Water quality shapes freshwater macroinvertebrate communities in northern Tunisia

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Introduction

Globally, freshwater ecosystems health specifically streams is of concern due to the combined effects with changing land use and anthropogenic activities (Dudgeon et al. 2006; Ormerod et al. 2010; Woodward et al. 2010; Dos Santos., 2011; Domisch et al. 2013; Slimani et al., 2020). Stream health is defined by peculiar structures and specific functional characteristics at spatial and temporal scales between biotic components and physico-chemical conditions of their environment (Karr, 1999; Maddock, 1999; Herman et al., 2015). Pollution imposes severe challenges of water quality, which is related on different analysis water quality criteria according to the pollution degrees (Awoke et al., 2016). Thus, the frequent assessment of the water quality represents a priority task for establish different water quality index which serve as guides for freshwater monitoring. In this context, chemical concentrations of the pollutants have been developed as ecosystem integrity guides's (Keith-Roach et al., 2015). Many indicators of ecological degradations may be selected to test stream health deviations from the healthy state or reference conditions (Vugteveen et al., 2006; Reza et al., 2011). Thus, the frequent supervision of the ecosystem integrity represents a priority task for water resource management. In this context, the concentration on both multiple abiotic and biotic components contribute significantly in monitoring the health of streams (Slimani et al., 2015; Von Schilleret al., 2017; Vollmer et al., 2018). To determine how component's choice, it has been must a better understanding of the local natural conditions, the management goals and the available resources (Hughes and Rood, 2003; Smith et al., 2016; Agboola et al., 2019). Nonetheless, a comprehensive biomonitoring program can be important evaluate stream health, identify degraded areas and suggest the suitable approach for restore and sustainable water resource management with the greatest needs (Reza and Abdullah, 2011; DWA, 2011; Vollmer et al., 2018; Slimani et al., 2020).

Worldwide awareness has demonstrated the values for freshwater assessment and monitoring is limited (Humphries et al., 1995; Caro and O'Doherty, 1999; Slimani et al., 2019).Thus, it's necessary understanding the values urgent of the economic ecosystem services to society (as flood control, purification of human and industrial wastes, habitat for plants and animals), to appreciate the obligatory of assessment and monitoring of freshwater ecosystems (Barbour, 2008; Mangadze et al., 2019). In fact, characterising the biodiversity conservation, water, habitat for organisms, food and recreation, etc., is becoming increasingly urgent in terms of ecosystem services face escalating pressures to human well-being (Millennium Ecosystem Assessment, 2005). There is growing understanding that biota's contribution primarily could provide a particular economically ecosystem services to society (Barbour and Paul, 2010). Another benefit to quality aquatic ecosystem integrity for evaluating, maintaining or restoring ecosystem services is that they not only take into account biological components but also the environmental components as physical and chemical characteristics of the system (Leigh et al., 2013).

North Africa's freshwater ecosystems are being heavily affected by anthropogenic activities altering water quality (e.g. rapid industrialization, agriculture, mining activities; overexploitation; water pollution; flow modification; degradation of habitat; and invasion by exotic species (Dudgeon et al. 2006; Ormerod et al. 2010; Woodward et al. 2010; Slimani et al., 2019; Slimani et al., 2020), groundwater depletion (ref), floods (ref) and climate change induced intensification of droughts (Heino et al., 2009; Domisch et al. 2013; Dai, 2013). Ensuring freshwater security is a major issue today and especially in the Maghreb countries in terms of rapid demographic, socio-economic, and climate changes(Labane,2002). Agricultural scope and food production will be a challenge in the near future, considering water scarcity and increasing completion for water use. Therefore, knowledge and control of the water quality is a priority for the future of human and his environment particularly around the North Africa. The current assessment of North African streams is determined with reference standard procedures which include: chemical, physical, and biological integrity of the surface water using established sampling methods for their collection and assessment (Goaziou, 2004; Slimani et al., 2019; Slimani et al., 2020). The results accuracy that integrates these three components can to be identifying the cause of degradations, water insecurity, threats to biodiversity, and how they can lead to better solutions to freshwater management (ref). Freshwater organisms are generally the main biological entity mostly used as bio-indicators due rapid respond to specific aquatic stressors. Such responses are at the heart of research on status of the aquatic ecosystem, which persistence attempts implementation to prediction, distinct, and taxonomically diverse (Griffith et al., 2005).

The macroinvertebrate communities in freshwater ecosystems are affected at time–space scales both directly and indirectly by a combination of abiotic and biotic components. Many abiotic components, such as altitude (ref), temperature and (ref) and salinity (ref), affect the taxonomic richness in the community. It has been suggested that transitional characteristics of upstream- downstrem ecosystems can also influence variation in community structure due to habitat heterogeneity (ref). Biotic components, such as the presence or absence of predation (as fish and amphibians) and competition (intraspecific and interspecific) a freshwater ecosystems, can become important in determining macroinvertebrate peculiar structures and specific functional characteristics. Thus, the presence of fish species in a river section makes low Macroinvertebrate biomass (Eidam et al. 2016). In particular, Cheimonopoulou et al. (2011) indicated that the taxon richness of macroinvertebrates was good indicators of local scale conditions, and frequently have been used in biomonitoring programs to detect ecosystem degradation, prioritize conservation are as and evaluate restoration progress.

Many studies have reported about the relationship between environmental components and macroinvertebrate for assessing the ecological health of ecosystems using multivariate data analyses. However, some analyses (e.g. principal component analysis, canonical correspondence analysis, and multidimensional scaling) between environmental and biological processes are difficult to assess because of the intercorrelation of parameters and the complexity of the patterns variation. The new multivariate analysis method, called STATICO (Thioulouse et al., 2004), presents a complete and coherent analysis structure to describe the spatio-temporal the characteristics of biological communities in function of abiotic environmental conditions. The aims of this study were: (1) to assess the spatial and seasonal variation of macroinvertebrate assemblages of three streams located in northern Tunisia, and (2) to examine which abiotic factors determine the spatial and temporal structure of these macroinvertebrate assemblages.

2.Methods

2.1. Study area

Sampling sites were established in the northern Tunisia (Fig. 1), a Mediterranean region located in the Maghreb (North Africa). The area represents one of the biotopes most severely threatened due to human pressures the main land use of the area is industrial and agricultural. The area is characterized by a Mediterranean climate semiarid, with hot and dry summers and rainy winters, and has the annual precipitation of about 462 mm. Annual mean air temperature is about 17.8°C (Zielhofer and Faust, 2008). The dominant vegetation of the area is *Polypagonmaritimus* (Poaceae), *Poaannua* (Poaceae) and *Phragmitescommunis* (Poaceae)(plant ensuring a purification ofwaters),because our aims were to assess the relationships between environmental factors and macroinvertebrate assemblages among six sites.Three streams were examined which are exposed to chemical pollution, with pristine sites [P] being located in the upstream section of each stream, while the section altered by anthropogenic activities [A] were situated downstream of the pollution sources.

2.2. Environmental data

Environmental variables were sampled concurrently with the macroinvertebrate seasonally in 2013, corresponding to February (winter), May (spring), August (summer), and November (autumn) 2013. Specifically, we measured 11 environmental parameters. Water temperature (WT) was measured using a mercury glass thermometer graduated at 0.1 °C intervals. Salinity (S), electrical conductivity (EC), dissolved oxygen (DO), and pH were measured in field using a portable multiparameter (WTW, MPP350). Using 2 L sterilized, clear, plastic bottles, the water samples were preserved in the field at 4 °C and transported to the laboratory for nutrient analyses. Orthophosphate concentration (PO_4^{3-}) was determined spectrometrically by colorimetry. The concentrations of ammonium (NH_4^+) and nitrate (NO_3^-) were determined using liquid chromatography. Determination of chemical oxygen demand (COD) was based on measuring the amount of potassium dichromate ($K_2Cr_2O_7$) consumed by the dissolved solids in suspension. Biochemical oxygen demand after 5 days (BOD_5) was measured by incubation of the water sample in the presence of a phosphate and allylthiourea solution in darkness and at 20°C.Turbidity (TUR) was measured in the laboratory using a turbidimeter (Hach Model 2100A).

2.3. Macroinvertebrate sampling and identification

At each study site, the macroinvertebrate were quantitative collected on ten occasions by surber nets (10 x 20cm^2, 300 μmmesh), during twenty-five minutes across the entire habitat heterogeneity (stones, gravel, sand, mud,vegetation marginal and aquatic). The samples were immediatelystored in 70% ethanol and transported to the laboratory for the identification of taxa which was made using a binocular stereomicroscope and available keys. The applied methodology is common in studies on freshwater macroinvertebrates (e.g., Picazo et al., 2012).

3. Results

3.1. Environmental factors

The mean values and standard deviations of the environmental factors in the six sites are indicated in Table 2. The pH values varied from 5.09 to 8.05 (mean = 7.08±0.99). The mean conductivity of sites varied from 1366 to 3469 µs/cm (mean = 2232 ± 948 (S.D.) The high conductivity at site 6 was probably due to the location near to the sea. All sites had mean salinity between 0.55 PSU and 1.88 PSU. Lower mean DO and higher mean turbidity (TUR), [NO3-], [NH4+], [PO42-], [COD], and [BOD5] were found at the three altered sites than at the three pristine sites. All sites had mean water temperature between 15.66°C and 20.33°C.

3.2. Macroinvertebrate assemblages

A total of 46 macroinvertebrate taxa were recorded in the 24 samples from 6 sampling sites, with a higher taxa richness of Arthropoda (31 taxa), followed sequentially by Annelida (8 taxa), Crustacea (4 taxa) and Mollusca (3 taxa). The mean number of taxa per site varied between 9 and 30, with an average of 19 taxa. Some sensitive taxa were dominant at pristine sites (ST1, ST3 and ST 5) namely the Ostracoda (26,34%) and *Echinogammaruspungens* (6,71%), compared to the pollution tolerant taxa in the three altered sites (ST2, ST4 and ST6) as *Simulium*sp (12,61%) and *Anopheles*sp (13,19%). Moreover, the taxonomic richness composition and abundance varied greatly among across the pristine (P) and altered (A) sites (Table. 2).

3.3 Community analysis and relationship with environmental parameters

Interstructure

The factor map of the interstructure, with by the first principal component explaining 43.65% of the total inertia and the second 24%, identified two main groups of seasons (Fig. 2A). This suggested that only the first axis should be selected for the compromise analysis. The correlation circle showed all the sampling dates displaying the same sign on the first interstructure factor (axis 1), indicating a positive correlation between the corresponding set of matrices (Fig. 2A).

To build the compromise, the weights of each pair of tables ranged from 0.425 to 0.589 (Fig. 2D). The Spring-Summer seasons were different from the Autumn-Winter seasons. This means that the co-structures between environmental parameters and macroinvertebrate communities were different in Spring-Summer and Autumn-Winter.

Compromise

The contribution of the different sampling dates to the compromise table building ranged from 0.455 to 0.803 (Fig. 2D). All seasons were well represented by the compromise. In the PCA factor maps of the compromise (Fig. 2B), the firstcomponent accounted for 82.66 % of the total inertia, and the secondone for 8.49%. The factor map of the environmental variables associated the first axis described a positive association with dissolved oxygen (OXY), pH and a negative association with the COD, BOD_5, [PO_4^{2-}] [NO_3^-], and [NH_4^+], and the second axis with salinity and electrical conductivityvariability (Fig. 2a), discriminating winter on the right vs. summer on the left. On the factor map of 46 macroinvertebrate taxa (Fig. 2C and

Table 2 for codes), two main macroinvertebrate groups were identifiedOn the first axis, the most abundant taxa (OligochaetaTubificidae and DipteraCulicidae) were associated with sites having higher BOD5 and COD, and were opposed to the other taxa, such as Ostracods, associated with sites characterized by higher DO.

Discussion

The composition of macroinvertebrate assemblages

The importance of the Mediterranean ecosystems of North Africa as a habitat of aquatic macroinvertebrates has been underlined until recently (Beauchard et al., 2003; Slimani et al., 2019). Slimani et al. (2019) studied inland aquatic systems in 49 localities from Northern Africa (Tunisia) and found 72 families, 157 genera and 280 species, However, the mean number of taxa in this study either less than that found by Slimani et al.(2019), this might not be surprising, because this study emphasizes the specificity of pollution Mediterranean ecosystems. The macroinvertebrate richness, thus, could provide a more insight into sampling sites is probably to be representative of degree impacted pollution in the region. Also, macroinvertebrate diversity with environmental seasonal dynamics might reflect as reliable parameters to understand the regional features, giving rise to identify pollution source at local scale. The impacted sites, therefore, may be an important component to highlighting the the exceptionally decline in macroinvertebrate abundance, were caused by the high of water column concentrations of NO3,COD and BOD.

Furthermore, a recent study in which 68 families of the OuedMartil River basin in northwestern Morocco were evaluated for vulnerability to under natural and anthropogenic pressures according to their physicochemical and bacteriological data demonstrated that at upstream reaches could be included in a good quality, but those of the downstream reaches were classified as poor quality (Guellaf and Kettani, 2020). Moreover, the evaluation of the surface quality in the Kebir-Rhumel catchment area, located in the South northeast of Algeria, has shown a very degraded quality at Rhumelwadi where most sensitive taxa have a vulnerability to pollution while the polluo-resistant taxa (Chironomidae) predominate in impacted sites (Saal et al, 2020). Although macrophytes exert many positive effects within aquatichabitats (e.g., by stabilizing bed surface, uptaking large nutrientamounts, increasing habitat complexity and heterogeneity, and pro-viding organic matter for many aquatic herbivores, grazers and detri-tivores), they also might cause negative effects if their populations gettoo dense (Wetzel, 2001; Caraco and Cole, 2002). Other studies have attributed bioaccumulation of heavy metals (Hg, Pb, Cu, and Zn) in anBaetispavidus (Baetidae; Ephemeroptera) to water temperature, calcium, and nitrates concentrations, indicating strong contamination of the El HarrachWadi (Algeria) (Bouchelouche, and Arab, 2020).

Many faunistic and taxonomic studies reported aquatic Coleoptera and Chironomidae could that constitute the highest diversity of the macroinvertebrate communities in the freshwater systems Palaearctic region (Ferrington, 2008; Ja¨ch&Balke, 2008; de Figueroa et al., 2013).

In our study, we also found that streams were predominated by Coleoptera at particularly in pristine sites [P] ST1, ST3, and ST5 but the Chironomids and Oligochaeta were a well-distributed in impacted sites (ST2, ST4, and ST6). Therefore, this distribution probably seemed to be related by their highly colonization in a water pollution, particularly in lentic systems. De Figueroa et al., 2013 indicated that Mediterranean freshwater are facing similar to five threat biodiversty as World freshwater biodiversity (Dudgeon et al., 2006). Here, we consider as agricultural runoff and industrial pollution are, therefore, limiting factors for the freshwater biodiversity, bringing decreases in the richness of many species, including Coleoptera. According to Henle et al. (2004), macroinvertebrate structure during this investigation were vastly influenced about pollution levels variation (Fig. ??,Table ??). These findings are consistent with most of studies that confirmed the sensitive of many organisms in urban environments, often resulting in greater habitat disturbance change on stream (Miserendino and Masi, 2010; Maseseet al., 2014). Moreover, the most urbanization areas, concentrated in the Mediterranean, who are them among World biodiversity hotspots, are also that make most vulnerable to habitat disturbance (Tierno de Figueroa et al., 2013).

Macroinvertebrate assemblages and environmental factors

The analysis of this study highlighted that the distribution of macroinvertebrate is principally related to a pollution gradient (Fig. 1B). The spatial differences in physico–chemical variables among upstream - downstream can be ascribed to the human activities i.e. intense urban and agricultural activities as has been observed in other studies (Mhamdi et al., 2016; Gasmi et al., 2016; Slimani et al., 2017; ......) (Table 2). Moreover, down streams are mainly susceptible to strong land-use impactsand major nutrient inputs in these downwater streams may exceed nutrient demands for benthic communities and lead to anoxicant of the aquatic systems (ref). In this sens, we also noted that there were important changes in macroinvertebrate richness, associated with water quality variables. Plus, salinization acidification effects, intense agricultural and mining activities are positively linked with nitrogen and phosphorous related water quality parameters (Slimani et al., 2020). For that reason, recent studies used macroinvertebrate as like biological indicators to assess ecological status in Mediterranean streams and classify sites affected regarding relative level of perturbations based on land use types (Sánchez-Montoya et al., 2010; Fierro et al., 2018). These anthropogenic disturbance also have synergistic effects on water quality that potentially have significant declines on of freshwater biodiversity. These were the case in this study, because all the sites in this study were discriminates very well between reference and impaired sites from point of view diversity, composition, and tolerance to pollution (Table 3).

Many studies (Dudgeon et al., 2006; Davis et al., 2015; Eerkes-Medrano et al., 2015) found that the freshwater ecosystems showed the most threatened systems globally due to increased anthropogenic disturbances.Our STATICO analyses also identified that [COD], [BOD_5], and [PO_4^{2-}] increasing levels as major stressors factors affecting macroinvertebrate diversity between reference and impaired sites in this study. The influence stressors on macroinvertebrate assemblages was generally a consequence of greater disturbances at the sites scale, higher extinction sensitive aquatic fauna risk due to land-use change, and the influence of a gradient pollution on stream ecosystems local reflecting broader scale disturbances.STATICO was effective illustrating risk pronounced at different scales local of environmental problem and represented the importance of using several metrics physicochemical to record a potential threat to streams along a gradient of pollution. In Mediterranean streams, land-use change has identified as a factor contributing to affect aquatic fauna loss (Bruno et al., 2014). STATICO combined of ecological condition indicators as of both biotic and abiotic factors providing a more realistic and complete picture of the stream ecosystems status. STATICO was combined of ecological condition indicators as of both biotic and abiotic factors providing a more realistic and complete picture of the stream ecosystems status. It has been shown that human pressures produced an impoverishment in the aquatic communities depending on its stenoic sensitive taxa.Our results are in agreement with Miserendino et al. (2011) that indicated the loss of insect richness is a common occurrence as a response to streams modified by urban, pasture and managednative forest land-uses.The effects of pollution on communities distribution patterns might reflect their importance as holistic and integrative indicators in monitoring programs, and scoring the occurrence of species human pressures effects on taxon richness (Table 3). Similarly, Fierro et al (2018) were able to find a significant urban and agricultural activities effect on the richness of macroinvertebrates in Mediterranean streams and suggested that other factors, such as biotic interactions such as trophic structure, might be important.

Seasonal and spatial variability of the benthic community

As we know, Mediterranean ecosystems are among the most threatened ecosystems in World because of anthropogenic-focused environmental problem (Grantham et al., 2010). Many studies have investigated the macroinvertebrate assemblages related to the spatio-temporal environmental variability in a Tunisia freshwater. However, most of these studies have not assessed the seasonal changes in urbanstreams. Our STATICO results indicate that the lowest abiotic condition in North Tunisiean Mediterranean streams occurs in urban and agricultural streams during the both dry seasons (Spring and Summer). This is also supported by other studies conducted in the sameecoregion (Gasmi et al., 2016). In addition, diversity metrics such as abundance can also be positively affected by the altered or degraded sites because of the increased abundance of tolerant species Diptera and Annelida. The tolerance mainly indicated elevated the levels of [COD], [BOD] and [PO4] at the sites in close proximity with urban stream (Fig. 2C).

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Table 1. Mean ± SE of environmental variables in 6 sites of northern Tunisia from February to November 2013

	ST1-P	ST2-A	ST3-P	ST4-A	ST5-P	ST6-A
pH	7.66±0.21	6.45±1.44	7.8±0.29	6.82±1.08	7.20±0.99	6.56±1.03
EC (µs cm^{-1} à 20°C)	1366±376.23	1380±415	2654±576	2595±981	1928±824	3469±247
S (PSU)	1.22±0.75	0.55±0.07	1.57±0.28	1.33±0.34	0.9±0.48	1.88±0.2
OXY (mg L−1)	6.14±1.78	0.94±0.24	7.2±1.72	1.12±1.23	6.58±0.78	1.2±0.93
T (°C)	16.29±6.12	15.66±6.21	18.83±10.91	17.76±9.62	20.33±8.26	18.83±9.41
TUR (NTU)	324.65±308.27	152.87±46	27.98±19.50	160.2±140.01	70.9±35.54	125.87±133.86
NO_3^- (mg L−1)	3.98±1.77	83.24±30.18	0.78±0.56	12.08±2.63	4.42±5.26	81.03±11.49
NH_4^+ (mg L−1)	0.51±0.41	3.24±5.61	0.87±1.01	3.75±6.38	0.45±0.58	3.27±6.02
PO_4^{2-} (mg L−1)	0.15±0.1	3.29±0.87	1.5±2.6	4.23±1.25	0.15±0.02	5.34±2.7
COD (mg L−1)	25.37±4.5	199.75±89.2	29.5±0.57	222±215.6	52.12±52	249±253
BOD_5 (mg L−1)	0.42±0.09	33.7±22.91	2.1±1.8	14.4±20.47	13.12±24.58	39.75±10.24

Table 2: Percent composition of 46 macroinvertebrate taxa collected by the Surber net sampler from the 6 sites in the freshwater area of northern Tunisia during the seasonally sampling period from February to November 2013.

		ST1-P	ST2-A	ST3-P	ST4-A	ST5-P	ST6-P
Oligochaeta	Abbr.						
Paranais birsteini	Pbir	-	4.7	-	4.84	0.19	0.56
Nais elinguis	Nel	-	0.58	-	0.28	0.19	1.42
Tubifex tubifex	Ttub	0.44	5.58	-	0.28	-	1.13
Aeolosma sp	Asp	-	0.88	-	0.57	0.77	1.7
Haplotaxis gordioides	Hgor	-	0.58	-	0.28	-	-
Eropbdella sp	Esp	-	-	-	-	0.19	-
Hemiclepsis marginata	Hma	-	-	-	0.28	-	1.7
Borebdella verrucata	Bver	-	1.17	-	0.56	-	-
Mollusca							
Ancylus fluviatilis	Aflu	1.11	-	0.45	-	-	-
Phsella acuta	Pacu	3.35	-	13.07	-	1.94	-
Pseudamnicola dupotetiona	Pdup	0.22	-	17.2	-	4.84	-
Crustacea							
Ostracodes	Ostr	57.49	-	41.28	-	39.92	-
Echinogammarus pungens	Epun	12.08	-	9.17	-	13.56	-
Atyaephyra desmarestii	Ades	0.44	-	-	-	0.19	-
Potamon algeriense	Pal	0.67	-	-	-	-	-
Insecta							
Baetis rhdani	Brh	0.44	-	-	-	0.77	-
Baetis pavidus	Bpav	-	-	0.45	-	0.58	-
Caenis luctuosa	Cluc	3.8	-	3.89	-	1.16	-
Erythromma lindeni	Elind	1.11	-	-	-	-	-
Coenagrion caeaulexus	Ccae	0.67	-	-	0.28	-	-

Ischnura graellsi	Igra	-	-	-	-	0.38	-
Onychogomphus forcipatus	Ofor	-	-	0.22	-	0.19	-
Orthetrum auceps	Oauc	-	-	1.14	-	0.19	-
Notonecta maculata	Nmac	-	-	-	-	0.19	-
Naucoris maculus	Nmacu	1.34	-	0.45	-	-	-
Nepa cinerea	Ncin	-	-	0.22	-	-	-
Aquarius cinereus	Acin	0.44	-	1.37	-	-	-
Hydrometra stagnorum	Hstr	0.22	-	0.23	-	1.94	-
Haliplus lineaticollis	Hlin	4.92	-	0.23	-	1.35	-
Noterus laevis	Nlae	-	-	0.45	-	-	-
Hydrovatus sp	Hsp	-	-	0.22	-	-	-
Laccophilus minutus	Lmin	-	-	5.73	-	-	-
Helochares lividus	Hliv	-	-	1.14	-	0.58	-
Berosus affinis	Baff	1.34	-	-	-	0.96	-
Laccobius atratus	Latr	-	-	-	-	0.19	-
Ochthebius bifoveolatus	Obif	1.11	-	-	-	2.32	-
Hydraena scabrosa	Hsca	0.22	-	-	-	-	-
Dryops sp	Dsp	0.44	-	-	-	-	-
Hydroptila aurora	Hau	0.67	-	0.23	0.28	0.97	-
Orthotrichia sp	Osp	0.44	-	-	0.28	0.19	-
Hydropsche maroccana	Hmar	2.68	-	1.37	-	3.1	-
Simulium sp	Simsp	2.46	23.82	1.37	29.34	12.2	12.53
Anopheles sp	Asp	0.22	25.88	-	25.92	6.97	30.19
Chironomus sp	Chisp	0.44	9.7	-	13.67	2.51	10.54
Hexatomini sp	Hesp	0.44	15.88	-	10.82	0.97	22.79
Atherix sp	Atsp	0.67	11.17	-	12.25	0.38	17.37

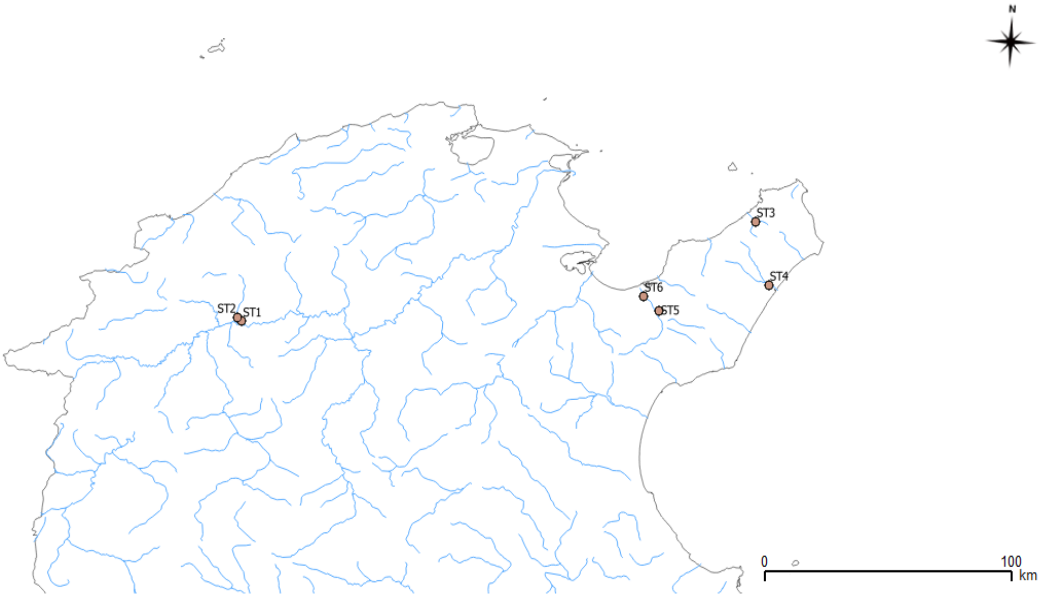

Fig. 1 Location of the sampling stations within the study area

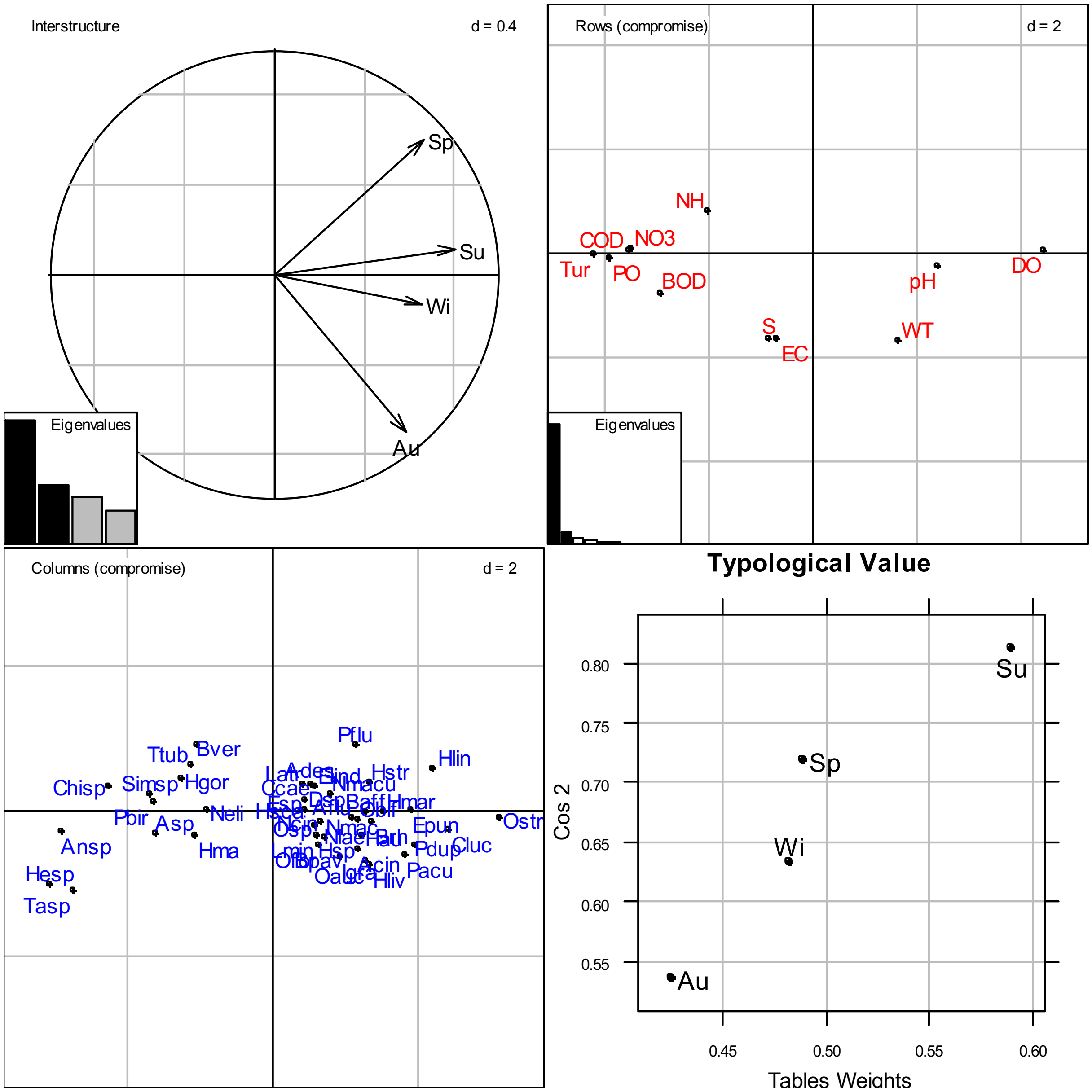

Figure 2. Results of the STATICO method. The four plots are as follows: (A) The interstructure plot. (B) Compromise analysis principal axes map (environmental variables). (C) Compromise analysis principal axes map (aquatic macroinvertebrates taxa). (D) Typological values of the four tables (cos^2 and table weights).