Most of Chlorophyceae genera seem to prefer relatively low sediment total DDT, except *Scenedesmus quadricauda*, which seem to prefer relatively moderate to high concentrations of sediment total DDT.

Most of Chlorophyceae genera seem to prefer relatively moderate to high concentrations of sediment total HCH.

On the other hand, *Monoraphidium convolutum* prefers lower pesticides concentrations in its environment.

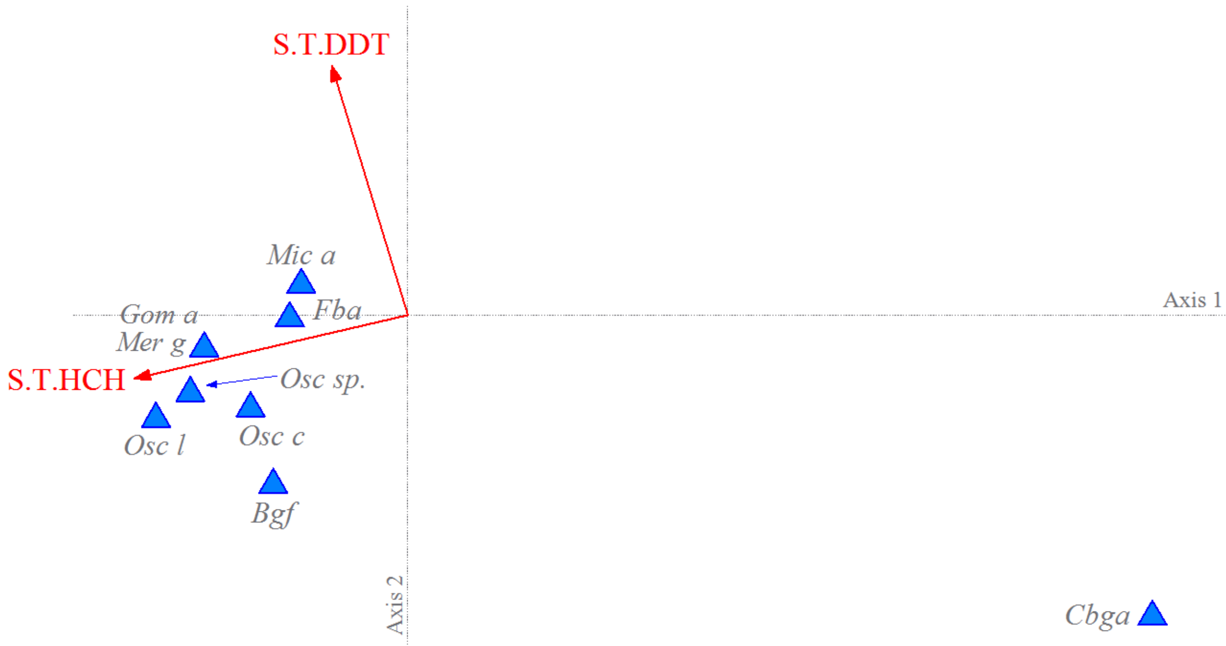


Figure 126: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Most of Cyanophyceae genera seem to prefer relatively low sediment total DDT and moderate to high concentrations of sediment total HCH, as shown above.

From the other hand, Coccoid blue – green algae prefer the lower pesticides concentrations in its environment.

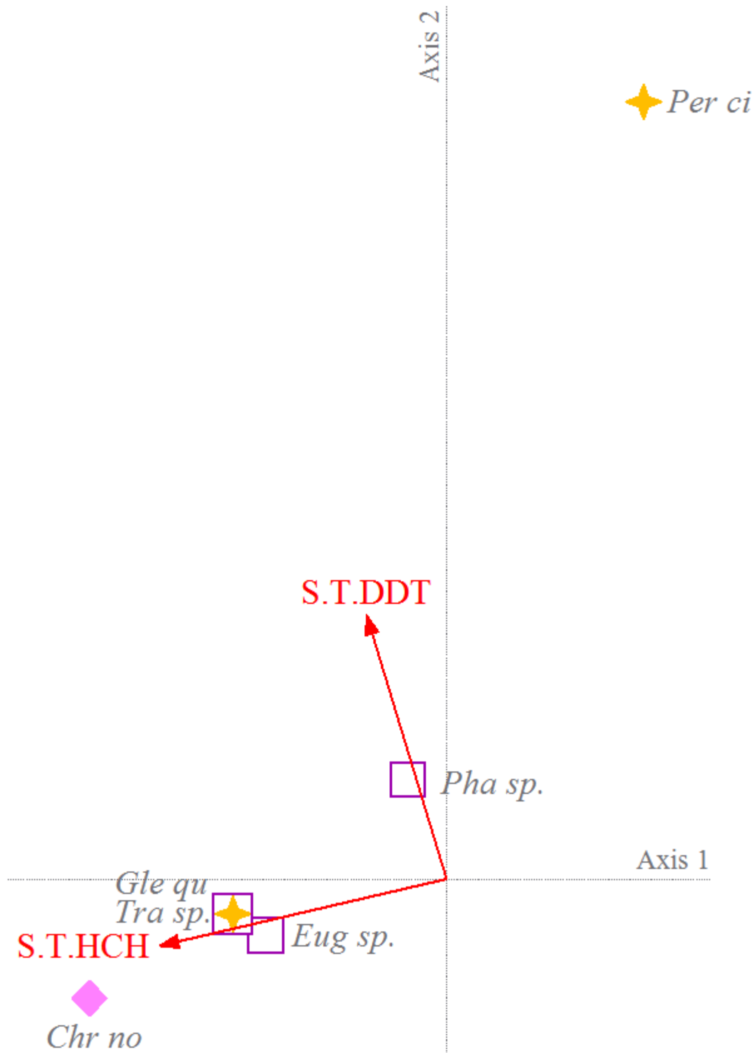


Figure 127: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera seem to prefer relatively low sediment total DDT, except *Peridinium cinctum*, which seem to prefer relatively high concentrations of sediment total DDT.

Most of Chlorophyceae genera seem to prefer relatively moderate to high concentrations of sediment total HCH, especially *Chroomonas nordstedtii*, which seems to prefer relatively higher concentrations of sediment total HCH than the other species.

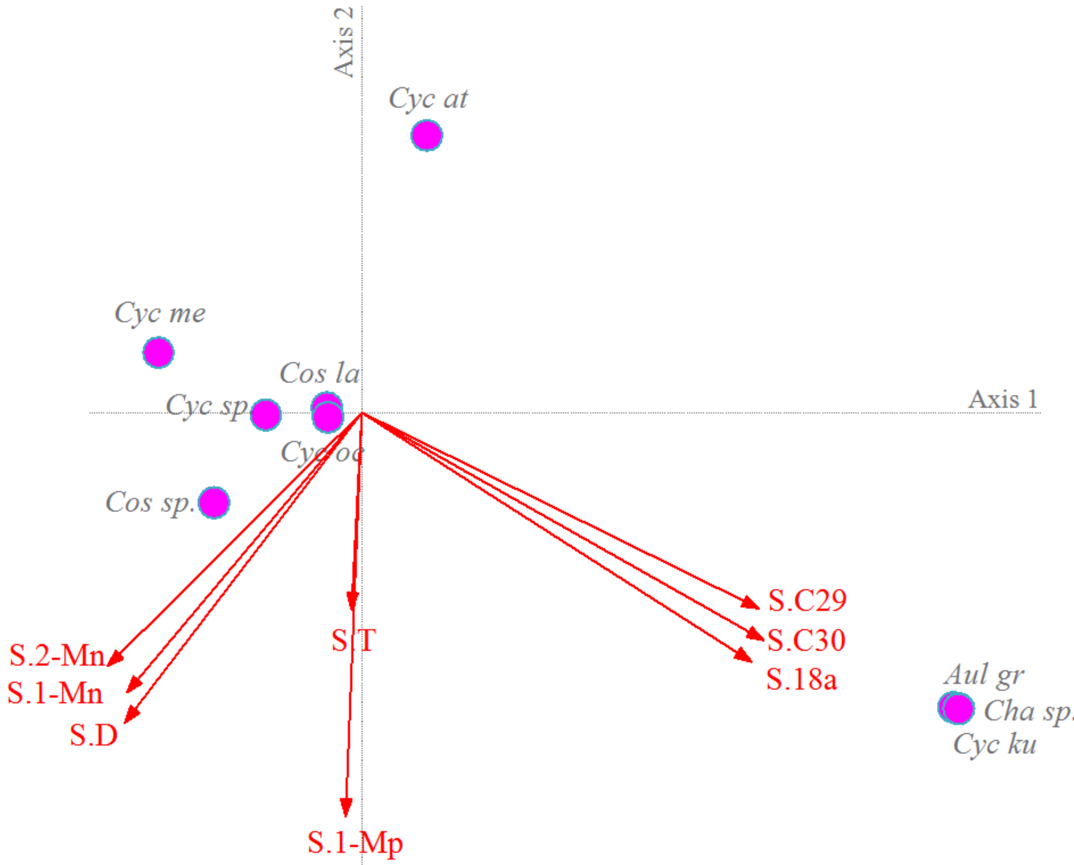


Figure 128: Ordination of Bacillariophyceae-Centrales community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May 2005 – September 2005).

Most of Bacillariophyceae-Centrales genera seem to prefer relatively low sediment Polynuclear Aromatic Hydrocarbons (PAHs), except the following species:

Coscinodiscus sp. seems to prefer relatively moderate concentrations of Sediment 2-Methylnaphthalene, Sediment 1-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, & Sediment 1,6,7-Trimethylnaphthalene.

Aulacoseira granulata, Chaetoceros sp., & *Cyclotella kuetzingiana* seem to prefer relatively high concentrations of Sediment C29-Hopane, Sediment C30-Hopane, Sediment 18a-Oleanane, & Sediment 1,6,7-Trimethylnaphthalene and moderate concentrations of Sediment 1-Methylphenanthrene.

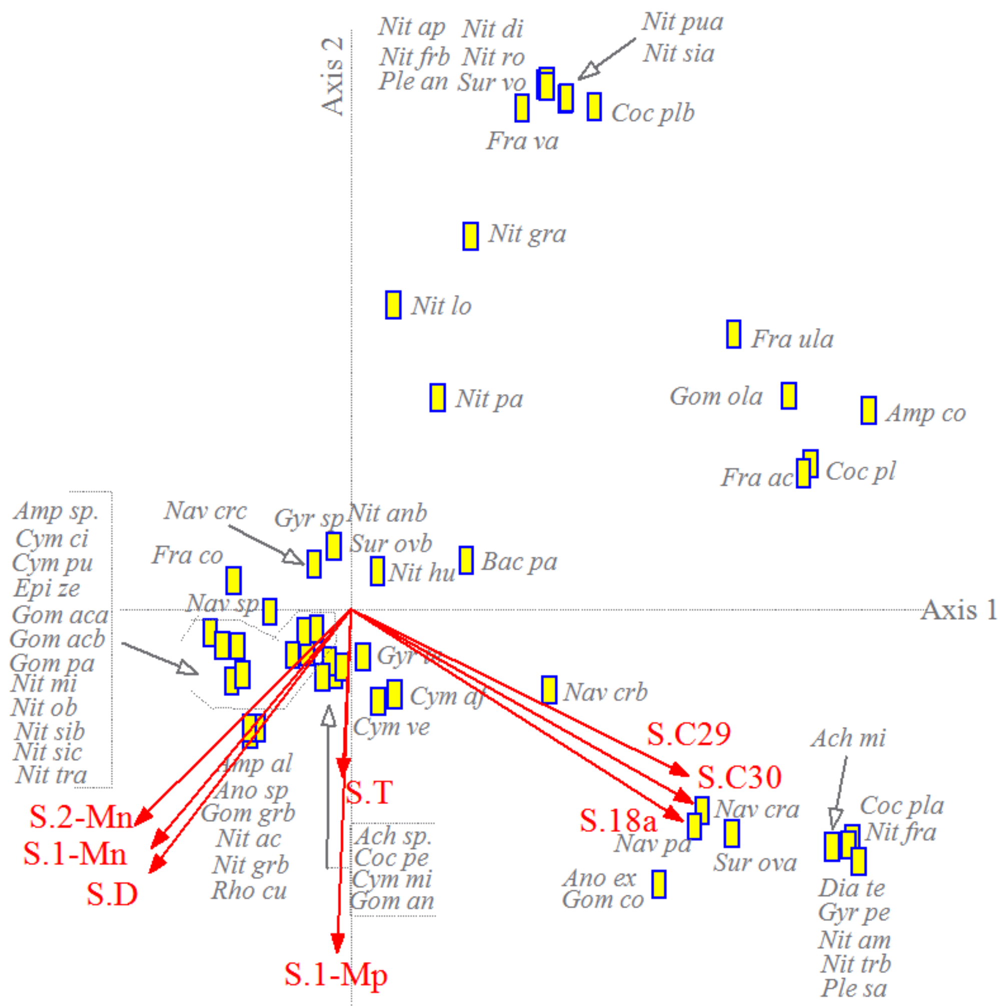


Figure 129: Ordination of Bacillariophyceae-Pennales community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May 2005 – September 2005).

Many of Bacillariophyceae-Pennales genera seem to prefer relatively low sediment Polynuclear Aromatic Hydrocarbons (PAHs), except the following species:

The species listed in the left of the diagram above seem to prefer relatively low to moderate concentrations of Sediment 2-Methylnaphthalene, Sediment 1-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, Sediment 1,6,7-Trimethylnaphthalene, & Sediment 1-Methylphenanthrene.

Gomphonema olivaceum, Navicula cryptocephala, Amphora coffeaeformis, Cocconeis placentula, Fragilaria acus, Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis, & *Pleurosigma salinarum* seem to prefer respectively moderate to high concentrations of Sediment C29-Hopane, Sediment C30-Hopane, Sediment 18a-Oleanane, & Sediment 1,6,7-Trimethylnaphthalene

Navicula crucicula, Navicula parva, Surirella ovalis, Anomoeoneis exilis, Gomphonema constrictum var. capitata, Achnanthes minutissima, Cocconeis placentula var. euglypta, Diatoma tenue var. elongatum, Gyrosigma peisonis, Nitzschia amphibia, Nitzschia frustulum, Tryblionella debilis, & *Pleurosigma salinarum* seem to prefer relatively high concentrations of Sediment 1,6,7-Trimethylnaphthalene & moderate concentrations of Sediment 1-Methylphenanthrene.

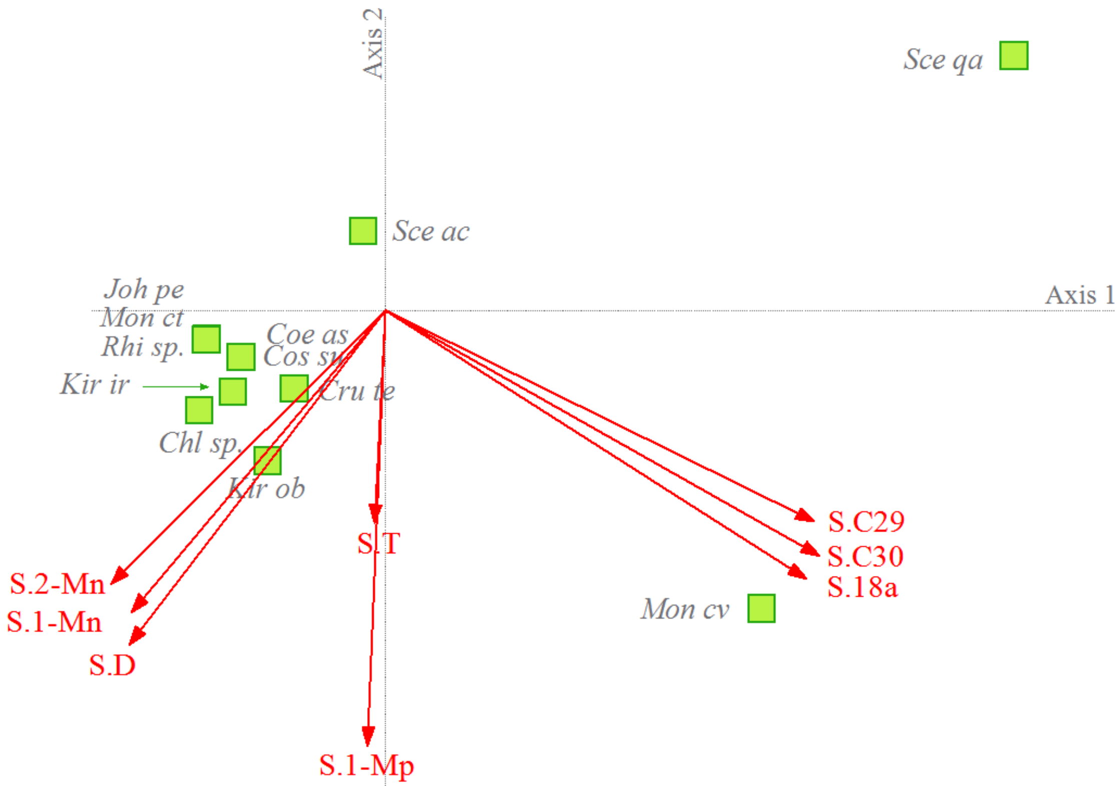


Figure 130: Ordination of Chlorophyceae community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May 2005 – September 2005).

Most of Chlorophyceae genera seem to prefer relatively low to moderate concentrations of Sediment 2-Methylnaphthalene, Sediment 1-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, Sediment 1,6,7-Trimethylnaphthalene, & Sediment 1-Methylphenanthrene.

Scenedesmus quadricauda and *Monoraphidium convolutum* seem to prefer relatively high concentrations of Sediment C29-Hopane, Sediment C30-Hopane, & Sediment 18a-Oleanane. *Monoraphidium convolutum* seem to prefer relatively high concentrations of Sediment 1,6,7-Trimethylnaphthalene and moderate concentrations of Sediment 1-Methylphenanthrene.

Scenedesmus acuminatus seems to prefer the lower concentrations of Polynuclear Aromatic Hydrocarbons (PAHs).

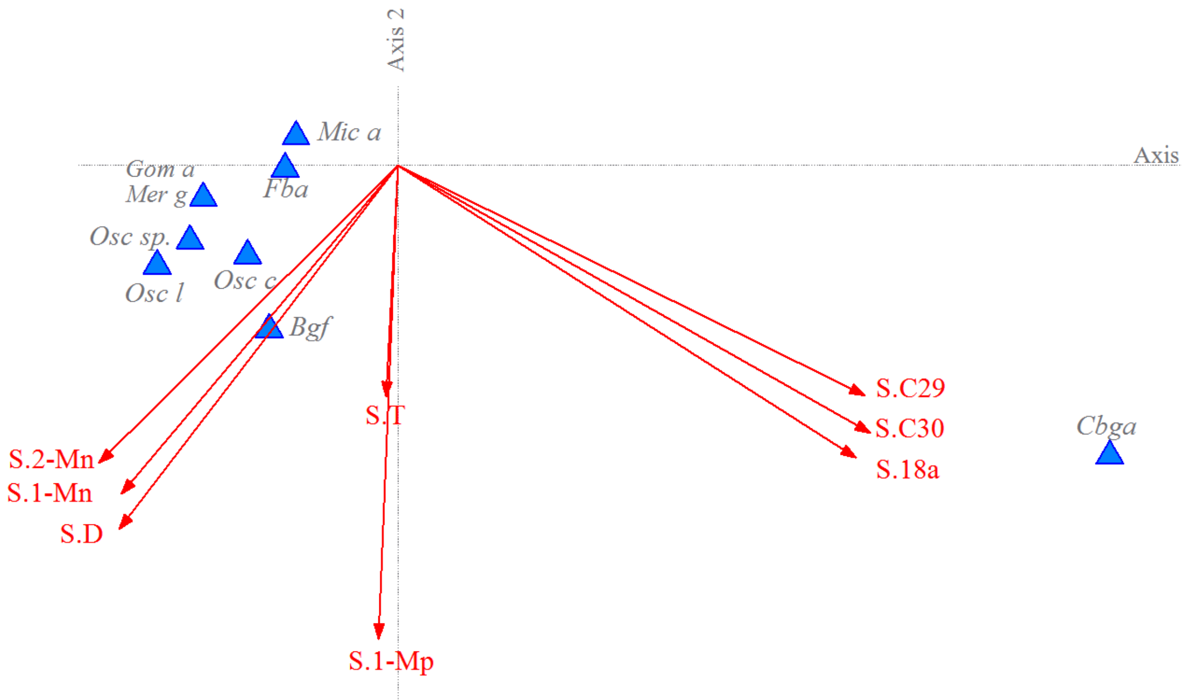


Figure 131: Ordination of Cyanophyceae community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May 2005 – September 2005).

Most of Cyanophyceae genera seem to prefer relatively low to moderate concentrations of Sediment 2-Methylnaphthalene, Sediment 1-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, Sediment 1,6,7-Trimethylnaphthalene, & Sediment 1-Methylphenanthrene.

Coccoid blue – green algae seem to prefer relatively high concentrations of Sediment C29-Hopane, Sediment C30-Hopane, & Sediment 18a-Oleanane, & Sediment 1,6,7-Trimethylnaphthalene and moderate concentrations of Sediment 1-Methylphenanthrene.

Microcystis aeruginosa seems to prefer the lower concentrations of Polynuclear Aromatic Hydrocarbons (PAHs)

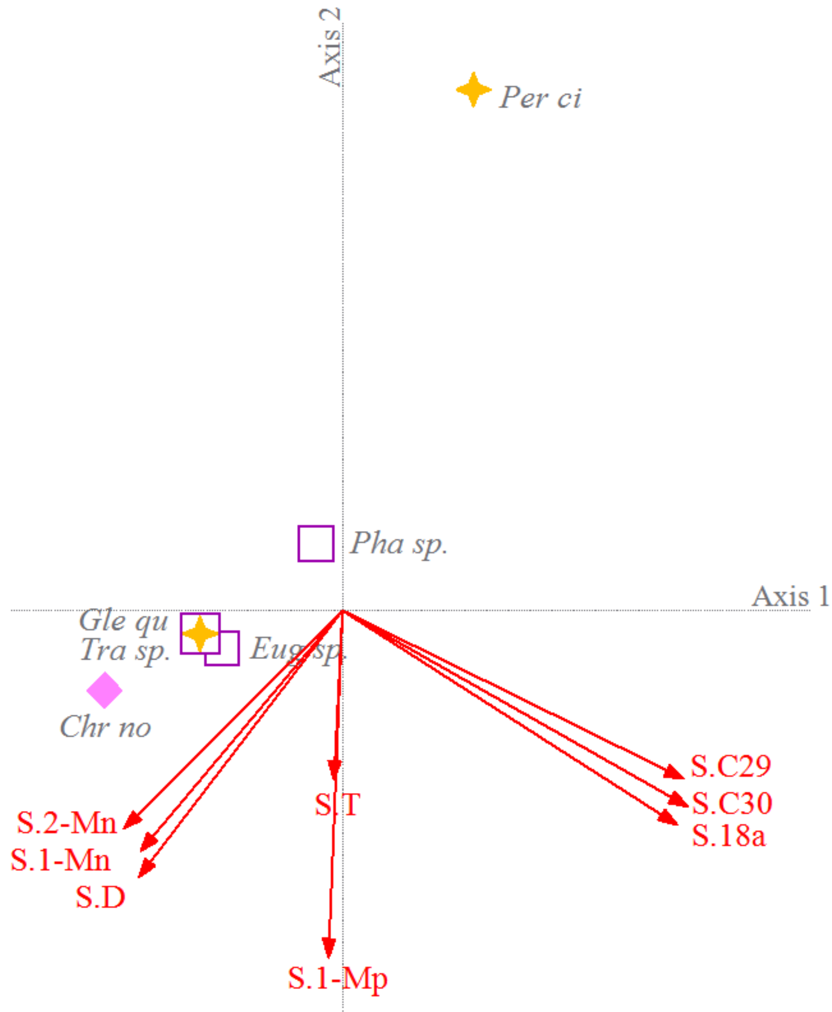


Figure 132: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May 2005 – September 2005).

Most of Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera seem to prefer relatively low to moderate concentrations of Sediment 2-Methylnaphthalene, Sediment 1-Methylnaphthalene, Sediment 2,6-Dimethylnaphthalene, Sediment 1,6,7-Trimethylnaphthalene, & Sediment 1-Methylphenanthrene.

Peridinium cinctum and *Phacus sp.* seem to prefer lower concentrations of Polynuclear Aromatic Hydrocarbons (PAHs)

PHYTOPLANKTON COMMUNITY ORDINATION AND HABITATS:

The results obtained from PCA showed that eigenvalues for the first and second axes were 0.18 and 0.142 respectively. In addition, Phytoplankton-Habitats correlations was strongly related to the first and second axes of the PCA (r = 0.628 and 0.757 respectively). The four canonical axes derived from the PCA accounted for 55.9% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 33.7% (Table 13).

Table 8: Eigenvalues and Phytoplankton-habitats correlations for the four axes derived from the Principal Components Analysis (PCA).

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.18	0.142	0.112	0.098
Phytoplankton-habitats correlations	0.628	0.757	0.629	0.76
Cumulative percentage variance				
of Phytoplankton data	18	32.3	43.4	53.2
of Phytoplankton-Habitat relation	15.7	33.7	43.4	55.9

The diagrams obtained from the CCA (Figure 115, Figure 116, Figure 117, Figure 118, Figure 119) represent the occurrence of different Phytoplankton genera. 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 are replaced by pie symbols. The segmentation of these symbols into slices is based on the classification of habitats. The relative size of particular pie-slice corresponds to the relative importance (measured either by its number of occurances or by its quantity) of the current species in the particular class of habitats (Ter Braak and Šmilauer, 2002).

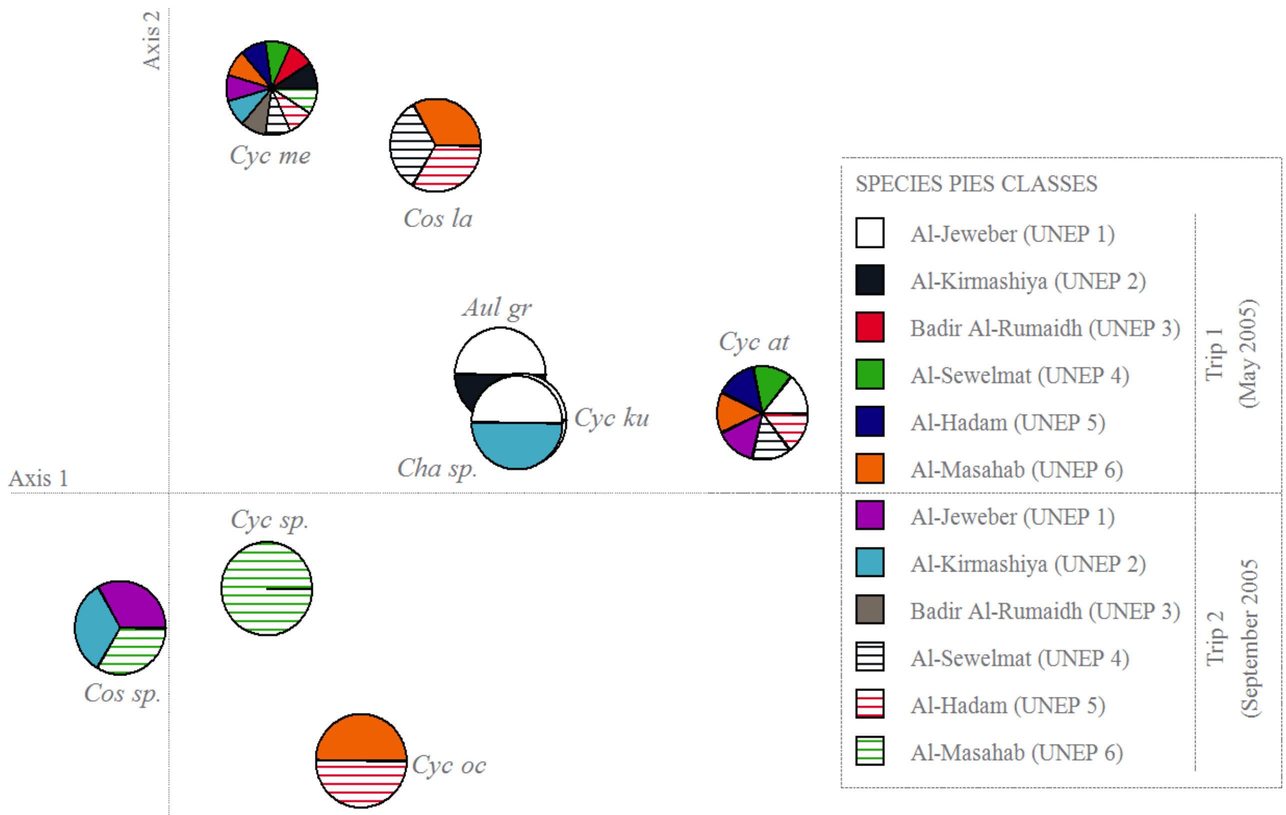


Figure 133: Ordination of Bacillariophyceae-Centrales pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

The distribution of Bacillariophyceae-Centrales genera was investigated in the UNEP sites and the results show that *Cyclotella atomus* & *Cyclotella meneghiniana* are distributed in most sites, whereas other species such as *Cyclotella sp.* inhabited UNEP 6 in September 2005 exclusively (Figure 115).

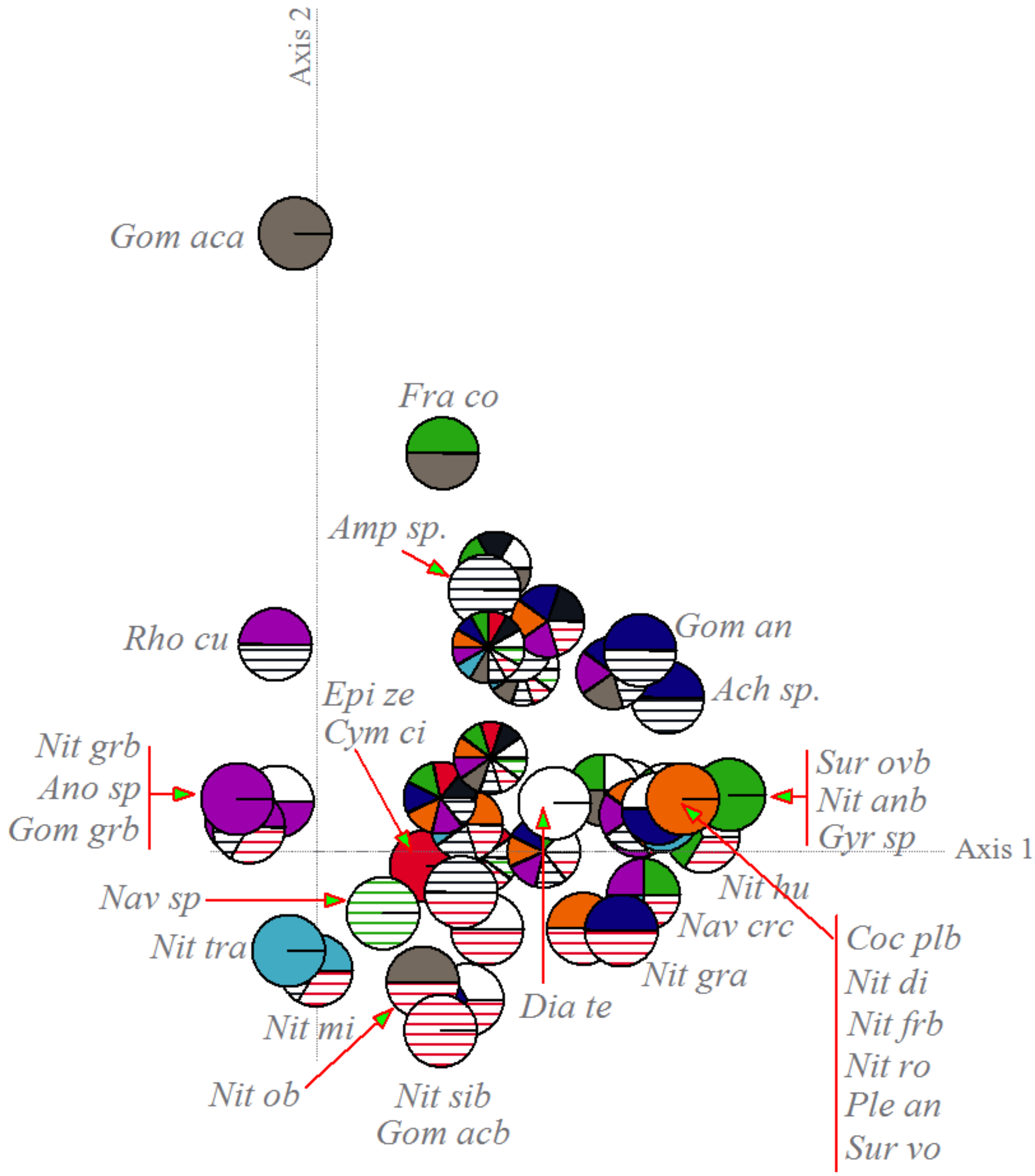


Figure 134: Ordination of Bacillariophyceae-Pennales pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

The distribution of Bacillariophyceae-Pennales genera in the studied site is demonstrated in the figure above. The species are distributed in their preferred habitats.

Some of them are present and associate in similar habitats reflecting their similar requirements. Others are limited to few sites, reflecting their preference for specific site and sensitivity to others. For instance, *Gomphonema turris* was exclusively found in UNEP 3 during September 2005, and *Diatoma tenue var. elongatum* occured exclusively in UNEP 1 during May 2005 (Figure 116).

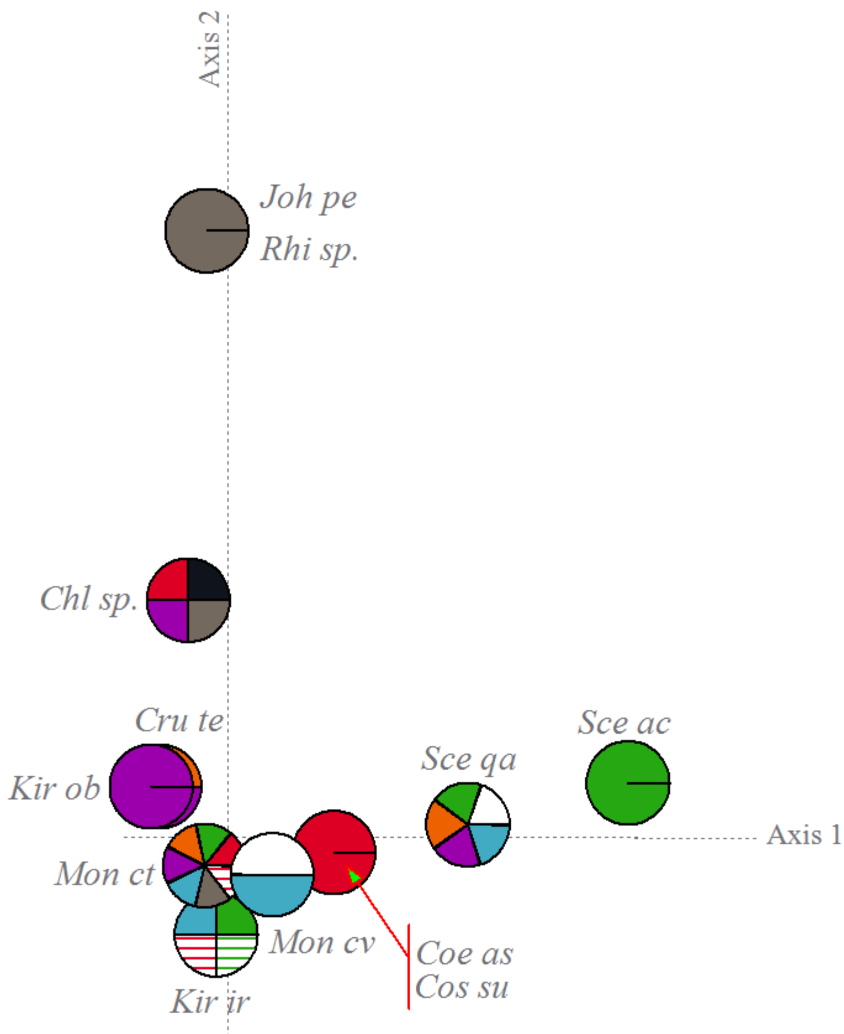


Figure 135: Ordination of Chlorophyceae pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

The Chlorophyceae genera showed an occurrence of *Monoraphidium contortum* in different habitats, reflecting its wide range of tolerance. While, other species such as *Coelastrum astroideum* & *Cosmarium subcostatum* were limited to UNEP 3 during May 2005 and in the same trip *Scenedesmus acuminatus* was observing in UNEP 4 exclusively.

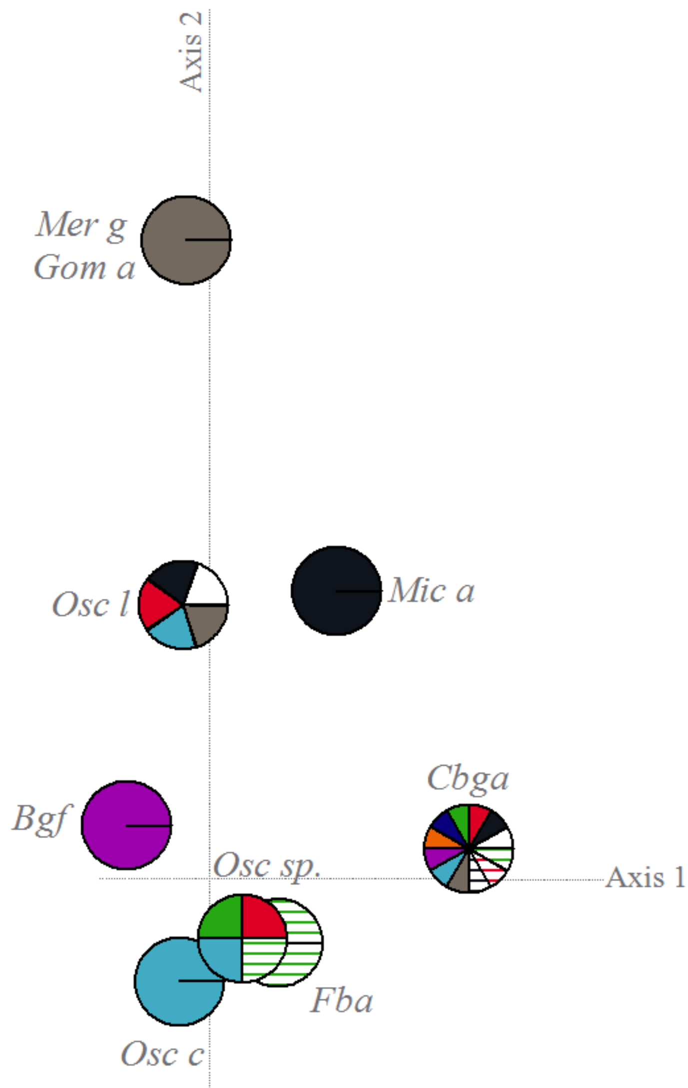


Figure 136: Ordination of Cyanophyceae pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

Cyanophyceae genera showed an occurrence of Coccoid blue – green algae in all habitats, reflecting its wide range of tolerance, whereas other species such as *Microcystis aeruginosa* was limited to UNEP 2 during May 2005 and in the same site *Phormidium chalybeum* was observed in September 2005 exclusively.

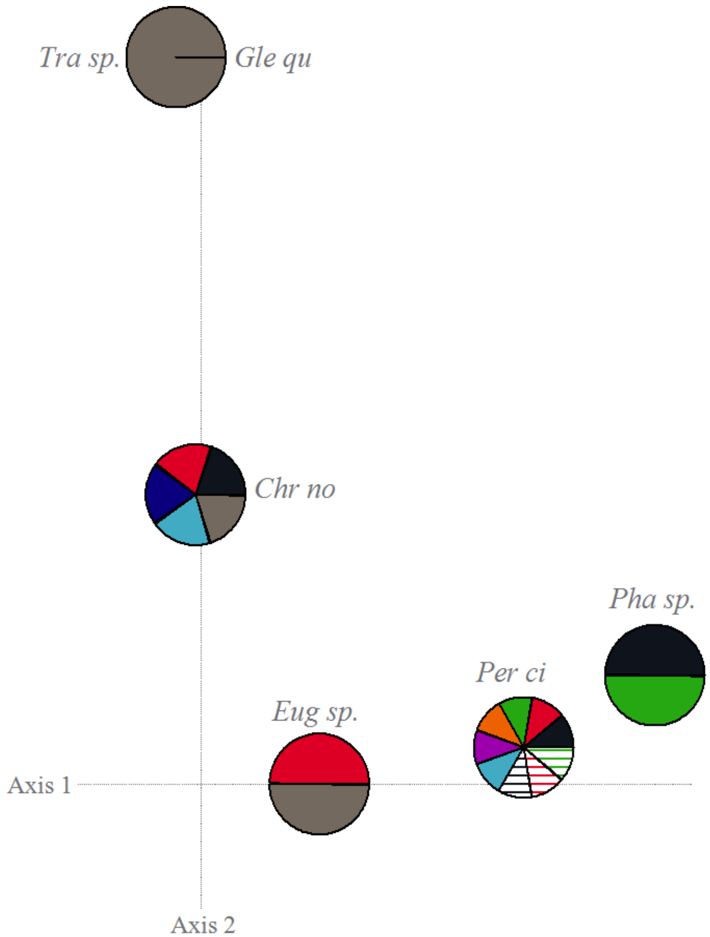


Figure 137: Ordination of Cryptophyceae, Euglenophyceae, and Pyrrophyceae pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

Cryptophyceae, Euglenophyceae, and Pyrrophyceae genera showed an occurrence of *Peridinium cinctum* in most habitats, reflecting a wide range of tolerance, whereas other species such as *Trachelomonas sp.* & *Glenodinium quadridens* were limited to UNEP 3 during September 2005.

D. ZOOPLANKTON

Prior to desiccation, the Iraqi marshes were characterized by high primary productivity caused by the thick density of aquatic plants (Hilli, 1977), which led to high secondary productivity of zooplanktons. These organisms are the vital foundation to properly functioning food chains.

ZOOPLANKTON COMMUNITY ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (this shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.63 and 0.41 respectively. In addition, the lengths of the gradient showed a clear unimodal response (Table 14), which implies the use of the canonical correspondence analysis (CCA) method in the next step to analyze the relations with the explanatory variables.

Table 9: Eigenvalues and Lengths of gradient for the four axes of the Zooplankton community derived from the detrended correspondence analysis (DCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.636	0.414	0.113	0.03
Lengths of gradient	4.331	3.086	2.044	2.238

The diagram obtained from the DCA (Figure 120) shows the samples as sample pies. The segmentation of these symbols into slices is based on the classification of the species. The relative size of particular pie-slice corresponds to the relative importance (measured either by its number of occurances or by its quantity) of the species belonging to a particular class in the corresponding sample (Ter Braak and Šmilauer, 2002).

From the diagram, it can be seen that UNEP 1, 2, 3, and UNEP 4 during both trips were dominated by the presence of the class Rotifera, whereas 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.

UNEP 6 during trip one and trip two was mainly dominated by the presence of Cladocera (Figure 120).

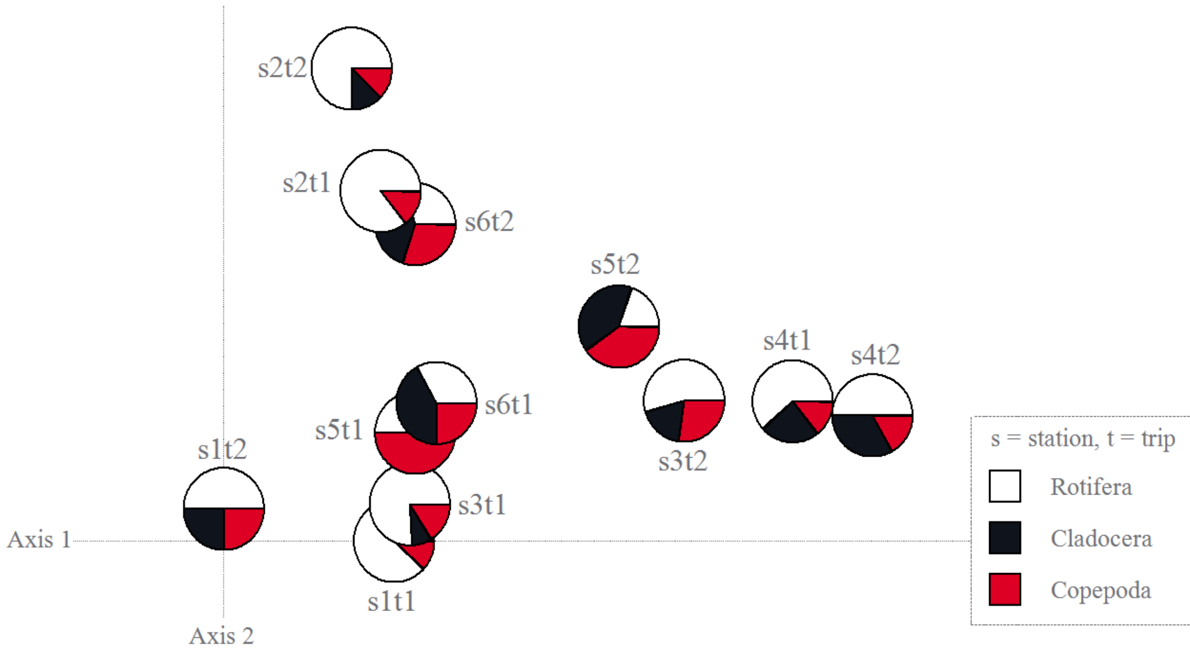


Figure 138: Ordination diagram [Axis 1 x Axis 2] with Zooplankton' samples pies classes, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

Furthermore, zooplankton diversity and richness across the studying period reflect the differences between the studied sites and demonstrate the recovery in these sites from May 2005 until September 2005. This is best seen in UNEP 5. However, the most diverse samples were the samples taken during May 2005; this is probably due to the seasonal variation of the zooplankton community after stabilizing in the preceding few years (Figure 121).

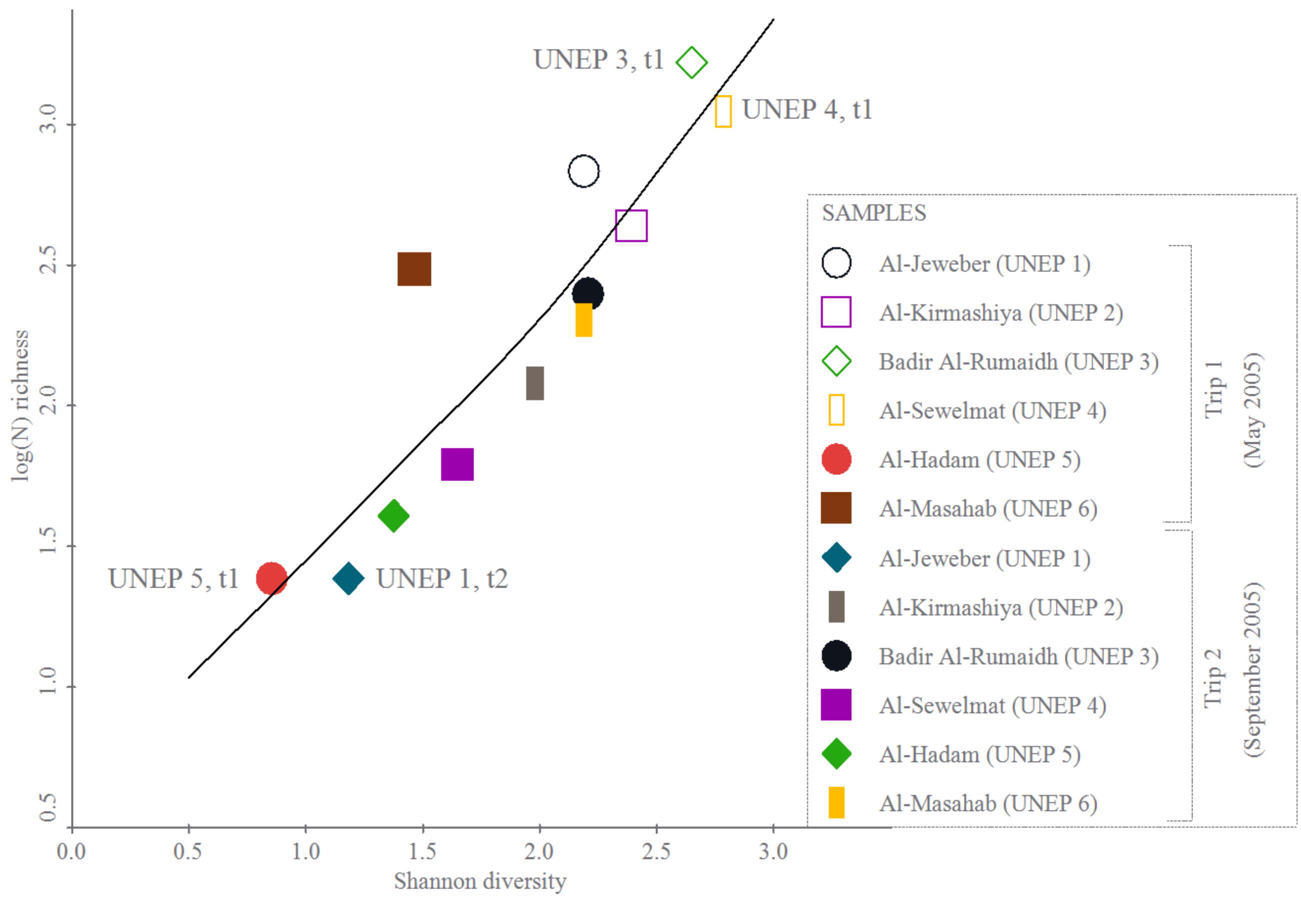


Figure 139: Zooplankton diversity & richness, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

From the above figure, it can be seen that the lower diversity and richness values were recorded in UNEP 5 and UNEP 1 during the first and second trip, respectively.

The higher values were recorded in UNEP 3 and UNEP 4 respectively, during trip one.

Mainly all the stations had higher diversity and richness values during the first trip when compared with the values obtained from the second trip, with the exception of UNEP 5.

According to the zooplankton diversity values it can be concluded that the higher values during the first trip were recorded in UNEP 4, 3, 2, and UNEP 1, respectively. While, the higher values of the Zooplankton diversity during the second trip were recorded in UNEP 3, 6, and UNEP 2, respectively (Table 5). Highest Overall Zooplankton Biodiversity was found in UNEP 3 and 2, although in one month it proved to be the highest in UNEP 4. (Figure)

Zooplankton richness values during the first trip were higher in UNEP 3, 4, 1, 2, and UNEP 6 respectively. Whereas, the lowest richness value during trip one was recorded in UNEP 5 (1.38).

During the second trip the higher richness values were recorded in UNEP 3, 6, and UNEP 2 respectively. The lowest richness values in the second trip were recorded in UNEP 1, 5, and UNEP 4 respectively (Table 5).

2. Zooplankton community ordination and environmental variables:

Due to the minimal information provided by the third and forth axes regarding variation in community structure (Eigenvalues = 0.008 and 0.0 respectively); (Table 15), these axes are not considered further. Moreover, the variables that exhibit associations with the third and fourth axes imply less ecological significance than variables that exhibit associations with the first and second axes (Lepš and Šmilauer, 2003). Therefore, our discussion will focus mainly on the variables associated with the first and second axes of the CCA. (Figure 122 through Figure 142)

The results obtained from the CCA showed that Zooplankton-environment correlations are related to the first and second axes of the CCA (r=0.83 and 0.61 respectively). The four canonical axes derived from the CCA accounted for 100% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 97.5% (Table 15).

Table 10: Eigenvalues and Zooplankton-environment correlations for the four axes derived from the canonical correspondence analysis (CCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.751	0.241	0.008	0
Zooplankton-environment correlations	0.832	0.611	0	0
Cumulative percentage variance				
of Zooplankton data	75.1	99.2	100	100
of Zooplankton-environment relation	33.9	97.5	100	100

The results showed that the most important environmental variables to explain the variance in the community structure were: Water Depth, Electrical Conductivity, Salinity, Total Dissolved Solids, Alkalinity, Total Hardness, Sulphates, Total Kjeldahl Nitrogen, Nitrate Nitrogen, Oil and grease, Biochemical Oxygen Demand, Water Total Organic Carbon, Total chromium, Mercury, Magnesium, Sediment Total Organic Carbon, Sediment Cadmium, Sediment Lead, Sediment Zinc, Sediment Total chromium, Sediment Arsenic, Sediment Selenium, Sediment Mercury, Sediment Nickel, Sediment Total DDT, and Sediment 1,6,7-Trimethylnaphthalene, based on their moderate to strong correlations with the first and second axes of the CCA, while the other parameters were less correlated with these axes. (Table 16)

Furthermore, weaker correlations with the first and second axes did not reflect significant correlations with the Zooplankton community structure. Therefore, weakly correlated variables are not representing in the diagrams.

Table 11: Inter-set correlations of environmental variables with axes, used to know the most important explanatory environmental variables for Zooplankton community.

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
1	Depth of water (m)	D	0.2904	0.5222	-0.379	-0.142
2	Air temperature (˚C)	AT	-0.1813	-0.304	-0.0524	-0.5422
3	Water temperature (˚C)	WT	-0.3474	0.0821	-0.2484	-0.6157
4	pH	pH	-0.1777	0.2351	-0.2785	-0.7501
5	Electrical Conductivity (mS/cm)	EC	-0.5224	-0.2677	0.1614	0.4097
6	Dissolved Oxygen (mg/L)	DO	0.025	0.4451	-0.3732	-0.501
7	Transparency (m)	Tra	-0.3347	-0.1758	0.0212	-0.1056
8	Salinity (ppt)	S	-0.6144	-0.317	0.1916	0.4075
9	Total Dissolved Solids (TDS) (mg/L)	TDS	-0.6085	-0.2257	0.1698	0.3814
10	Turbidity (NTU)	Tur	0.1855	-0.042	-0.0335	0.7223
11	Total Suspended Solids (TSS) (mg/L)	TSS	-0.0661	-0.3341	0.2688	0.4896
12	Alkalinity (mg $CaCO_3$/L)	Alk	0.0545	-0.5587	0.4634	0.3819
13	Total Hardness ($CaCO_3$/L)	T.H	-0.5411	-0.2923	0.2519	0.4382
14	Sulphates (SO4) (mg/L)	SO4	-0.524	-0.1956	0.1693	0.3724
15	Chlorides (Cl) (mg/L)	Cl	-0.4073	-0.3402	0.0484	0.5356
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	0.9565	0.0029	0.0495	0.1174
17	Nitrate Nitrogen (NO_3-N) (mg N/L)	NO3	0.9029	0.0094	0.052	0.1995
18	Nitrite Nitrogen (NO_2-N) (mg N/L)	NO2	-0.0484	-0.0114	-0.0061	0.1844
19	Phosphates (PO_4-P) (mg P/L)	PO4	-0.0419	0.3369	-0.3469	0.3717

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
20	Chlorophyll-a (mg/L)	Ch-a	-0.1546	0.0938	-0.1237	-0.0693
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	-0.7939	-0.0498	0.0615	0.217
23	Biochemical Oxygen Demand (BOD5) at 20 °C (mg/L)	BOD	0.7251	0.3313	0.0281	0.1224
24	Water Total Organic Carbon (TOC) (mg/L)	W.TOC	-0.4693	0.0474	-0.2447	-0.1883
25	Total plate count (colony/mL)	T.PCC	0.2884	-0.0744	0.1601	-0.1486
26	Fecal coliform count (CFU/100mL)	FCC	0.1687	-0.0274	0.2679	0.0413
27	E.coli (CFU/100mL)	Eco	-0.0674	0.0669	0.1193	0.3094
28	Cadmium (Cd) (mg/l)	Cd	-0.4099	0.3159	0.0249	0.5186
29	Lead (Pb) (mg/l)	Pb	-0.3035	0.286	-0.0245	-0.5754
30	Zinc (Zn) (mg/l)	Zn	-0.3518	0.0985	0.1247	0.6806
31	Total chromium (T-Cr) (mg/l)	T.Cr	-0.0344	-0.4851	0.4876	0.0471
32	Arsenic (As) (mg/l)	As	-0.3348	-0.1118	-0.0371	0.4685
33	Selenium (Se) (mg/l)	Se	-0.227	0.2743	-0.2977	-0.744
34	Mercury (Hg) (mg/l)	Hg	-0.6617	-0.008	-0.1983	-0.2671
37	Iron (Fe) (mg/l)	Fe	-0.0136	0.4123	-0.5174	0.0325
39	Calcium (Ca) (mg/l)	Ca	-0.2777	-0.1962	0.1575	0.689
40	Magnesium (Mg) (mg/l)	Mg	-0.5926	0.1837	-0.1592	0.268
41	Sediment Total Organic Carbon (TOC) %	S.TOC	0.0563	-0.5281	0.2045	0.1203
42	Sediment Cadmium (Cd) (μg/kg)	S.Cd	0.7409	-0.419	0.2613	0.2556
43	Sediment Lead (Pb) (μg/kg)	S.Pb	0.285	-0.5808	0.392	0.4504
44	Sediment Zinc (Zn) (μg/kg)	S.Zn	0.4907	-0.365	0.292	0.6015
45	Sediment Total chromium (T-Cr) (μg/kg)	S.T.Cr	0.0662	-0.4744	0.2553	0.723
46	Sediment Arsenic (As) (μg/kg)	S.As	0.0129	-0.629	0.341	0.5879
47	Sediment Selenium (Se) (μg/kg)	S.Se	-0.1597	-0.677	0.2428	-0.4109
48	Sediment Mercury (Hg) (μg/kg)	S.Hg	-0.3474	-0.5125	0.191	0.423

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
49	Sediment Copper (Cu) (μg/kg)	S.Cu	-0.1205	-0.0125	0.2706	0.5041
50	Sediment Nickel (Ni) (μg/kg)	S.Ni	-0.1719	-0.4913	0.3153	0.6792
51	Sediment Iron (Fe) (μg/kg)	S.Fe	0.2509	-0.4485	0.3083	0.6894
52	Sediment Manganese (Mn) (μg/kg)	S.Mn	0.0726	-0.4434	0.3678	0.6558
53	Sediment Calcium (Ca) (μg/kg)	S.Ca	-0.0263	0.3372	-0.349	-0.6737
54	Sediment Magnesium (Mg) (μg/kg)	S.Mg	0.1704	-0.3387	0.2079	0.7593
55	Sediment Total HCH (μg/dry g)	S.T.HCH	-0.2888	0.1556	-0.2538	-0.7714
56	Sediment Total Chlordane (μg/dry g)	S.T.Ch	0.0715	0.2669	-0.2315	-0.845
57	Sediment Total DDT (μg/dry g)	S.T.DDT	0.8534	-0.1876	0.1309	0.2648
59	Sediment 2-Methylnaphthalene (μg/dry g)	S.2-Mn	-0.0047	-0.2888	0.0854	-0.5547
60	Sediment 1-Methylnaphthalene (μg/dry g)	S.1-Mn	-0.0629	-0.1702	0.021	-0.6042
61	Sediment 2,6-Dimethylnaphthalene (μg/dry g)	S.D	-0.0969	-0.1281	0.0057	-0.6594
62	Sediment 1,6,7-Trimethylnaphthalene (μg/dry g)	S.T	0.5222	0.1641	-0.0119	0.0856
63	Sediment 1-Methylphenanthrene (μg/dry g)	S.1-Mp	0.2057	-0.0528	0.1952	-0.1069
64	Sediment C29-Hopane (μg/dry g)	S.C29	-0.3461	0.431	0.0094	0.3698
65	Sediment 18a-Oleanane (μg/dry g)	S.18a	-0.3486	0.4386	0.0122	0.3183
66	Sediment C30-Hopane (μg/dry g)	S.C30	-0.3345	0.4311	0.0133	0.3877

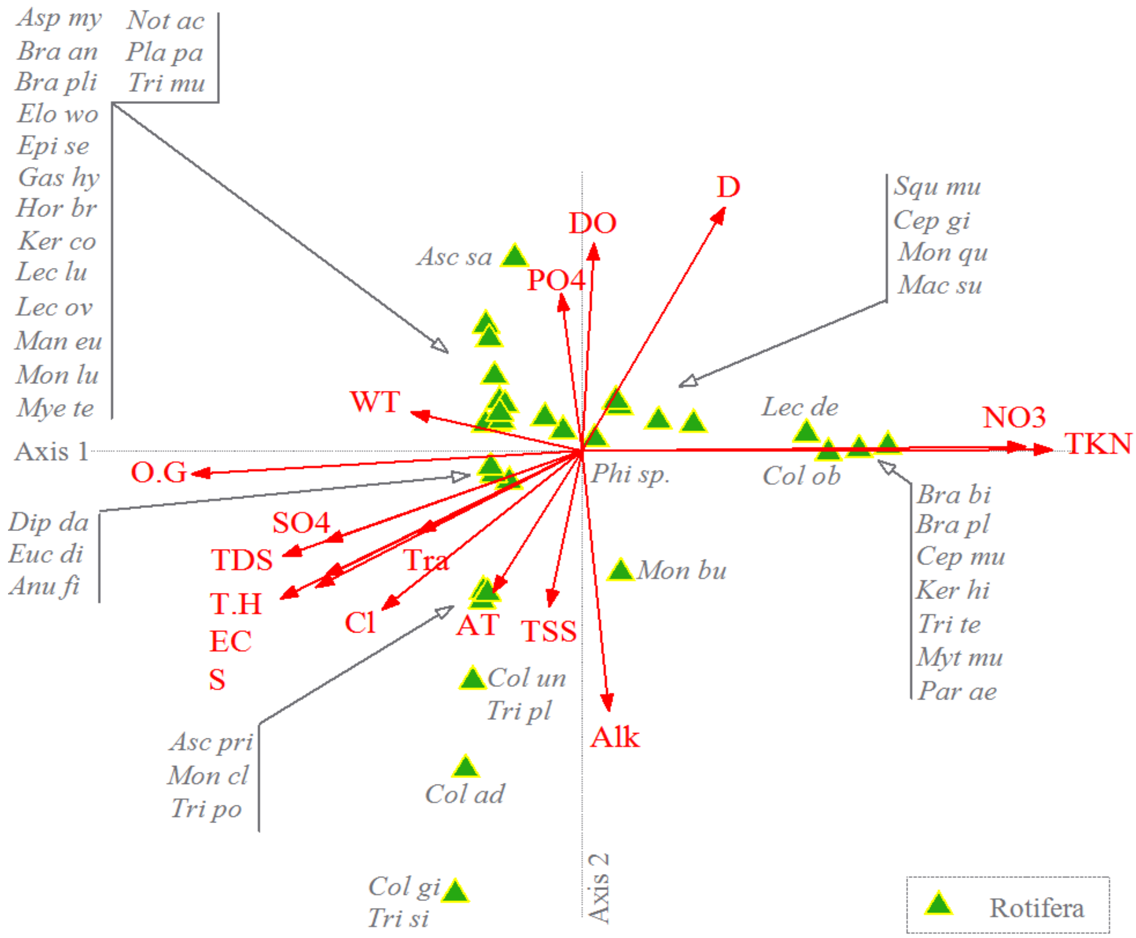


Figure 140: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

Most of Rotifera genera prefer relatively higher Water Temperatures, Phosphates, and Dissolved Oxygen concentrations. The species: *Philodina sp., Squatinella mutica, Cephalodella gibba, Monostyla quadridentata, Macrochaetus subquadratus, Lecane depressa, Colurella obtusa, Brachionus bidentata, Brachionus plicata, Cephalodella mucronata, Keratella hiemalis, Trichotria tetractis, Mytilina mucronata* and *Paracolurella aemula* seem to prefer relatively low to moderate concentrations of Nitrate-Nitrogen and Total Kjeldahl Nitrogen when compared with the other Rotifera species.

On the other hand the species *Monostyla bulla, Asplanchna priodonta, Monostyla closterocerca Trichocerca porcellus, Colurella uncinata, Tripleuchlanis plicata, Colurella adriatica, Colurella gibba,* and T*richocerca similis* mainly prefer relatively moderate to high Transparency, Chlorides, Air temperature, Total Suspended Solids, and Alkalinity values and concentrations.

Generally, most of the Rotifera species indicated preferred relatively low Water Depth, Electrical Conductivity, Salinity, Total Dissolved Solids, Total Hardness, Sulphates, Chlorides, Alkalinity, Total Kjeldahl Nitrogen, Nitrate Nitrogen, and Oil and grease.

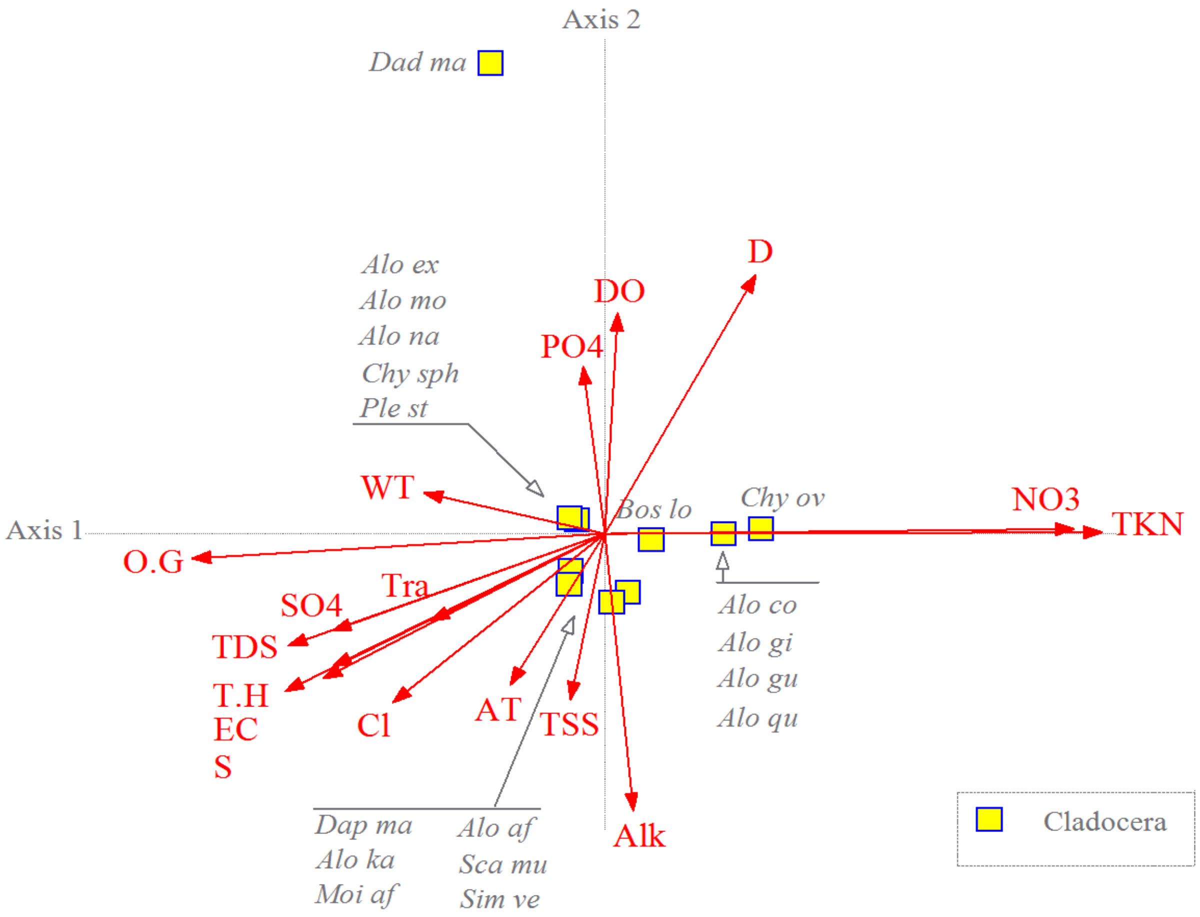


Figure 141: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

The figure above indicates that most of the Cladocera species indicated preferred mainly relatively low values and concentrations of the measured and analyzed physico-chemical environmental variables. It is also clear that the species *Alona costata, Alona gibba, Alona guttata, Alona quadrangularis*, and *Chydorus ovalis* preferred higher concentrations of Nitrate-Nitrogen and Total Kjeldahl Nitrogen when compared with the other Cladocera species indicated.

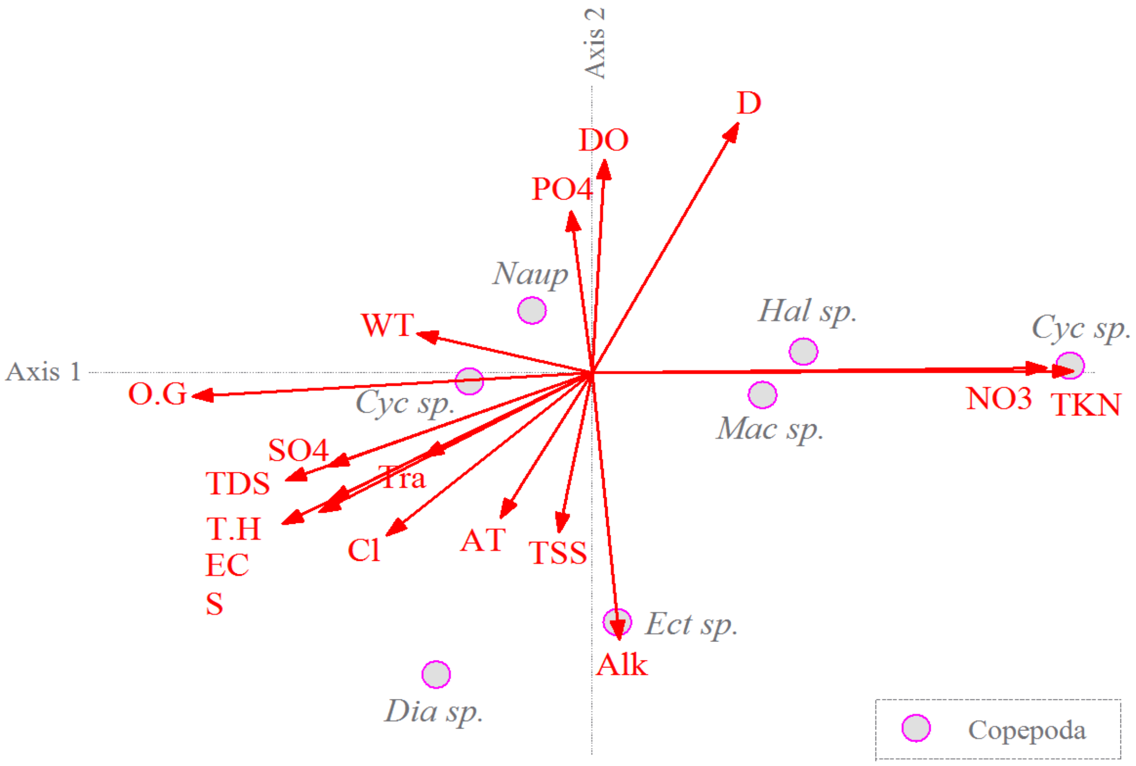


Figure 142: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

From the figure above it can be noticed that the species *Cyclops sp.*2, *Halicyclops sp.,* and *Macrocyclops sp.* seem to prefer higher to moderate concentrations of Nitrate-Nitrogen and Total Kjeldahl Nitrogen respectively. The two species *Eucyclops sp.* and *Diaptomus sp.* prefer relatively higher Alkalinity concentrations when compared with the other species.

The species *Cyclops sp.* seems to prefer relatively low Oil and Grease concentrations than the other species.

Nauplii of Copepoda seem to prefer higher concentrations of Phosphates and Dissolved Oxygen concentrations.

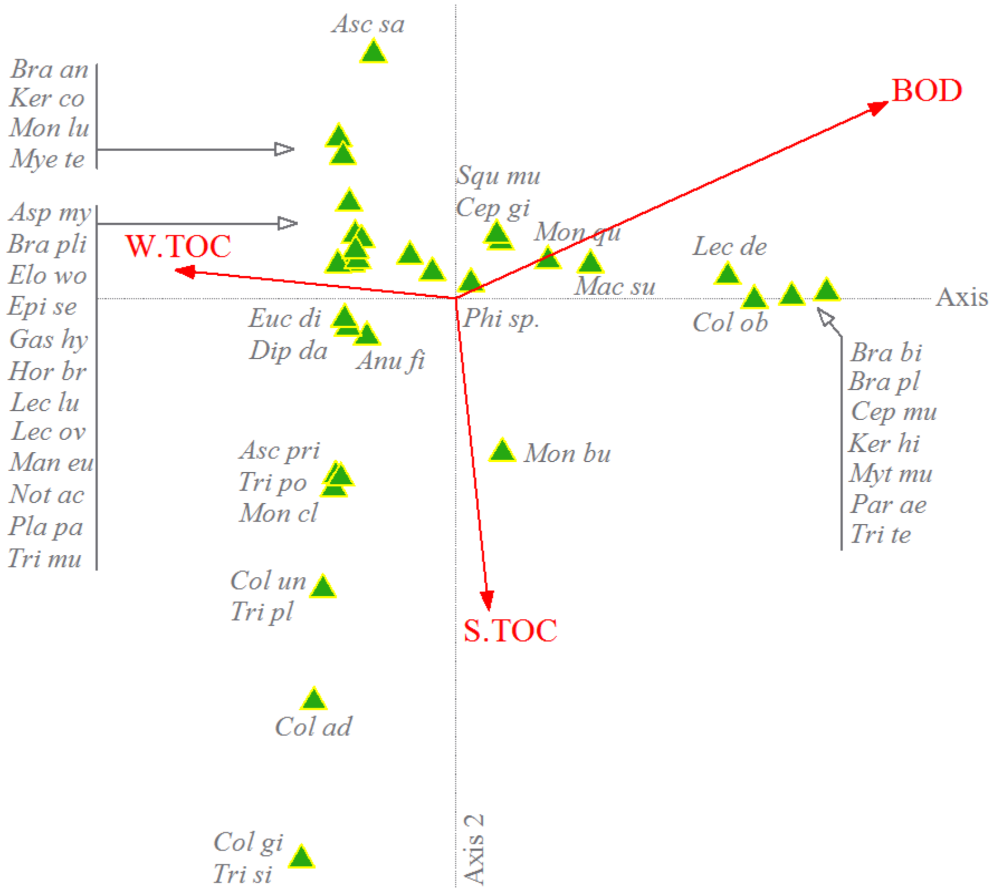


Figure 143: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Generally, it can be noticed that mainly most of the Rotifera species (left half of the figure), favor relatively moderate Water Total Organic Carbon and lower Biochemical Oxygen Demand and Sediment Total Organic Carbon concentrations.

While the remaining species indicated, seem to favor relatively low to moderate Biochemical Oxygen Demand, compared with Water Total Organic Carbon and Sediment Total Organic Carbon.

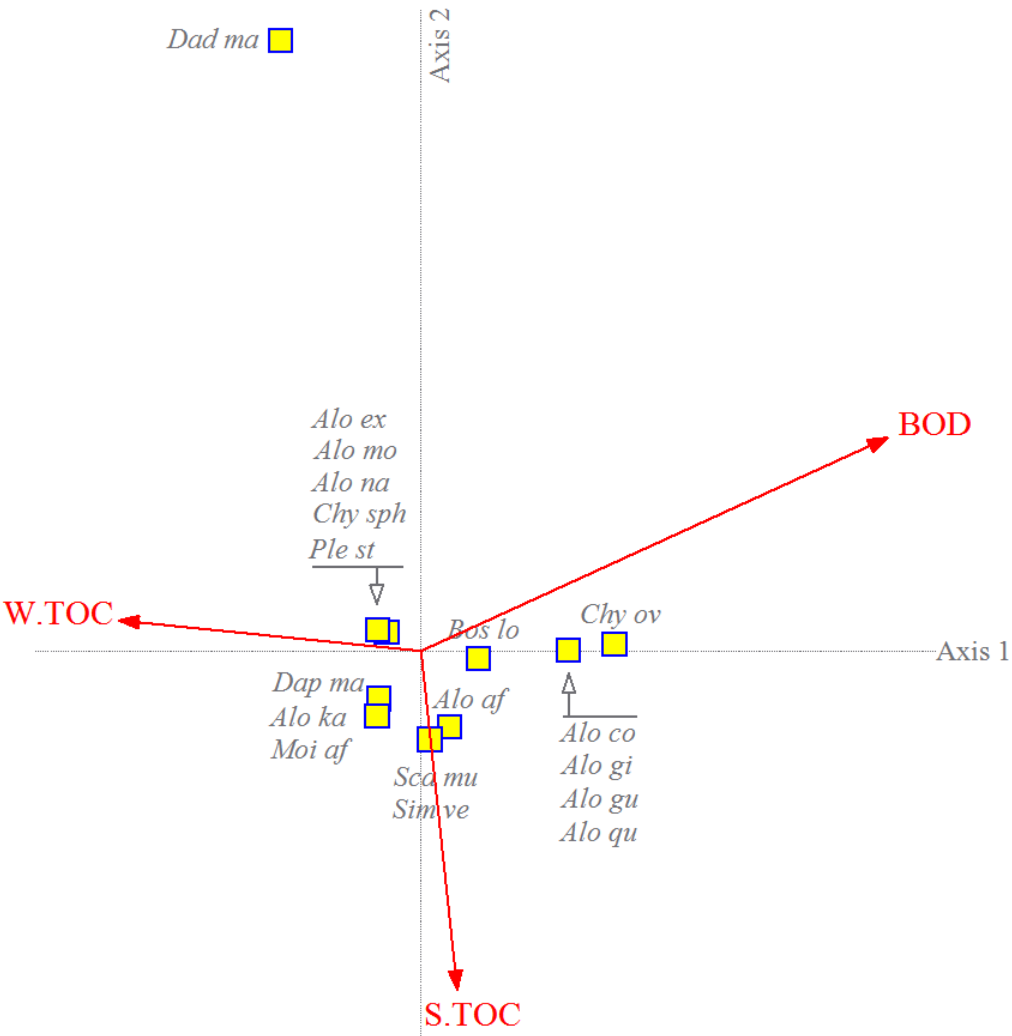


Figure 144: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Generally, it is clear that most of the Cladocera species identified favor relatively low to moderate Water Total Organic Carbon, Sediment Total Organic Carbon, and Biochemical Oxygen Demand concentrations.

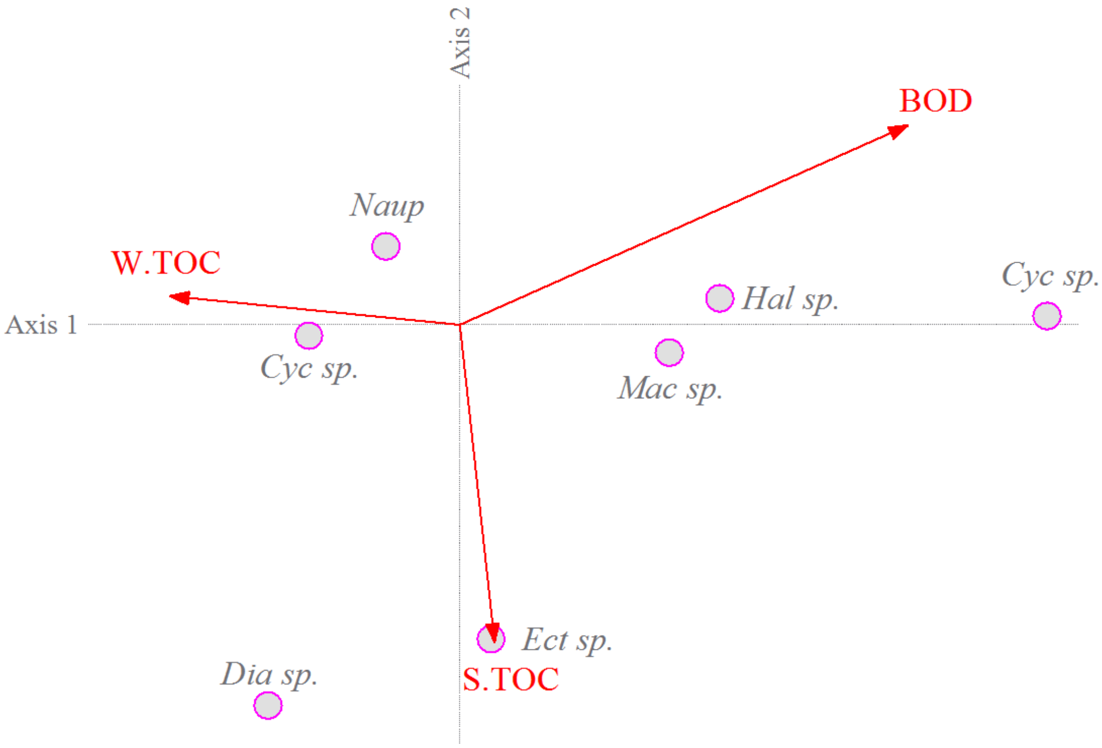


Figure 145: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

Nauplii of Copepoda and Cyclops sp. favor relatively low to moderate Water Total Organic Carbon than Sediment Total Organic Carbon, and Biochemical Oxygen Demand concentrations.

While, the species Cyclops sp.2, Halicyclops sp., and Macrocyclops sp. favor relatively high to moderate Biochemical Oxygen Demand concentrations when compared with Water and Sediment Total Organic Carbon.

On the other hand, the two species Eucyclops sp. and Diaptomus sp. favor relatively higher Sediment Total Organic Carbon concentrations than W.TOC & BOD when compared with the other species.

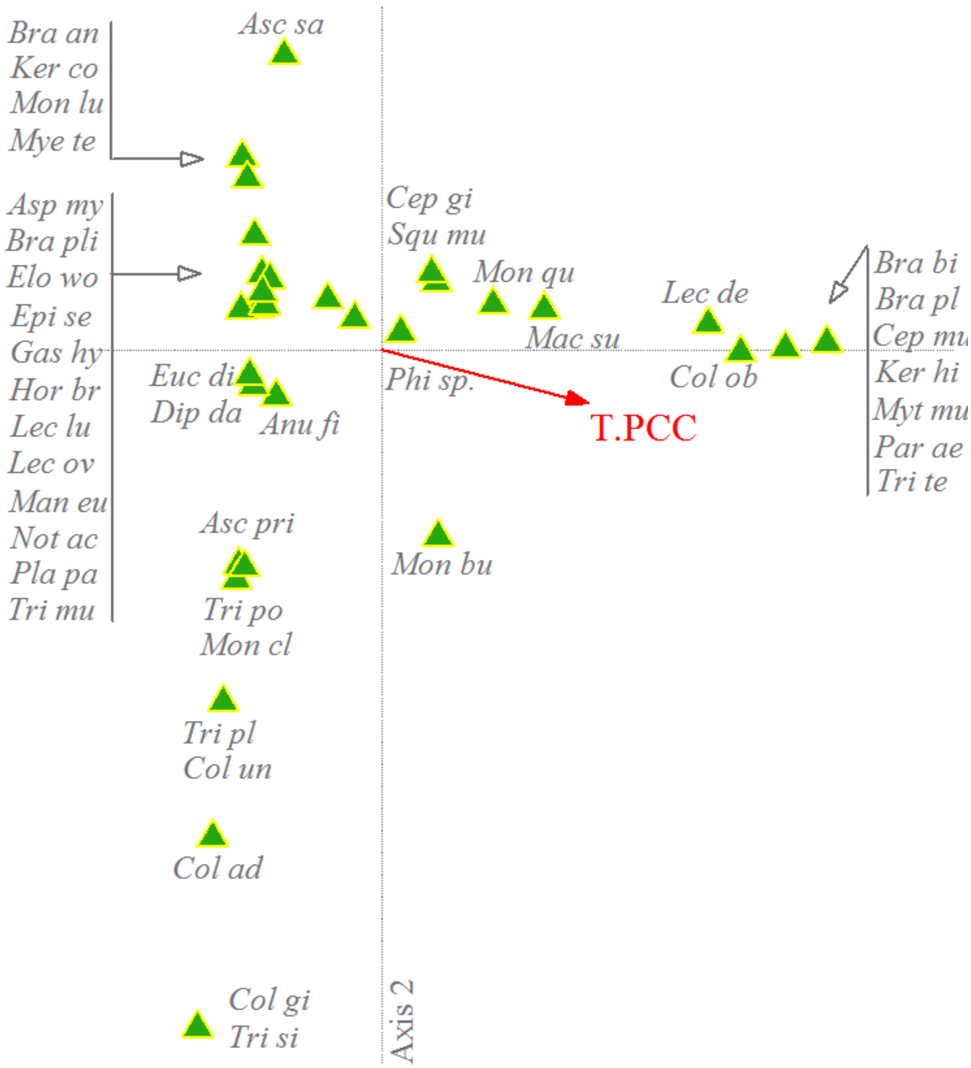


Figure 146: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

It is clear that most of the Rotifera species (left half of figure) tolerate low Total Plate Count Colony, while the remaining species seem to tolerate relatively moderate to high Total Plate Count Colony.

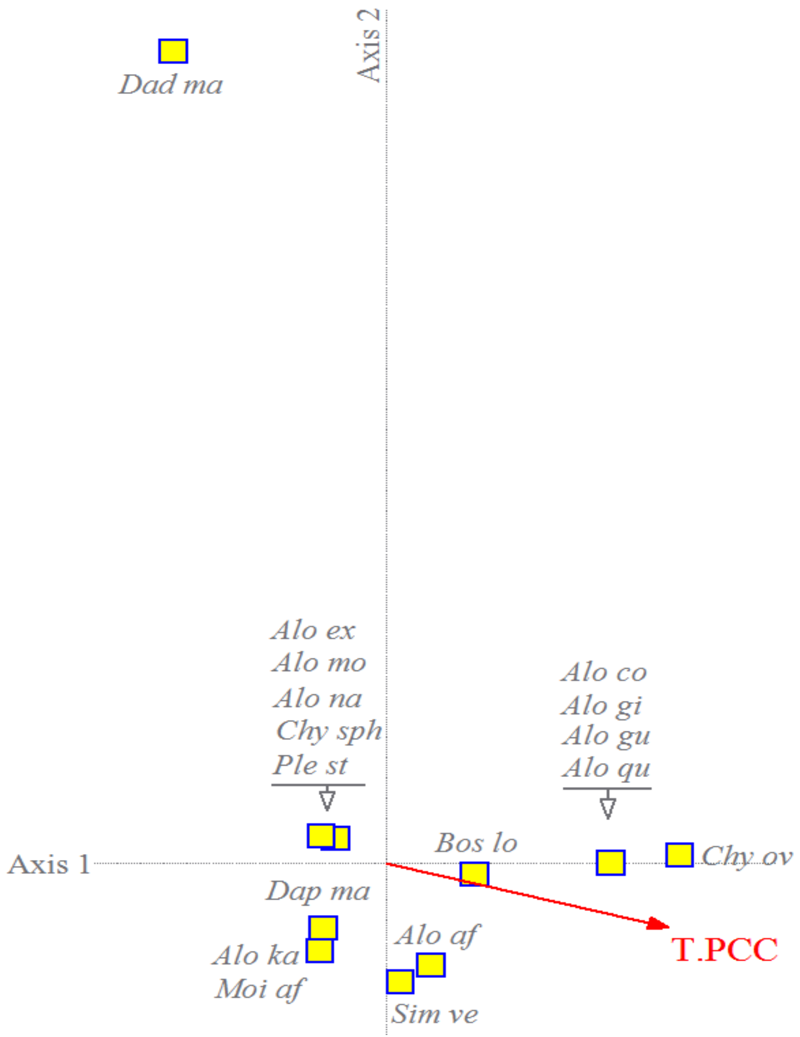


Figure 147: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

From the above figure, it can be noticed that mainly most of the Cladocera species identified tolerate relatively low Total Plate Count Colony, especially the species *Dadaya macrops*.

The remaining species that include; *Alona costata, Alona gibba, Alona guttata, Alona quadrangularis*, and *Chydorus ovalis* seem to tolerate relatively high Total Plate Count Colony.

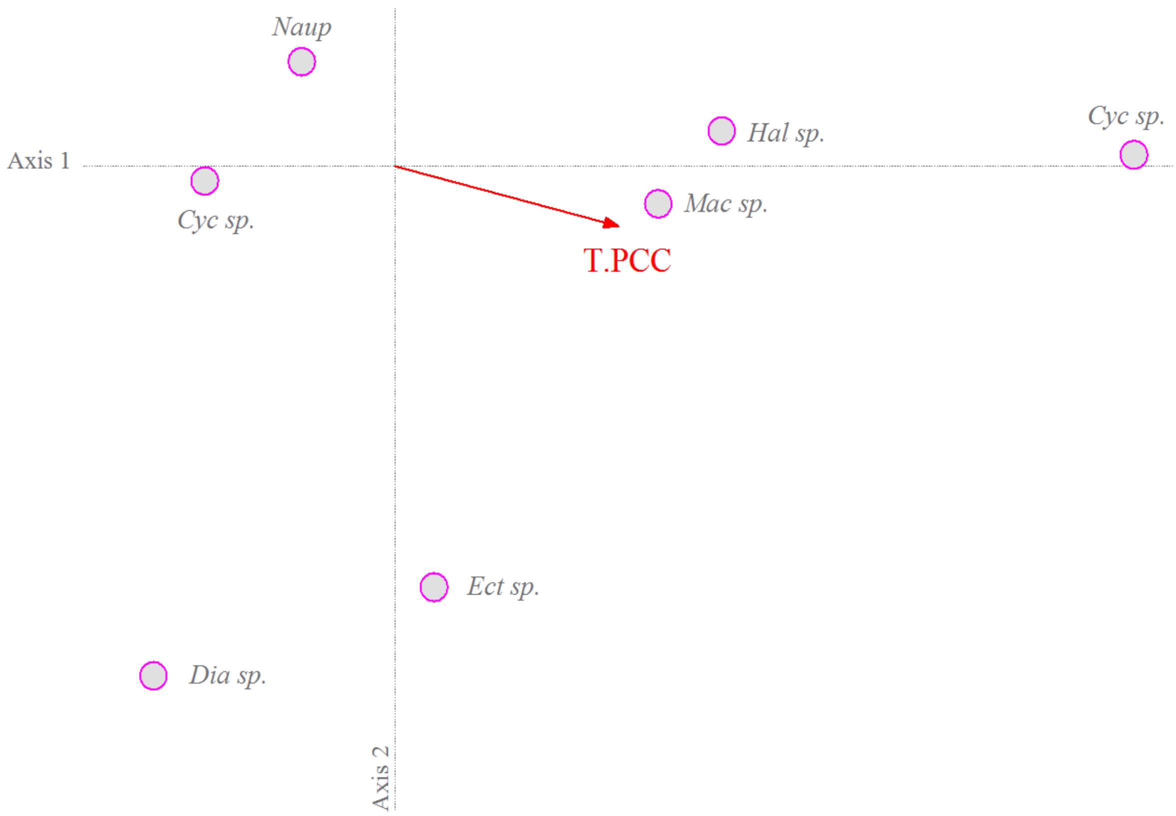


Figure 148: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

The above figure shows that Nauplii of Copepoda, *Cyclops sp., Eucyclops sp.*, and *Diaptomus sp.* seem to tolerate low Total Plate Count Colony.

On the other hand, the other three species; *Halicyclops sp., Macrocyclops sp.,* and *Cyclops sp.*2 seem to tolerate relatively high Total Plate Count Colony.

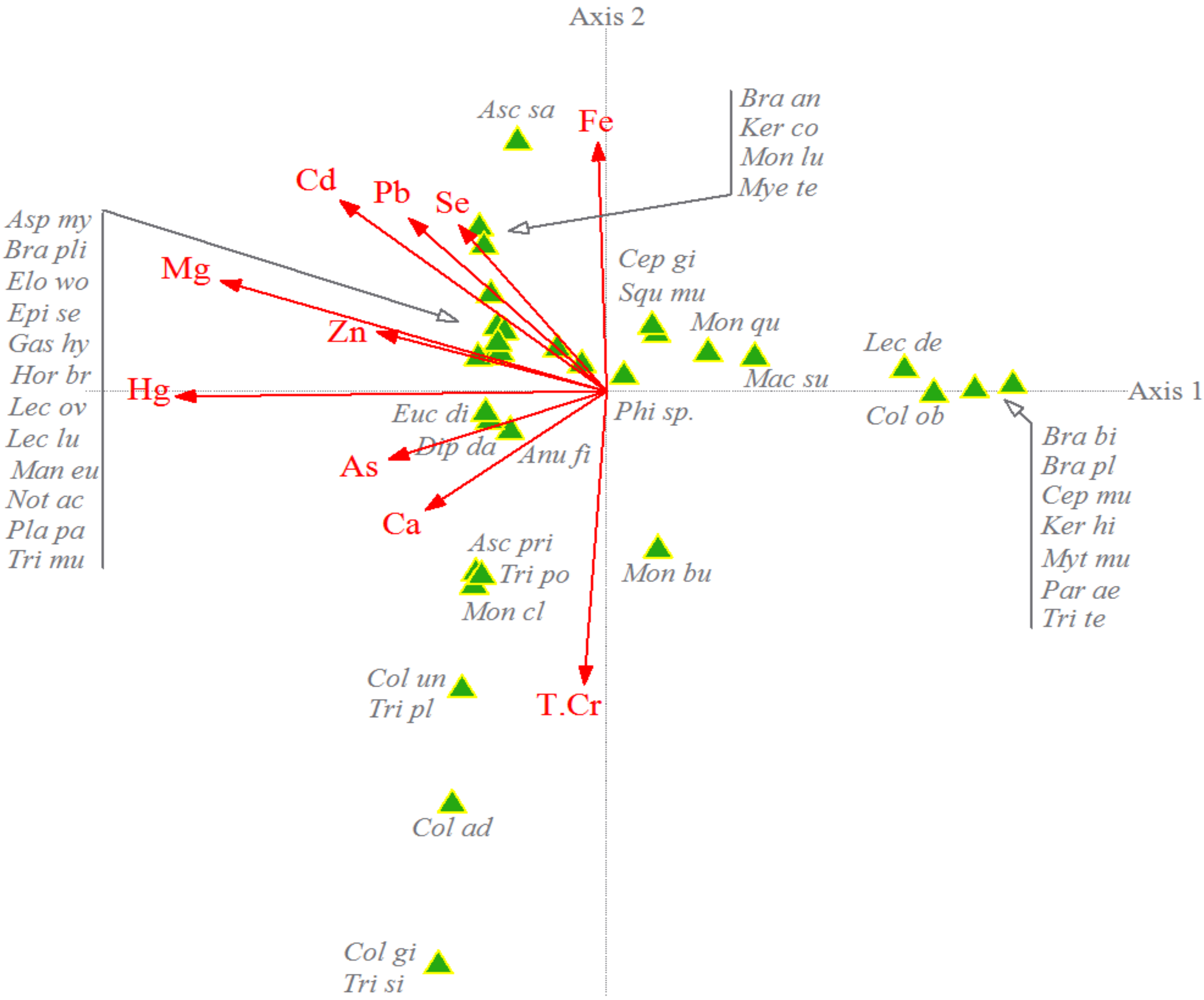


Figure 149: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Generally, the figure above shows that most of the Rotifera species (left of the figure) seem to tolerate conditions with relatively low to moderate concentrations of most the heavy metals and toxins measured.

The remaining species seem to tolerate conditions with low concentrations of measured heavy metals and toxins.

On the other hand, the five species Ascomorpha saltans, Brachionus angularis, Keratella cochlearis, Monostyla lunaris, and Myersinella tetraglena seem to tolerate relatively higher Selenium, Lead, Cadmium, and Iron concentrations compared with the other Rotifera species.

While, the species; Monostyla bulla, Asplanchna priodonta, Trichocerca porcellus, Monostyla closterocerca, Colurella uncinata, Tripleuchlanis plicata, Colurella adriatica, Colurella gibba, and Trichocerca similis seem to tolerate relatively higher Total chromium concentrations than the other species.

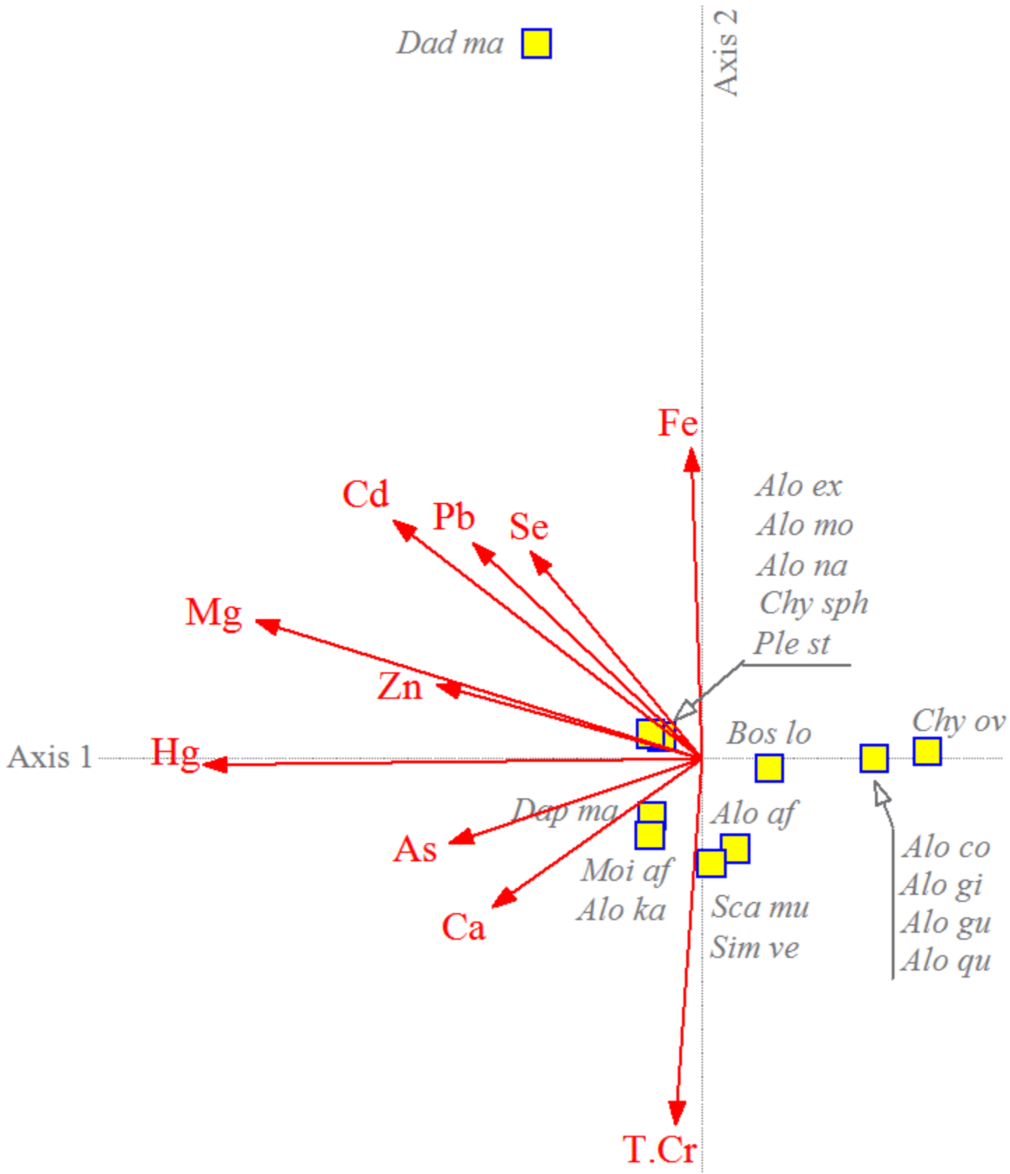


Figure 150: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

The above figure shows that mainly most of the Cladocera species tolerate relatively low concentrations of the measured heavy metals and toxins. With Alona affinis, Scapholebris mucronata, and Simocephalus vetulus tolerating higher Total chromium compared with the other species.

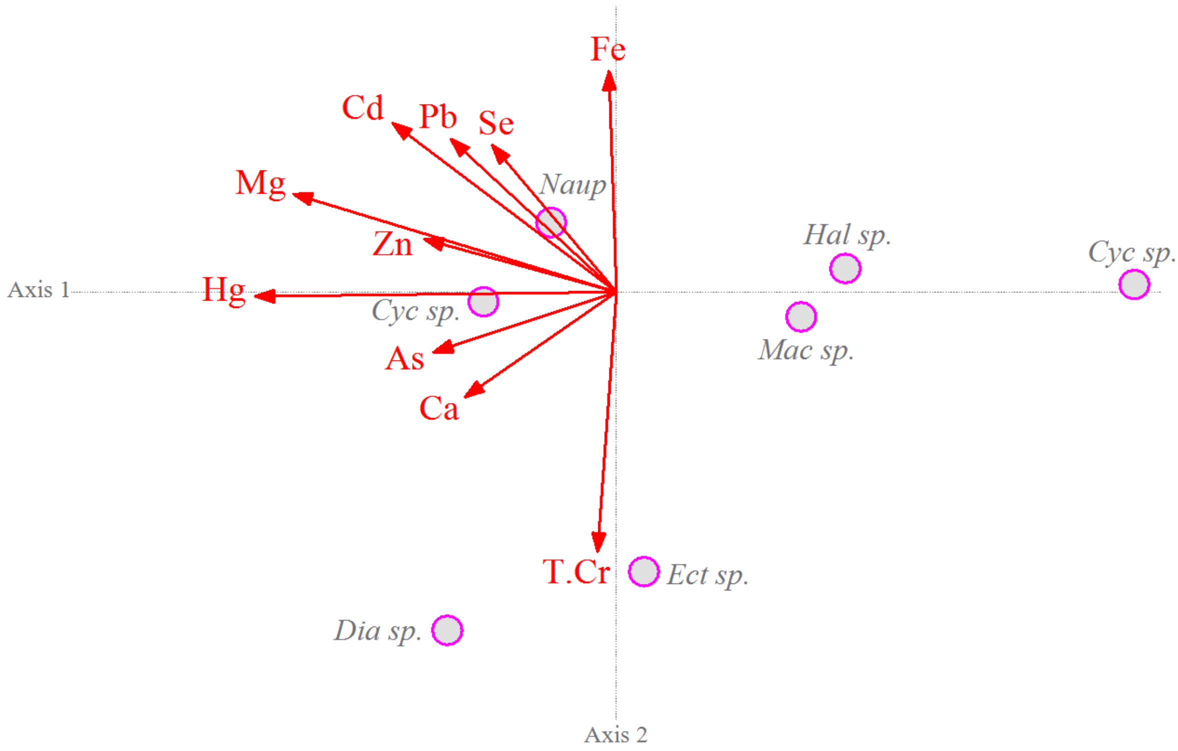


Figure 151: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

It can be seen from the above figure that, the three Copepoda species; Cyclops sp.2, *Halicyclops sp.*, and *Macrocyclops sp.* tolerate low concentrations of most of the heavy metals and toxins measured.

While, Nauplii of Copepoda seem to tolerate relatively moderate concentrations of Iron, Selenium, Lead, and Cadmium than the other heavy metals and toxins.

The species, *Cyclops sp.* tolerates relatively moderate to high concentrations of Zinc, Arsenic, Calcium, Magnesium, and Mercury.

The two species; *Eucyclops sp.* and *Diaptomus sp.* tolerate relatively higher Total Chromium concentrations compared with the other species.

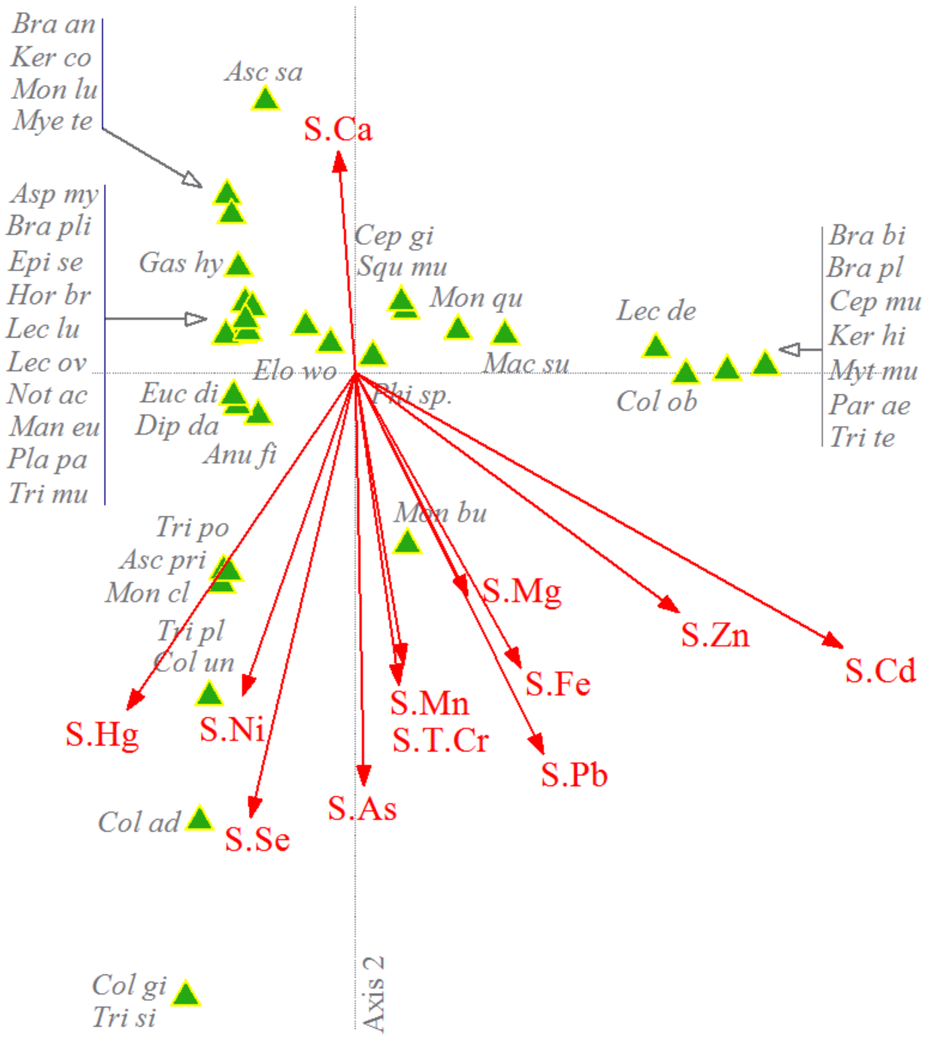


Figure 152: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

In general, the above figure shows that most of the identified Rotifera species can tolerate higher Sediment Calcium concentrations compared with the remaining sediment heavy metals and toxins measured.

The species; *Trichocerca porcellus, Asplanchna priodonta, Monostyla closterocerca, Tripleuchlanis plicata, Colurella uncinata, Colurella adriatica, Colurella gibba,* and *Trichocerca similis* tolerate relatively high to moderate concentrations of Sediment Mercury, Sediment Nickel, Sediment Selenium, and Sediment Arsenic according to the other Rotifera species identified.

The species *Monostyla bulla* unlike the other species seems to tolerate relatively moderate concentrations of Sediment Magnesium, Sediment Iron, Sediment Manganese, Sediment Total chromium, and Sediment Lead, with lower concentrations of Sediment Arsenic, Sediment Zinc, and Sediment Cadmium.

The species; *Lecane depressa, Colurella obtusa Brachionus bidentata, Brachionus plicata, Cephalodella mucronata, Keratella hiemalis, Mytilina mucronata, Paracolurella aemula,* and *Trichotria tetractis* unlike the other species seem to tolerate relatively moderate concentrations of Sediment Zinc and Sediment Cadmium.

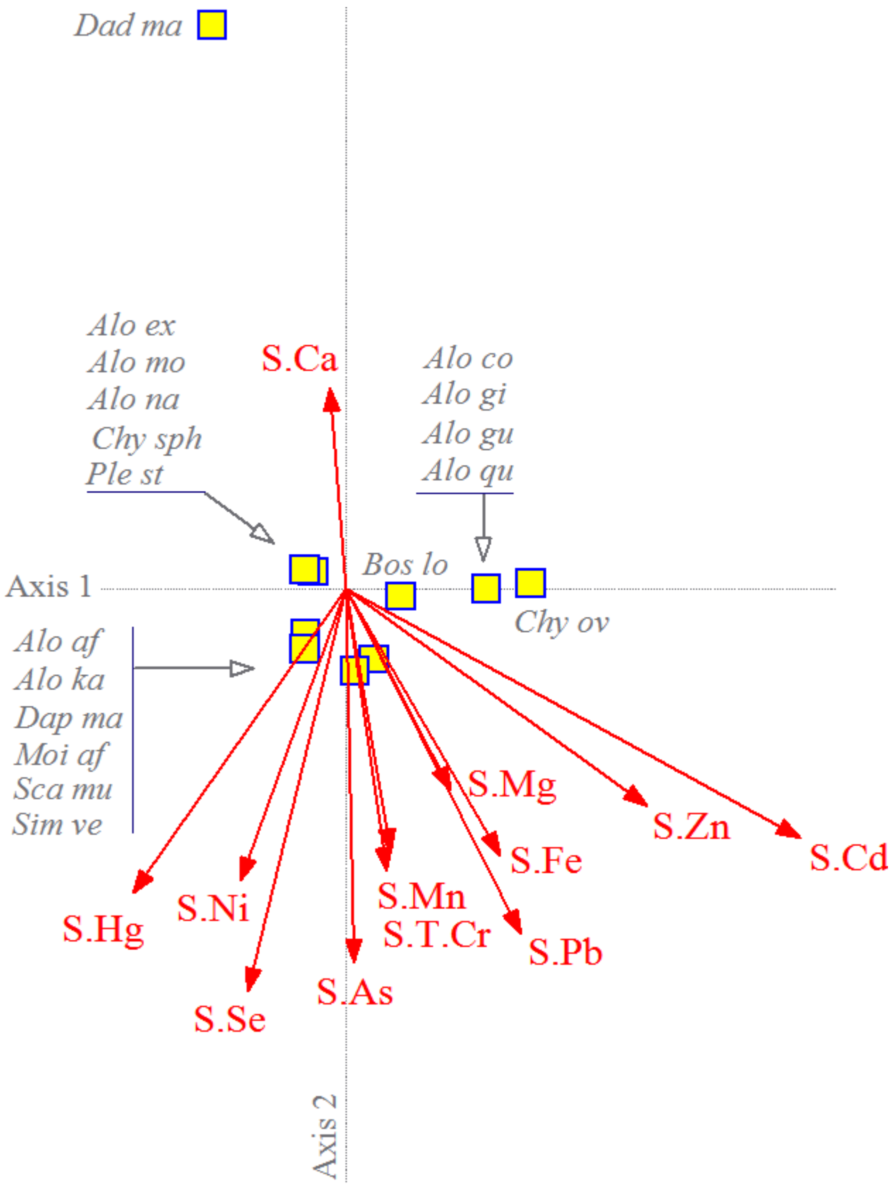


Figure 153: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of the Cladocera species identified seem to tolerate relatively low concentrations of the sediment heavy metals and toxins measured.

The species *Alona costata, Alona gibba, Alona guttata, Alona quadrangularis,* and *Chydorus ovalis* seem to tolerate higher concentrations of Sediment Zinc and Sediment Cadmium compared with the other species.

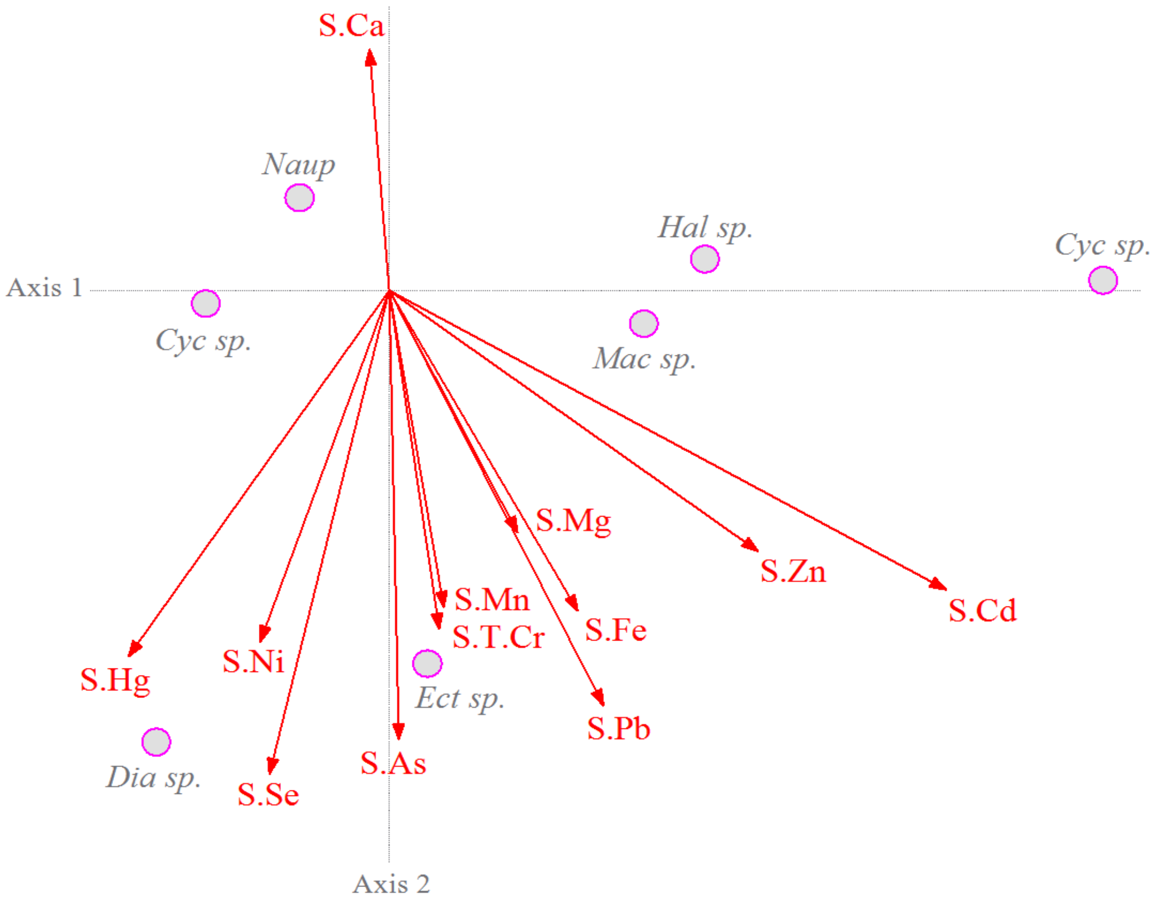


Figure 154: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

From the above figure, the three Copepoda species (*Cyclops sp.2, Halicyclops sp.,* and *Macrocyclops sp.)* seem to tolerate relatively high to moderate concentrations of Sediment Zinc and Sediment Cadmium compared with the other Copepoda species.

Nauplii of Copepoda seem to tolerate relatively moderate concentrations of Sediment Calcium unlike the other species.

While *Diaptomus sp.* can tolerate relatively high concentrations of Sediment Mercury, Sediment Selenium, and Sediment Nickel with lower concentrations of Sediment Arsenic.

On the other hand, *Eucyclops sp.* tolerates relatively higher concentrations of Sediment Manganese, Sediment Total chromium, Sediment Arsenic, and Sediment Lead with lower concentrations of the other sediment heavy metals and toxins, when compared with the other species.

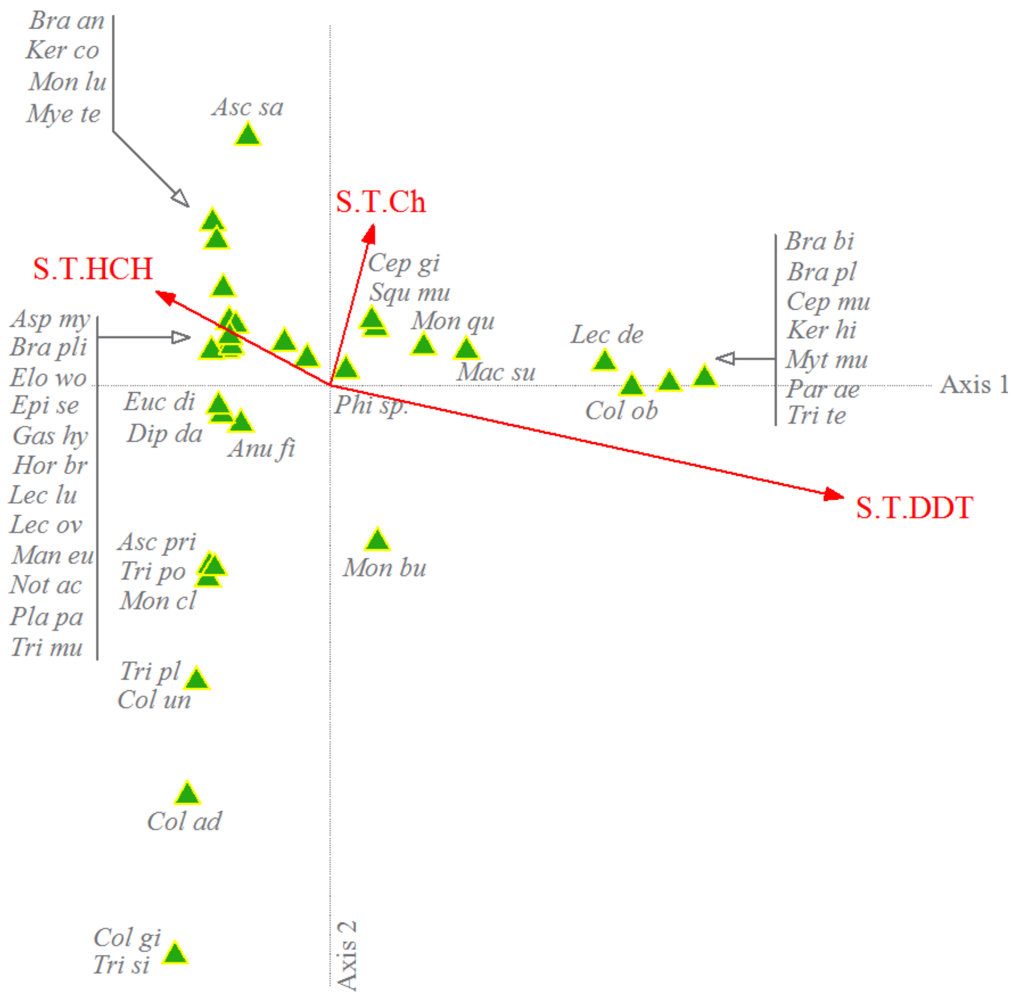


Figure 155: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

The figure above shows that most of the Rotifera species tolerate relatively moderate Sediment Total HCH and Sediment Total Chlordane with relatively low to moderate Sediment Total DDT concentrations.

The remaining species (low left of the figure) appear to tolerate low concentrations of Sediment Total HCH, Sediment Total Chlordane, and Sediment Total DDT.

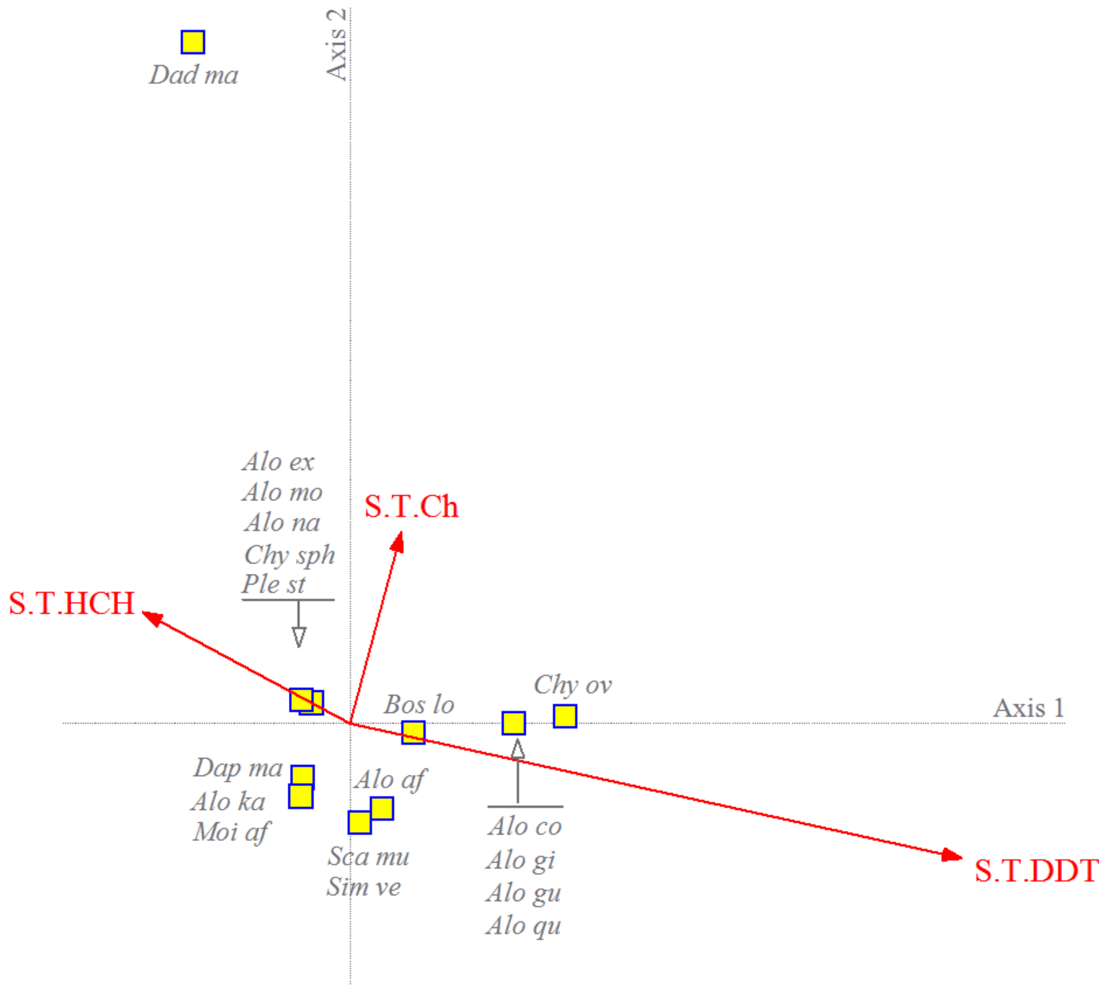


Figure 156: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

As shown in the above figure, most Cladocera species appear to tolerate relatively low Sediment Total HCH, Sediment Total Chlordane, and Sediment Total DDT concentrations.

Chydorus ovalis, Alona costata, Alona gibba, Alona guttata, and *Alona quadrangularis* tolerate slightly higher Sediment Total DDT concentrations than the other species.

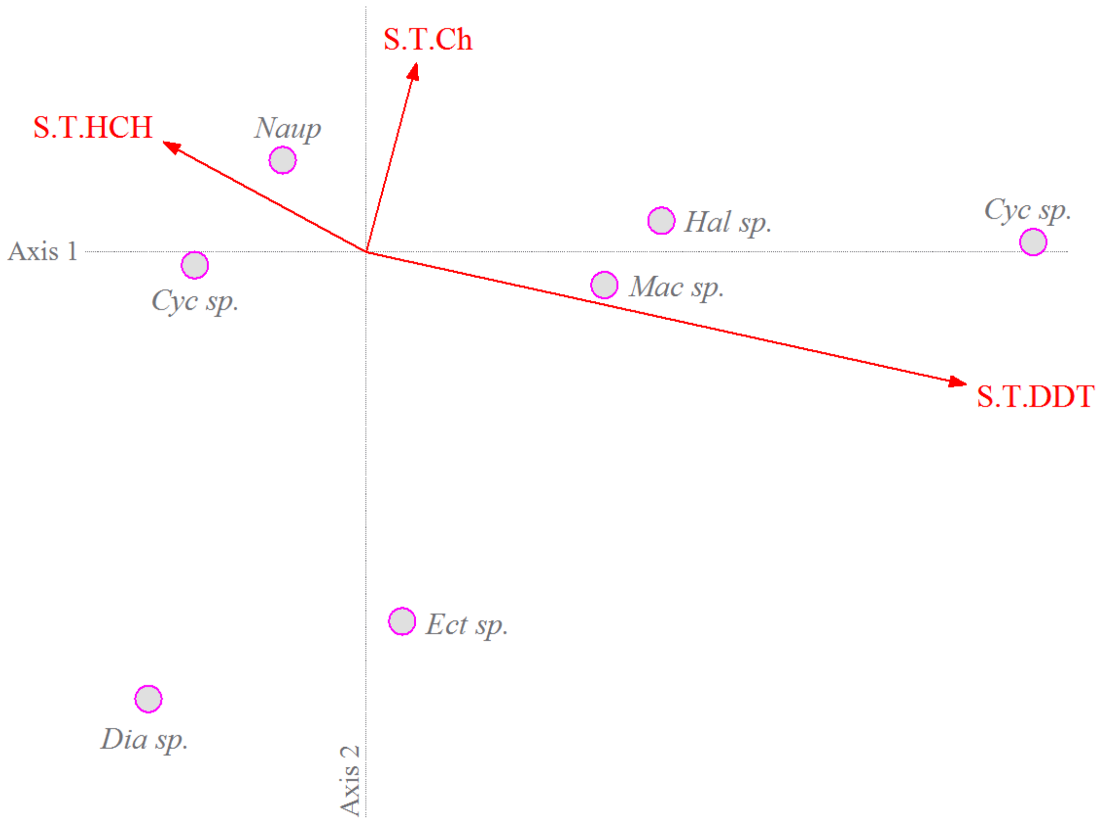


Figure 157: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

Nauplii of Copepoda and *Cyclops sp.* seem to tolerate higher Sediment Total HCH than the other two sediment pesticides.

While, *Cyclops sp.*2, *Halicyclops sp.,* and *Macrocyclops sp.* tolerate moderate concentrations of Sediment Total DDT compared with the other two sediment pesticides.

On the other hand, *Eucyclops sp.* and *Diaptomus sp.* seem to tolerate low sediment pesticides and PCBs.

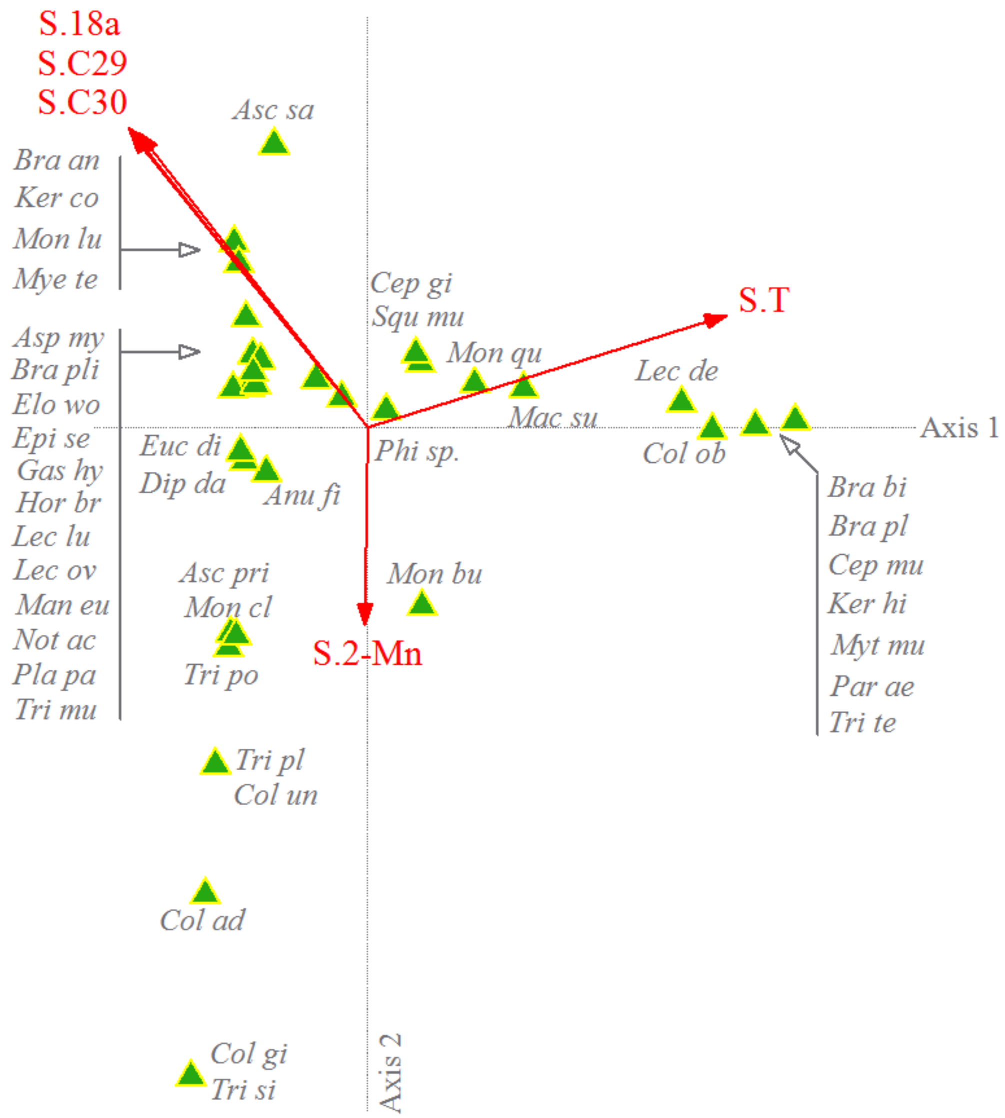


Figure 158: Ordination of Rotifera genera in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

As clear in the above figure, most of the Rotifera species shown seem to tolerate conditions with relatively moderate to high Sediment 18a-Oleanane, Sediment C29-Hopane, Sediment C30-Hopane, and Sediment 1,6,7-Trimethylnaphthalene concentrations, and lower concentrations of Sediment 2-Methylnaphthalene.

Whereas, the remaining species; *Asplanchna priodonta, Monostyla bulla, Monostyla closterocerca, Trichocerca porcellus, Tripleuchlanis plicata, Colurella uncinata, Colurella adriatica, Colurella gibba*, and *Trichocerca similis* seem to tolerate conditions with relatively higher concentrations of Sediment 2-Methylnaphthalene than Sediment 18a-Oleanane, Sediment C29-Hopane, Sediment C30-Hopane, and Sediment 1,6,7-Trimethylnaphthalene concentrations.

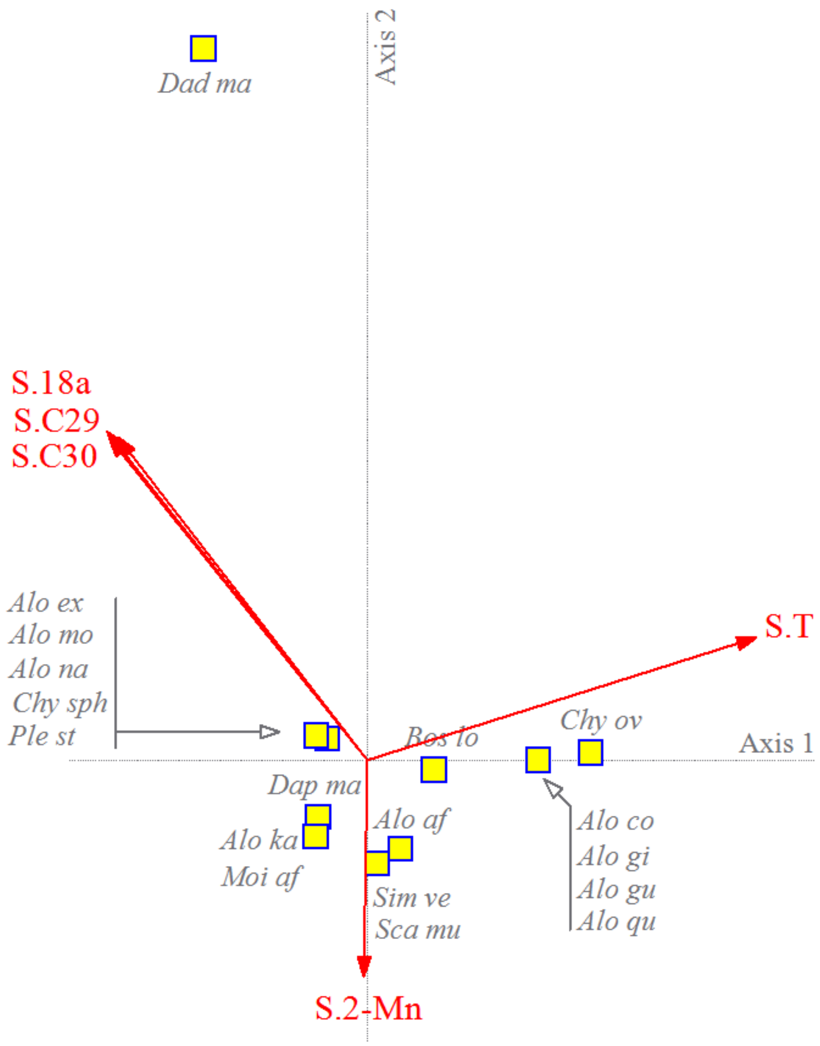


Figure 159: Ordination of Cladocera genera in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

Dadaya macrops, unlike the other species seemed to tolerate conditions with higher 18a-Oleanane, Sediment C29-Hopane, and Sediment C30-Hopane than the other Cladocera species.

Whereas *Chydorus ovalis*. *Alona costata, Alona gibba, Alona guttata, Alona quadrangularis* and *Bosmina longirostris* seemed to tolerate conditions with relatively low to moderate concentrations of Sediment 1,6,7-Trimethylnaphthalene.

On the other hand, the remaining Cladocera species seemed to tolerate conditions with higher Sediment 2-Methylnaphthalene concentrations than the other sediment Polynuclear Aromatic Hydrocarbons (PAHs).

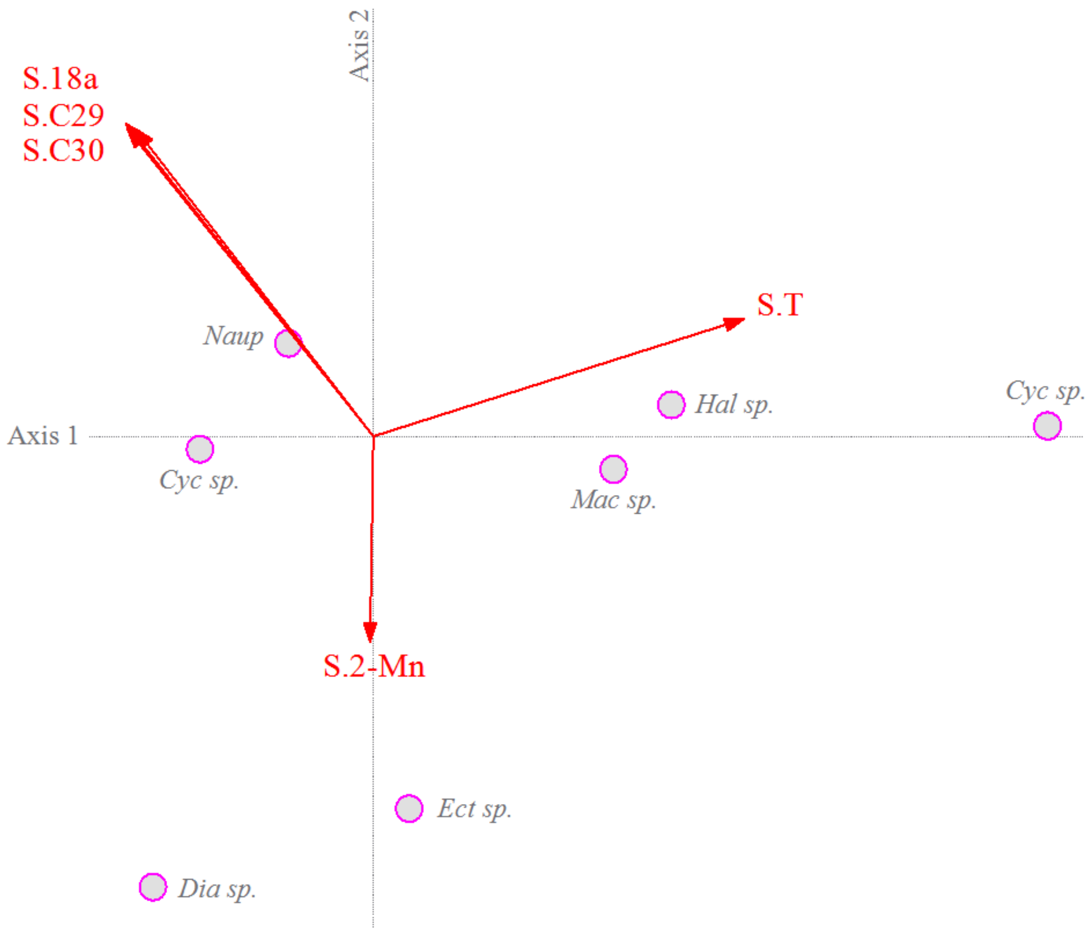


Figure 160: Ordination of Copepoda genera in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

*Cyclops sp.*2, *Halicyclops sp.*, and *Macrocyclops sp.* seemed to tolerate relatively higher Sediment 1,6,7-Trimethylnaphthalene than the other measured sediment Polynuclear Aromatic Hydrocarbons.

While, Nauplii of Copepoda and *Cyclops sp.* unlike the other Copepoda species seemed to tolerate higher 18a-Oleanane, Sediment C29-Hopane, and Sediment C30-Hopane than Sediment 1,6,7-Trimethylnaphthalene and Sediment 2-Methylnaphthalene concentrations.

Eucyclops sp. and *Diaptomus sp.* on the other hand seemed to tolerate relatively higher Sediment 2-Methylnaphthalene concentrations compared with the other sediment Polynuclear Aromatic Hydrocarbons.

ZOOPLANKTON COMMUNITY ORDINATION AND HABITATS:

The results obtained from CCA showed that eigenvalues for the first and second axes were 0.62 and 0.48 respectively. In addition, Zooplankton-Habitats correlations was strongly related to the first and second axes of the CCA (r = 0.99 and 0.97 respectively). The four canonical axes derived from the CCA accounted for 89.3% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 55.4% (Table 17).

Table 1: Eigenvalues and Zooplankton-habitats correlations for the four axes of the Zooplankton community derived from the canonical correspondence analysis (CCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.618	0.479	0.415	0.256
Zooplankton-habitats correlations	0.994	0.973	0.989	0.956
Cumulative percentage variance				
of Zooplankton data	15.7	27.9	38.4	44.9
of Zooplankton-Habitat relation	31.2	55.4	76.4	89.3

The diagram obtained from the CCA (Figure 143, Figure 145, & Figure 147) can show the dissimilarity of distribution of relative abundance of Zooplankton' species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Each arrow points in the expected direction of the steepest increase of values of the habitat. Each arrow shows the marginal effect of the particular habitat upon the sample scores in the ordination diagram.

The species symbols can be projected perpendicularly onto the line overlaying the arrow of particular habitat. These projections can be used to approximate the occurrence of individual species in respect to that habitat. Therefore, one can infer that most of the Rotifera species had higher abundance and distribution in UNEP 1, 3, and UNEP 6 with lower distributions in the other sites (Figure 143).

UNEP 4 and UNEP 6 were the main two stations to have higher abundance and distribution of Cladocera species than the other UNEP sites. (Figure 145)

While, only a few Copepoda species were identified (compared with the Rotifera and Cladocera) they were found in abundance and distribution in most of the UNEP sites. (Figure 147)

In addition, Figure 144, Figure 146, & Figure 148 are other representations of the occurrence of Zooplankton 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 are replaced by pie symbols. The segmentation of these symbols into slices is based on the classification of habitats. The relative size of particular pie-slice corresponds to relative importance (measured either by its number of occurances or its quantity) of the current species in the particular class of habitats. (Ter Braak and Šmilauer, 2002)

Zooplankton species differ in their distribution and occurrence in the different stations as shown in the figures below.

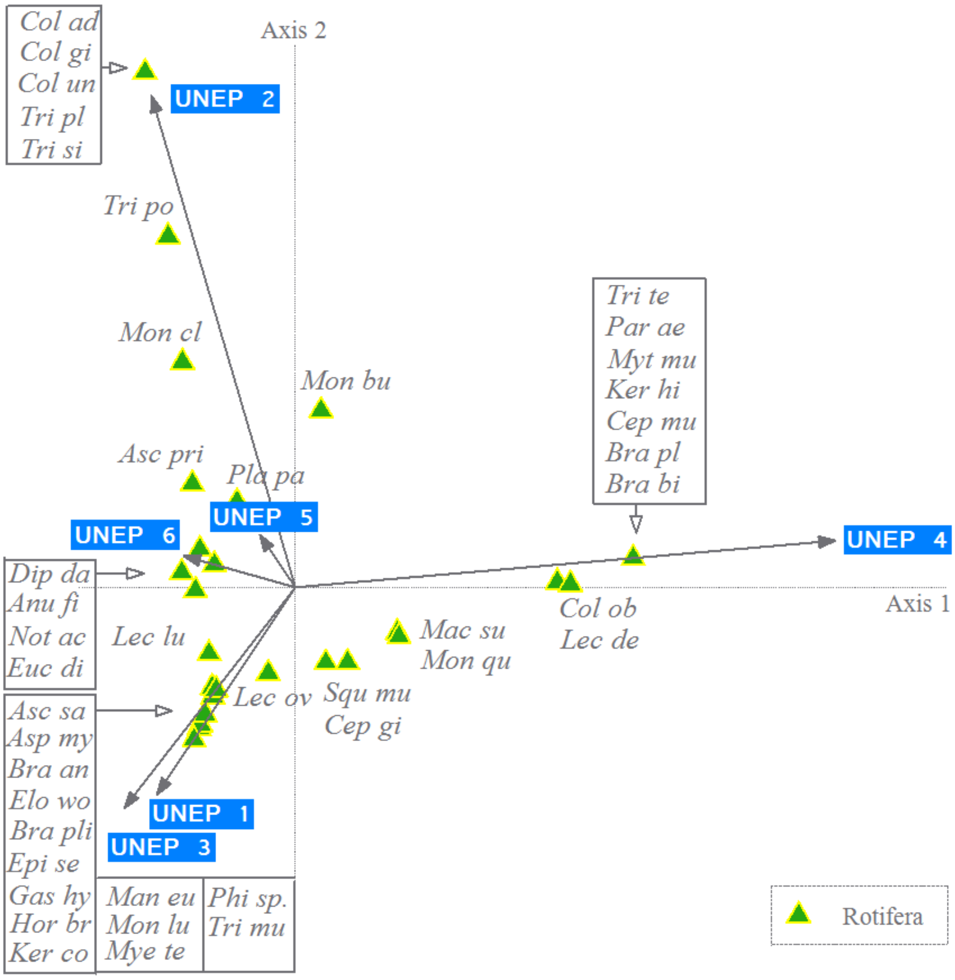


Figure 161: Ordination of Rotifera genera in relation to preferred habitats, southern Iraq (May – September 2005).

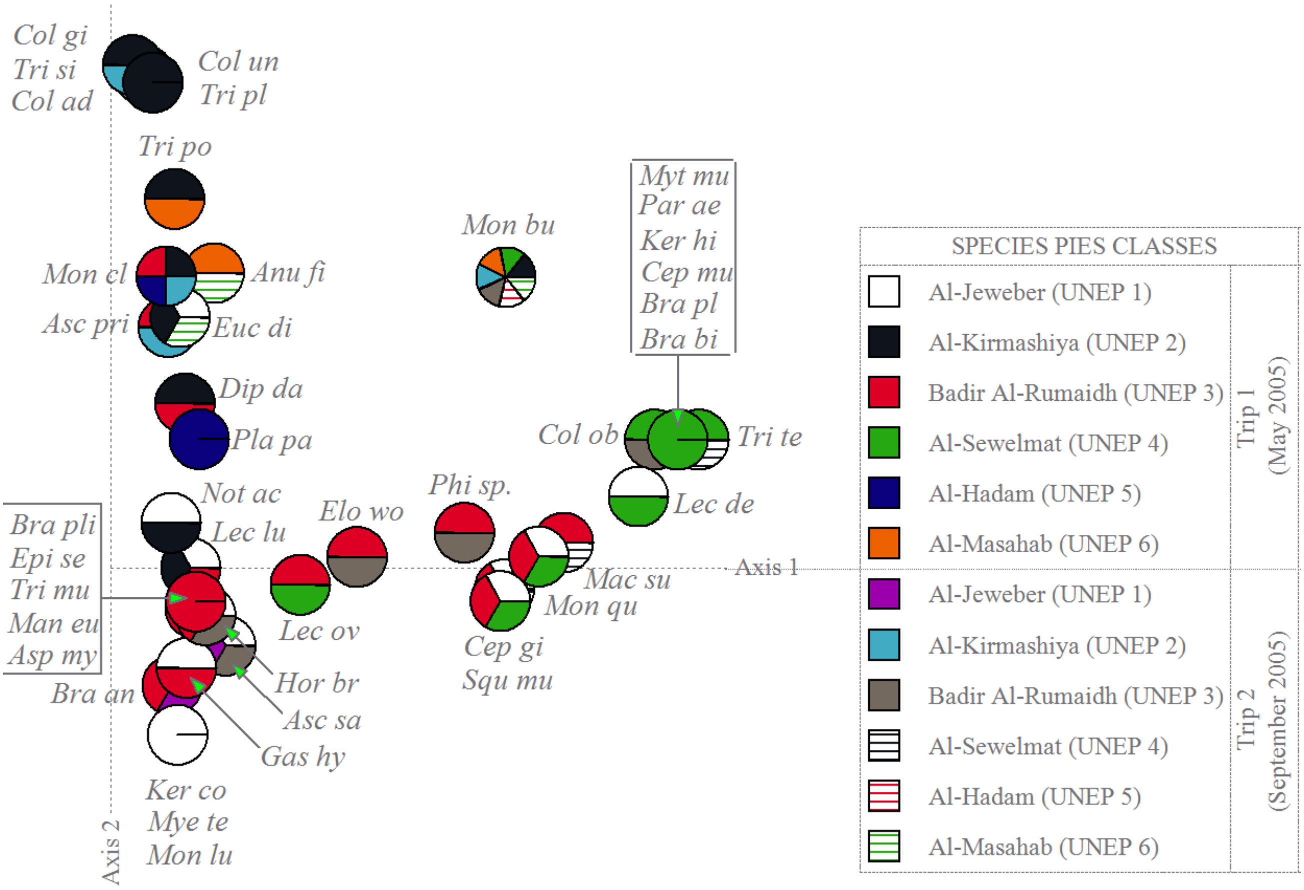


Figure 162: Ordination of Rotifera genera pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

The above figure shows that most of the Rotifera species were present in UNEP 1, 2, 3, 4, and UNEP 5 during the first trip only.

UNEP 1, 3, and UNEP 4 had more variety in Rotifera species especially during trip one compared with the other UNEP sites.

Monostyla bulla was the main species that was not focused in specific sites and had wider distribution in the different UNEP sites compared to the other species.

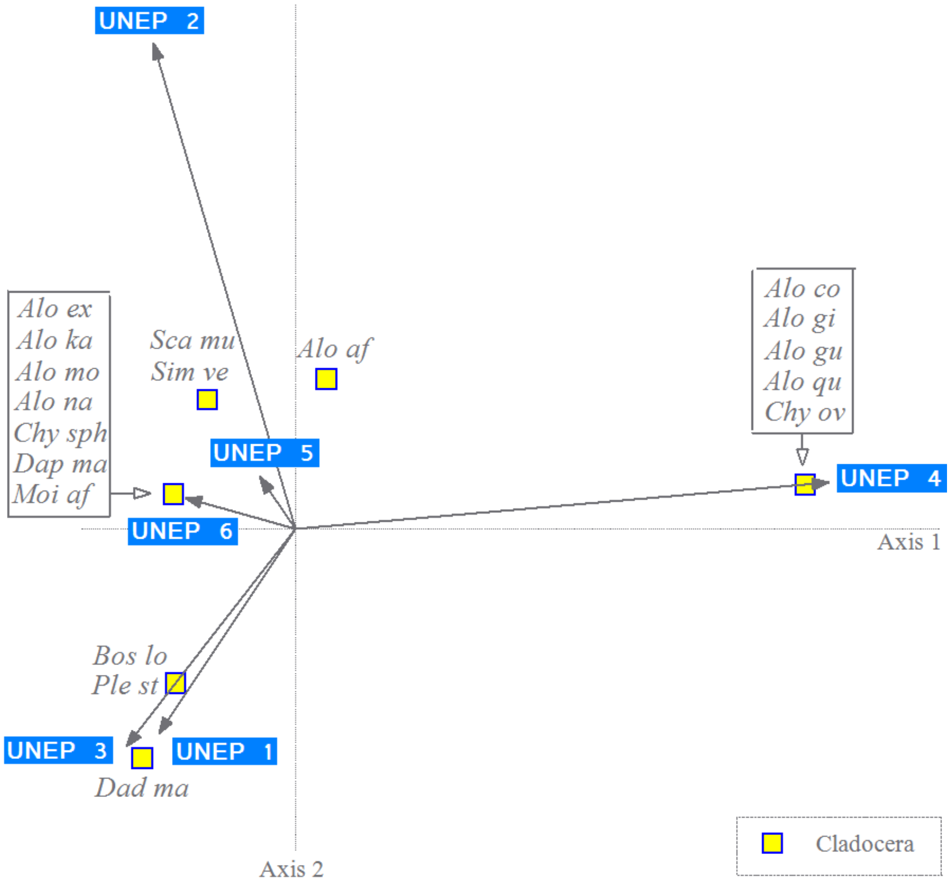


Figure 163: Ordination of Cladocera genera in relation to preferred habitats, southern Iraq (May – September 2005).

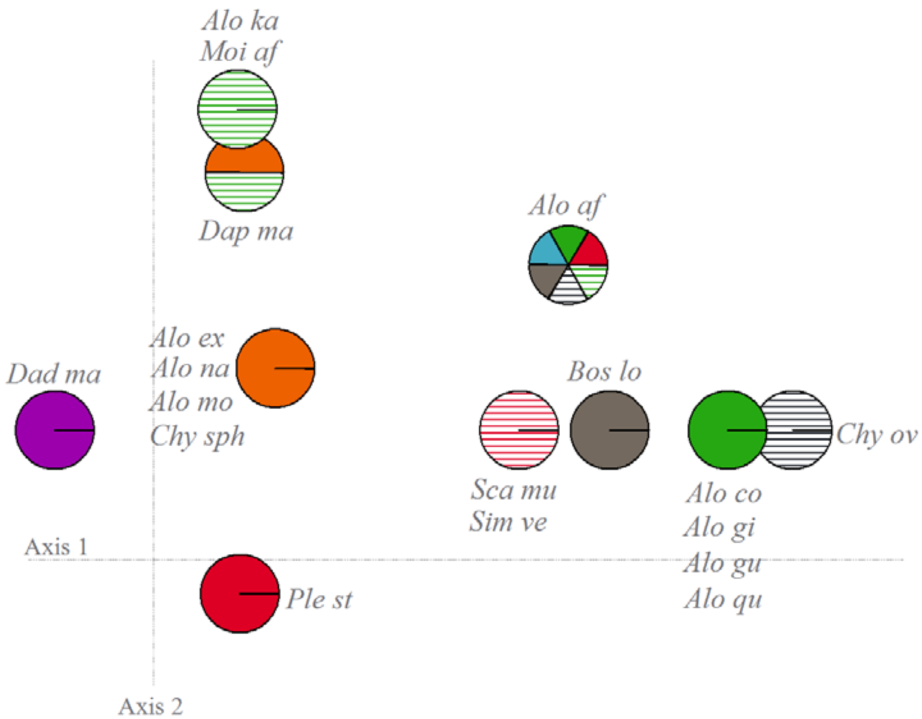


Figure 164: Ordination of Cladocera genera pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

Most Cladocera species were present in specific UNEP sites in either trip one or in trip two. With the exception of *Alona affinis* that was present in more than one UNEP site during both trips (Figure 146).

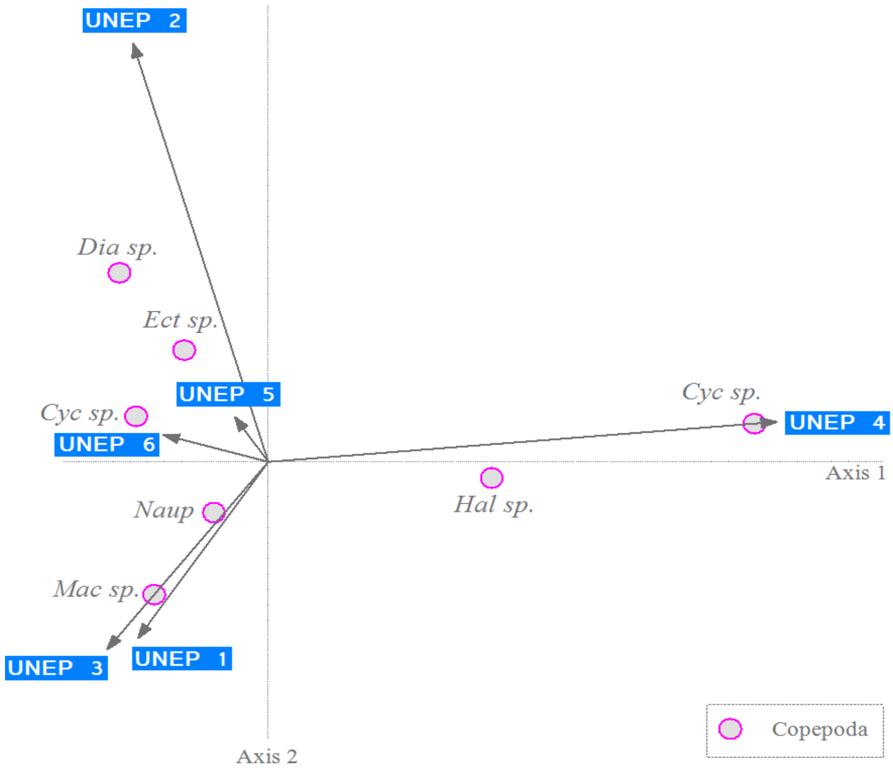


Figure 165: Ordination of Copepoda genera in relation to preferred habitats, southern Iraq (May – September 2005).

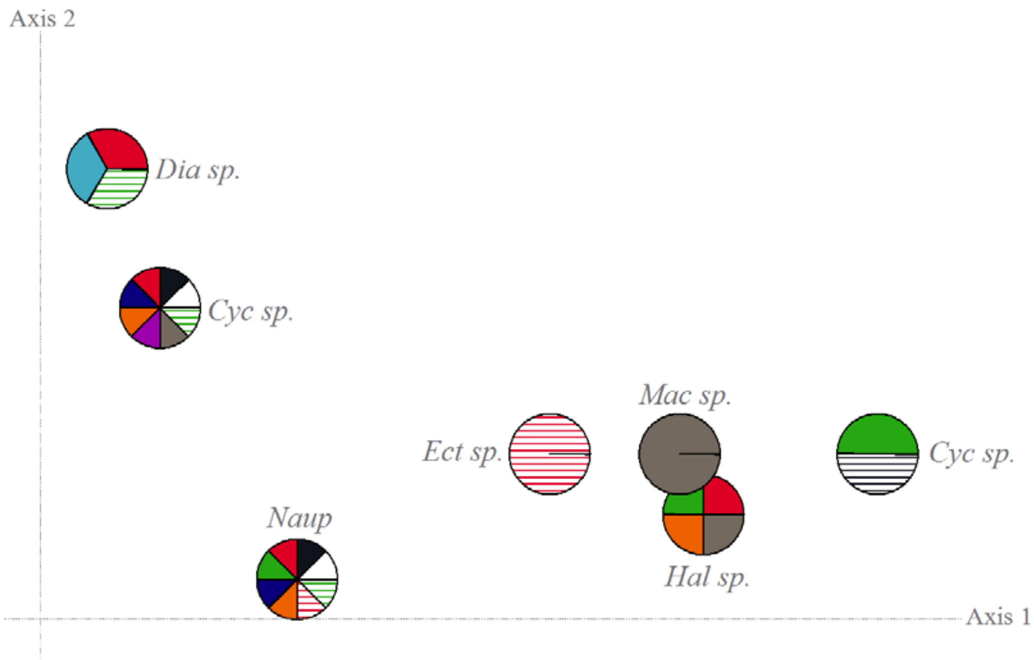


Figure 166: Ordination of Copepoda genera pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

Most of the Copepoda species identified, unlike the Rotifera and Cladocera species had occurrences in different UNEP sites during both trips.

With the exception of *Eucyclops sp.* that occurred in UNEP 5, *Macrocyclops sp.* that occurred in UNEP 3 during the second trip only, and *Cyclops sp.2* that occurred in UNEP 4 during both trips.

E. MACRO-BENTHOS

Bottom communities, consisting of mainly restricted motion and attached animals, are sensitive system, which are able to quantitative changes in an environment i.e. survival of organisms, which have adapted to new conditions and the die off of others, which cannot. Thus, zoo-benthos and their populations should be considered in order to show quality of waters and the condition of ecological system most clearly.

MACROBENTHOS COMMUNITY ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.2 and 0.09 respectively. In addition, the lengths of the gradient showed a clear linear response (Table 18), which implies the use of the Principal Components Analysis (PCA) method in the next step to analyze the relations with the explanatory variables.

Table 2: Eigenvalues and Lengths of gradient for the four axes of Macrobenthos community derived from the detrended correspondence analysis (DCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.2	0.09	0	0
Lengths of gradient	1.44	0.94	0	0

The diagram obtained from the DCA (Figure 149) shows that UNEP 1 during trip one and trip two was dominated by the class Mollusca with the other two classes Insecta and Amphibia having lower but equal occurrence.

UNEP 2 during the first trip was the same as UNEP 5 by having on both trips equal occurrences of the three classes. While UNEP 2, during the second trip was the same as UNEP 4 by having Mollusca the dominant class, and lower but equal occurrences of Insecta and Amphibia.

UNEP 3 appeared at exactly the same point during both trips and had the same occurrences of the three classes that appeared during UNEP 2 (t2) and UNEP 4 (t1 & t2).

On the other hand UNEP 6 and in both trip one and trip two showed equal occurrences of both classes, Insecta and Amphibia, with the absence of Mollusca.

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 species. The relative size of particular pie-slice corresponds to relative importance (measured either by its number of occurances or by its quantity) of the species belonging to a particular class in the corresponding sample. (Ter Braak and Šmilauer, 2002)

Furthermore, Macrobenthos diversity and richness across the studying period reflect the differences between the studied sites and demonstrate the recovery in these sites from May 2005 until September 2005, best seen in UNEP 2, that showed higher diversity and richness values in trip two than the values obtained in trip one.

In addition, it can be seen that UNEP 6 throughout both trips had the same and lowest diversity and richness values. Whereas, UNEP 1 had the highest diversity and richness values during both trips when compared with the other stations (Figure 150).

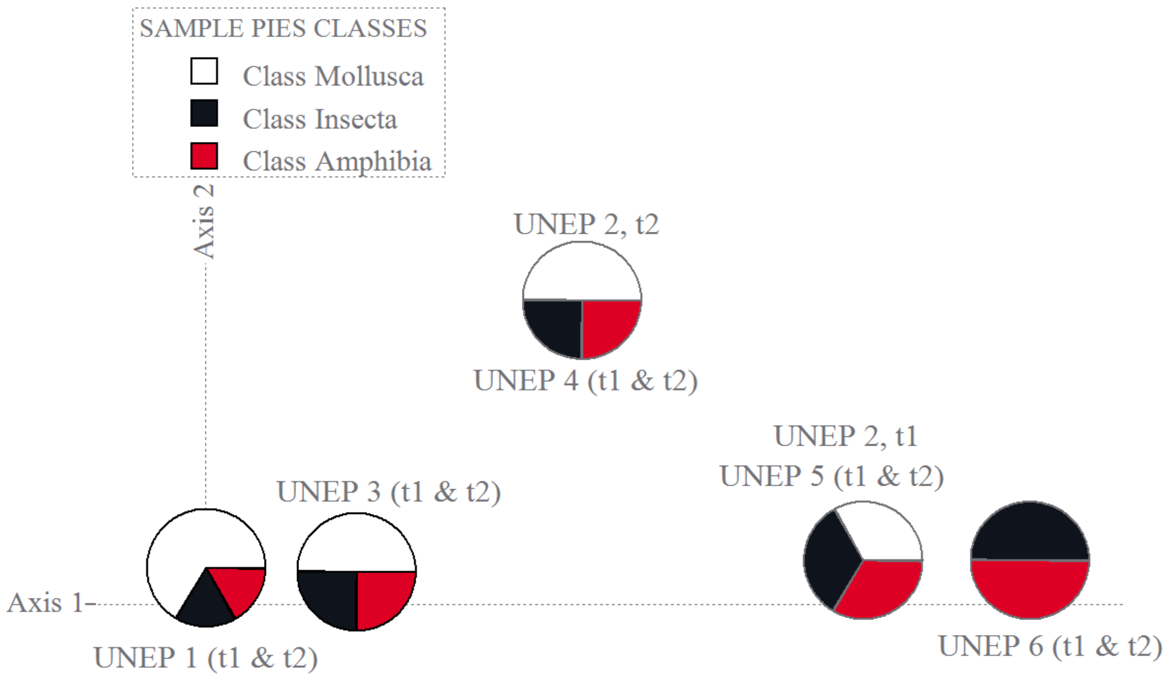


Figure 167: Ordination diagram [Axis 1 x Axis 2] with Macrobenthos' samples pies classes, southern Iraq (May - September 2005), obtained from the Detrended Correspondence Analysis (DCA) method.

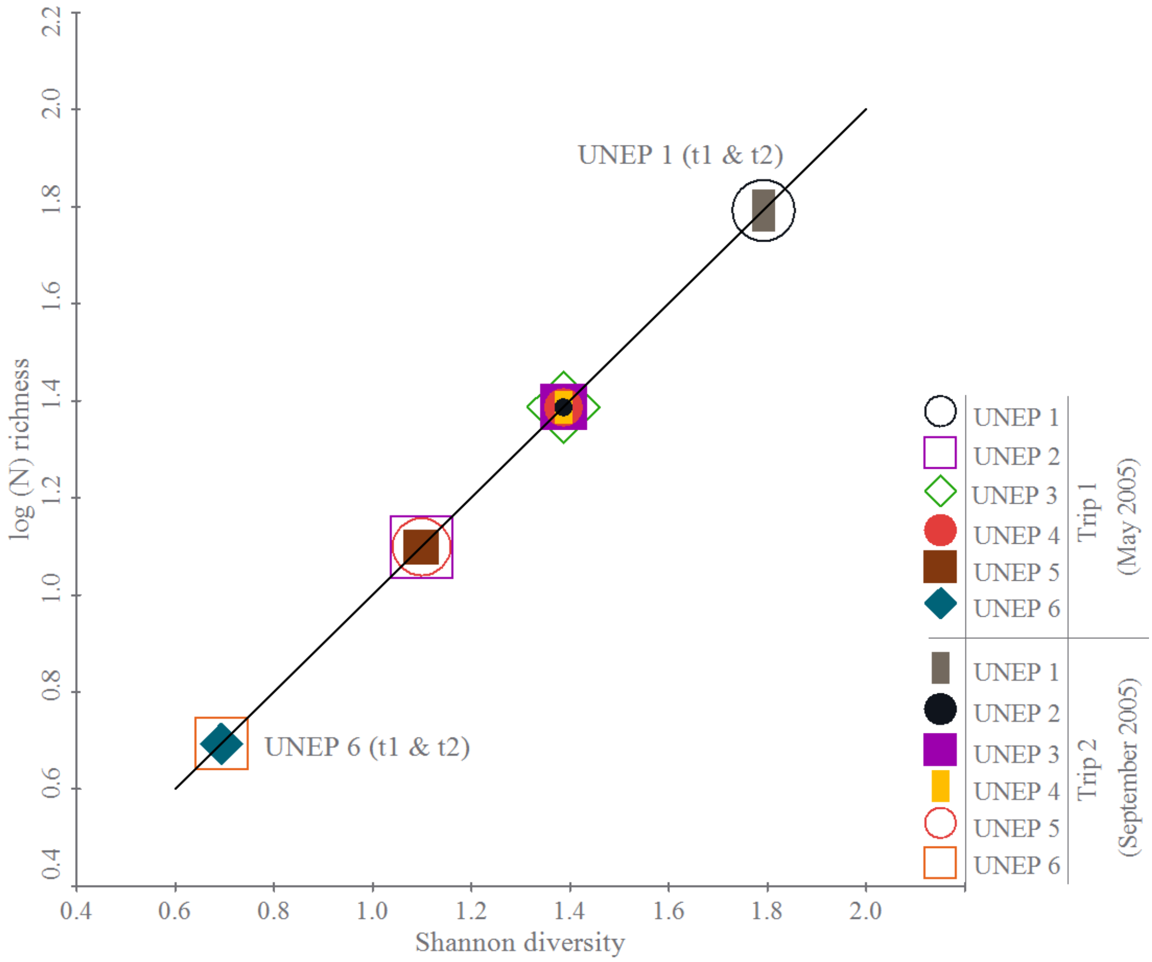


Figure 168: Macrobenthos diversity & richness, southern Iraq (May - September 2005), obtained from the detrended correspondence analysis (DCA) method.

It can be concluded from the above figure that UNEP 1 had the highest diversity and richness values on both trips (1.79).

UNEP 2 during trip one had the same diversity and richness values as UNEP 5 on both trips (1.09).

On the other hand, UNEP 2 in trip two along with UNEP 3 and UNEP 4 on both trips had the same values of diversity and richness (1.38). In addition, UNEP 6 had the same and lowest values on both trips (0.69) (Table 5).

Higest Overall Macrobenthos diversity is in UNEP 1 although UNEP 4 has the second highest which equals UNEP 3. (Figure)

MACROBENTHOS COMMUNITY ORDINATION AND ENVIRONMENTAL VARIABLES:

Due to the minimal information provided by the third and forth axes regarding variation in community structure (Eigenvalues = 0.12, and 0.09, respectively); (Table 19), these axes are not considered further. Moreover, the variables, which exhibited associations with the third and fourth axes, imply less ecological significance than the variables that exhibited associations with the first and second axes (Lepš and Šmilauer, 2003). Therefore, our discussion will focus mainly on the variables associated with the first and second axes of the PCA (Figure 151 through Figure 156).

The results obtained from the PCA showed that Macrobenthos-environment correlations are related to the first and second axes of the PCA (r = 0.8 and 1 respectively). The four canonical axes derived from the PCA accounted for 90.1% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 66.7% (Table 19).

Table 3: Eigenvalues and Macrobenthos-environment correlations for the four axes derived from the Principal Components Analysis (PCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.3	0.2	0.12	0.09
Macrobenthos-environment correlations	0.8	1	0.94	0.58
Cumulative percentage variance				
of Macrobenthos data	30.2	49.8	61.6	71
of Macrobenthos-environment relation	33.2	66.7	84.6	90.1

The results obtained from the PCA showed that the most important environmental variables to explain the variance in the community structure were: Water Temperature, pH, Turbidity, Alkalinity, Nitrate Nitrogen, Biochemical Oxygen Demand, Water Total Organic Carbon, Cadmium, Lead, Arsenic, Selenium, Mercury, Magnesium, Sediment Cadmium, Sediment Lead, Sediment Zinc, Sediment Total chromium, Sediment Arsenic, Sediment Mercury, Sediment Copper, Sediment Nickel, Sediment Iron, Sediment Manganese, Sediment Calcium, Sediment Magnesium, Sediment Total HCH, Sediment Total Chlordane, Sediment 1,6,7-Trimethylnaphthalene, Sediment 1-Methylphenanthrene, Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane, based on there moderate to strong correlations with the first and second axes of the PCA, while the other parameters were less correlated with these axes. (Table 20)

Furthermore, weaker correlations with the first and second axes did not reflect significant correlations with the Macrobenthos community structure. Therefore, weakly correlated variables are not represented in the diagrams.

Table 4: Inter-set correlations of environmental variables with axes, used to know the most important explanatory environmental variables for Macrobenthos community.

No.	**Environmental Variables**	**Codes used in figures**	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
1	Depth of water (m)	D	-0.0606	0.1976	-0.0723	-0.275
2	Air temperature (˚C)	AT	-0.3935	0.1431	0.1875	-0.458
3	Water temperature (˚C)	WT	0.1488	0.586	0.0557	0.0186
4	pH	pH	0.3912	0.5343	0.3758	-0.29
5	Electrical Conductivity (mS/cm)	EC	-0.1634	0.2305	-0.3901	0.6197

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
6	Dissolved Oxygen (mg/L)	DO	0.3276	0.1212	-0.0421	-0.264
7	Transparency (m)	Tra	-0.1808	0.3317	-0.1706	0.3122
8	Salinity (ppt)	S	-0.1184	0.0977	-0.3808	0.5404
9	Total Dissolved Solids (TDS) (mg/L)	TDS	-0.0233	0.1641	-0.3618	0.6404
10	Turbidity (NTU)	Tur	-0.627	-0.0404	-0.3764	0.0961
11	Total Suspended Solids (TSS) (mg/L)	TSS	-0.3145	-0.1113	-0.2774	0.0663
12	Alkalinity (mg $CaCO_3$/L)	Alk	-0.1812	-0.6711	0.1242	0.1572
13	Total Hardness ($CaCO_3$/L)	T.H	-0.0031	-0.0437	-0.2908	0.6273
14	Sulphates (SO4) (mg/L)	SO4	0.0096	0.2808	-0.351	0.6086
15	Chlorides (Cl) (mg/L)	Cl	-0.437	0.2908	-0.2317	0.5042
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	-0.1163	-0.2474	0.6023	0.3839
17	Nitrate Nitrogen (NO_3-N) (mg N/L)	NO3	-0.2849	-0.5107	0.3427	-0.139
18	Nitrite Nitrogen (NO_2-N) (mg N/L)	NO2	-0.2676	-0.2497	-0.1816	-0.343
19	Phosphates (PO_4-P) (mg P/L)	PO4	-0.1563	-0.1969	-0.2992	-0.241
20	Chlorophyll-a (mg/L)	Ch-a	-0.1058	0.1893	0.239	0.1935
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	0.215	0.269	-0.4574	0.415
23	Biochemical Oxygen Demand (BOD5) at 20°C (mg/L)	BOD	0.4846	-0.3482	0.1608	0.0106
24	Water Total Organic Carbon (TOC) (mg/L)	W.TOC	-0.1544	0.9087	-0.1452	0.3135
25	Total plate count (colony/mL)	T.PCC	-0.065	0.0651	0.2917	-0.302
26	Fecal coliform count (CFU/100mL)	FCC	0.099	-0.014	0.1869	-0.021
27	E. coli (CFU/100mL)	Eco	0.1112	0.2065	-0.1472	0.3539
28	Cadmium (Cd) (mg/L)	Cd	0.4959	-0.0447	-0.6674	0.5432
29	Lead (Pb) (mg/L)	Pb	0.9107	-0.025	0.0923	-0.266
30	Zinc (Zn) (mg/L)	Zn	0.2085	-0.2423	-0.724	0.5582
31	Total chromium (T-Cr) (mg/L)	T.Cr	-0.0619	-0.0635	0.1569	0.223
32	Arsenic (As) (mg/L)	As	-0.3752	0.4711	-0.3831	0.6507
33	Selenium (Se) (mg/L)	Se	0.3708	0.7542	0.2304	-0.432

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
34	Mercury (Hg) (mg/L)	Hg	-0.0828	0.8795	-0.2089	0.156
37	Iron (Fe) (mg/L)	Fe	-0.0636	-0.0033	-0.1697	-0.151
39	Calcium (Ca) (mg/L)	Ca	-0.2603	-0.0162	-0.4759	0.6902
40	Magnesium (Mg) (mg/L)	Mg	0.055	0.6192	-0.5116	0.568
41	Sediment Total Organic Carbon (TOC) %	S.TOC	-0.2986	-0.1612	0.1705	-0.019
42	Sediment Cadmium (Cd) (µg/kg)	S.Cd	-0.4511	-0.4831	0.5675	0.3044
43	Sediment Lead (Pb) (µg/kg)	S.Pb	-0.4322	-0.6008	0.1894	0.2159
44	Sediment Zinc (Zn) (µg/kg)	S.Zn	-0.4944	-0.6281	0.1468	0.4964
45	Sediment Total chromium (T-Cr) (µg/kg)	S.T.Cr	-0.783	-0.3897	-0.2249	0.2836
46	Sediment Arsenic (As) (µg/kg)	S.As	-0.7053	-0.5011	-0.0968	0.0211
47	Sediment Selenium (Se) (µg/kg)	S.Se	-0.1635	0.088	0.4069	0.0338
48	Sediment Mercury (Hg) (µg/kg)	S.Hg	-0.5246	0.1119	-0.1757	0.4047
49	Sediment Copper (Cu) (µg/kg)	S.Cu	0.3879	-0.7023	-0.3784	0.2538
50	Sediment Nickel (Ni) (µg/kg)	S.Ni	-0.5512	-0.4596	-0.3133	0.2132
51	Sediment Iron (Fe) (µg/kg)	S.Fe	-0.6355	-0.5876	-0.0737	0.364
52	Sediment Manganese (Mn) (µg/kg)	S.Mn	-0.4222	-0.7703	-0.1856	0.076
53	Sediment Calcium (Ca) (µg/kg)	S.Ca	0.2456	0.7675	0.2665	-0.243
54	Sediment Magnesium (Mg) (µg/kg)	S.Mg	-0.7024	-0.3196	-0.2379	0.5602
55	Sediment Total HCH (µg/dry g)	S.T.HCH	0.2936	0.7811	0.2906	-0.468
56	Sediment Total Chlordane (µg/dry g)	S.T.Ch	0.5437	0.5308	0.5272	-0.247
57	Sediment Total DDT (µg/dry g)	S.T.DDT	-0.3188	-0.232	0.5493	0.5545
59	Sediment 2-Methylnaphthalene (µg/dry g)	S.2-Mn	-0.1398	-0.3112	0.3203	-0.843
60	Sediment 1-Methylnaphthalene (µg/dry g)	S.1-Mn	-0.0516	-0.2411	0.2773	-0.888
61	Sediment 2,6-Dimethylnaphthalene (µg/dry g)	S.D	0.0509	-0.1941	0.311	-0.896
62	Sediment 1,6,7-Trimethylnaphthalene (µg/dry g)	S.T	-0.1202	-0.468	0.011	-0.518
63	Sediment 1-Methylphenanthrene (µg/dry g)	S.1-Mp	0.1733	-0.7281	0.1113	-0.616
64	Sediment C29-Hopane (µg/dry g)	S.C29	0.7073	-0.1571	-0.5877	0.3597

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
65	Sediment 18a-Oleanane (µg/dry g)	S.18a	0.7442	-0.2105	-0.5761	0.2597
66	Sediment C30-Hopane (µg/dry g)	S.C30	0.6844	-0.2336	-0.6253	0.2712

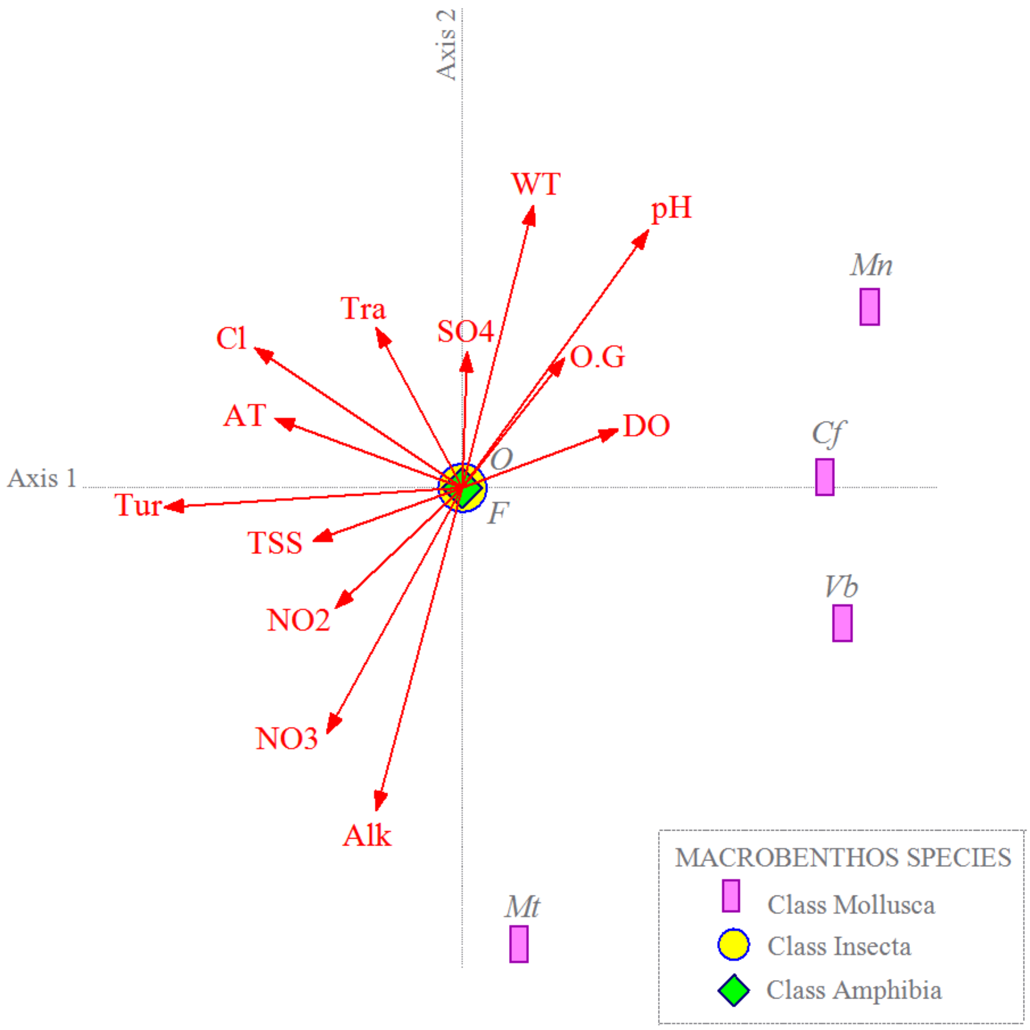


Figure 169: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

According to the diagram above, the distance between the symbols in the diagram approximates the dissimilarity of distribution of relative abundance of the species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together.

Each arrow points in the expected direction of the steepest increase in values of environmental variable. The angles between arrows indicate correlations between individual environmental variables. More precisely, we can read the approximated correlations of one environmental variable with the others by projecting their arrowheads onto the imaginary axis running in the direction of that variable's arrow.

The species symbols can be projected perpendicularly onto the line overlaying approximate the optima of individual species in respect to values of that environmental variable. Species projection points are in the order of the predicted increase of optimum value for that variable. Therefore, one can infer that generally, the Mollusca species are affected by the relatively moderate to high Water Temperatures, pH, Dissolved Oxygen, Alkalinity, Nitrate-Nitrogen, and relatively lower values of the remaining environmental variables, especially low Turbidity values.

The species *Melanopsis nodosa* favors relatively higher Water Temperatures, pH values, Sulphates, Dissolved Oxygen, and Oil and grease values when compared with the other species. While the species *Melanoides tuberculata* favors relatively higher Alkalinity, Nitrate Nitrogen, and Nitrite-Nitrogen compared with the other species.

Furthermore, it can be noticed that Odonata and Amphibia are located in this figure and all the following figures in the centre; meaning that they were found in all environmental conditions.

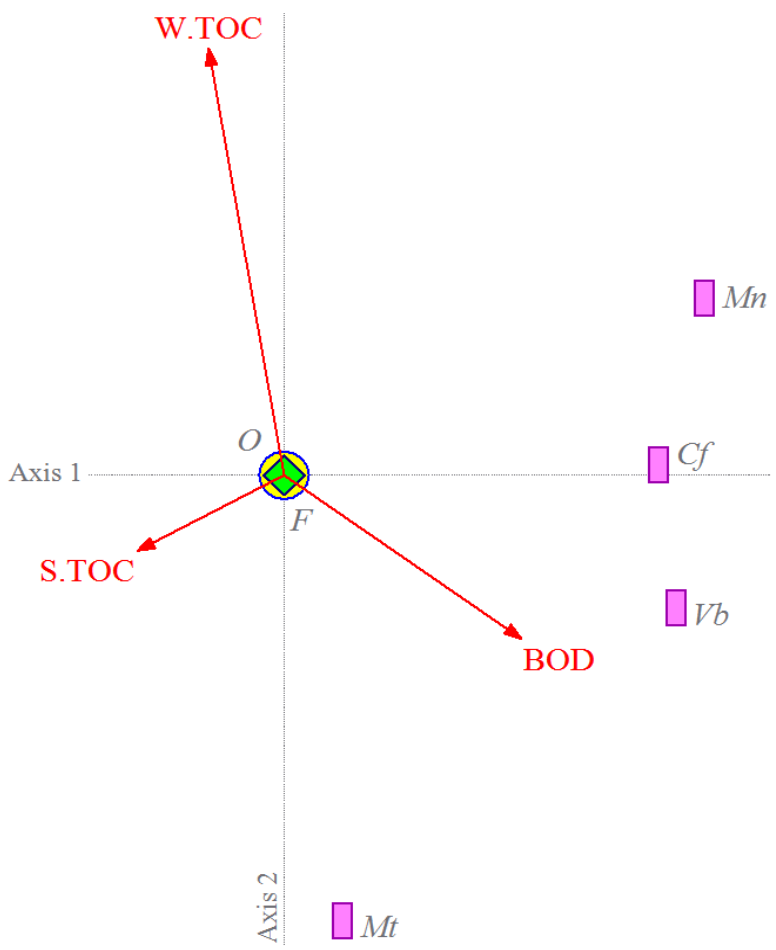


Figure 170: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

From the above figure, it can be noticed that *Melanoides tuberculata* unlike the other three Mollusca species favors higher Sediment Total Organic Carbon concentrations. While, *Melanoides tuberculata, Melanopsis nodosa*, and *Corbicula fluminalis* seem to favor relatively moderate Biochemical Oxygen Demand with the species *Viviparus bengalensis* favoring higher Biochemical Oxygen Demand values.

On the other hand *Melanopsis nodosa* seemed the only species to favor relatively moderate Water Total Organic Carbon compared with the other species.

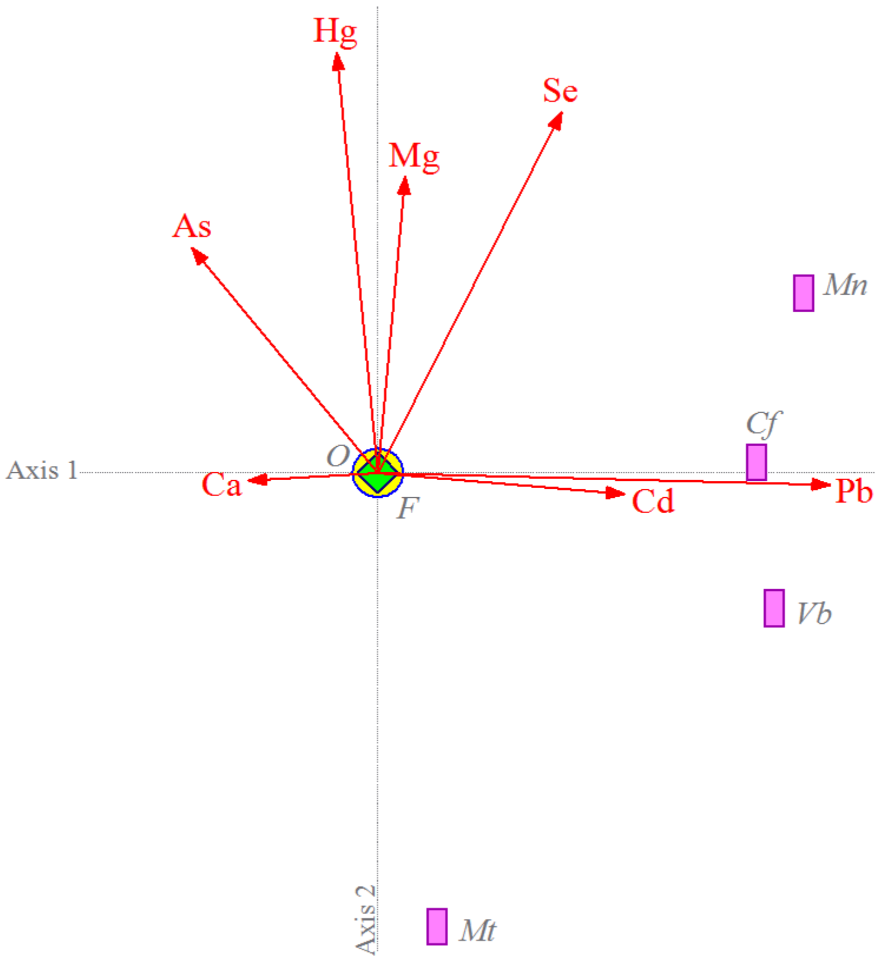


Figure 171: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

The above figure shows that the Mollusca species *Melanopsis nodosa, Corbicula fluminalis*, and *Viviparus bengalensis* tolerate relatively high Lead and Cadmium concentrations compared with the other heavy metals and toxins measured. The species *Melanopsis nodosa* unlike the other species seemed to tolerate relatively moderate concentrations of Selenium, Magnesium, and Mercury.

While the species *Melanoides tuberculata* seemed to tolerate relatively low concentrations of all the heavy metals and toxins measured.

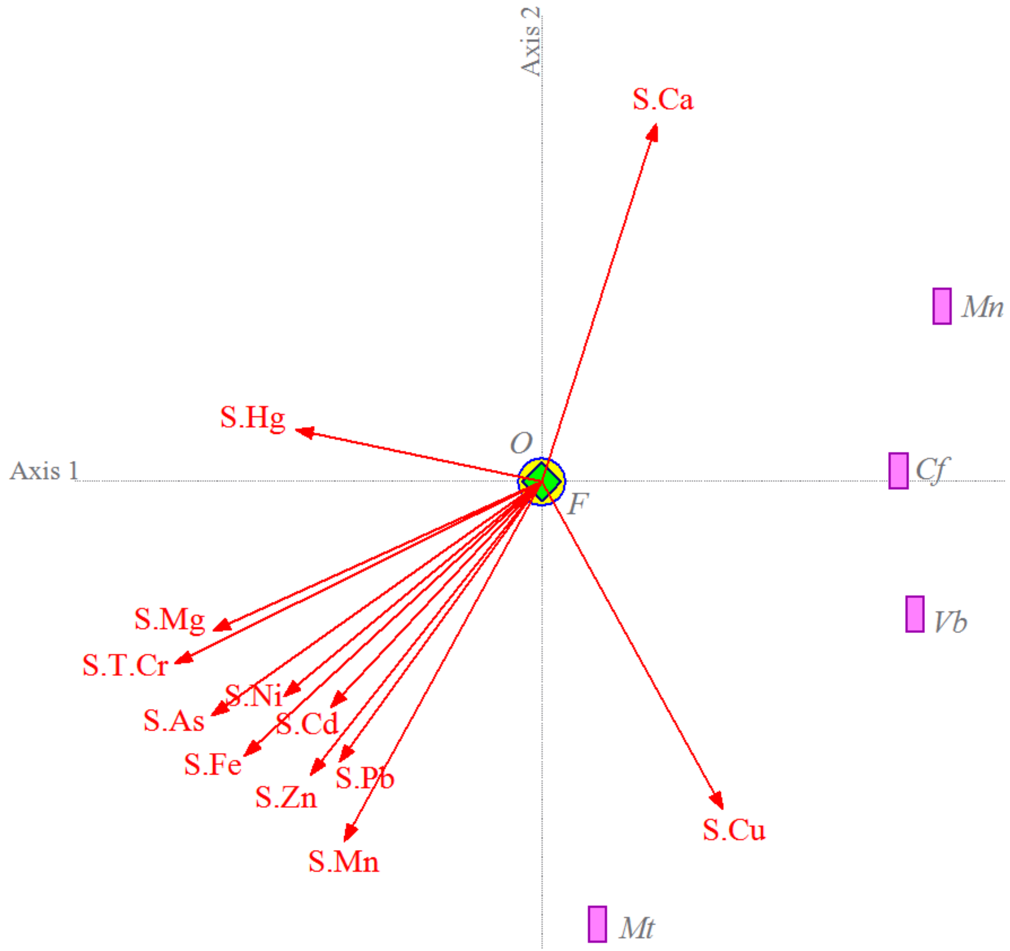


Figure 172: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Generally, from the above figure it can be shown that the species *Melanoides tuberculata* can tolerate the presence of almost all the sediment heavy metals and toxins measured compared with the other three Mollusca species indicated. Although, the species *Melanopsis nodosa* can tolerate relatively moderate concentrations of Sediment Calcium and *Viviparus bengalensis* can tolerate relatively moderate concentrations of Sediment Copper.

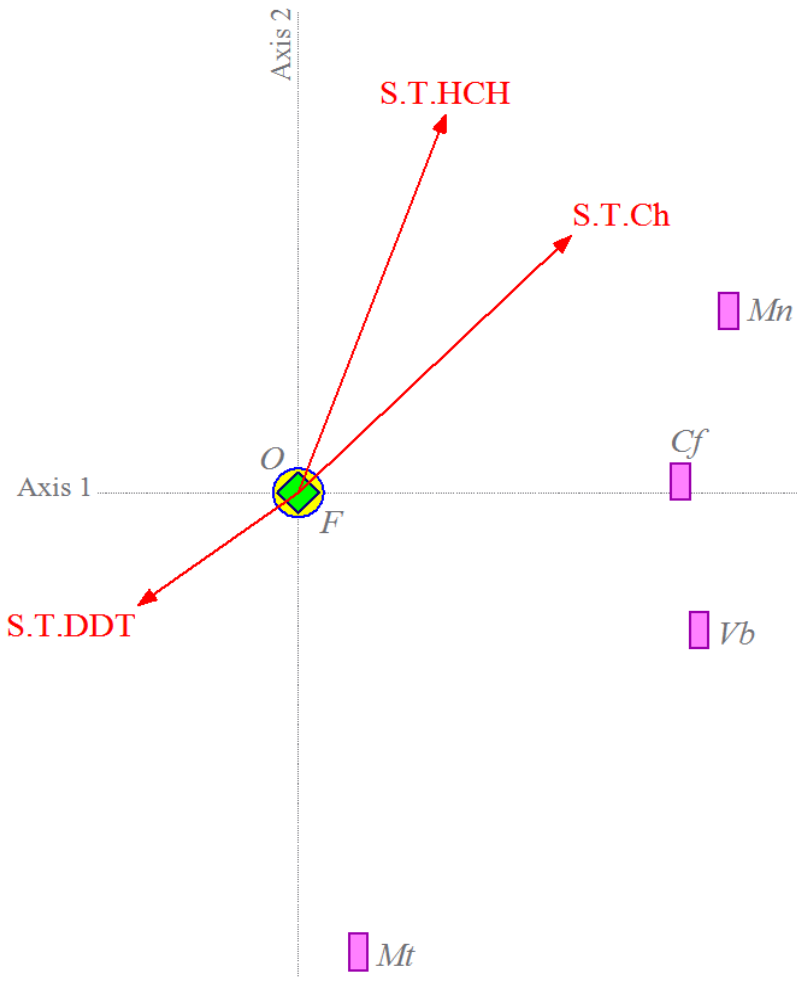


Figure 173: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

The above figure shows that *Melanoides tuberculata* is the only species from the four Mollusca species identified that can tolerate relatively higher concentrations of Sediment Total DDT, with *Viviparus bengalensis* tolerating relatively moderate concentrations of the same pesticide and Sediment Total Chlordane.

The species *Melanopsis nodosa* seemed to tolerate relatively higher Sediment Total HCH and Sediment Total Chlordane concentrations, while *Corbicula fluminalis* tolerated relatively moderate concentrations of the same two pesticides.

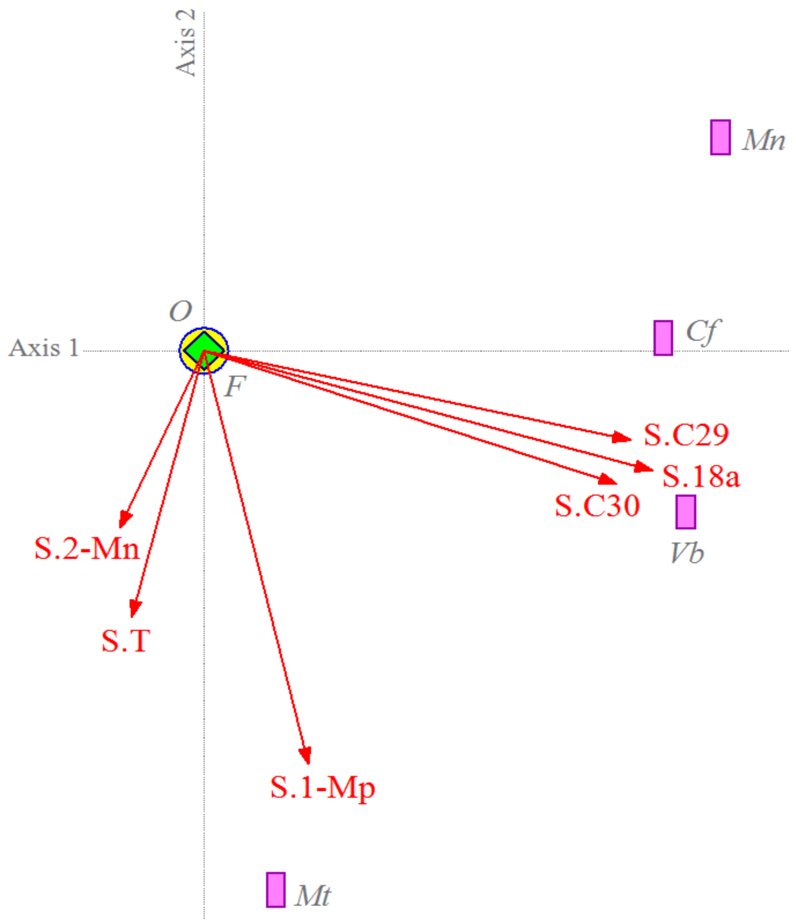


Figure 174: Ordination of Macrobenthos community in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

It can be clear from the above figure that the two Mollusca species *Melanoides tuberculata* and *Viviparus bengalensis* can tolerate relatively higher concentrations of all the measured sediment Polynuclear Aromatic Hydrocarbons.

While, the two species *Melanopsis nodosa* and *Corbicula fluminalis* on the other hand seem to tolerate relatively high concentrations of Sediment C29-Hopane, Sediment 18a-Oleanane, and Sediment C30-Hopane and low concentrations of Sediment 1-Methylphenanthrene, Sediment 1,6,7-Trimethylnaphthalene, and Sediment 2-Methylnaphthalene.

MACRO-BENTHOS COMMUNITY ORDINATION AND HABITATS:

The results obtained from PCA showed that eigenvalues for the first and second axes were 0.45 and 0.27 respectively. In addition, Macrobenthos-Habitats correlations was strongly related to the first and second axes of the PCA (r = 0.98 and 1 respectively). The four canonical axes derived from the PCA accounted for 100% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 72.8% (Table 21).

Table 5: Eigenvalues and Macro-benthos-habitats correlations for the four axes derived from the Principal Components Analysis (PCA).

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.45	0.27	0.21	0.07
Macrobenthos-habitats correlations	0.98	1	0.94	0.99
Cumulative percentage variance				
of Macrobenthos data	44.7	71.5	92.7	100
of Macrobenthos-Habitat relation	44.8	72.8	92.5	100

The diagram obtained from the CCA (Figure 157) shows the dissimilarity of distribution of relative abundance of Macrobenthos' species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Each arrow points in the expected direction of the steepest increase of values of the habitat. Each arrow shows the marginal effect of the particular habitat upon the sample scores in the ordination diagram.

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. Therefore, one can infer that *Melanoides tuberculata* was mainly present in UNEP 1, 2, 4, and UNEP 5. The species *Corbicula fluminalis* and *Melanopsis nodosa* were present mainly in UNEP 3.

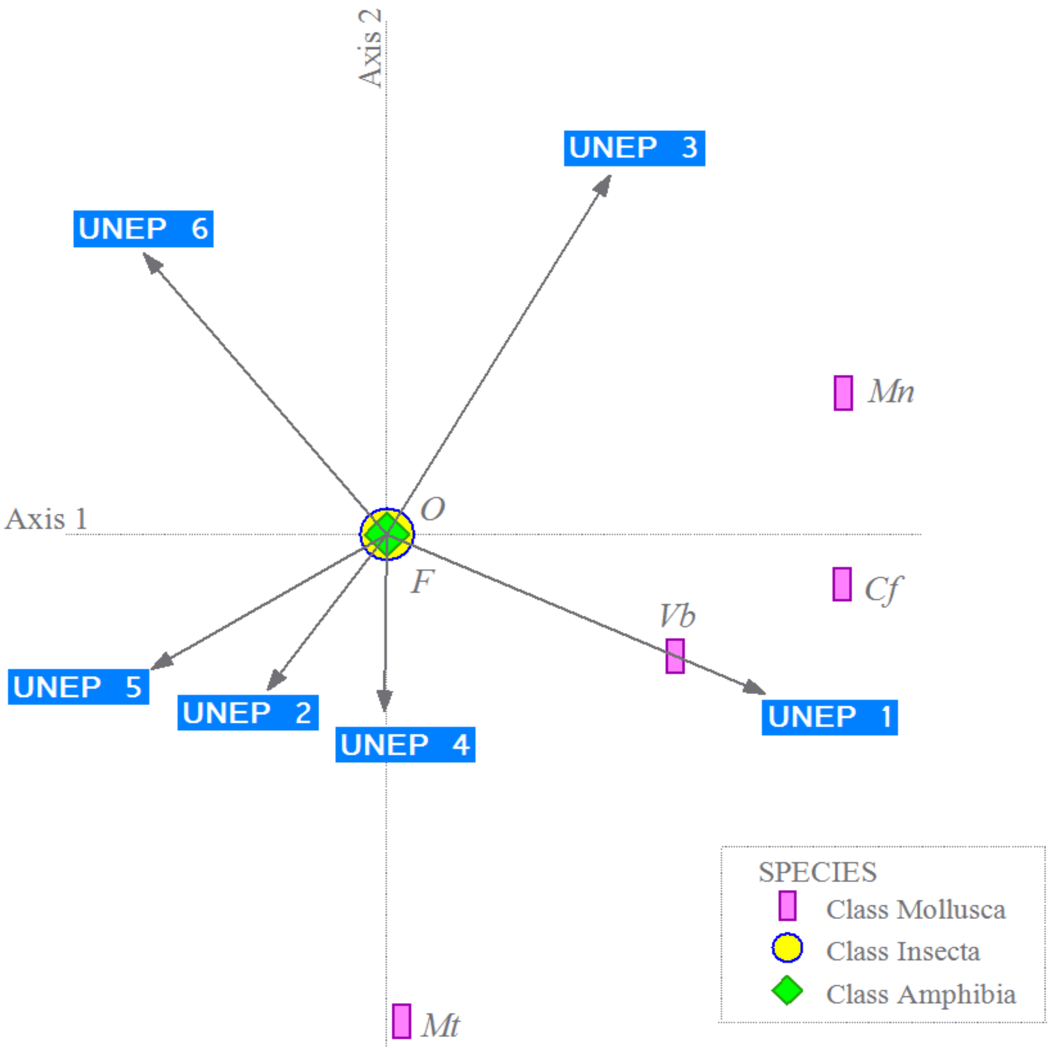


Figure 175: Ordination of Macrobenthos community in relation to preferred habitats, southern Iraq (May – September 2005).

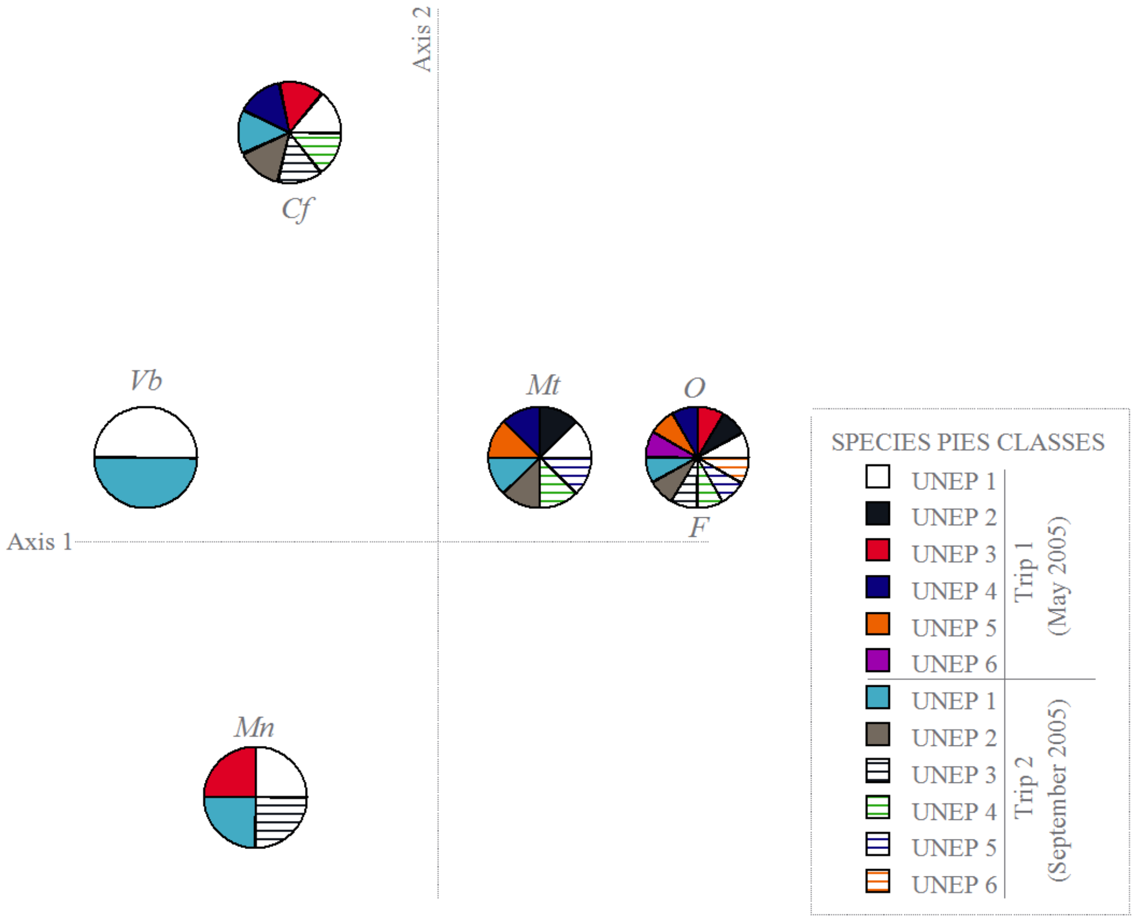


Figure 176: Ordination of Macrobenthos pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

Figure 158 is another representation of the occurrence and abundance of Macrobenthos' 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 are replaced by pie symbols. The segmentation of these symbols into slices is based on the classification of the habitats. The relative size of a particular pie-slice corresponds to relative importance (measured either by its number of occurances or its quantity) of the current species in the particular class of habitats. (Ter Braak and Šmilauer, 2002)

Odonata and Amphibia are the dominant Classes appearing in all stations and on both trips during May and September 2005. While, the other species vary in their distribution and occurrence in the different stations. For instance, *Viviparus bengalensis* occurred only in UNEP 1 on both trips.

F. FISH

FISH COMMUNITY ORDINATION:

The results obtained from the statistical program Canoco 4.5 (detrended correspondence analysis (DCA) method) showed that the eigenvalues (shows the importance of each axis and its range is from 0.0 up to 1.0) for the first and second axes were 0.59 and 0.16 respectively. In addition, the lengths of the gradient showed a clear unimodal response (Table 22), which implies the use of the canonical correspondence analysis (CCA) method in the next step to analyze the relations with the explanatory variables.

Table 6: Eigenvalues and Lengths of gradient for the four axes of the Fish community derived from the detrended correspondence analysis (DCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.59	0.16	0.06	0.01
Lengths of gradient	4.08	2.33	1.37	1.35

The diagram obtained from the DCA (Figure 159) shows the samples as sample pies. The sample symbols are replaced by pie symbols. The segmentation of these symbols into slices is based on the classification of species. The relative size of a particular pie-slice corresponds to relative importance (measured either by the number of occurances or by its quantity) of the species belonging to a particular class in the corresponding sample (Ter Braak and Šmilauer, 2002).

From the diagram, it can be seen that UNEP 2 during the first trip was represented by the presence of only Cyprinidae and Pocilidae, with the presence of Mugilidae in the same station in the second trip during September 2005. Cyprinidae was the only fish family presented in UNEP 1 during the first trip with the appearance of Mugilidae in the same station, during the second trip. 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 UNEP 4, 5, and UNEP 6 the families demonstrated in each station remained the same and had the same occurrences during the two trips. (Figure 159)

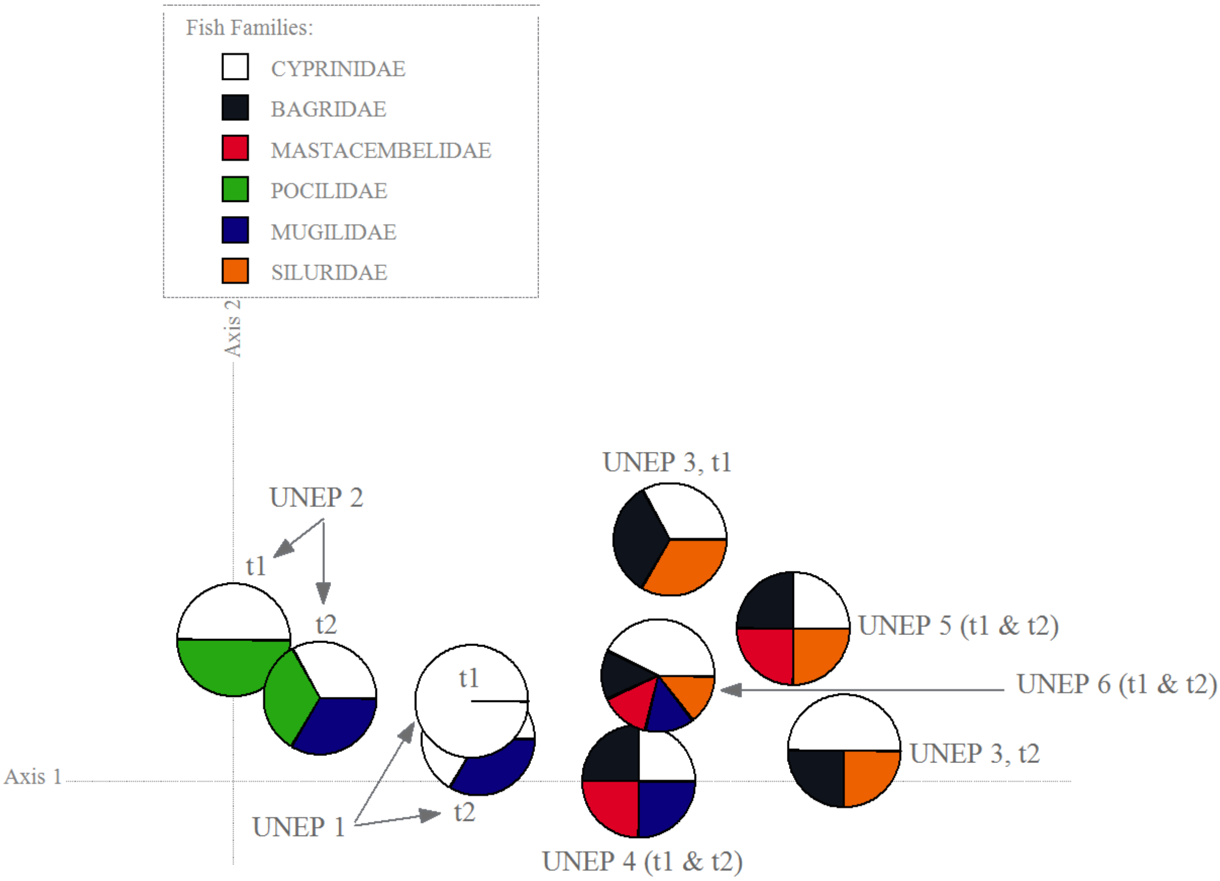


Figure 177: Ordination diagram [Axis 1 x Axis 2] with Fish' samples pies classes, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

Furthermore, fish diversity and richness across the studying period reflect the differences between the studied sites and demonstrate the recovery in these sites from May 2005 until September 2005, best seen in UNEP 1, UNEP 2, and UNEP 3 (Figure 160).

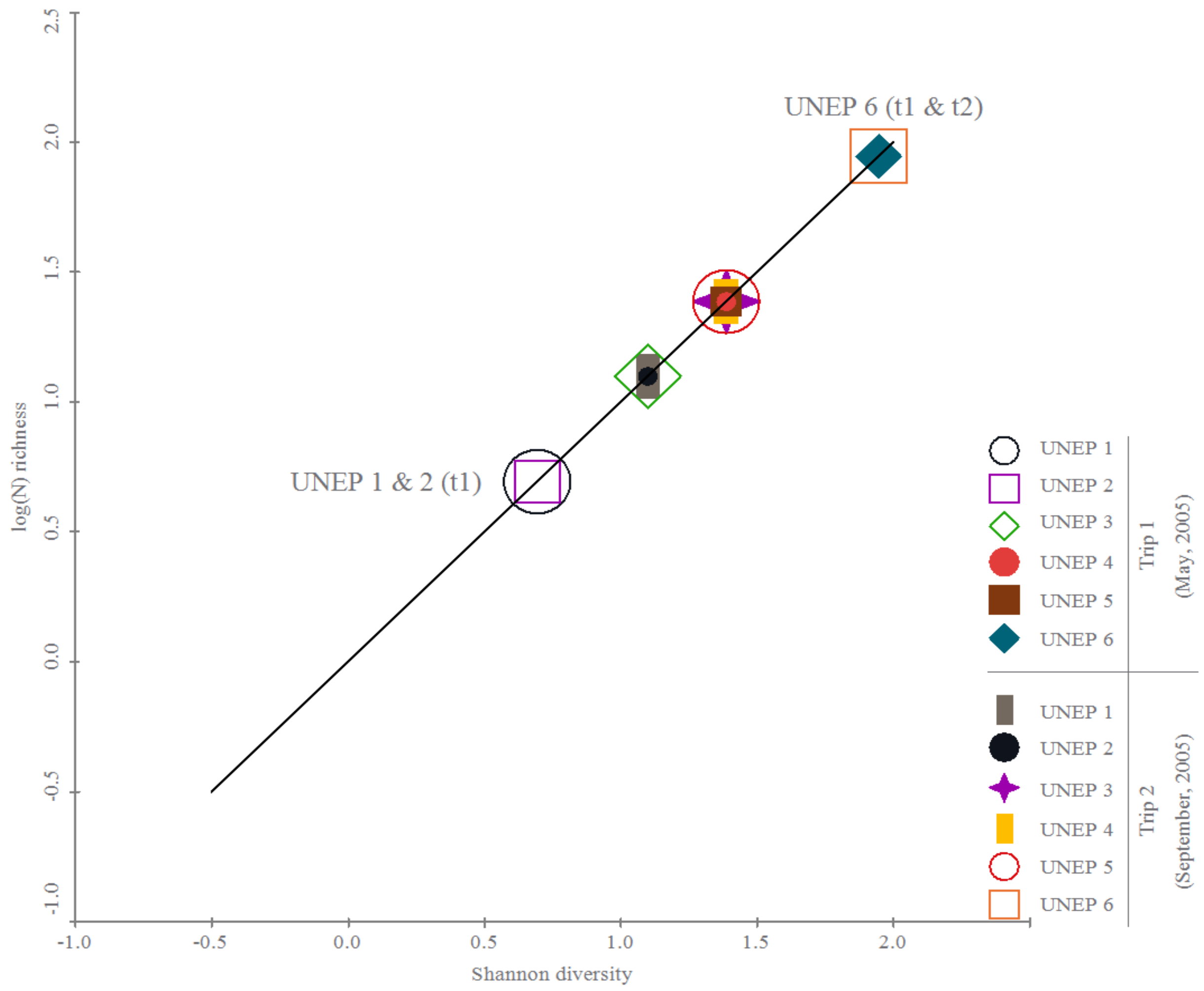


Figure 178: Fish diversity & richness, southern Iraq (May - September 2005); obtained from the detrended correspondence analysis (DCA) method.

From the above diagram, it can be inferred that UNEP 1 and UNEP 2 during the first trip had the lowest diversity and richness values and increased in the second trip. On the other hand, UNEP 6 had the highest diversity and richness values during both trip one and trip two. UNEP 3 also witnessed an increase in diversity and richness values in the second trip, while UNEP 4 and UNEP 5 had the same values on both trips.

According to fish diversity it can be concluded that UNEP 6 had the highest and same diversity values on both trips (1.94).

UNEP 4 and UNEP 5 on both trips along with UNEP 3 during trip two had the same diversity values (1.38).

UNEP 3 in trip one, UNEP 2 and UNEP 1 during trip two had the same diversity values (1.09). While UNEP 1 and UNEP 2 in the first trip had same values (0.69) (Table 5). Higest Overall Fish Biodiversity was found in UNEP 6 although has a relative high biodiversity which equals that of UNEP 5. (Figure)

As for the fish community, richness values were similar to the diversity values on both trips for all stations.

2. *FISH COMMUNITY ORDINATION AND ENVIRONMENTAL VARIABLES:*

Due to the minimal information provided by the third and forth axes regarding variation in community structure (Eigenvalues = 0.0 and 0.0 respectively); (Table 23), these axes are not considered further. Moreover, the variables that exhibit associations with the third and fourth axes imply less ecological significance than variables that exhibit associations with the first and second axes (Lepš and Šmilauer, 2003). Therefore, our discussion will focus mainly on the variables associated with the first and second axes of the CCA. (Figure 161 through Figure 166)

The results obtained from the CCA showed that Fish-environment correlations are related to the first and second axes of the CCA (r=0.84 and 0.98 respectively). The four canonical axes derived from the CCA accounted for 99.9% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 99.4% (Table 23).

Table 7: Eigenvalues and Fish-environment correlations for the four axes derived from the canonical correspondence analysis (CCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.41	0.03	0	0
Fish-environment correlations	0.84	0.98	0.87	0.65
Cumulative percentage variance				
of Fish data	66.6	70.9	71.1	71.2
of Fish-environment relation	93.4	99.4	99.7	99.9

The results showed that the most important environmental variables to explain the variance in the community structure were: Water Depth, Turbidity, Alkalinity, Total Hardness, Lead, Selenium, Sediment Total Organic Carbon, Sediment Lead, Sediment Zinc, Sediment Total chromium, Sediment Arsenic, Sediment Selenium, Sediment Copper, Sediment Nickel, Sediment Iron, Sediment Manganese, Sediment Calcium, Sediment Magnesium, Sediment Total HCH, and Sediment Total Chlordane, based on there moderate to strong correlations with the first and second axes of the CCA, whereas the other parameters were less correlated with these axes. (Table 24)

Furthermore, weaker correlations with the first and second axes did not reflect significant correlations with the Fish community structure. Therefore, weakly correlated variables are not representing in the diagrams.

Table 8: Inter-set correlations of environmental variables with axes, used to know the most important explanatory environmental variables for the Fish community.

No.	**Environmental Variables**	**Codes used in figures**	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
1	Depth of water (m)	D	-0.919	-0.104	-0.151	0.0718
2	Air temperature (°C)	AT	0.1571	-0.168	-0.553	0.0212
3	Water temperature (°C)	WT	0.0592	0.0111	-0.071	0.4626
4	pH	pH	-0.302	0.3889	-0.005	0.1832
5	Electrical Conductivity (mS/cm)	EC	0.2368	-0.168	0.1139	0.2518
6	Dissolved Oxygen (mg/L)	DO	-0.395	-0.162	0.1525	0.3857
7	Transparency (m)	Tra	-0.03	-0.116	-0.017	0.1747
8	Salinity (ppt)	S	0.4653	-0.162	0.0927	0.2642
9	Total Dissolved Solids (TDS) (mg/L)	TDS	0.3395	-0.143	0.156	0.2815
10	Turbidity (NTU)	Tur	-0.56	-0.623	-0.179	0.0229
11	Total Suspended Solids (TSS) (mg/L)	TSS	-0.174	-0.386	-0.124	0.0427
12	Alkalinity (mg $CaCO_3$/L)	Alk	0.455	-0.521	-0.005	-0.288
13	Total Hardness ($CaCO_3$/L)	T.H	0.4826	-0.177	0.2012	0.2003
14	Sulphates (SO_4) (mg/L)	SO4	0.3276	0.0234	0.1595	0.2457
15	Chlorides (Cl) (mg/L)	Cl	0.1836	-0.201	-0.117	0.1605
16	Total Kjeldahl Nitrogen (TKN) (mg N/L)	TKN	-0.175	-0.14	0.5677	-0.582
17	Nitrate Nitrogen (NO_3-N) (mg N/L)	NO3	-0.412	-0.39	0.105	-0.5
18	Nitrite Nitrogen (NO_2-N) (mg N/L)	NO2	-0.269	-0.324	-0.334	-0.029
19	Phosphates (PO_4-P) (mg P/L)	PO4	-0.052	-0.285	-0.2	0.2011
20	Chlorophyll-a (mg/L)	Ch-a	-0.264	0.0758	0.171	-0.229
21	Oil and grease (n-Hexane Extract) (mg/L)	O.G	0.4656	0.1518	0.1118	0.4448
23	Biochemical Oxygen Demand (BOD5) at°C20 (mg/L)	BOD	-0.281	0.1603	0.4553	-0.188
24	Total Organic Carbon (TOC) (mg/L)	W.TOC	-0.129	0.2212	-0.089	0.2971
25	Total plate count (colony/mL)	T.PCC	-0.395	0.3419	-0.164	-0.396
26	Fecal coliform count (CFU/100mL)	FCC	-0.28	0.281	0.1356	-0.351
27	E.coli (CFU/100mL)	Eco	-0.159	0.1833	0.2741	-0.048

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
28	Cadmium (Cd) (mg/L)	Cd	0.1721	-0.02	0.5243	0.5702
29	Lead (Pb) (mg/L)	Pb	0.3512	0.6455	0.1746	0.2196
30	Zinc (Zn) (mg/L)	Zn	0.2665	-0.277	0.3823	0.4414
31	Total chromium (T-Cr) (mg/L)	T.Cr	0.012	0.0214	0.0619	-0.267
32	Arsenic (As) (mg/L)	As	0.019	-0.161	0.0794	0.218
33	Selenium (Se) (mg/L)	Se	-0.379	0.7057	-0.269	0.2267
34	Mercury (Hg) (mg/L)	Hg	0.0128	0.2963	-0.227	0.3769
37	Iron (Fe) (mg/L)	Fe	0.0445	-0.219	-0.084	0.2966
39	Calcium (Ca) (mg/L)	Ca	0.3049	-0.305	0.2024	0.1896
40	Magnesium (Mg) (mg/L)	Mg	-0.032	0.0671	0.152	0.4447
41	Sediment Total Organic Carbon (TOC) %	S.TOC	0.7535	0.0264	-0.137	-0.282
42	Sediment Cadmium (Cd) (µg/kg)	S.Cd	0.3365	-0.345	0.2801	-0.73
43	Sediment Lead (Pb) (µg/kg)	S.Pb	0.7024	-0.456	0.0528	-0.493
44	Sediment Zinc (Zn) (µg/kg)	S.Zn	0.3736	-0.607	0.335	-0.496
45	Sediment Total chromium (T-Cr) (µg/kg)	S.T.Cr	0.2131	-0.719	-0.158	-0.203
46	Sediment Arsenic (As) (µg/kg)	S.As	0.4108	-0.665	-0.347	-0.301
47	Sediment Selenium (Se) (µg/kg)	S.Se	0.7662	0.2655	-0.163	-0.281
48	Sediment Mercury (Hg) (µg/kg)	S.Hg	0.4324	-0.243	-0.123	0.0182
49	Sediment Copper (Cu) (µg/kg)	S.Cu	0.6332	-0.213	0.4378	0.1596
50	Sediment Nickel (Ni) (µg/kg)	S.Ni	0.4821	-0.605	-0.176	-0.08
51	Sediment Iron (Fe) (µg/kg)	S.Fe	0.378	-0.711	0.0589	-0.35
52	Sediment Manganese (Mn) (µg/kg)	S.Mn	0.498	-0.657	-0.09	-0.248
53	Sediment Calcium (Ca) (µg/kg)	S.Ca	-0.591	0.5943	-0.116	0.1442
54	Sediment Magnesium (Mg) (µg/kg)	S.Mg	0.1441	-0.661	0.1042	-0.164
55	Sediment Total HCH (µg/dry g)	S.T.HCH	-0.208	0.7311	-0.372	0.1851
56	Sediment Total Chlordane (µg/dry g)	S.T.Ch	-0.116	0.7461	0.0825	-0.019
57	Sediment Total DDT (µg/dry g)	S.T.DDT	0.0475	-0.241	0.5325	-0.594
59	Sediment 2-Methylnaphthalene (µg/dry g)	S.2-Mn	0.0718	0.0415	-0.551	-0.25

No.	Environmental Variables	Codes used in figures	Axis 1	Axis 2	Axis 3	Axis 4
60	Sediment 1-Methylnaphthalene (μg/dry g)	S.1-Mn	-0.005	0.0936	-0.545	-0.18
61	Sediment 2,6-Dimethylnaphthalene (μg/dry g)	S.D	0.034	0.1815	-0.514	-0.157
62	Sediment 1,6,7-Trimethylnaphthalene (μg/dry g)	S.T	-0.413	-0.289	-0.219	-0.178
63	Sediment 1-Methylphenanthrene (μg/dry g)	S.1-Mp	0.0933	-0.085	-0.174	-0.186
64	Sediment C29-Hopane (μg/dry g)	S.C29	0.1499	0.108	0.6104	0.6107
65	Sediment 18a-Oleanane (μg/dry g)	S.18a	0.1468	0.1279	0.5663	0.6113
66	Sediment C30-Hopane (μg/dry g)	S.C30	0.0886	0.0393	0.5465	0.6151

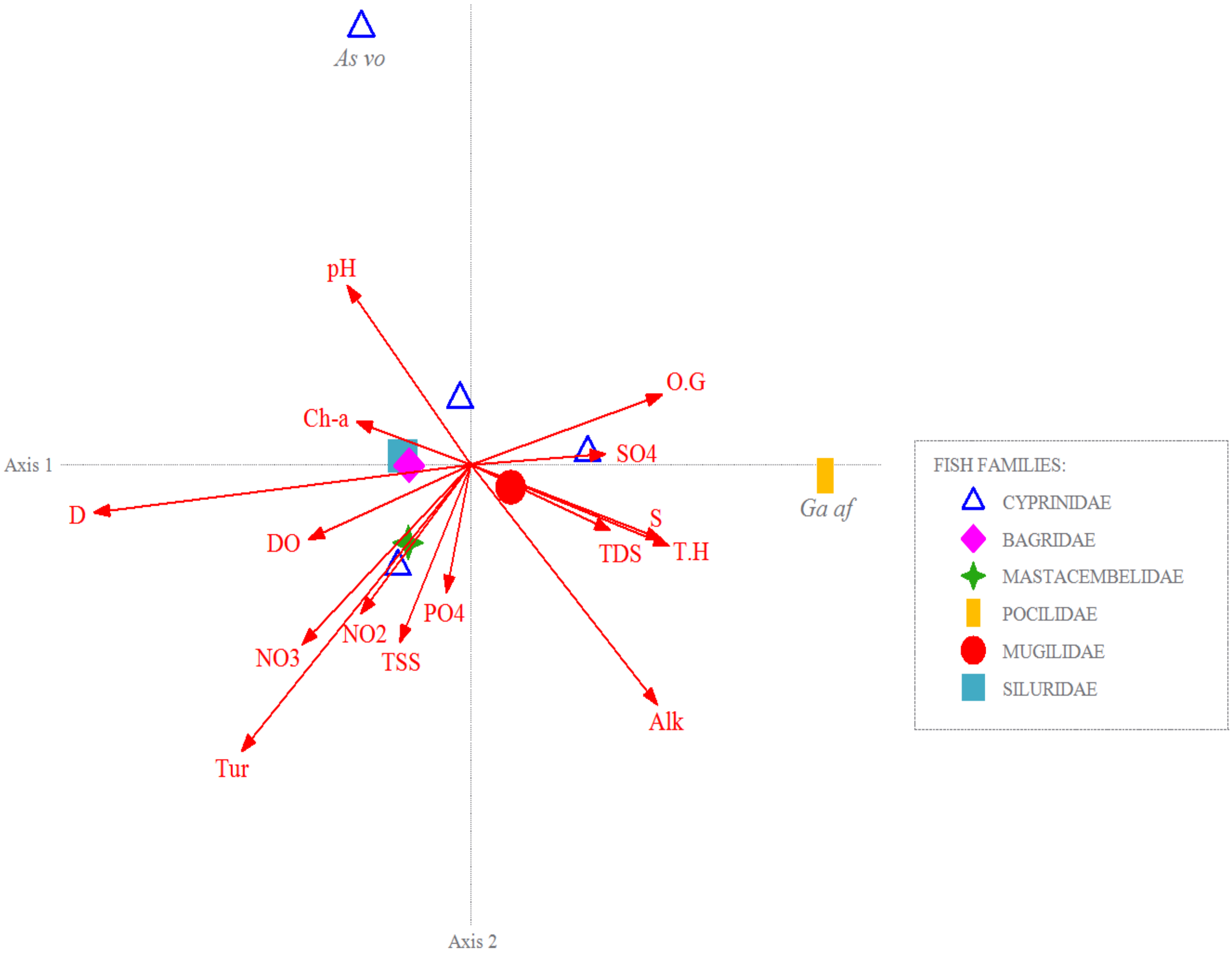


Figure 179: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important physico-chemical environmental variables (May 2005 – September 2005).

The above figure demonstrates the species in relation to the physical and chemical environmental parameters. Most of the fish communities prefer relatively low to moderate water depth, turbidity, total hardness, alkalinity, and the other less correlated physico-chemical variables. However, the response of different species differs with changes in the environmental variables; *Aspius vorax* is present in environmental conditions with relatively high pH and chlorophyll-a concentrations when compared with the other species. Whereas *Gambusia affinis* is present with relatively high alkalinity, total hardness, salinity, total dissolved solids, sulphates, and oil and grease compared to the other species.

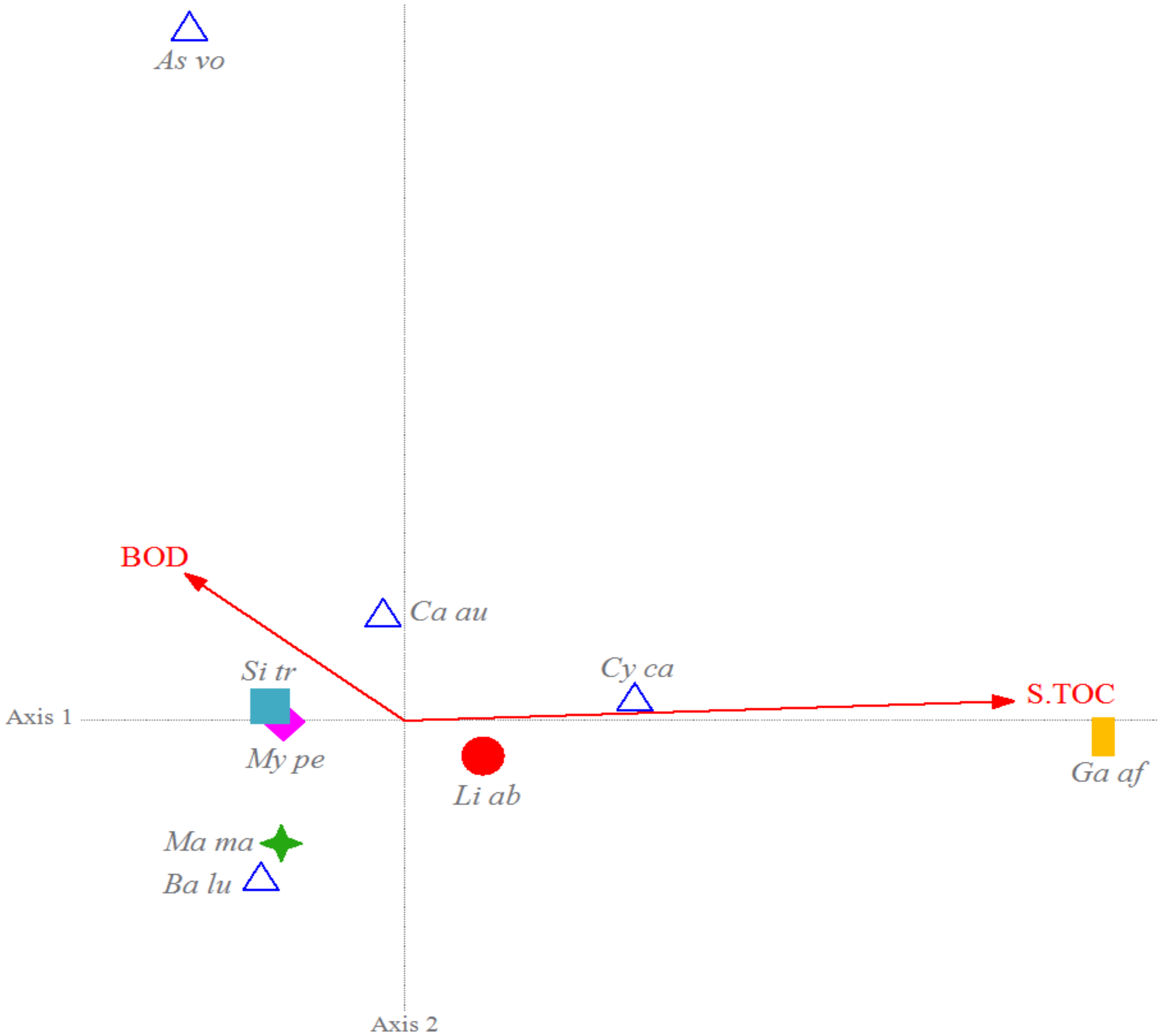


Figure 180: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important bio-chemical and organic environmental variables (May 2005 – September 2005).

The above figure shows the preference of *Aspius vorax* to conditions with relatively high Biochemical Oxygen Demand values, while *Gambusia affinis* prefers relatively high Sediment Total Organic Carbon concentrations compared to the other species. Generally, it can be seen that most of the species prefer relatively low Biochemical Oxygen Demand and Sediment Total Organic Carbon concentrations.

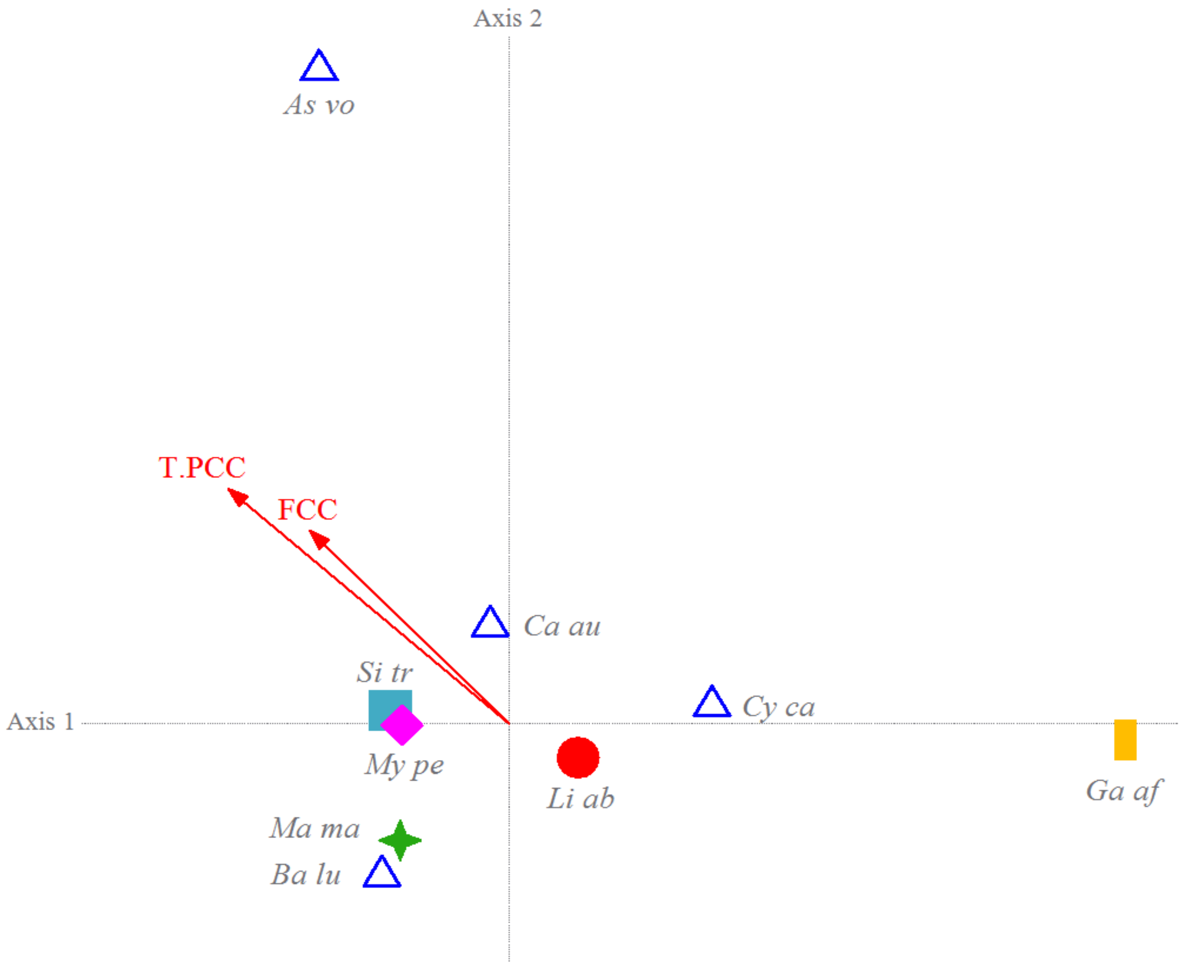


Figure 181: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important Bacteriological and Biological environmental variables (May 2005 – September 2005).

Most of the species in the above figure seem to prefer relatively low Total plate count colony and Fecal coliform counts with the exception of *Aspius vorax* that seems to tolerate conditions with relatively high Total plate count colony and Fecal coliform count values.

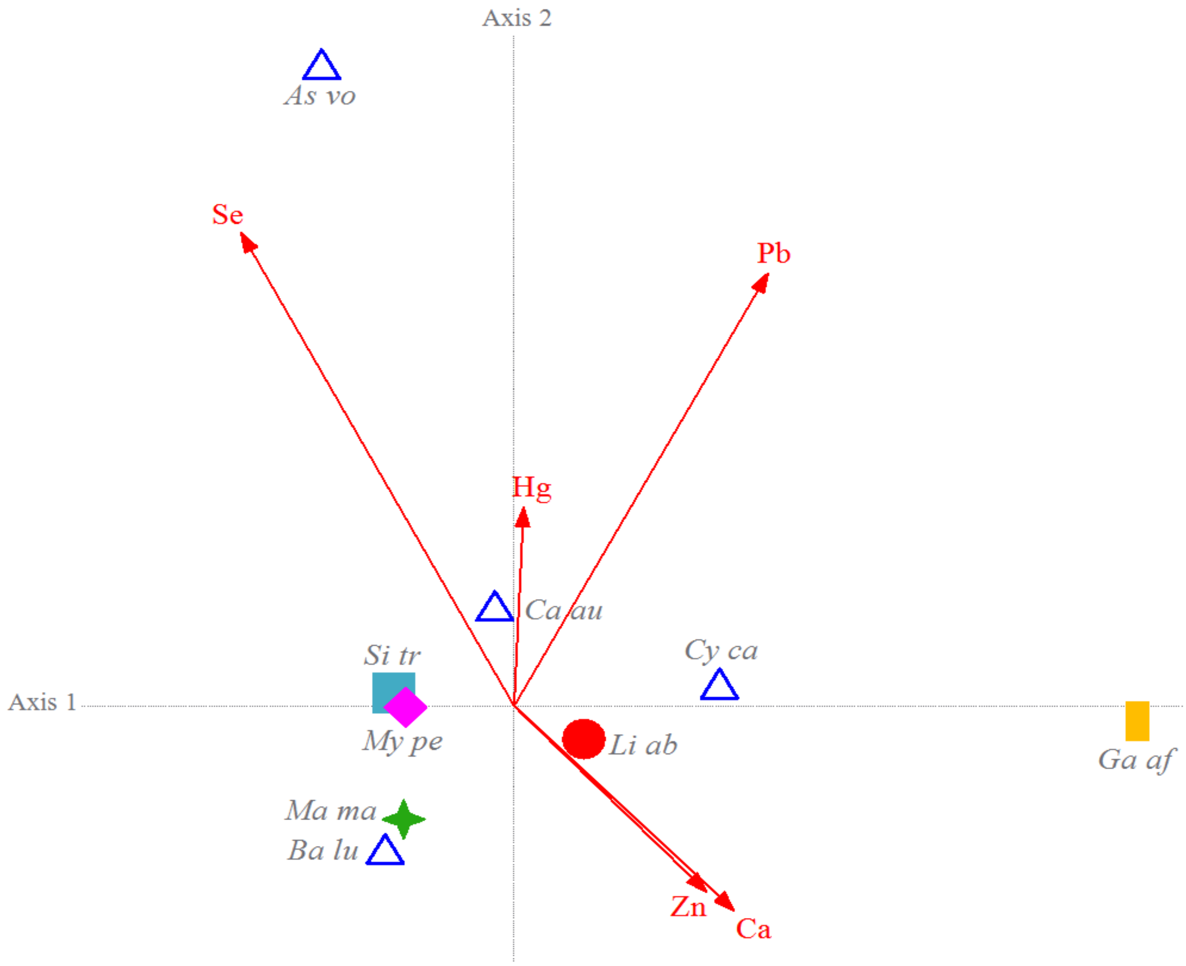


Figure 182: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of the fish communities seem prefer low to moderate heavy metals. However, *Aspius vorax* and *Carassius auratus* can tolerate conditions with relatively high Selenium, Lead, and Mercury concentrations, and *Gambusia affinis* can tolerate conditions with relatively high Zinc, Calcium, and Lead concentrations.

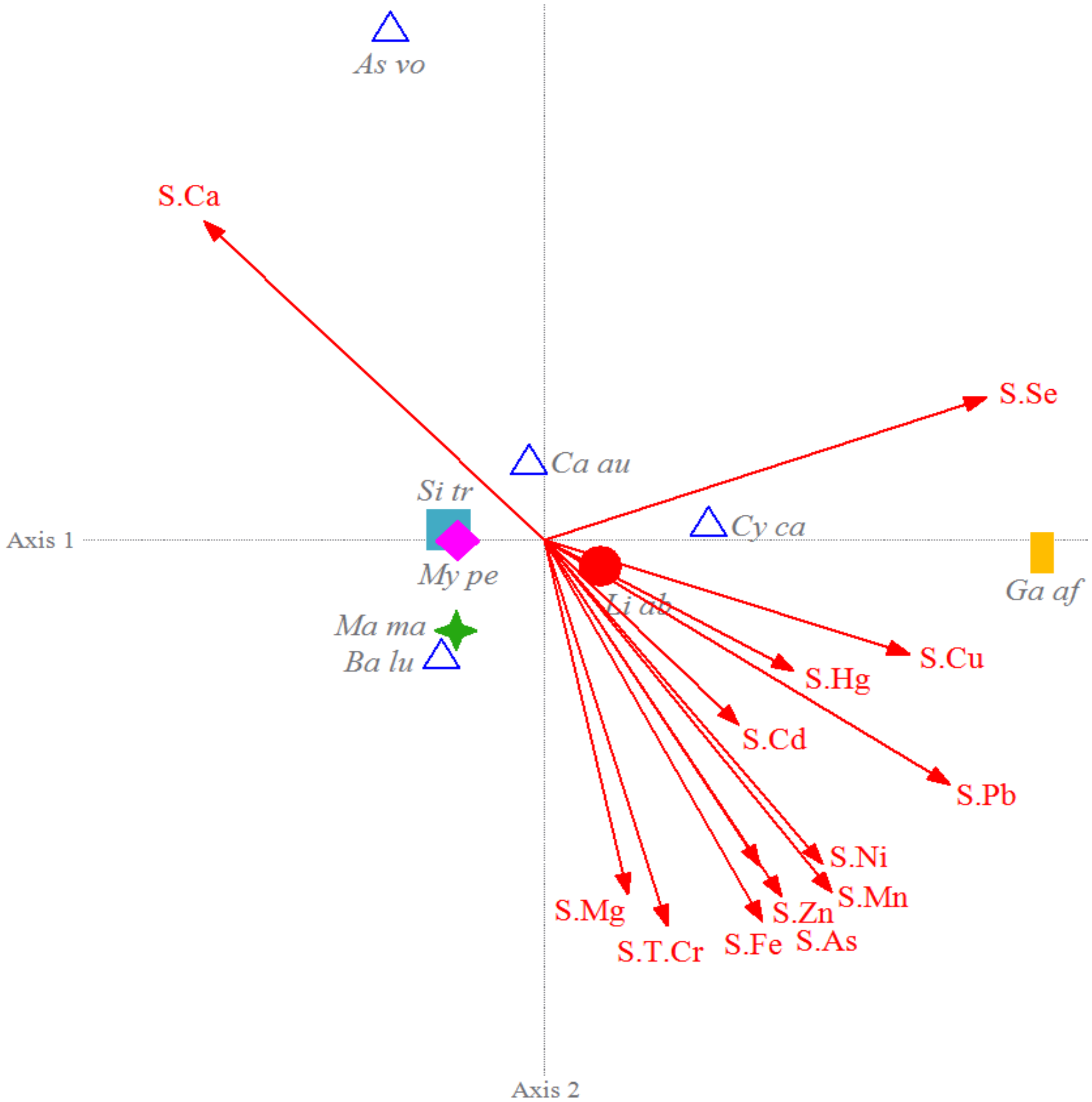


Figure 183: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important sediment heavy metals, toxics and other environmental variables (May 2005 – September 2005).

Most of the fish communities seem prefer low to moderate sediment heavy metals. However, *Aspius vorax* tolerates conditions with rather high Sediment Calcium. In addition, *Gambusia affinis* can tolerate conditions were the sediment heavy metals are rather high with the exception of Sediment Calcium.

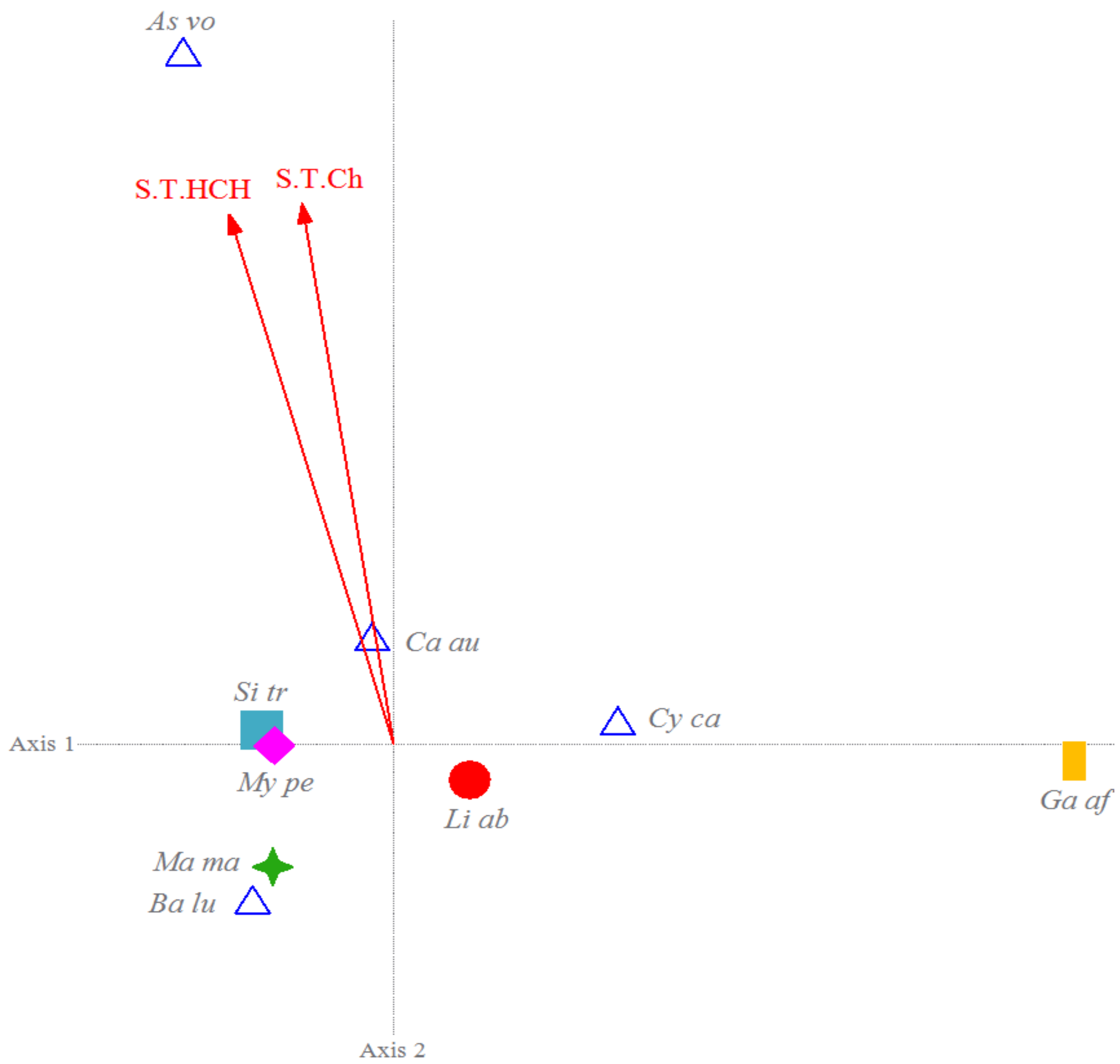


Figure 184: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important sediment pesticides & PCBs (May 2005 – September 2005).

The above figure shows that *Aspius vorax* is present with relatively high Sediment Total Chlordane and Sediment Total HCH, while the remaining species are present with relatively low Sediment Total Chlordane and Sediment Total HCH concentrations.

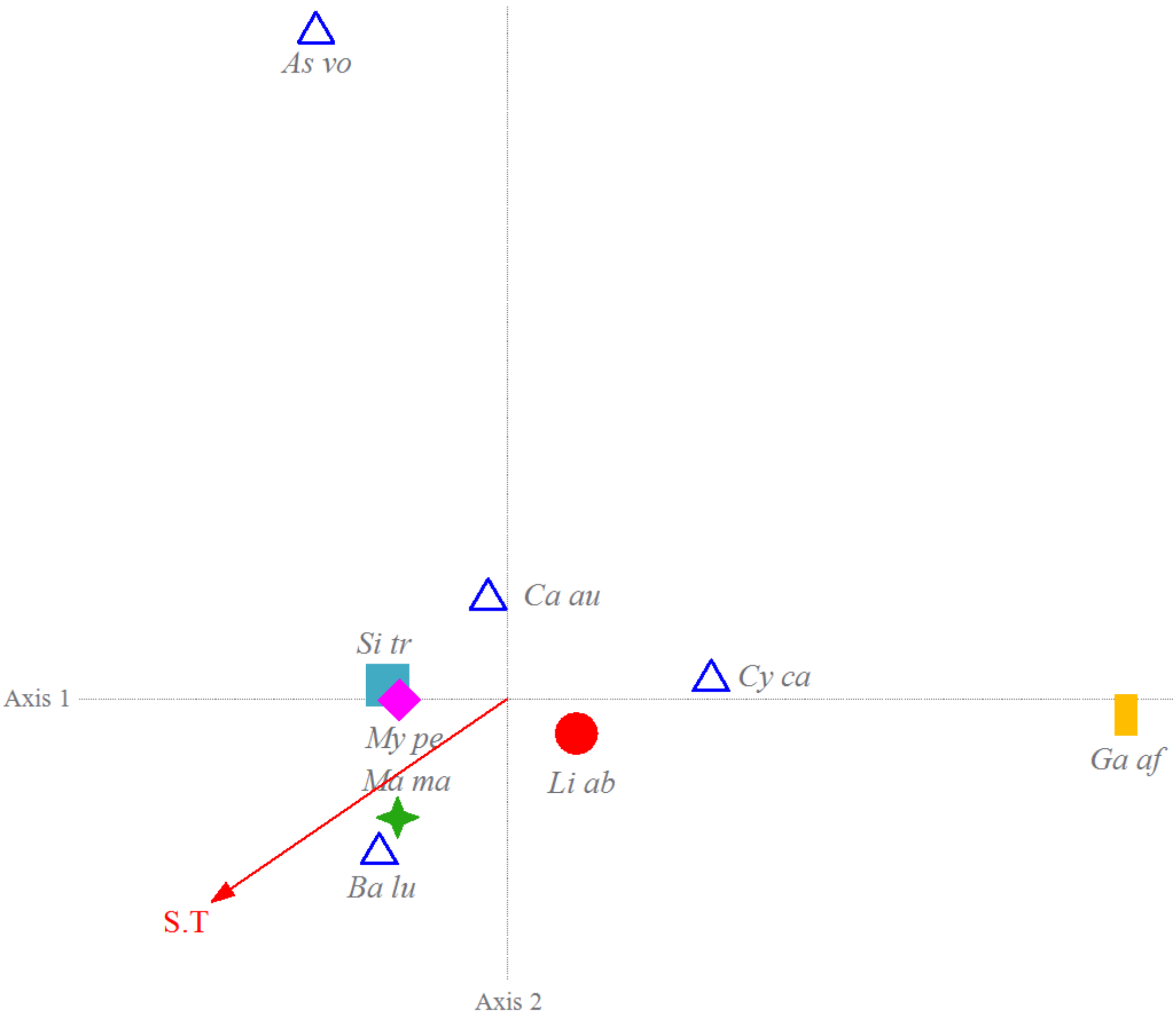


Figure 185: Ordination of Fish communities in southern Iraq, in relation to preferred values of the important sediment Polynuclear Aromatic Hydrocarbons (PAHs); (May - September 2005).

It can be noticed from the figure above that the two species *Barbus luteus* and *Mastacembelus mastacembelus* tolerate relatively moderate to high 1,6,7-Trimethylnaphthalene when compared to the other species.

3. FISH COMMUNITY ORDINATION AND HABITATS:

The results obtained from CCA showed that eigenvalues for the first and second axes were 0.57 and 0.3 respectively. In addition, Fish-Habitats correlations was strongly related to the first and second axes of the CCA (r = 0.99 and 0.97 respectively). The four canonical axes derived from the CCA accounted for 94.5% of the cumulative percentage variance of species-environment relation, with the first two axes accounting for 68.4 %. (Table 25)

Table 9: Eigenvalues and Fish-habitats correlations for the four axes of the Fish community derived from the canonical correspondence analysis (CCA) method.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.57	0.3	0.24	0.09
Fish-habitats correlations	0.99	0.97	0.94	0.85
Cumulative percentage variance				
of Fish data	37.1	56.5	71.9	78
of Fish-Habitat relation	44.9	68.4	87	94.5

The diagram obtained from the CCA (Figure 167) shows the dissimilarity of distribution of relative abundance of Fish' species across the samples, measured by their Chi-square distance. Points in proximity correspond to species often occurring together. Each arrow points in the expected direction of the steepest increase of values of the habitat. Each arrow shows the marginal effect of the particular habitat upon the sample scores in the ordination diagram.

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. Therefore, one can infer that UNEP 2 is the deficient station, while the other stations are characterized by the occurrence of various species.

In addition, Figure 168 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.

Species symbols are replaced by pie symbols. 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 occurances or its quantity) of the current species in the particular class of habitats (Ter Braak and Šmilauer, 2002).

Fish species vary in their distribution and abundance in the different stations as shown in the figures below. However, most species are quite distributed in the studied sites, except *Aspius vorax*, which occur in UNEP 3 during the second trip (September 2005), and *Gambusia affinis*, which appear only in UNEP 2 on both trips.

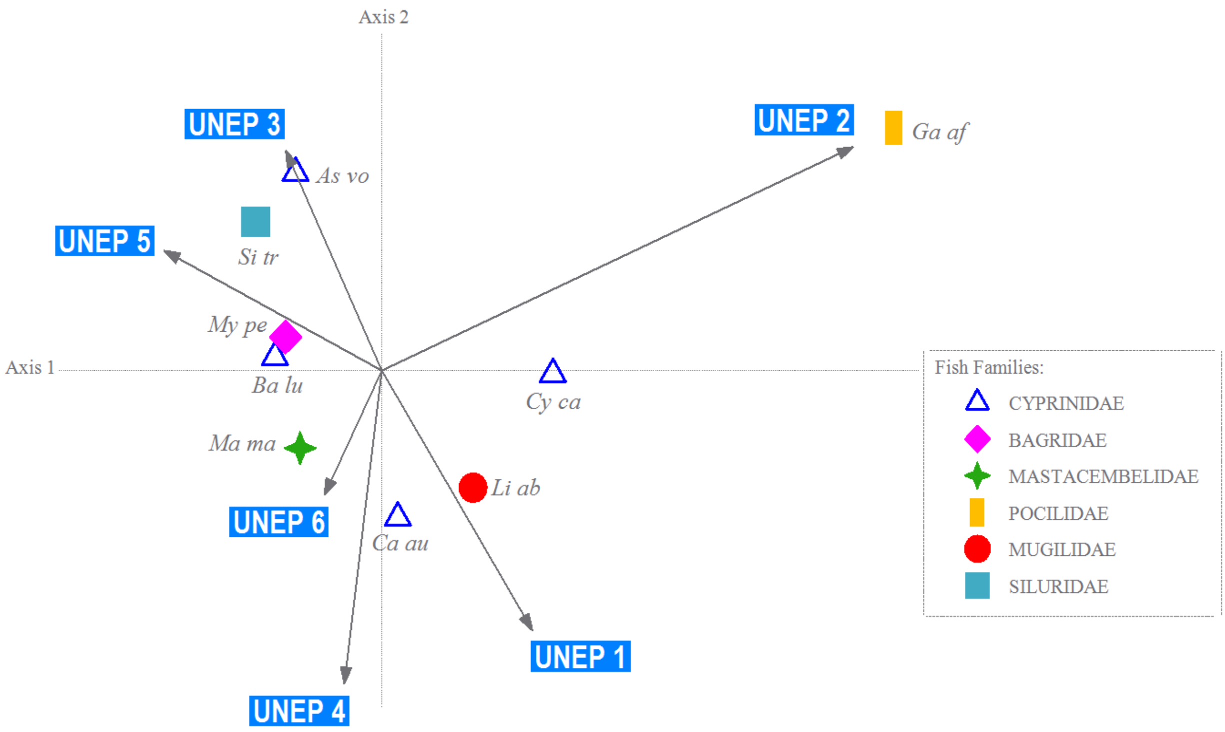


Figure 186: Ordination of Fish communities in relation to preferred habitats, southern Iraq (May – September 2005).

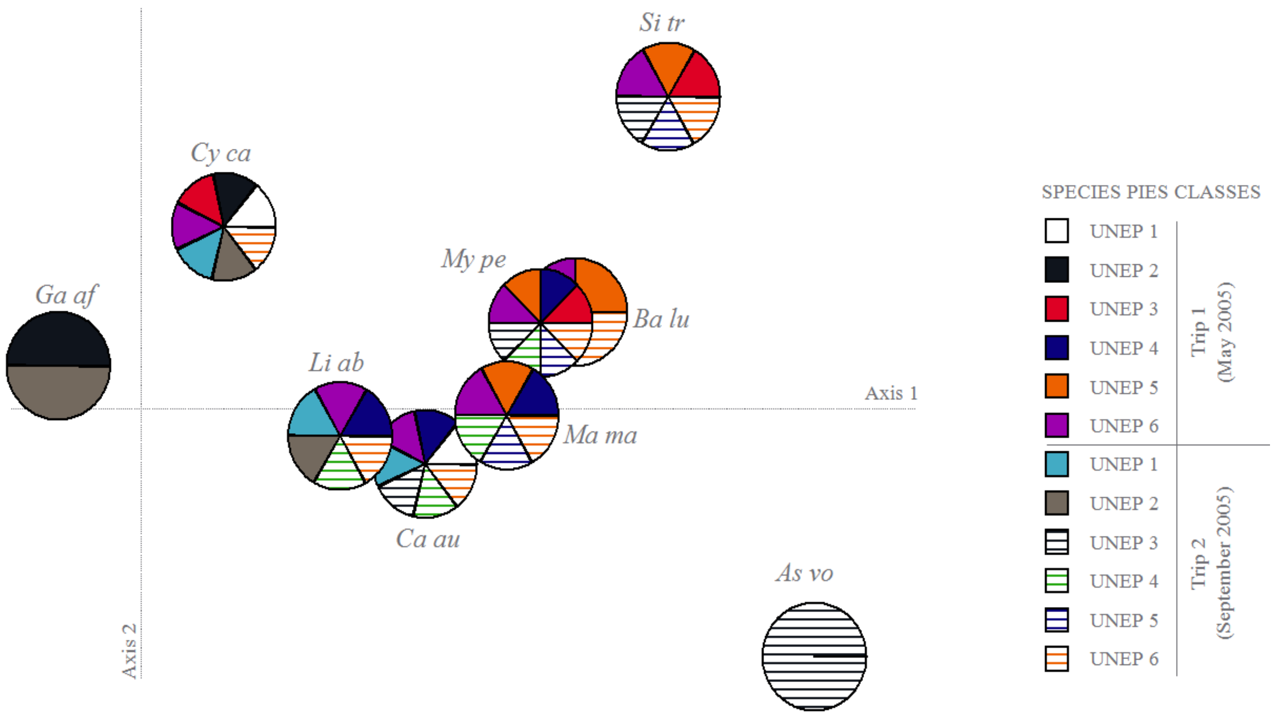


Figure 187: Ordination of Fish pies classes in relation to preferred habitats, southern Iraq (May – September 2005).

G. BIRDS

Annex 2.G presents the types and numbers of bird species observed in the seven sites during our monitoring period. Birds were only present in Al Sewelmat Site (UNEP # 5) and Al Hadam Site (UNEP # 6). This can be explained by the fact that these two sites are within Huweizah Marsh, which receives sustained water inflow from Iran. The main birds recorded for the survey were Black-wing Stilt, Gull, Little Egret, Terns and White-tailed plover.

H. POSSIBLE RELATIONSHIPS BETWEEN THE SAMPLED COMMUNITIES IN THE SITES BASED ON THE SHANNON INDEX

The present comparison (figure 170) has been undertaken based on the Diversity Indexes (H) as provided in the detrended correspondence for each of the communities.

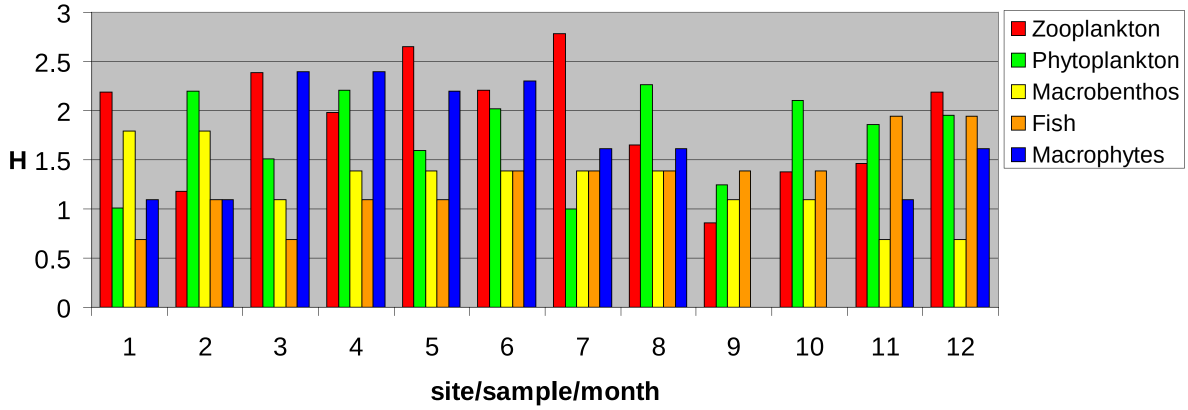


Figure 188: Community Shannon index (H) per site, month and sample, southern Iraq (May – September 2005). 1, 2=Al-Jeweber (sample1, sample2); 3, 4=Al-Karmashia (sample1, sample2); 5, 6= Badir Al-Rumahid (sample1, sample2); 7, 8= Al-Sewelmat (sample1, sample2); 9, 10=Al-Haddam (sample1, sample2); 11, 12= Al-Masahab (sample1, sample2).

From the figure above, it could be inferred that:

1. An inverse relationship between Zooplankton and Phytoplankton indexes exists within and between each sample, location and month. This relationship can be explained due to grazing. Figure 171 shows the consistency of the relationship (with few exceptions).

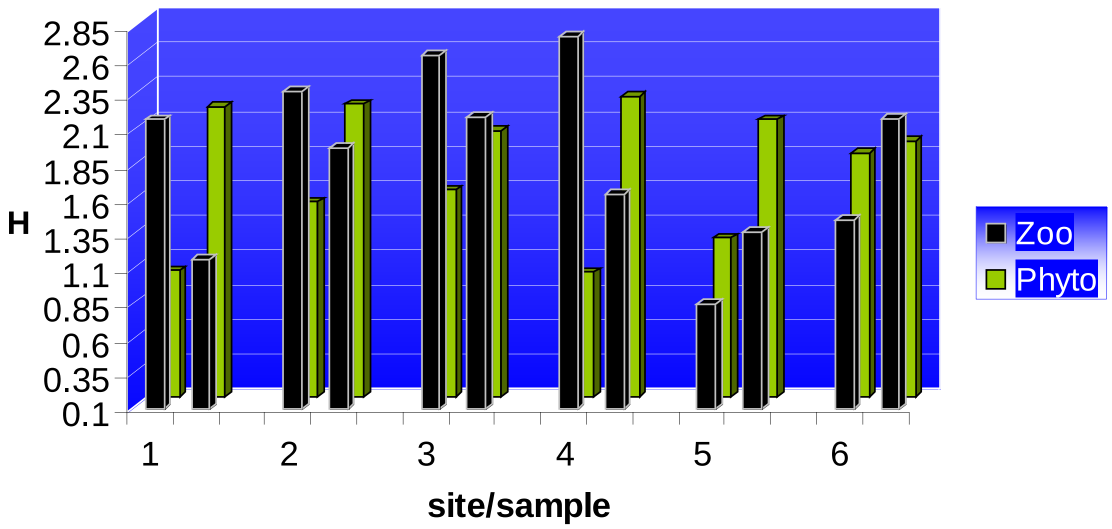


Figure 189: Zooplankton and Phytoplankton Shannon diversity indexes in UNEP sites, southern Iraq (May – September 2005).

2. An inverse relationship between Zooplankton and Fish indexes exists within and between each sample, location and month. This relationship can be explained due to feeding preferences too. Figure 172 shows the consistency of the relationship (with few exceptions).

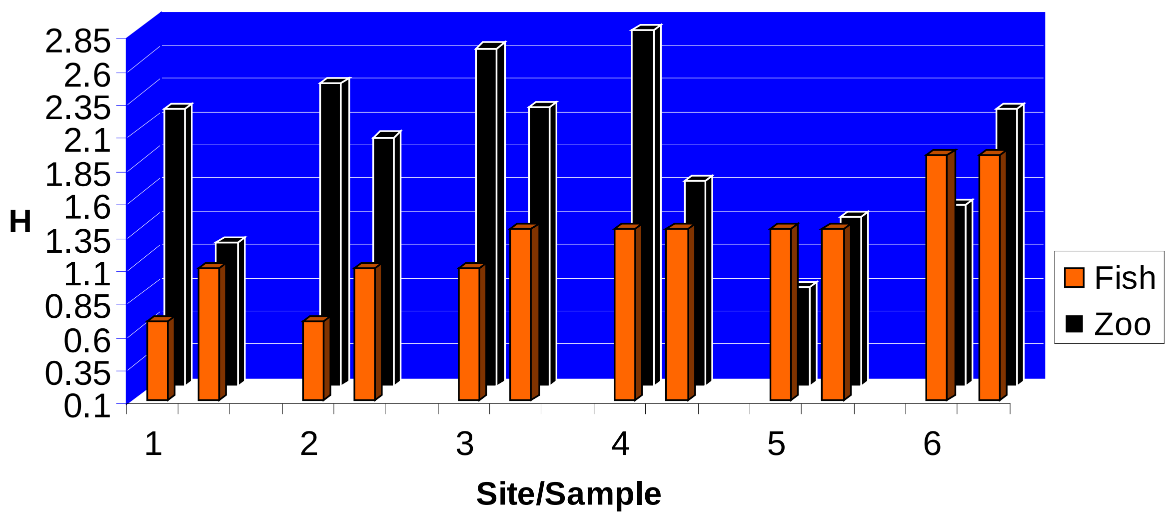


Figure 190: Fish and Zooplankton Shannon diversity indexes in UNEP sites, southern Iraq (May – September 2005).

3. An inverse relationship between Fish and Phytoplankton exists within and between each sample, location and month as seen in (Figure 173). The existing variation could be due to the prevailing type of fish community (zooplanktivorous or grazers).

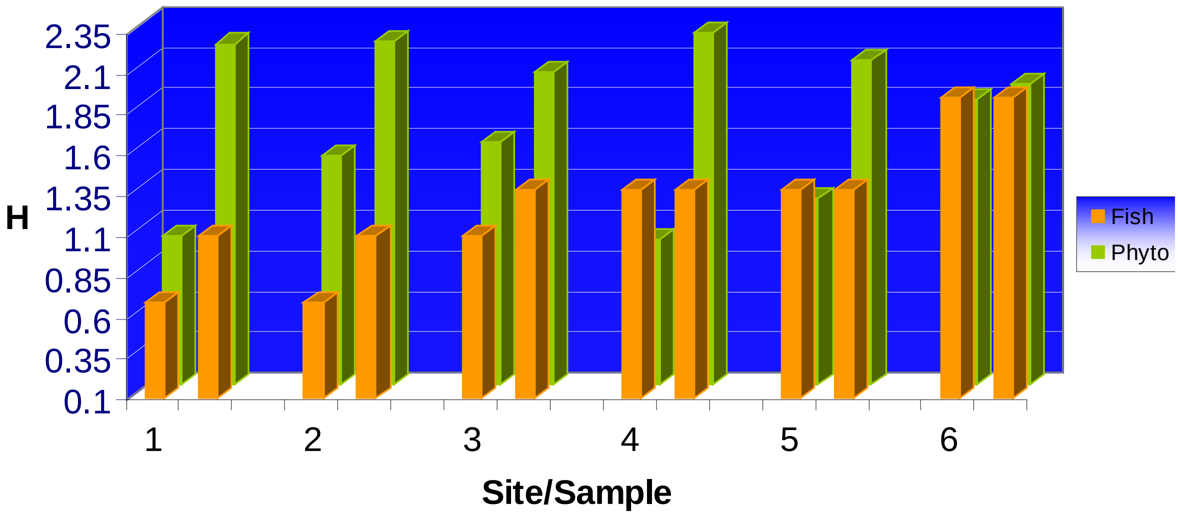


Figure 191: Fish and Phytoplankton Shannon diversity indexes in UNEP sites, southern Iraq (May – September 2005).

CONCLUSIONS

Water quality, sediment quality, biodiversity, and richness can be used to evaluate the quality of UNEP sites respectively; thus

- UNEP 3 (Badir Al Ramaidh Site) ranks in the first position. It has relatively good water quality. In addition, it has relatively high sediment quality and its diversity and richness is characterized by relatively highest phytoplankton and zooplankton, and comes in the second position in macrobenthos and macrophytes diversity and richness, but its fish diversity and richness is relatively low;
- UNEP 2 (Al Karmashia Site) is ranked second with relatively highest macrophytes diversity and richness. In addition, its phytoplankton, and zooplankton diversity and richness come in the second position after UNEP 3 (Badir Al Ramaidh Site). However, its fish and macrobenthos diversity and richness is relatively low and its water and sediment quality comes after UNEP 6 (Al Masahab Site).
- UNEP 4 (Al Sewelmat Site) ranks third; it has relatively high water & sediment quality. Its fish diversity and richness comes in the second position after UNEP 6 (Al Masahab Site) and its phytoplankton, zooplankton, macrophytes, and macrobenthos comes in third position in diversity and richness;
- UNEP 5 (Al Hadam Site) ranks in the fourth position. It has relatively good water and sediment quality and relatively third position in fish diversity and richness. However, the lowest macrophytes and zooplankton diversity and richness were also found in this site;
- UNEP 1 (Al Jeweber Site) comes in the fifth position. Its water and sediment quality comes after UNEP 5 (Al Hadam Site), but it does have the highest macrobenthos diversity and richness;
- UNEP 6 (Al Masahab Site) ranks in the last position. Its water quality comes after UNEP 2 (Al Karmashia Site), but its sediment quality is better than UNEP 2. Although, it has the highest fish diversity and richness, the lowest macrobenthos and phytoplankton diversity and richness are found in this site. In addition, it has relatively low zooplankton diversity and richness.

Generally speaking, from the present data it is evident that the water quality of the six sites lies within the permissible range of values reported for fresh water by the WHO.

Biological communities as well as the ecological parameters of the Iraqi marshes are exercising active restoration processes leading to stabilization.

The trace pollutants including hydrocarbons, PAH, pesticides and trace metals are within acceptable limits for drinking water. These pollutants have very limited effects on the studied communities such as macrophytes, phytoplankton, zooplankton, benthos and fish.

RECOMMENDATION

Nature Iraq/Iraq Foundation Team strongly recommends that the monitoring program should continue for a further 12 months to understand various restoration processes and should include addition sites within the Iraqi Marshes as well as tributary rivers.

REFERENCES

Al Daham, N.K. (1977). Fishes of Iraq and the Arabian Gulf. Al Irshad Press, Baghdad.

Al Lami A.A., Jaweir H.J. and Nashaat, M.R., (1998). Benthic invertebrates community of the River Euphrates upstream and downstream sectors of Al Qadisia Dam, Iraq. Reg. Riv. 14,383-390.

Al Lami A.A., Mangalo, H.H., Abdul Kareem, T.K. and Abbas, E.K. (1999). Zooplankton Occurance in Euphrates River, I. Rotifera. Sci. J. I.A.E.C. 1:74-82.

Al Saadi, H.A. and Al Mayah, A.R. (1983). Aquatic Plants of Iraq. Basrah University Press.

Hilli, M.R. (1977). Studies on the plant ecology of the Ahwar region in southern Iraq. PhD. Thesis. Fac. Sci. Univ. Cairo, Egypt.

Lepš, J., Šmilauer, P. (2003). Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press. Cambridge, United Kingdom.

Maulood, B.K., Hinton, G.C.F., Kamees, H.S., Saleh, F.A.K., Shaban, A.A. and Al-Shahawini,S.M.H. (1979). An ecological survey of some aquatic ecosystems in southern Iraq.Trop. Ecol. 2020, 27-40.

Maulood, B.K., Hinton, G.C.F. Witton, B.A.and Al-Saadi H.A. (1981). On the algal ecology of the lowland Iraqi marshes. Hidrobiologia. 80, 269-276.

Pankow, H., al-Saadi, H.A., Hug, M.F. and Hadi, R.A.M. (1979) On the Algal Flora of the Marshes near Qurna (Southern Iraq). Willdenowia 8,493-506.

Ter Braak, C.J.F., Šmilauer, P. (2002). CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY, USA, 500 pp.

World Health Organization (WHO) (2005) Guidelines for Drinking-Water Quality. Third Edition. 52 pages.