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Chironomid taxocenosis in a South Mediterranean wadi, the Kebir-East (Algeria)

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SUMMARY - *Chironomid taxocenosis in a South Mediterranean wadi, the Kebir-East (Algeria)* - A total of 37 chironomid species were recorded during a survey of the catchment of the Kebir-East wadi, northeast Algeria. Chironomids spatial and temporal distributions were investigated based on 23 sampling sites, situated mainly within the El Kala National Park, across 4 seasons. Chironomid assemblages in the Kebir-East were similar to the ones known from other Mediterranean areas and were composed mostly of tolerant species (*Chironomus riparius, Cricotopus (Isocladius) sylvestris*), but some intolerant species (*Paratrissocladius excerptus*, *Parakiefferiella gracillima*, *Thienemanniella partita*) were present in some samples. A coinertia analysis was carried out to match 21 environmental variables at different spatial scales with the 37 chironomid species recorded in 90 samples: A longitudinal gradient was found along the first axis, which accounted for 42 % of the total variance; the samples ordered along the second axis, which accounted for 13 % of the total variance, were separated according to water temperature, water chemistry and site's morphometry. The influence of anthropogenic pressures was evaluated with different benthic quality indices based on species diversity and on species optima (i.e. mean value of environmental variables weighted for species abundance). Results showed that the trophic status index was influenced by water quality and habitat type (krenal, rhithral, potamal), while the biotic indices were more influenced by season. To improve knowledge on the response of intolerant species, we suggest the implementation of a regular, more intensive sampling program.

RIASSUNTO - *Comunità di Chironomidi nel bacino del Kebir-East, Algeria settentrionale* - Durante un'indagine condotta nel bacino del Kebir-East, nord Algeria, sono state raccolte 37 specie di Chironomidi. La distribuzione spazio-temporale dei Chironomidi è stata analizzata in 23 siti di campionamento, molti dei quali situati nel Parco nazionale El Kala, in 4 stagioni. La tassocenosi a Chironomidi nel Kebir-Est è risultata simile ad altre osservate in area Mediterranea, ed era costituita soprattutto da specie tolleranti (*Chironomus riparius, Cricotopus (Isocladius) sylvestris*), ma sono state rinvenute anche specie intolleranti (*Paratrissocladius excerptus*, *Parakiefferiella gracillima*, *Thienemanniella partita*). Un'analisi della coinerzia è stata condotta al fine di mettere in relazione 21 variabili ambientali misurate a differenti scale spaziali con le 37 specie di Chironomidi raccolte nei 90 campioni: il primo asse, che spiegava il 42 % della varianza totale, ha evidenziato un gradiente monte-valle, mentre il secondo asse, che spiegava il 13 % della varianza totale, ~~ha messo~~ è risultato in relazione con la temperatura dell'acqua, la sua composizione chimica e la morfometria. L'influenza della pressione antropica è stata valutata con diversi indici di qualità dell'acqua, basati sulla diversità di specie e sul loro optimum, calcolato come media della variabile ambientale ponderata sull'abbondanza della specie. I dati analizzati hanno evidenziato che l'indice di stato trofico dipendeva dalla qualità dell'acqua e dal tipo di habitat (krenal, rhithral, potamal), mentre gli indici biotici erano più influenzati dalla stagione di raccolta. È apparsa la necessità in futuro di un più intenso campionamento con una maggiore frequenza temporale, al fine di meglio descrivere la risposta delle specie intolleranti.

Key words: Chironomidae, streams, biotic index, spatial and temporal variations, Mediterranean area, Kebir-East wadi, Algeria
Parole chiave: Chironomidae, torrenti, indici biotici, variazioni spazio-temporali, Area Mediterranea, Kebir-East wadi, Algeria

1. INTRODUCTION

In Mediterranean climate areas biological communities and their ecological traits are constrained by a great seasonal variability of temperature and rainfall (Bonada *et al*. 2007a). Hydrological conditions are strongly influenced by seasonality and many rivers and streams (known as wadi in North Africa) have intermittent flows, with a strong shift between lotic and lentic conditions through the year (Pinto 1994; Morais *et al*. 2004). Lotic conditions become lentic when water is reduced to residual pools and several environmental parameters, along with major energy sources and biological communities, show strong dynamics. In the summer season, portions of the channel can become partly or totally dry and lotic macroinvertebrates can survive by aestivating in cool, moist microhabitats (Samraoui 2009), while lentic species prevail; during high flow periods rheophilic species complete their life cycle and are dominant.

Therefore in some areas seasonal factors related to the hydrological cycle are the major variables influencing community structure and function (Coimbra *et al.* 1996), but elsewhere macroinvertebrate assemblages seem to be more influenced by longitudinal gradients (Cortes 1992).

Hydrological instability due to a substantial different volume of precipitations in different years determines highly unpredictable conditions. In years with very low precipitations rivers may become dry for a large part of the year (Marziali *et al.* 2009a). Pools increase is parallel to a reduction of riffles, with thinner substrates prevailing over larger size substrates, river stretches may become disconnected (Bonada *et al.* 2007b, 2008) and the river becomes a succession of temporary ponds, or totally dry.

These conditions may be still more accentuated in African countries lining the Mediterranean shores. Up to now, North African streams or wadi have been scantily studied, particularly their ecological aspects (e.g. Lounaci *et al.* 2000a). Nevertheless, some studies on benthic communities were carried out recently (e.g. Lounaci *et al.* 2000b; Arab *et al.* 2004; Belaidi *et al.* 2004), showing some peculiar characters of Northern African lotic ecosystems: wadi are strongly influenced by marked Mediterranean climate (i.e. extreme temperature values during summer and short extreme flooding events in winter followed by long periods of drought), and few species are present in comparison to continental European Mediterranean regions (Giudicelli *et al.* 1985; Lounaci *et al.* 2000a).

Among benthic macroinvertebrates, chironomids often constitute one of the most abundant and species-rich group in those intermittent streams (Arab *et al.* 2004). Extensive taxonomical studies concerning chironomids were carried out in the Mediterranean region, where more than 700 species were reported; in North Africa, taxocenosis were similar to other Mediterranean areas, except for the presence of some Afro-tropical species (Laville & Reiss 1992) and for a lower species richness. Contributions, however, focused on the response of chironomid species to environmental factors in the Mediterranean area suggest the need for further studies (Marziali *et al.* 2009b; Akbulut *et al.* 2009).

Chironomids are good indicators of the ecosystem integrity in both lentic and lotic habitats, they are common in almost all water body types and respond to variation of many environmental variables, such as dissolved oxygen, water temperature, substrate and salinity (Thienemann 1954). In Mediterranean rivers, they were shown to be highly resistant to hydrological variability and to be among the first colonizers after the drought (Langton & Casas 1999; Marziali *et al.* 2009a). Species level chironomid data have been shown to provide the same information given by the whole macrobenthic communities on ecosystem (Marziali *et al.* 2009b). Thus, they can act as indicators of aquatic ecosystem ecological integrity and it would be interesting to test their value as bioindicators in Southern Mediterranean regions.

Water abstraction for drinkable supply and irrigation make the natural condition of Mediterranean streams even more unfavorable for the benthic fauna, because the anthropogenic stressors may work in the same direction as natural factors, being even more limiting for benthic communities. Rivers are naturally subjected to high evaporation rate inducing low current velocities and low habitat heterogeneity, along with increased salinity and nutrient concentration (Lounaci *et al.* 2000a). Consequently, a reduced diversity is expected. In densely populated areas, pollution is enhanced by reduced flow rate and only few tolerant species can survive. In those conditions, the assessment of the ecological status of river ecosystems may be hampered by natural factors, which may hinder the effects of anthropogenic impacts. Therefore a deeper knowledge of these ecosystems is needed for an ecological and management perspective.

The aims of the present study are to analyze: a) the chironomid taxocenosis of a South Mediterranean river system, the Kebir-East, b) the response of species to natural environmental factors, c) the seasonal variation of the chironomid assemblages, c) the response of species to natural environmental factors, and d) to anthropogenic stress.

2. MATERIALS AND METHODS

2.1. Study area and sampling sites

A total of 90 chironomid samples were collected at 23 sites distributed along the main course of the Kebir-East wadi and its 10 principal tributaries (Table 1) in the extreme northeast Algeria (Fig. 1). Sampling sites were selected on the basis of land use information with the aim of sampling across a broad gradient of altitude (from 8 to 650 m a.s.l.) and contamination levels (near farmlands and, from near-pristine to heavily urbanized areas). In order to account for the inter-seasonal variability in chironomid communities, sampling was carried out during winter (January-February), spring (April-May), summer (July-September) and autumn (October-November) 2007, provided that water was present: station 19 was dry during both summer and autumn.

Alpine Algeria consists of a number of structural-sedimentary units. It is during the Quaternary (former and average *Pleistocene*), that the digging of eastern Algeria valleys was born with the implementation of the river system, then at the end of the *Miocene*, the beginning of the set of faults. In the East of Bouteldja and in the South of El Tarf's plain arose blue marls *Pliocene* (Marre 1987), which explains the existence of this zone at the time of the transgressive *Pliocene*. The progress of the Mediterranean Sea up to the valley of the Kebir-Est wadi formed what we call a strait. The progressive withdrawal of the sea during the recent *Quaternary* and the formation of a littoral of massive dunes favored the creation of marine lagoons. These last ones were transformed into swampy zones and lakes where argilo-muddy sediments settled during the dry period. The climate of the Kebir-East basin, Northeast Algeria, is typically Mediterranean with a dry, hot summer and with rainfall concentrated in the winter months. The sampled sites (Fig.1) have a wide range of conductivity (100 - 2000 μScm^{-1}), river bed width (1.5-55 m), current velocity (0.25 - 80 cms^{-1}) and hydroperiod (temporal and permanent effluents) (Zouini 1997).

Most sites are distributed within the El Kala National Park, created in 1983 and classified in the list of the National Heritage and a Biosphere Reserve by UNESCO in 1990: the Bougous and R'Mel Souk protected areas and at the outlets of Lake Oubeïra (classified as a Ramsar site in 1990).

Tab. 1 - Principal tributaries of the Kebir-East wadi. Habitat: K= krenal, R= rhithral, Ep= epipotamal, P= potamal, L= limnetic, M= ephemeral, Impact: R= natural, pristine, A= agriculture, P= polluted.
Tab. 1 - Principali tributari del wadi Kebir-East. Habitat: K= krenal, R= rhithral, Ep= epipotamal, P= potamal, L= lacustre, M= temporaneo, Impact: R= naturale, originario, A= agricoltura, P= inquinato.

Tributaries	Length (km)	Station number	Coordinates X	Coordinates Y	Altitude	Mean Width	Habitat	Impact	Hydroperiod
Kebir main course	96	3	8°30'10"	36°46'55"	80	40	Ep	A	Permanent
		8	8°21'57"	36°45'59"	30	18	R	P	
		14	8°18'51"	36°46'49"	23	11	P	P	
		16	8°16'43"	36°46'36"	25	12	R	P	
		20	8°12'48"	36°47'48"	14	16.5	P	A P	
		21	8°09'35"	36°48'51"	11	13	P	P	
		23	8°09'07"	36°48'59"	10	55	P	P	
Leben	3	1	8°30'32"	36°46'56"	77	3	K	A	Permanent
Mellili	6	2	8°30'28"	36°46'50"	80	20	K	R	Permanent
Louar	9	4	8°22'58"	36°36'52"	652	2	K	R	Permanent
		5	8°21'56"	36°39'01"	200	11	R	A	
Bougous	44	6	8°21'53"	36°39'06"	203	12	R	A	Permanent
		7	8°24'27"	36°42'36"	69	20	R	A	
Oubeïra lake tributaries	-	9	8°23'10"	36°51'47"	24	3	L	A	Permanent
		10	8°25'15"	36°51'29"	24	5	L	A P	
		11	8°24'12"	36°49'29"	22	26	L	A	
Messida	20	12	8°24'09"	36°49'23"	22	25	P	A	Permanent
		13	8°22'30"	36°47'37"	25	14	P	P	
Dardan	6	19	8°13'16"	36°46'39"	15	3	M	A	Ephemeral
Zitoun	21	18	8°13'02"	36°39'06"	193	5	K	P	Permanent
Boulathan	20	22	8°06'06"	36°49'42"	8	11	Ep	P	Permanent
Guergour	5	15	8°16'52"	36°46'32"	25	1.5	P	P	Ephemeral
Bourdim	12	17	8°14'50"	36°47'22"	20	13	R	A	Permanent

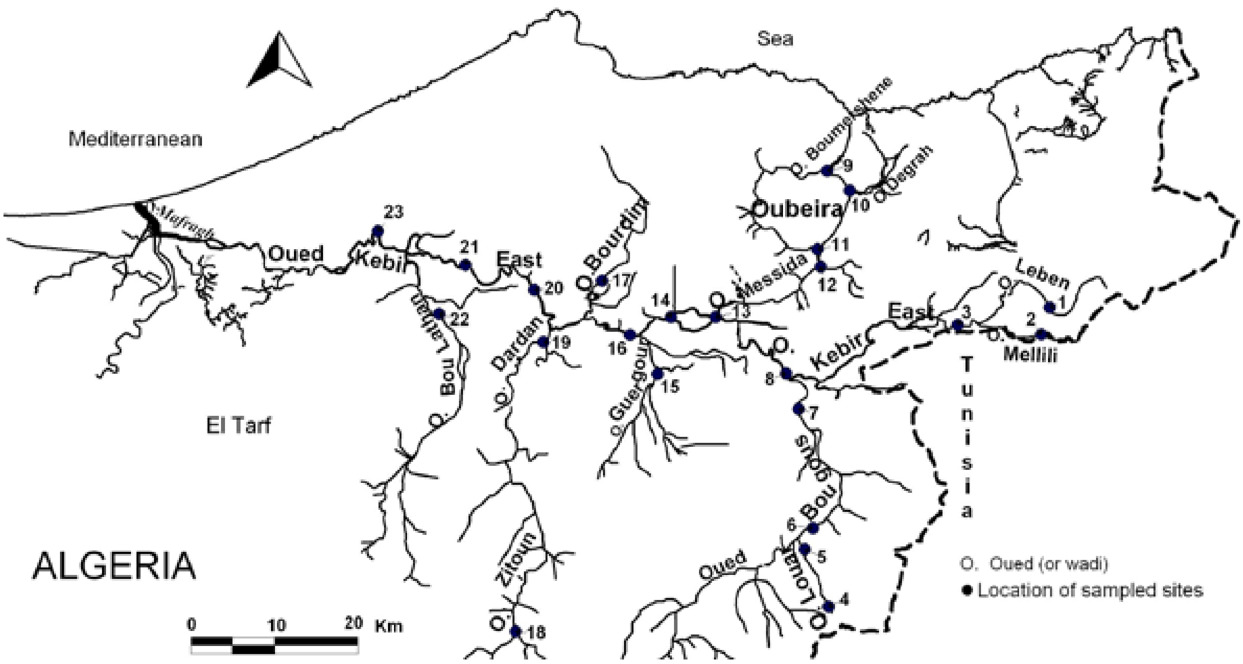

Fig. 1 - Sampling sites location on the Kebir-East Creek and principal effluents (extreme Northeast Algeria).
Fig. 1 - Mappa dei siti campionati nel fiume Kebir-Est e nei principali affluenti (estremo Nord Algeria).

The Bougous (stations 4, 5, 6, 7) and Aïn Kerma (station 18) catchments are mostly covered by zeen oak (*Quercus faginea*), cork oak (*Quercus suber*) and kermes oak (*Quercus coccifera*) forests. The Northern part of the R'Mel Souk (stations 1-2), a protected area, is covered by cork oak forests. The catchment area of the lake Oubeïra functions in an endoreic way, and is fed by ten tributaries, mainly, the tributaries of Boumerchen (station 9), Degrah (station 10) and Messida (stations 11, 12, 13). In winter, at the time of strong rainfall, water of the Kebir-East wadi flows to the lake mainly by the Messida wadi which occurs in the South (station 13) (Fig. 1). In summer, when the level of the Kebir-East wadi is at its lowest of the year, the hydrological system functions in the opposite direction, the Messida wadi , thus, flows in two directions (Ramsar 1990; Frazier 1996; Alayat *et al.* 2007).

Nutrient concentration, conductivity and temperature are very variable in the sampled sites. The southeastern part of the Kebir-East catchment is considered slightly impacted, showing low nutrient concentrations, low conductivity and turbidity. The lowlands are characterized by intensive farmlands and heavy urbanization, showing high nutrient concentrations, high conductivity and turbidity (Table 2).

Sampling sites, showing a gradient from slightly impacted to heavily impacted ones, are located in the Bouteldja and the El-Tarf plains (Kherici *et al.* 1996; Derradji *et al.* 2007) ; they have similar morphometric characteristics (stations 8, 12, 13, 14, , 16, 20, 21, 22 and 23). Stations (9, 10 and 11) located at the outlets of Lake Oubeïra are also heavily impacted by farming activity. There is direct sewage discharge from the town of Guergour (El Tarf) to station 15, which is highly impacted. Sites located in the R'Mel Souk (stations 1, 2, 3), Bougous (stations 5, 6, 7) and in Aïn Kerma (station 18) are also impacted by farming, but to a lesser extent, they show intermediate levels of nutrients, conductivity and turbidity. Station 19 presents the main characteristics of Mediterranean seasonal streams which are flooded in winter and spring, and are dry in summer and autumn. Overall, water conductivity is high on the whole Kebir-East basin. It results naturally from hydraulic erosion of the calcareous and marl rocks in the Bougous catchment (station 4) and from marine intrusion through Bouteldja's massive dunes on the side of Bourdim (station 17) in the northern part of Kebir-East wadi and principally from the contact with the strongly mineralized underground water in Bouteldja and El-Tarf plains (Kherici *et al.* 1996; Derradji *et al.* 2005; Derradji *et al.* 2007).

2.2. *Physico-chemical and environmental data*

Water samples were collected with the same frequency and time as chironomid sampling. The following parameters were measured during this study: Nitrates (NO_3), Nitrites (NO_2^-), Ammonium (NH_4^+), Orthophosphates (PO_4^{3-}), pH, conductivity (Cond), Chloride (Cl^-), turbidity (Turb), dissolved oxygen (O_2), percent of oxygen saturation (O_2%), alkalinity (TAC), total hardness (TH) and sulfates (SO_4^{2-}). Granulometry was not measured in the sampled stations.

2.3. *Chironomid data*

All chironomid samples were collected with a Surber net (300 μm mesh size, 50 cm width). Ten hauls were made in the opposite sense of the current along the sampling station, in the middle of the current and near the banks. We also randomly scrutinized by hands 5 submerged stones with a total surface area of 1 m^2, dislodging any hidden larvae. Samples were preserved in 5% formaldehyde (larvae, pupae), then examined under a dissecting microscope. The specimens were grouped by morphotypes according to external characteristics visible through the stereo-microscope in the laboratory. Subsequently permanent mounts were prepared in Faure mounting media, to enable the taxonomic determination of the different morphotypes. The entire sample was always examined for Chironomid counts. The species identifications were based on the presence of some prepupae, where the pupal characters were visible and mature pupae. Italian keys for larvae determination were used (Ferrarese 1983; Ferrarese & Rossaro 1981; Nocentini 1985; Rossaro 1982), along with keys for Palaearctic pupae (Langton & Visser 2003).

2.4. *Data analysis*

Physico-chemical and environmental data and chironomid species abundances were expressed as ind.m^{-2}. Two physico-chemical and environmental variables were expressed as multistate variables: 1- granulometry (granulo) was classified as a value ranging from stones (100) to lime (10), higher values meaning higher percentage of large sized particles, 2- mesohabitat type was codified as: krenal (K) = 1, rhithral (R) = 2, epipotamal (Ep) = 3, potamal (P) = 4, limnetic (L) = 5, ephemeral (M) = 6.

Environmental variables included were: altitude, river width, water temperature, turbidity, current velocity and chemical variables (Table 2).

Coinertia analysis (CoA) was carried out using ADE-4 package in R environment (Dolédec and Chessel 1987, 1989; Thioulouse *et al.* 1997; Dray *et al.* 2003; Chessel *et al.* 2004), The analysis maximized the covariance between the two matrices prepared as sites * environmental variables and sites * chironomid species. The species matrix was log(x+1) transformed before analysis. The two coordinate systems were superposed thus demonstrating the relation between the two tables. Different randomization procedures can be used to test the association between the environmental and the faunal table. Random permutations of the rows of one table are followed 1- by the calculation of a parameter measuring the association between the original and the permuted table, 2- by plot of the frequency distribution of the parameter calculated and 3- by plot of the parameter calculated with the observed data . In PROtest (Jackson 1995) a Monte-Carlo Test is performed on the sum of the singular values of a procrustean rotation of the faunistic and environmental table, in the RV test (Heo & Gabriel 1998) a Monte-Carlo Test is performed on the sum of eigenvalues of a coinertia analysis, in the R-squared test the analysis is performed on the R-squared calculated between the two tables of a co-inertia analysis (Chessel *et al.* 2004). Coinertia analysis allows the mapping of each site in the space of the first two axes calculated from both environmental and faunal matrix. The coinertia factorial map explains the part of variability similar to each separate analysis.

Diversity indices and biotic indices based on species weights were also calculated.

The indices included in the analysis can be separated into 1- diversity index (Shannon diversity index), 2- weighted diversity index, where a sensitivity value for each taxon is included into the Shannon formula (Ozzola *et al.* 1992), 3- biotic indices calculated multiplying species abundances by a sensitivity value estimated as mean of environmental variables weighted for species abundance (Rossaro *et al.* 2007), according to the formula:

$$BQIW_j = \sum_{i=1}^{n}\left(\frac{z_i}{\sum_{i=1}^{n} y_{ij}} * y_{ij}\right) \quad [1]$$

Where $BQIW_j$ is the sensitivity value of the taxon j calculated as weighted mean of the environmental variable z_i, weighted by the abundances of each taxon, and y_{ij} is the abundance of the taxon j in the i of n sites. Different $BQIW_j$ for each taxon were calculated using a large database from lentic and lotic waters (Rossaro 1991b; Rossaro *et al.* 2006a; Rossaro *et al.* 2007); different strategies or different sets of environmental variables were used to calculate different $BQIW_j$: 1- *BQIWTS* measuring eutrophication (total phosphorous, O_2 % saturation, transparency), 2- *BQIWENV* measuring anthropogenic stress (number of inhabitants, NO_2, NH_4, PO_4,), 3- *BQIWEJ* expressing a measure based on expert judgment.

Species tolerance values (*ESW* or $ES_{50,0.05}$) were also calculated as the value of ES_{50} which separates 5% of the frequency distribution curve of each species (Rosenberg *et al.* 2004). The *ESW* were calculated assuming that the most tolerant species are associated to sites with the lowest ES_{50} values, while the most intolerant species are associated to sites with the highest ES_{50}.

The different indices were abbreviated as:

H: Shannon diversity index

Hw: weighted Shannon diversity, calculated with the following formula:

$$H_w = \sum_{j=1}^{p}\left(\frac{y_{ij}}{\sum_{j=1}^{p} y_{ij}} * \log_2 \frac{y_{ij}}{\sum_{j=1}^{p} y_{ij}} * BQIWEJ_j\right) \quad [2]$$

BQITS: weighted mean index using *BQIWTS*, calculated with the following formula:

$$BQITS_i = \sum_{j=1}^{p}\left(\frac{y_{ij}}{\sum_{j=1}^{p} y_{ij}} * BQIWTS_j\right) \quad [3]$$

BQIENV: weighted mean index using *BQIWENV*, calculated as ***BQITS*** using *BQIWENV* instead of *BQIWTS,*

ES: this diversity index was calculated using the *ESW* weights derived from rarefaction method, in agreement with WFD this index includes a measure of total abundance of specimens in a sample. The *ESW* may be known only from *p* of *m* species, the formula used was (Leonardsson *et al.* 2009):

$$ES_i = \left[\sum_{j=1}^{p}\left(\frac{y_{ij}}{\sum_{j=1}^{p} y_{ij}} * ESW_j\right)\right] * \log_{10}(m+1) * \left(\frac{\sum_{j=1}^{m} y_{ij}}{\sum_{j=1}^{m} y_{ij} + 5}\right) \quad [4]$$

BQIES: weighted mean index calculated as ***ES,*** but using *BQIWTS* instead of *ESW*.

BQIEJ: weighted mean index calculated as above, but using *BQIWEJ*.

A trophic status index (TSI) using only environmental variables was also calculated as follows: the environmental variables were rescaled between 0 and 1, the ones increasing with anthropogenic stress (nutrient and ammonia concentration, number of inhabitants) were further transformed to the complement to 1, the ones increasing with water quality (dissolved oxygen, transparency) were left unchanged; at last a weighted mean of all the variables, weighted by species abundances, was calculated.

A correlation matrix between all environmental variables and the indices was calculated.

A factorial analysis of variance was carried out with trophic status index (TSI*)* and biotic indices as dependent variables and habitat type (krenal, rhithral, epipotamal, potamal, limnetic and ephemeral), season (winter, spring, summer, autumn) and water quality (reference, agriculture impact and organic pollution) as factors.

3. RESULTS

Environmental data are reported in Table 2.

The list of the 37 recorded chironomid species found in Kebir-East is given in Table 3.

The coinertia analysis carried out with 21 environmental variables and 37 chironomid species ordered the 90 samples. The first axis accounted for 42 % of total variance and the second axis for 13 % (Table 4). The PROtest, the RV and R-squared tests all emphasized that the environmental and faunistic tables were near the limit of significance (Fig. 2), the correlation between the two sets was 0.571 for the first axis and 0.674 for the second axis.

In Fig. 3 each white circle positions a station by its environmental variables and each black circle locates a station by its species composition. Inertia axes may be projected on to co-inertia axes to visualize the relationships between each table structure and their co-structure.

The inertia of each separate analysis and the projections of inertia on co-inertia axes are given in Table 4.

CoA emphasized the relations between environmental variables and the first two maximum covariance axes (Fig. 4) and between the 37 chironomid species (Table 3) and the same axes (Fig. 5).

A longitudinal gradient was apparent along the first two axes: upstream stations were richer in oxygen, had lower water temperature and larger granulometry, the downstream

Tab. 2 - Water physico-chemical variables of the sampled sites recorded over four seasons of the year 2007 along the Kebir-East river (Extreme Northeast Algeria), G = granulometry (%), T = turbidity (NTU), V = current velocity (cm s^{-1}), C = conductivity (μS cm^{-1}), TH = hardness (mg $CaCO_3$ l^{-1}), TAC = alkalinity (mg $CaCO_3$ l^{-1}), M. =Mean values of the year, S.E. = Standard Error.

Tab. 2 - Variabili fisico-chimiche dell'acqua nei siti e nelle 4 stagioni campionate nel 2007 nel fiume Kebir-East (Estremo Nordest dell'Algeria), G = granulometria (%), T = torbidità (NTU), V = velocità di corrente (cm s^{-1}), C = conducibilità (μS cm^{-1}), TH = durezza (mg $CaCO_3$ l^{-1}), TAC = alcalinità (mg $CaCO_3$ l^{-1}), M. = media, S.E. = errore standard.

Codes sites	G	NO_3		NO_2		NH_4		PO_4		T		V		O2%		O2	
		M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.
1	70	19.3	4.9	0.3	0.1	0.5	0.4	0.1	0.1	68.3	27.3	23.0	30.9	115.7	20.6	12.5	2.8
2	60	11.2	1.8	0.2	0.2	0.2	0.1	0.2	0.2	51.4	35.8	33.5	30.6	128.6	14.0	13.6	2.5
3	20	10.1	1.4	0.3	0.0	0.2	0.1	0.1	0.0	65.0	23.3	46.9	26.9	141.3	19.7	15.8	2.2
4	100	1.5	0.3	0.1	0.1	0.1	0.1	0.0	0.0	20.2	24.4	33.2	31.5	168.9	9.9	19.1	2.1
5	10	2.2	0.3	0.3	0.1	0.4	0.4	0.3	0.2	30.4	38.1	20.8	12.1	129.5	13.9	14.1	2.3
6	60	10.0	4.9	0.2	0.1	0.6	0.4	0.4	0.5	101.8	77.2	22.3	16.6	136.1	12.5	14.9	1.4
7	70	9.0	1.1	0.2	0.1	0.7	0.3	0.5	0.2	323.3	181.8	28.7	21.8	138.4	12.9	14.9	2.2
8	40	16.6	1.2	0.7	0.5	0.8	0.8	0.6	0.4	853.4	849.6	39.7	31.6	118.6	18.7	12.9	2.6
9	10	24.6	1.8	0.3	0.2	1.8	0.1	3.6	1.4	98.7	65.2	11.3	5.0	107.6	9.4	10.7	0.2
10	10	22.8	2.9	0.6	0.6	1.5	0.7	1.9	0.7	201.5	123.4	18.1	11.7	103.1	1.3	11.0	0.7
11	10	23.7	2.3	0.5	0.4	2.2	0.9	1.5	0.2	174.0	96.3	13.1	10.2	103.5	8.2	10.8	0.3
12	20	23.7	1.5	0.7	0.2	1.0	0.6	0.7	0.6	240.4	284.1	24.8	33.9	102.5	5.7	10.4	0.8
13	20	23.3	1.6	0.9	0.6	1.7	0.5	1.0	0.7	264.8	333.9	22.6	28.7	102.4	6.9	10.3	0.9
14	30	21.0	0.7	0.5	0.5	0.7	0.1	0.6	0.1	196.8	229.0	29.3	16.5	99.8	6.0	10.3	1.4
15	10	29.6	2.3	1.0	0.1	1.4	1.4	3.5	1.7	617.5	444.5	12.1	10.0	92.2	4.3	9.5	1.2
16	30	15.5	6.7	0.2	0.2	0.4	0.3	1.5	1.1	208.3	95.5	16.6	6.1	104.3	29.0	12.2	2.8
17	60	6.0	0.7	0.3	0.1	0.8	0.1	0.6	0.3	291.5	115.1	29.3	22.4	151.2	12.2	16.4	0.7
18	80	7.5	1.3	0.6	0.2	0.9	0.5	0.8	0.1	201.5	235.9	45.2	8.6	139.0	15.4	15.0	2.3
19	10	7.8	0.7	0.3	0.0	1.1	0.9	1.6	0.4	451.5	598.9	20.3	9.5	81.4	17.6	8.3	0.7
20	20	7.1	0.9	0.6	0.4	0.1	0.0	0.8	0.1	351.3	412.9	14.9	6.0	107.7	4.5	10.6	0.7
21	10	9.6	0.7	0.9	0.4	0.1	0.0	0.8	0.3	331.0	265.1	20.2	14.3	106.5	4.9	10.6	0.9
22	20	8.1	1.3	0.5	0.2	1.2	0.3	0.7	0.1	70.8	16.1	18.3	10.7	109.1	2.6	11.8	1.0
23	10	6.9	1.4	0.3	0.2	0.1	0.0	0.9	0.2	194.8	105.1	15.0	15.9	107.9	3.2	11.2	0.9

Codes sites	temp		Cl		C		TH		pH		SO4		Ca		Mg		TAC	
	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.	M.	S.E.
1	12.0	2.7	95.0	18.0	637.3	87.0	81.3	12.7	7.2	0.4	129.5	57.6	83.6	9.0	133.4	3.6	182.3	24.6
2	13.2	3.4	120.8	26.7	724.8	74.0	84.5	8.0	6.9	0.4	184.5	20.8	60.3	31.4	137.4	26.3	184.3	26.0
3	10.3	3.6	155.3	57.0	770.3	53.9	63.3	12.5	6.9	0.3	179.5	36.2	132.3	45.5	118.1	4.6	259.3	113.2
4	9.9	2.7	107.8	14.7	295.0	149.0	277.0	63.2	7.0	0.4	149.8	59.4	147.8	40.0	136.5	13.7	170.3	46.1
5	14.3	7.2	111.0	52.0	493.1	64.0	126.8	7.8	7.1	0.5	116.0	29.9	141.3	23.7	147.5	25.4	162.0	33.5
6	11.3	2.7	205.8	139.0	543.5	159.7	167.8	28.1	7.0	0.3	179.3	17.7	140.5	16.4	136.3	16.7	175.0	33.6
7	13.6	3.4	148.0	87.7	564.8	47.8	131.5	13.2	7.2	0.3	144.3	34.2	171.5	11.7	137.3	13.1	175.7	21.6
8	11.7	2.2	109.3	35.3	512.4	91.1	104.4	17.2	7.1	0.7	167.1	19.8	99.0	29.1	136.9	14.7	174.0	36.0
9	15.5	4.3	85.3	24.0	522.3	163.4	67.5	7.4	7.7	1.0	96.8	56.7	61.0	20.3	31.8	18.9	107.7	42.1
10	12.4	2.6	99.0	29.7	498.8	102.3	60.8	32.9	7.3	0.7	49.3	33.2	77.8	7.6	30.5	6.2	105.7	34.1
11	13.5	4.4	102.0	24.5	455.8	133.6	57.5	25.3	7.5	1.0	42.8	27.4	62.0	5.6	32.3	17.2	141.7	54.6
12	14.7	5.1	120.1	14.6	559.3	122.6	64.6	11.4	6.7	0.3	46.6	21.0	59.6	14.7	27.1	6.6	138.9	42.0
13	15.2	5.2	119.5	15.1	559.9	123.1	54.0	10.7	7.0	0.5	46.0	20.7	59.0	14.3	26.5	6.4	138.3	42.1
14	14.4	4.7	170.0	72.0	569.8	135.4	59.0	25.6	6.8	0.3	82.9	50.2	71.5	14.8	25.5	4.5	141.3	52.5
15	14.2	3.6	316.3	185.1	898.0	144.2	33.3	25.5	6.7	1.2	46.8	38.4	90.3	41.2	38.0	11.4	235.7	26.4
16	14.1	4.5	223.5	49.9	732.3	97.6	64.3	19.9	7.9	0.6	117.8	43.8	97.3	30.8	81.0	48.5	205.7	98.2
17	11.5	2.7	170.8	60.4	784.5	83.3	91.3	9.9	7.1	0.4	141.8	31.0	139.5	71.1	138.6	15.5	143.3	75.0
18	12.0	2.9	173.3	45.6	733.0	78.0	131.0	16.2	7.2	0.1	147.3	23.8	32.5	19.5	131.8	8.5	242.7	19.6
19	14.3	6.3	349.0	43.8	813.0	244.7	31.0	8.5	6.9	0.4	160.0	25.5	40.0	14.1	28.5	4.9	270.0	168.3
20	16.0	4.5	161.8	43.2	777.3	199.7	26.8	5.3	7.2	0.3	123.3	6.9	68.3	34.1	32.0	22.2	147.3	22.5
21	16.1	5.1	137.5	39.1	636.3	156.8	24.0	10.8	7.3	0.3	139.5	27.0	78.8	44.8	60.3	58.6	197.3	45.5
22	11.9	3.6	130.0	19.2	698.5	89.7	33.3	35.4	6.7	0.2	115.0	35.1	88.3	41.4	115.0	12.3	201.7	88.1
23	13.8	3.2	152.3	27.6	643.0	177.5	25.3	12.0	6.7	0.1	121.0	29.6	68.3	25.1	97.6	54.7	186.3	53.5

	Winter	Spring	Summer	Autumn
Tanypodinae				
Tanypus punctipennis Meigen, 1818	0	9	8	0
Procladius choreus (Meigen, 1804)	0	21	0	15
Rheopelopia ornata (Meigen, 1838)	18	18	47	16
Sympotthastia spinifera (Serra-Tosio, 1968)	0	1	0	0
Prodiamesa olivacea Kieffer ,1906	0	2	0	0
Orthocladiinae				
Cardiocladius fuscus (Kieffer, 1924)	12	15	19	26
Eukiefferiella claripennis (Lundbeck, 1898)	5	0	11	17
Rheocricotopus chalybeatus (Edwards, 1929)	62	11	108	112
Hydrobaenus distylus (Potthast, 1914)	3	72	0	7
Paratrissocladius excerptus (Walker, 1856)	0	0	2	0
Psectrocladius sordidellus (Zetterstedt, 1838)	1	0	0	1
Orthocladius (Euorthocladius) rivicola Kieffer, 1911	142	115	11	10
Orthocladius pedestris (Kieffer, 1909)	98	159	6	18
Paracladius conversus (Walker, 1856)	1	0	0	0
Cricotopus bicinctus (Meigen, 1818)	676	491	372	579
Cricotopus (Isocladius) sylvestris Kieffer, 1909	108	265	77	116
Parametriocnemus stylatus (Sparck, 1923)	2	2	12	1
Parakiefferiella gracillima (Kieffer, 1924)	0	1	3	0
Thienemanniella partita (Schlee, 1968)	25	3	0	0
Corynoneura scutellata Winnertz, 1846	0	3	1	0
Tanytarsini				
Rheotanytarsus photophilus (Goetghebuer, 1921)	30	20	8	5
Cladotanyta[illegible]*ancus* (Walker, 1856)	10	85	0	0
Tanytarsus sp[illegible]	0	9	9	1
Micropsectra atrofasciata (Kieffer, 1911)	0	5	0	0
Chironomini				
Polypedilum (Tripodura) scalaenum (Schrank, 1803)	2	44	20	49
Polypedilum cultellatum (Goetghebuer, 1931)	48	161	93	92
Microtendipes pedellus (De Geer, 1776)	2	5	4	12
Synendotendipes dispar (Meigen, 1830)	6	5	3	3
Dicrotendipes nervosus (Stæger, 1839)	0	0	16	20
Glyptotend[illegible]*allens* (Meigen, 1804)	3	0	1	3
Einfeldia s[illegible]	0	1	0	0
Chironomus plumosus (Linnæus, 1758)	13	120	36	38
Chironomus riparius Meigen, 1804	37	348	92	154
Microchironomus tener (Kieffer, 1818)	0	0	0	1
Cryptochironomus rostratus Kieffer, 1921	3	2	2	3
Paracladopelma camptolabis (Kieffer, 1913)	0	0	1	0
Harnischia fuscimana Kieffer, 1921	0	0	1	2
Total number of species	1307	1993	963	1494

Tab. 3 - List of chironomid species collected in the sampling sites, along with their abundance (number of larvae and pupae collected in a sample) recorded over four seasons: winter, spring, summer and autumn (2007).
Tab. 3 - Lista delle specie di chironomidi raccolte nei siti di campionamento, unitamente alla loro abbondanza (numero di larve e pupe raccolte in un campione) nelle 4 stagioni: inverno, primavera, estate e autunno (2007).

Tab. 4 - Comparison of results from the co-inertia analysis with inertia resulting from the separate analyses. F1 and F2 are the first two co-inertia axes. Covar: covariance of the two sets of coordinates projected on to co-inertia axes. Corr: correlation between the two sets of coordinates resulting from the co-inertia analysis. VarE and VarF are inertia of environmental and faunistic table respectively projected on to co-inertia axes. InerE and InerF are maximal inertia of environmental and faunistic table respectively resulting from separate analysis. Ratio: ratio VarE/InerE or VarF/InerF.
Tab. 4 - Confronto tra i risultati della coinerzia e dell'inerzia come risulta dalle analisi dei dati separate. F1 e F2 sono gli assi di coinerzia. Covar: covarianza tra i due insiemi di coordinate proiettati sugli assi di coinerzia. Corr: correlazione tra i due insiemi di coordinate ottenibile dall'analisi della coinerzia.. VarE e VarF sono le misure dell'inerzia delle variabili ambientali e faunistiche proiettate sugli assi di coinerzia. InerE e InerF sono la inerzia massima della tabella dei dati ambientali e faunistici che risultatno dalle analisi separate. Ratio: rapporto VarE/InerE o VarF/InerF.

	Eigenvalue	Covar	Corr
F1	0.736	0.858	0.571
F2	0.222	0.471	0.674
Environmental axis	VarE	InerE	Ratio
F1	0.331	0.533	0.621
F2	0.351	0.489	0.046
Faunistic axis	VarF	InerF	Ratio
F1	6.824	7.286	0.937
F2	1.395	2.015	0.692

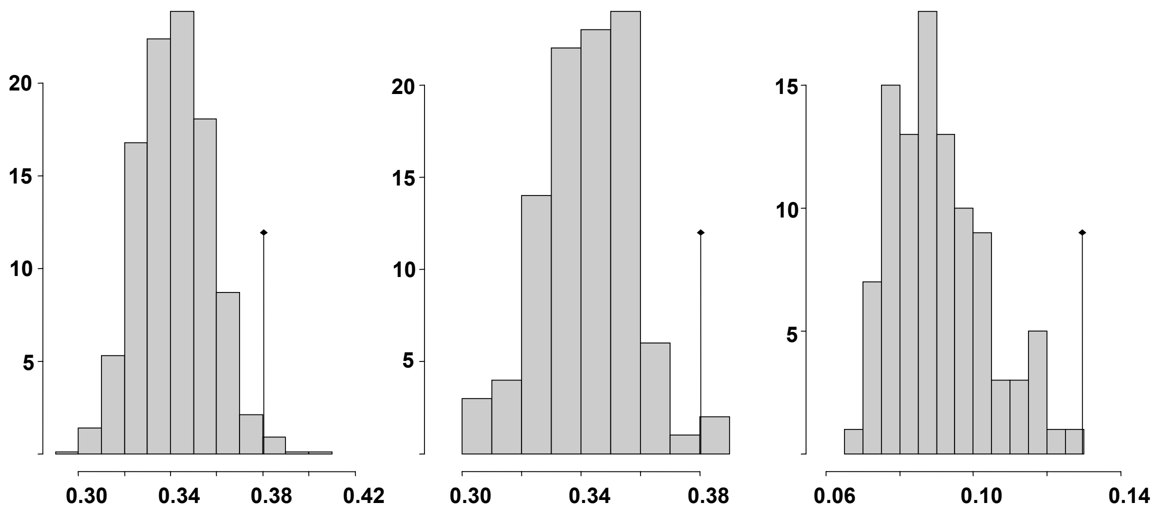

Fig. 2 - Plot of PROTEST, RV and R-squared test: histograms of simulated values (gray bars) with the observed value (vertical line).
Fig. 2 - Valori dei test PROTEST, RV e R-quadro: istogrammi dei valori simulati (barre grige) e osservati (linea verticale).

sites had higher conductivity and nutrient content. The krenal upstream stations (4 and 5) were plotted on the right part of the factorial 1x2 plane, potamal stations were plotted on the left side (Figs. 3-4). The second axis was related to water temperature, chloride concentration and hardness (Figs. 3-5); it was also related to anthropogenic stress separating impacted nutrient-rich sites from unimpacted sites. Different water temperatures reflected samples collected in different seasons. Limnetic habitat types were also separated from ephemeral sites in the second axis (Fig. 3).

The chironomids were ordered along the first axis with species like *Paratrissocladius excerptus*, *Paracladopelma camptolabis*, *Microchironomus tener, Orthocladius (Euorthocladius) rivicola, Harnischia fuscimana, Rheopelopia ornata*, occupying krenal and rhithral habitats, plotted on the right and *Thienemanniella partita*, *Procladius choreus*, *Chironomus plumosus*, *Glyptotendipes pallens, Corynoneura scutellata* dominant in downstream, potamal sites plotted on the left (Fig.5). The second axis discriminated between species like *T. partita, Sympotthastia spinifera, Micropsectra atrofasciata* present in cold waters in spring-winter, from species like *Dicrotendipes nervosus, Einfeldia* sp.*, P. choreus, Tanypus punctipennis* prevailing in warm waters in summer and autumn; warm waters are also rich in nutrient as emphasized by the second axis.

At last the influence of habitat type, season and anthro-

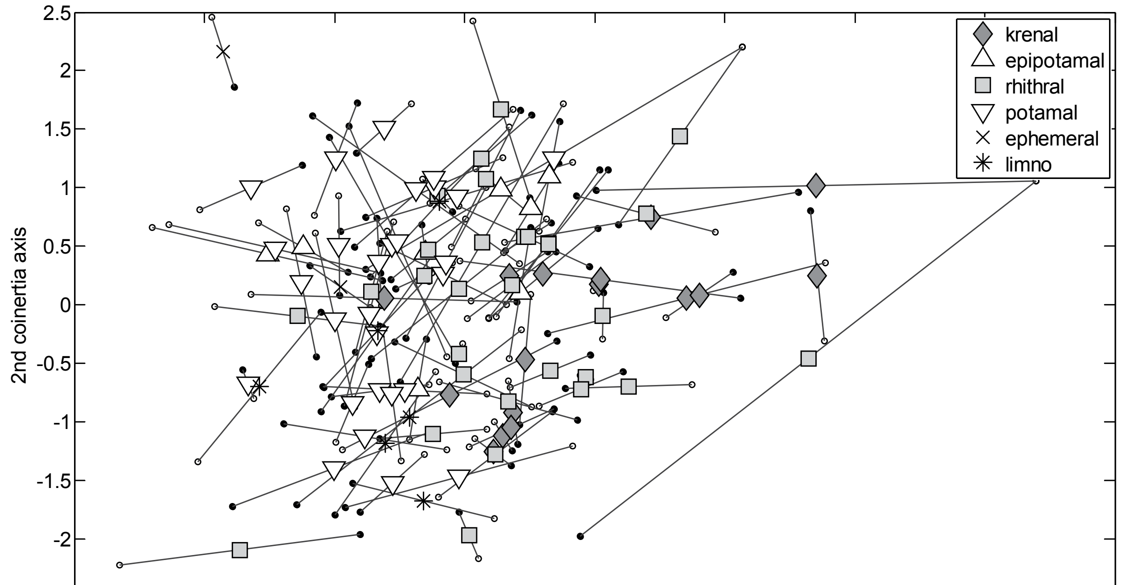

Fig. 3 - Co-inertia analysis results; plot of sites, black circles from species matrix, white circles from environmental data matrix. Stations from different habitat are expressed with different symbols.
Fig. 3 - Risultati dell'analisi della coinerzia, circoli neri dalla matrice delle specie, circoli bianchi dalla matrice dlle variabili ambientali. Stazioni di habitat different espresse con simboli differenti.

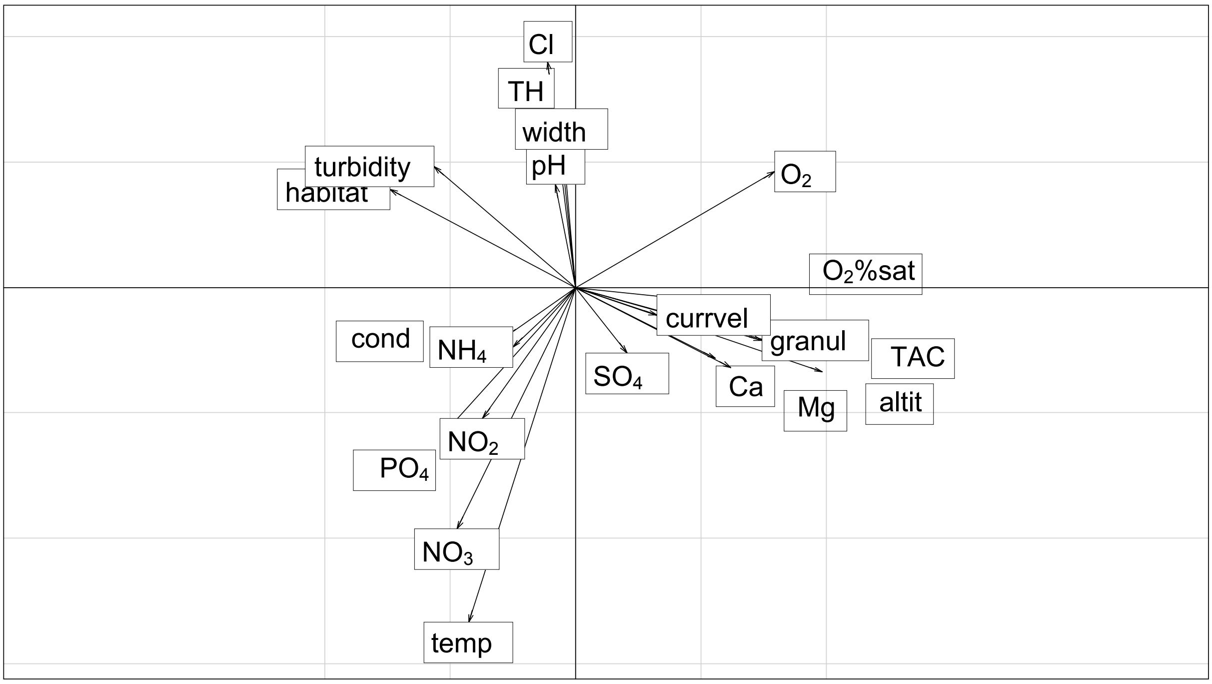

Fig. 4 - Co-inertia analysis results; plot of abiotic descriptors.
Fig. 4 - Risultati dell'analisi della coinerzia, mappaggio dei descrittori abiotici.

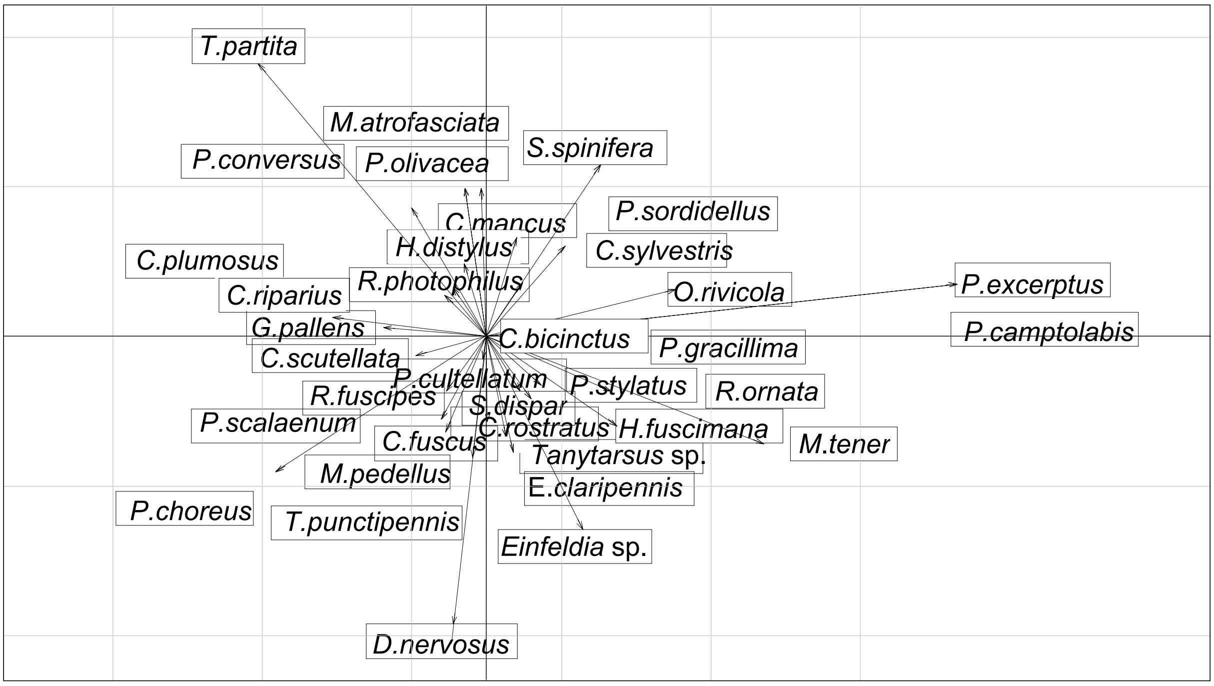

Fig. 5 - Co-inertia analysis results; plot of species.
Fig. 5 - Risultati dell'analisi della coinerzia, mappaggio delle specie.

pogenic pressures were a suite of benthic macroinvertebtes based on ecological assessment indices, which based on species diversity and their response to different environmental variables. The trophic status index (TSI) was obviously correlated with the environmental variables; biotic indices were correlated with dissolved oxygen, water temperature, Mg (*BQIENV, BQIES*), altitude, total alkalinity (*ES, BQIEJ*), granulometry, O_2, conductivity and NO_3 (*BQIEJ*) (Table 5). The biotic index which weighted species according to expert judgment (*BQIEJ*) had higher values in pristine sites, but differences between pristine and impaired sites were never statistically significant (Table 6). Weighted diversity index (*Hw*) and *BQIENV* had higher values in limnetic stations; in general, biotic indices were more sensitive to season than to

Tab. 5 - r: correlation coefficients, p: significance probability, values are from correlations calculated between environmental variables and biotic indices. Significant values ($p<0.05$) are underlined, highly significant values ($p<0.01$) are underlined and in bold character. See text for explanation of biotic indices abbreviations.
Tab. 5 - r: coefficienti di correlazione, p: probabilità di avere valori significativi, I valori derivano dalle correlazioni calcolate tra variabili ambientali e indici biotici. I valori significativi ($p<0.05$) sono sottolineati, quelli altamente significativi ($p<0.01$) sono sottolineati ed in grassetto. Vedi il testo per le spiegazioni delle abbreviazioni degli indici biotici.

r	***TSI***	***BQITS***	***BQIENV***	***BQIES***	***ES***	***H***	***Hw***	***BQIEJ***
Granul	**0.666**	0.000	0.244	0.154	0.249	0.007	-0.034	**0.214**
Habitat	**-0.687**	-0.031	-0.221	-0.166	-0.220	0.058	0.105	-0.185
NO_3	**-0.627**	0.024	-0.120	-0.095	-0.074	0.116	0.060	**-0.246**
NO_2	**-0.639**	-0.001	-0.077	-0.051	-0.163	-0.068	-0.013	-0.085
NH_4	**-0.610**	0.034	0.047	-0.076	0.050	0.012	0.053	0.109
PO_4	**-0.739**	0.042	-0.137	-0.154	-0.056	0.055	0.036	-0.096
Turbidity	**-0.424**	-0.028	-0.090	-0.021	-0.091	-0.077	-0.044	-0.091
Velocity	**0.260**	-0.043	0.163	0.095	0.125	-0.054	0.001	0.046
O_2	**0.782**	0.090	**0.329**	**0.270**	0.230	-0.178	-0.104	0.236
Temperature	**-0.369**	-0.020	**-0.380**	**-0.246**	-0.130	0.216	0.106	-0.166
Cl	-0.074	0.008	0.137	0.158	0.014	-0.015	0.052	0.089
Cond	-0.243	0.104	-0.064	0.039	-0.050	0.127	0.096	-0.129
TAC	**0.635**	0.154	0.261	0.114	**0.311**	0.036	0.059	**0.359**
pH	0.012	0.036	0.019	0.048	-0.060	-0.089	-0.092	-0.053
SO_4	**0.484**	0.140	0.174	0.228	0.222	0.122	0.060	0.146
Ca	**0.393**	0.133	0.100	0.139	0.132	0.184	0.132	0.088
Mg	**0.668**	**0.219**	**0.281**	0.251	0.245	0.072	0.028	0.205
TH	0.149	0.028	0.135	0.144	0.130	0.036	0.017	0.118
Altitude	**0.740**	0.123	0.236	0.119	**0.310**	-0.117	-0.139	**0.387**
Width	0.026	0.069	-0.157	-0.012	-0.197	0.018	0.084	-0.159

p	***TSI***	***BQITS***	***BQIENV***	***BQIES***	***ES***	***H***	***Hw***	***BQIEJ***
Granul	**0.000**	0.997	0.021	0.148	0.018	0.946	0.753	0.043
Habitat	**0.000**	0.771	0.037	0.117	0.037	0.590	0.326	0.082
NO_3	**0.000**	0.824	0.261	0.373	0.486	0.275	0.574	**0.019**
NO_2	**0.000**	0.991	0.470	0.630	0.125	0.522	0.907	0.428
NH_4	**0.000**	0.750	0.660	0.478	0.643	0.909	0.622	0.308
PO_4	**0.000**	0.695	0.198	0.148	0.603	0.609	0.737	0.368
Turbidity	**0.000**	0.795	0.399	0.847	0.393	0.472	0.679	0.392
Velocity	**0.013**	0.688	0.124	0.374	0.240	0.611	0.990	0.666
O_2	**0.000**	0.400	**0.002**	**0.010**	0.029	0.093	0.328	0.025
Temperature	**0.000**	0.855	**0.000**	0.020	0.223	0.041	0.320	0.119
Cl	0.490	0.943	0.199	0.138	0.895	0.887	0.628	0.405
Cond	0.021	0.331	0.547	0.713	0.639	0.234	0.370	0.225
TAC	**0.000**	0.147	0.013	0.286	**0.003**	0.738	0.584	**0.001**
pH	0.908	0.738	0.861	0.655	0.575	0.402	0.387	0.622
SO_4	**0.000**	0.189	0.101	0.031	0.036	0.251	0.576	0.169
Ca	**0.000**	0.212	0.349	0.191	0.214	0.083	0.216	0.412
Mg	**0.000**	**0.038**	**0.007**	0.017	0.020	0.499	0.792	0.052
TH	0.160	0.791	0.204	0.177	0.223	0.740	0.872	0.269
Altitude	**0.000**	0.248	0.025	0.265	**0.003**	0.274	0.191	**0.000**
Width	0.805	0.521	0.141	0.908	0.063	0.866	0.434	0.133

Tab. 6 - Factorial analysis of variance results; indices are dependent variables; season, pollution (poll) and habitat are factors.
Tab. 6 - Risultati dell'analisi Fattoriale della varianza; gli indici sono le variabili dipendenti; i fattori sono stagione, inquinamento (poll) e habitat.

TSI	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**		***ES***	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**	
season	0.129	3	0.043	2.182	0.097		season	6.886	3	2.295	1.449	0.235	
poll	0.295	2	0.148	7.512	0.001	**	poll	0.083	2	0.041	0.026	0.974	
habitat	1.085	5	0.217	11.051	0.000	**	habitat	16.861	5	3.372	2.129	0.071	
error	1.552	79	0.020				error	125.150	79	1.584			
total	3.583	89					total	152.674	89				
BQITS	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**		***H***	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**	
season	0.060	3	0.020	5.793	0.001	**	season	4.083	3	1.361	3.703	0.015	**
poll	0.006	2	0.003	0.788	0.458		poll	1.248	2	0.624	1.698	0.190	
habitat	0.025	5	0.005	1.429	0.223		habitat	2.295	5	0.459	1.249	0.295	
error	0.274	79	0.004				error	29.036	79	0.368			
total	0.357	89					total	35.725	89				
BQIENV	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**		***Hw***	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**	
season	0.137	3	0.046	3.925	0.011	**	season	23.623	3	7.874	1.597	0.197	
poll	0.004	2	0.002	0.164	0.849		poll	11.105	2	5.553	1.126	0.329	
habitat	0.171	5	0.034	2.937	0.017	**	habitat	61.075	5	12.215	2.478	0.039	*
error	0.920	79	0.012				error	389.487	79	4.930			
total	1.255	89					total	481.251	89				
BQIES	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**		***BQIEJ***	**Sum Sq.**	**d.f.**	**Mean Sq.**	**F**	**Prob>F**	
season	0.098	3	0.033	1.453	0.234		season	5.837	3	1.946	1.166	0.328	
poll	0.025	2	0.012	0.552	0.578		poll	2.082	2	1.041	0.624	0.538	
habitat	0.161	5	0.032	1.436	0.221		habitat	9.060	5	1.812	1.086	0.375	
error	1.768	79	0.022				error	131.808	79	1.669			
total	2.062	89					total	154.539	89				

habitat type and water quality, *BQITS, BQIENV* and *H* with statistically significant differences among seasons (Fig. 6).

4. DISCUSSION

Up until the last three decades of the twentieth century, the chironomid fauna of North Africa was poorly studied and knowledge of this faunistic group was patchy (Reiss 1977). Over the past decades, knowledge has steadily been built up in Morocco (Azzouzi & Laville 1987; Azzouzi *et al*. 1992; Kettani *et al*. 2001), Tunisia (Boumaiza & Laville 1988) and Algeria (Moubayed *et al*. 1992 2007, Lounaci *et al*. 2000a, 2000b). However, the chironomids of eastern Algeria have so far retained little attention (Zerguine *et al*. 2009) despite a wide range of habitats hosted by the region well known as an Afrotropical relict pocket and a hotspot for a diversity of aquatic species (Samraoui *et al*. 1998a; Samraoui & Menaï 1999). A recent survey of temporary ponds of northeast Algeria recorded 30 species of chironomids and an additional 5 taxa identified to genus level (Zerguine *et al*. 2009). Owing to the present study and accounting for an overlap of 5 species between the two surveys, the number of chironomids known from northeast Algeria amounts to 60 species plus a further 7 taxa known to genus level.

North African wadi share with other Mediterranean rivers the characteristics of being subjected to a wide range of hydrological fluctuations and extreme physical conditions and, as expected, our results confirm the low species diversity revealed in previous studies (Arab *et al*. 2004; Belaidi *et al*. 2004). The North African chironomid species assemblage is characterized by lower species diversity than that found in European streams (Lounaci *et al*. 2000b). Due to the harsh local climate, rivers are subjected to high water temperatures (> 30° C) acting as a restricting factor for the fauna (Lounaci *et al*. 2000a). High water temperature induces a high evaporation rate and low current velocities, leading to low habitat diversity, and consequently to a reduced diversity. Therefore tolerant species generally show a larger spatial distribution than in European streams, where they are usually restricted to the lowland stretches. As a consequence, few habitats are vacant for stenothermal species, inducing lower species diversity due to the lack of potential habitats and to the presence of competitors (Arab *et al*. 2004).

Chironomid species communities are structured according to habitat characteristics and, in particular, to the

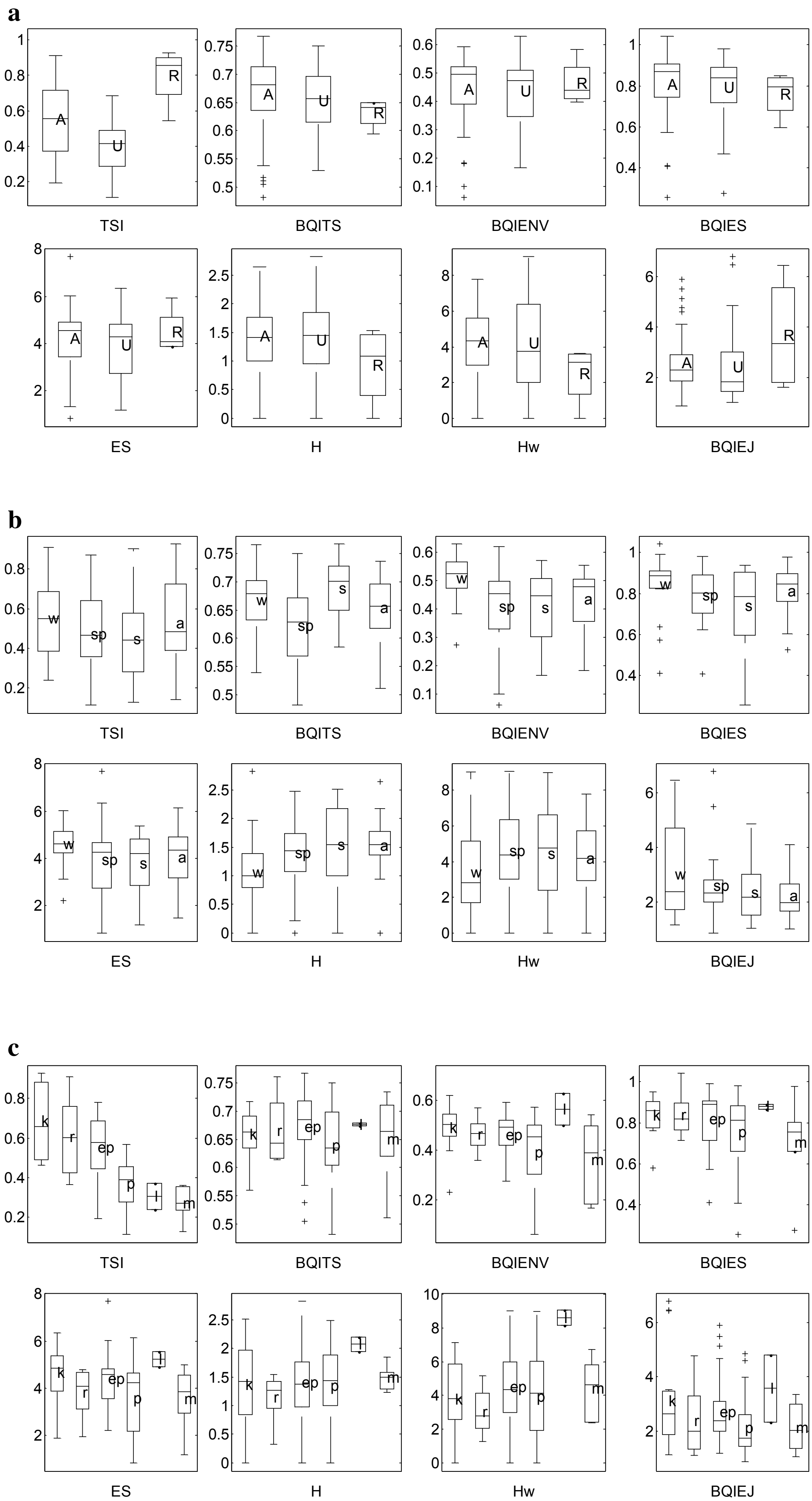

Fig. 6 - Boxplot of: a) indices classified according to impact, b) indices classified according to season, c) indices classified according to habitat. Box = 25-75° percentile; whiskers = min-max range; orizontal bar = median; + = outlier values. Impact: R= natural, pristine, A= agriculture, P=sewage polluted; Season: W=winter, Sp=spring, S=summer, A=autumn; Habitat: K= krenal, R= rhithral, Ep= epipotamal, P= potamal, L= limnetic, M= ephemeral.

Fig. 6 - Mappaggio di: a) indici classificati secondo gli impatti, b) indici classificati secondo la stagione, c) indici classificati secondo l'habitat. Box = 25-75° percentile; baffi = intervallo min-max; barre orizzontali = mediana; + = valori estremi. Imptto: R= naturale, non alterato, A= agricoltura, P=inquinamento urbano; Stagione: W=inverno, Sp=primavera, S=estate, A=autunno; Habitat: K= krenal, R= rhithral, Ep= epipotamal, P= potamal, L= lacustre, M= temporaneo.

longitudinal gradient, known to be an important factor determining species assemblages. A succession of tribes is often observed in lotic waters, with Diamesini and Orthocladiini prevailing upstream, and Tanytarsini and Chironomini dominating downstream (Rossaro 1991a, 1991b). Both a longitudinal gradient and a seasonal gradient were evident in Kebir-East wadi from coinertia analysis mapping sites in the plane formed by the first two axes. Some of the species like *Procladius choreus*, *Chironomus plumosus* and *Tanypus punctipennis*, found dominant on downstream sites have been recorded in the region in lentic habitats (Zerguine *et al*. 2009). The Kebir-East wadi has some peculiarities that are typical of Mediterranean intermittent streams, i.e. Chironomini species were frequently collected in upstream stations: *Paracladopelma camptolabis* was scarce and present only in krenal station 4 in summer, *Microchironomus tener* and *Harnischia fuscimana* were collected in station 6 (immediately below station 4) in autumn. All these findings are from the dry season, in water with high temperature and almost standing waters; as already stressed in other studies (e.g. Bonada *et al*. 2007a; Marziali *et al*. 2009a), in Mediterranean streams during the hot season the upstream reaches may reproduce conditions similar to ones observed in downstream stations in North European countries. Habitats of the dragonfly *Aeshna cyanea* in North Africa are typical of this ecological shift (Samraoui & Corbet 2000).

Some peculiarities are here emphasized as the presence of *Corynoneura scutellata* in spring season in stations 8 and 19 and in station 2 in summer. The species was captured in different habitats in Europe, but it is known to be relatively cold stenothermal, it is surely very abundant in high altitude alpine lakes (e.g. Marziali *et al*. 2009b). The present captures suggest an enlargement of the known ecological niche of the species. The presence of *Thienemanniella partita* in downstream stations in winter in waters with high conductivity is also noteworthy, the species was found in waters with low conductivity (Rossaro *et al*. 2006b) even if in the middle Po river it was collected in winter in waters with relatively high conductivity (Rossaro 1984).

The biotic indices calculated using chironomid species had low values in species poor sites (station 12 in spring and station 23 in summer), where only *Chironomus* species were present. Low values were also obtained in stations 9 and 13 in winter, colonized by few species as *Cricotopus bicinctus* and *Cricotopus (Isocladius) sylvestris*.

It must be stressed that station 19, which dried up in summer, had the highest biotic indices both in winter and in spring, but in spring the high values were due to the high species number (12), while in winter the high index was bound to the presence of species with a high indicator value (*Thienemanniella partita*).

As a conclusion, community composition was influenced by both season and water quality, with seasonal differences in species assemblagesdominating.

Chironomid taxocenosis was composed by opportunistic species which prevailed and disappeared in a short time (e.g. Langton & Casas 1999), so a seasonal sampling strategy is not enough to detect the species temporal fluctuations and to describe the system using chironomid species alone.

These results are to some extent in agreement with the ones observed in other Mediterranean areas, where the appearance and disappearance of chironomid species was observed in a short time, as found in the Lambro (Rossaro & Ferrarese 1980), Vera (Rossaro *et al*. 1996b), Taro (Rossaro *et al*. 2004) and in the Potenza river (Rossaro 1988), with a rapid spatial and temporal succession of species. In these rivers chironomid species have a very short life cycle, still shortened in warm waters.

In the studied rivers, lowland plains are subjected to high disturbances induced by dry periods followed by violent floods and by anthropogenic pollution (e.g. agriculture, water abstraction). In densely populated areas, pollution is enhanced by reduced flow rate and only a few tolerant species can survive (e.g. *Chironomus*) during dry conditions. Therefore conservation and maintenance of unimpacted sites as source of recolonization is highly recommended (Lounaci *et al*. 2000a).

In the semi-arid regions of North Africa and Southern Europe, many invertebrates have life cycles characterized by adaptations that allow them to bridge the hot, dry season. These strategies often involve aestivation at high altitude sites that act as refuges until the arrival of autumnal rains. Chironomids inhabiting temporary habitats exhibit a large spectrum of adaptations allowing them to persist (McLachlan 1983; McLachlan & Laddle 2001), but the ecological strategies of chironomids living in temporary streams is insufficiently understood (Frouz *et al*. 2003). It remains to be seen whether some chironomids adopt such strategies found in a wide range of invertebrate species spread across different orders of insects: Lepidoptera (García-Barros 1988; Samraoui 1998), Odonata (Samraoui *et al*. 1998b; Samraoui 2009) and Hemiptera (unpublished). All these species exhibit movement and postponed maturation by adults; Chironomids may however use their short life cycle to complete larval development in upstream sites before recolonizing downstream reaches by passive drift or active dispersal. Future studies need a more frequent sampling plan; probably weekly samples are needed to follow seasonal cycles and to understand their relation to environmental factors in such extreme habitats.

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