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Macrobenthos structure in the watershed of a river of central Italy

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ABSTRACT

A study was undertaken to define the benthic populations, the environmental-ecological variability and trophic aspects according to the functional feeding groups in the upper reaches of the Nera River, a tributary of the Tiber, in central Italy. A total of 12 681 individuals was collected and 83 taxa were identified; 11 proved to be endemic for Italy, 7 of them typical of the central Apennines. The greatest number of taxa (58), and the highest values of diversity were recorded at the lowest sampling station, 37 km from the source. A dendrogram constructed by the UPGMA method based on values of similarity revealed two main clusters, one identified with *crenon* (at the source) and the other with *rhithron* (the downstream stations) fluvial typology. Correspondence analysis on the environmental matrix parameters confirmed this finding. Taxa abundance was evaluated by grouping the individuals collected into classes using semi-quantitative sampling. The results of trophic-functional analysis, calculated on the basis of the estimated abundance and tested with statistical methods, agreed with fauna composition analysis clusters for the filtering collector and shredder categories. The zonal and clinal patterns reveal that there may be a weak up-stream to downstream gradient within a single fluvial zone and almost discontinuity in contiguous tracts when the abiotic gradient changes suddenly.

KEY WORDS: Stream ecosystems - Benthic invertebrates - Functional feeding groups.

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INTRODUCTION

The zoobenthos of a river basin can be characterized from different points of view (Ward *et al.*, 1994) either on the basis of a zonal model (Illies & Botosaneanu, 1963) or of the river continuum concept (Vannote *et al.*, 1980) and even discontinuum situations can be hypothesized (Perry & Schaeffer, 1987). There should be no anthropic alterations to reduce the biodiversity and/or modify the natural trophism of the water course.

The Sibilline Mountains National Park (instituted in 1990) and the proposed Coscerno-Aspra Regional Park, including the study area in the upper reaches of the River Nera basin (Marches-Umbria), are also of prime naturalistic importance from the point of view of the macrobenthic invertebrate communities.

Much information on this area comes from studies carried out in the 50's when the Natural History Museum of Verona undertook a vast research programme on the fauna of the Sibilline Mountains (Magistretti & Ruffo, 1969). The Trichoptera were collected and classified by Moretti (University of Perugia) but not published within this research programme. Trichoptera (Moretti *et al.*, 1974; Moretti & Mearelli, 1981), Plecoptera (Consiglio, 1971) and the communities peculiar to temporary pools (Cianficconi *et al.*, 1976) were the main subjects of later research.

The present investigation attempted to define the basin of the upper reaches of the River Nera according to: (1) the qualitative and quantitative composition of the benthic communities; (2) the variability of the environmental-ecological parameters; (3) trophic aspects in relation to the functional feeding groups (Cummins *et al.*, 1984; Ward *et al.*, 1994).

MATERIALS AND METHODS

Study area

The River Nera, a left-bank tributary of the River Tiber, rises in the Sibilline Mountains in the Marches and flows for about 116 km through the Nera valley and across the Terni plain. The 4 280 km^2 watershed is mainly composed of calcareous permeable rocks (Lippi-Boncambi, 1948) that store rain water and release it reasonably regularly, thereby determining an overland fluvial flow with discharges as a rule higher than those of the River Tiber. The study area was: the mountain reaches of the basin and included the first 40 km of the River Nera's course, which for long tracts is channelled between rocks, the River Corno, a left-bank tributary and the River Sordo, the main tributary of the Corno (Fig. 1). The two River Nera stations were situated at the source (St.1 - 844 m a.s.l., a 3 m wide pool, 10 to 15 cm deep) and 37 km downstream (St. 4 - 340 m a.s.l., width from 10 to 15 m). Since 1932, a diversion canal has diverted water upstream and discharged it into Lake Piediluco. However, in July 1990, due to the temporary closure of this diversion canal (Gianotti *et al.*, 1988) and the consequent increased water mass, this tract of the River Nera (St. 4) became extremely turbulent and the depth which normally ranges between 40 and 50 cm, exceeded one metre. The River Sordo, which is about 8 km long, was sampled about 3 km from its source (St. 2 - 550 m a.s.l., depth about 60 cm and width around 3 m), while the River Corno, which is about 57 km long, was assayed 47 km from its source (St. 3 - 486 m a.s.l., depth 30-40 cm, width from 15 to 20 m).

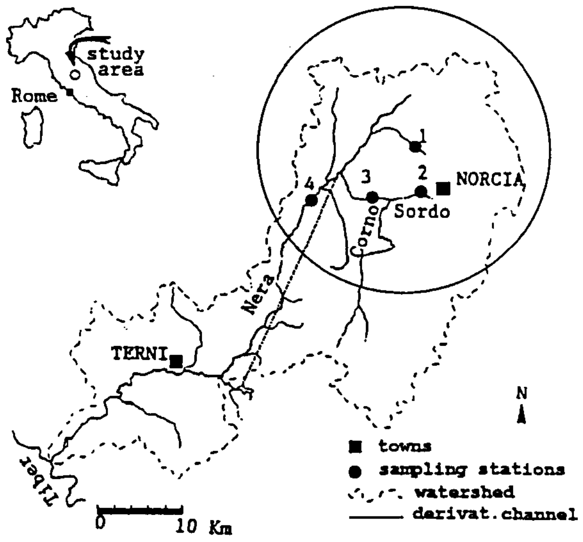

Fig. 1 - Map of the River Nera watershed showing the four sampling stations.

Samplings and methods

Seasonal samples were carried out between September 1989 and July 1990. Physico-chemical analyses were carried out according to standard methods (A.W.W.A., A.P.H.A., W.P.C.F., 1971). A *0.335-mm-mesh (21/cm) drag-net was used for collecting macrobenthos.*

The Shannon-Weaver (1949) function

$$H = -\sum_{i=1}^{s} n_i / N \cdot \log_2(n_i / N)$$

was used to estimate biotic diversity, where $N = \sum_{i=1}^{s} n_i$ is the total density measured (in this case the number of individuals), s the total number of species, and n the density measure of the *i-th* species. An increase in the H value corresponds to an increase in benthic diversity.

The Evenness Value (E) (Pielou, 1966), is determined from $E = H / \log_2(S)$, where H is the diversity index, s the total number of species, and $\log_2 (s) = H_{max}$, theoretical maximum of diversity, corresponding to the situation limit of $S = N / k$, where individuals are distributed equally (k) among species. The index has a range between 0 (minimum equitability) and 1 (maximum equitability, that is each taxa has the same number of individuals).

The Sorensen Quotient of Similarity (Sorensen, 1948) $QS = 2c/(a + b)$, where a is the number of taxa in sample A, b the number of taxa in sample B, and C the number of taxa common in the two samples, was adopted for assessing the degree of similarity of benthic taxa at paired stations: 0 = no species in common, 1 = all species in common. As this index considers only presence/absence of taxa, it gives only a qualitative interpretation.

To express the degree of quantitative similarity between stations, the QS coefficient was modified (Di Giovanni *et al.*, 1996) according to the formula:

$$QS' = 100 \cdot 2 \sum_{i=1}^{c} P_i / (P_A + P_B) \Rightarrow \sum_{i=1}^{c} P_i$$

where $\sum_{i=1}^{c} P_i = \sum_{i=1}^{c} \min (a, b)$ is the sum of percentage of the minimum taxa common to paired samples, P_i is the minimun density (%) value of each common taxon, c is the number of taxa common to paired samples, P_A is 100 (% density value of sample A), P_B = is 100 (% density value of sample B).

Among station differences are graphically represented by a dendrogram constructed by the unweighted pair-group method using arithmetical averages (UPGMA) (Sneath & Sokal, 1973).

Functional feeding analysis (Cummins & Wilzbach, 1985) applied to macrobenthic populations was based on the taxa frequency value obtained by grouping the specimens according to the five classes of the Biotic Score (Chandler, 1970), and a frequency value was assigned to each abundance class to estimate the number of specimens of each taxon (Table I). This method was selected because it seemed to be the most suitable for investigating the trophism of the biocenotic components in a situation where only semi-quantitative samples were available. Other central European researchers have employed the same method, particularly the technique for calculating the Biologically Effective Organic Load (B.E.O.L.) index (Knopp, 1954). In consequence, trophic analysis is expressed as the contribution of each taxon according to its assigned frequency value. Angular transformation was applied to percent values of trophic categories at the four stations so that ANOVA could be employed to reveal differences among the means. The Tukey test (SAS Institute, Inc., 1989) was adopted for revealing significant differences in the pairwise trophic categories.

The data obtained were subjected to further statistical elaboration by principal components analysis (PCA) and correspondence analysis (CA) to establish associations among environmental parameters using SAS/STAT software (SAS Institute, Inc., 1989) for data processing.

RESULTS

The physico-chemical parameters examined (Table II) showed that the environmental conditions of the four biotopes were not significantly affected by the organic matter and, in consequence, the biocenosis was not subjected to stress due to lack of oxygen during the study period. PCA analysis (Fig. 2) of the physico-chemical characteristics of samples carried out at the four stations shows that the first two axes accounted for 70% of the standardized variance and so provide a good statistic summary of the data. Euclidean space distribution of the samples reveals a negative correlation between axis 1 (44%) and all station 1 samplings, but a positive correlation with summer and spring samplings at the other three stations.

The benthic macrofauna (Table III) was reasonably distributed over the study period with a maximum of 58 taxa at station 4 and a minimum of 31 at station 1, a value

TABLE I - *Abundance classes and frequency values of the benthic taxa.*

Abundance class (n specimens)	Abundance evaluation	Frequency values
1-2	present	1
3-10	scarce	2
11-50	common	3
51-100	abundant	4
>100	very abundant	5

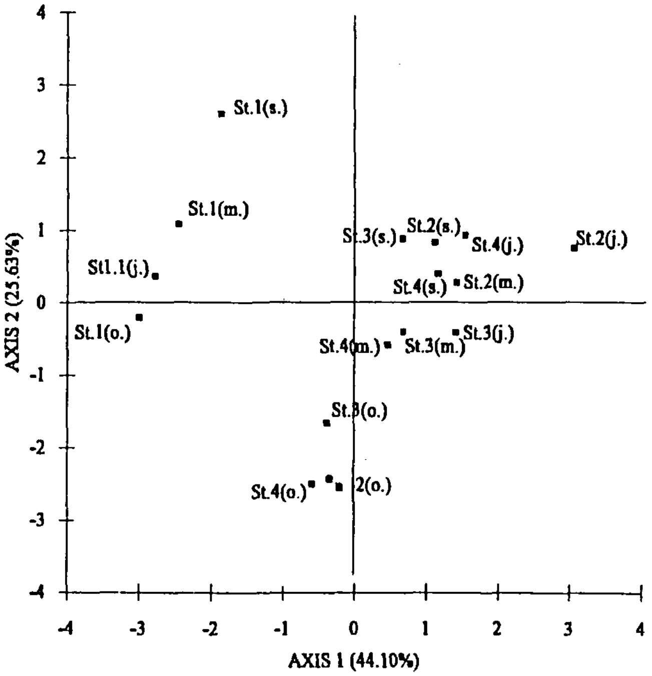

Fig. 2 - River Nera watershed: physico-chemical characterization of the samples according to first two axes of the PCA. (s.), September; (o.), October; (m.), May; (j.), July.

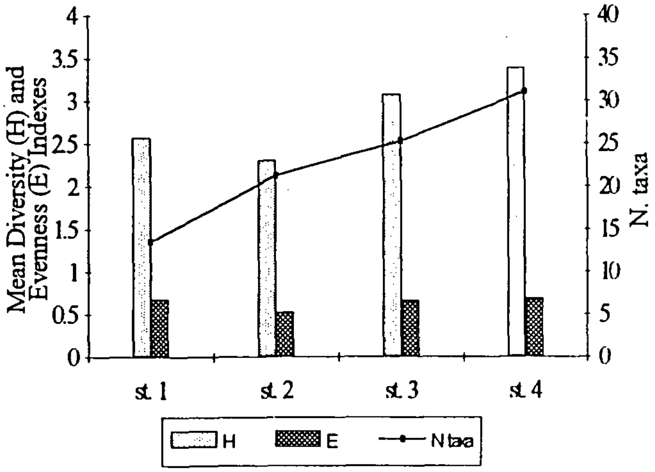

Fig. 3 - Number of benthic taxa, mean Diversity and Evenness Indexes at the sampling stations.

due to the characteristics of source environment. A total of 12 681 individuals was collected; 496 at St.1, 3827 at St. 2, 3936 at St. 3 and 4422 at St. 4. Mean values and the number of taxa (Fig. 3) increased from station 1 to station 4, except at station 2; mean H values followed the same trend. Mean E values were less variable and did not exceed 0.70 (St.1).

The dendrograms constructed by UPGMA (Figs 4, 5) method give a clear picture of the among mean values of biocenosis similarity and evidenced that qualitative interpretation (QS) is in agreement with quantitative interpretation (QS'). The maximum similarity value is recorded between stations 3 and 4.

A synthesis between biotic and abiotic data is obtained from the correspondence analysis on the environmental parameter matrix (Fig. 6). Axis 1 (72%) emphasizes that station 1 is associated with dissolved oxygen and the other three stations with permanent hardness, organic matter and number of taxa. Axis 2 (27%) reveals that station 2 is associated with organic matter and permanent hardness, and station 4 with the number of taxa and the Diversity Index.

Trophic-functional analysis of the benthic populations at the study sites identified five functional groups: shredders (Sh), scrapers (Sc), filtering collectors (FC), gathering collectors (GC) and predators (P) (Fig. 7). The mean values show that shredders reached their peak at St. 2, scrapers at St. 3, gathering collectors at St. 1 and St. 4, filtering collectors at St. 3, and predators at St. 3. In contrast, there was little variation in the mean among station values of predators; no filtering collectors were detected at St. 1.

ANOVA applied to transformed data (Table IV) revealed significant differences among the four stations only in the mean percent values of shredders and filtering collectors. The Tukey test revealed a highly significant difference among the mean values for shredders at station 2 *versus*

TABLE II - *Means and standard deviations (± SD) of physico-chemical data obtained at the four sampling stations in the water system of the River Nera.*

Stations	Air temp. (°C)	Water temp. (°C)	Temperature hardness (Fr.dgr.)	Permanent hardness (Fr.dgr.)	Dissolved oxygen (mg/l)	Organic matter (mg/l)	Reduced matter (mg/l)
St. 1 - River Nera	19.00±2.00	8.25±0.50	10.25±0.96	3.50±0.58	11.76±1.11	0.41±0.32	2.48±1.99
St. 2 - River Sordo	20.00±5.48	13.25±1.26	15.25±3.77	14.00±2.31	10.38±1.48	1.32±0.77	2.84±2.03
St. 3 - River Corno	19.38±5.62	12.88±0.85	15.75±1.50	10.25±1.26	9.61±2.71	0.98±0.28	3.02±1.36
St. 4 - River Nera	20.00±6.48	13.25±0.96	15.75±2.63	10.00±1.15	9.56±0.91	0.94±0.51	2.75±2.22

TABLE III - *Macrobenthos taxa of the sampling stations.*

Taxa	F.F.G.	st.1	st.2	st.3	st.4
Planorbis sp.	Sc	.	+	.	+
Ancylus fluviatilis	Sc	.	.	+	+
Lumbricidae indet.	GC	.	+	+	+
Lumbriculidae indet.	GC	+	+	.	+
Tubificidae indet.	GC	.	+	+	+
Erpobdella actoculata	P	.	+	.	.
Helobdella stagnalis	P	.	+	.	+
Haemopis sanguisuga	P	.	.	.	+
Dina lineata	P	+	+	.	+
Aseullus aquaticus	Sh	.	+	+	+
Gammarus sp.	Sh	.	+	+	+
Baetis rhodani	Sc	+	+	+	+
Baetis sp.	Sc	+	+	+	+
Epeorus sylvicola	Sc	.	.	+	.
Epeorus sp.	Sc	.	.	+	.
Rhithrogena sp.	Sc	+	+	+	+
Ecdyonurus sp.	Sc	+	.	+	+
Heptageniidae indet.	Sc	.	.	.	+
Ephemerella ignita	GC/Sc		+	+	+
Caenis sp.	GC	.	.	.	+
Habroleptoides confusa	GC/Sc	.	.	.	+
Habroleptoides sp.	GC/Sc	.	.	+	+
Ephemera danica	GC	.	.	.	+
Amphinemura sulcicollis	Sh	+	.	.	.
Nemoura sp.	Sh	+	+	.	.
Protonemura ausonia	Sh	+	.	.	.
Protonemura sp.	Sh	+	.	.	+
Leuctra leptogaster	Sh	.	.	+	.
Leuctra sp.	Sh	.	.	+	+
Isoperla sp.	P	+	+	.	.
Dinocras cephalotes	P	+	+	+	+
Perlidae indet.	P	.	.	.	+
Haliplus sp.	Sc	.	.	.	+
Oreodytes sp.	P	.	.	.	+
Ilybius sp.	P	.	+	.	+
Elmis sp.	Sch/Sh	+	+	+	+
Limnius sp.	Sc/Sh	.	+	+	+
Rhyacophila dorsalis subacutidens	P	+	+	+	+
Rhyacophila foliacea	P	+	+	+	+
Rhyacophila sp.	P	+	.	+	.
Catagapetus nigrans	Sc	+	.	.	+
Agapetus nimbulus	Sc	.	.	.	+
Hydropsyche modesta	FC	.	.	+	.
Hydropsyche pellicidula	FC	.	+	+	+
Hydropsyche spiritoi	FC	.	+	+	+
Hydropsyche sp.	FC	.	+	+	+
Micrasema setiferum dolcinii	Sc/Sh	.	+	+	+
Mirasema sp.	Sc/Sh	+	.	+	+
Plectrocnemia geniculata	FC	.	+	.	+
Drusus camerinus	SC	+	.	.	.
Potamophilax cingulatus	Sh	+	.	.	.
Halesus appenninus	Sh	.	+	.	.
Allogamus ausoniae	Sh	.	+	+	.
Chaetopteryx gesneri tomaszewskii	Sh	.	.	.	+
Lasiocephala basalis	Sh	.	.	+	.
Sericostoma italicum	Sh	.	+	+	+
Sericostoma pedemontanum	Sh	+	+	.	+
Sericostoma sp.	Sh	.	.	+	.
Odontocerum albicorne	Sh/P	.	+	+	+
Tipula sp.	Sh	+	.	+	+
Tipulidae indet.	Sh	+	.	.	.

(continued)

Taxa	F.F.G.	st.1	st.2	st.3	st.4
Limoniidae indet.	P	+	.	+	.
Psychodidae indet.	Sc	+	.	.	.
Simuliidae indet.	FC	.	+	+	+
Procladius sp.	P	.	.	+	+
Natarsia sp.	P	.	+	+	+
Tanypodinae indet.	P	.	.	.	+
Diamesina sp.	GC	.	.	.	+
Prodiamesia olivacea	GC	.	.	.	+
Orthocladinae indet.	GC	+	+	+	+
Microtendipes sp.	GC	.	.	.	+
Polypedilium sp.	GC	.	+	+	+
Dicrotendipes sp.	GC	.	+	.	.
Einfeldia sp.	GC	+	.	.	.
Chironomus sp.	GC	.	.	.	+
Chironomini indet.	GC	+	.	.	.
Tanytarsus sp.	GC	.	.	+	.
Micropsectra sp.	GC	+	+	+	+
Cladotanytarsus sp.	GC	+	.	.	.
Chironomidae indet.	GC	+	+	+	+
Ceratopogonidae indet.	Sh	.	.	.	+
Empididae indet.	P	.	.	+	.
Atherix ibis	P	.	.	+	+
Total taxa		31	38	44	58

F.F.G. (functional feeding groups): Sh, shredders; Sc, scrapers; P, predators; FC, filtering collectors; GC, gathering collectors.

stations 3 and 4, and among station 1 and stations 2, 3 and 4 for filtering collectors. The correspondence analysis confirms these relationships (Fig. 8). Axis 1 (61%) indicates a positive correlation with station 2 and shredders, but negative correlation with station 3 and station 4. Axis 2 (34%) shows a negative correlaction with filtering collectors, but a positve one with station 1.

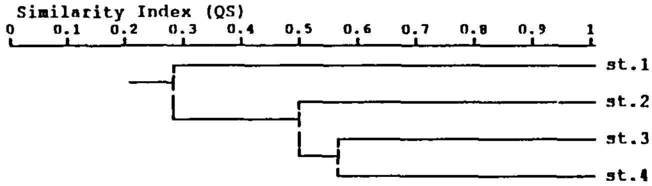

Fig. 4 - Cluster analysis dendrogram (UPGMA method) based on the Sorensen Index (QS): qualitative interpretation.

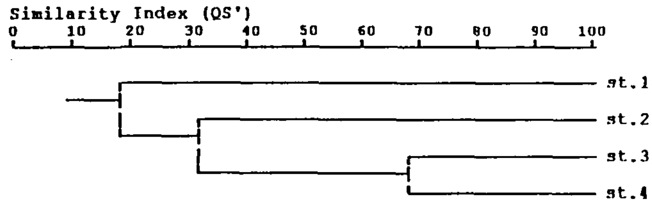

Fig. 5 - Cluster analysis dendrogram (UPGMA method) based on modified Sorensen Index values (QS'): quantitative interpretation.

TABLE IV - *ANOVA of means of arcsin-transformed percent values.*

	St. 1	St. 2	St. 3	St. 4	F	P
Sh**	24.21%	34.12%	16.26%	14.78%	6.39	0.0078
Sc	20.56%	11.76%	27.86%	21.14%	1.84	0.1935
GC	32.52%	23.17%	16.65%	30.54%	1.35	0.3050
FC**	0.00%	13.08%	13.72%	11.05%	57.64	0.0001
P	22.71%	17.89%	25.52%	22.49%	0.51	0.6836

** P < 0.01

DISCUSSION

The four biotopes of the upper reaches of the River Nera yielded 83 benthic taxa. The benthic fauna collected contained 11 taxa that are endemic to Italy, seven of which are mainly limited to central Apennines: *Rhyacophila dorsalis subacutidens, Micrasema setiferum dolcinii, Drusus camerinus, Halesus appenninus, Allogamus ausoniae, Chaetopteryx gessneri tomaszewski, Sericostoma italicum*, and four with a wider distribution: *Protonemura ausonia, Rhyacophila foliacea, Catagapetus nigrans* and *Hydropsyche spiritoi* (Consiglio, 1971; Cianficconi & Moretti, 1989). The greatest number of taxa, as well as the highest H index values, were recorded at station 4 on the River Nera, except during the period of marked turbulence in July 1990. Because of the preponderance of *Gammarus* (about 45%) and *Ephemerella ignita* (about 21%), H and E values were lowest at station 2 on the River Sordo.

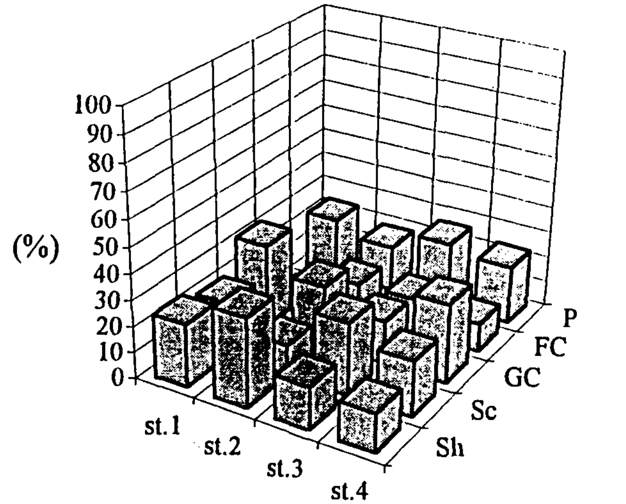

Fig. 7 - Mean percent values of functional feeding groups at the sampling stations. Sh, shredders; Sc, scrapers; P, predators; FC, filtering collectors; GC, gathering collectors.

Taken together, the biological (Table III, Fig. 3) and physico-chemical data (Table II, Fig. 2) not only provide evidence that the study area environment is not altered by organic pollution, but also supply certain general indications on zonal and river continuum models in the upper reaches of a water corse.

The fact that the benthic communities of station 3 (River Corno) and station 4 (River Nera) manifested the

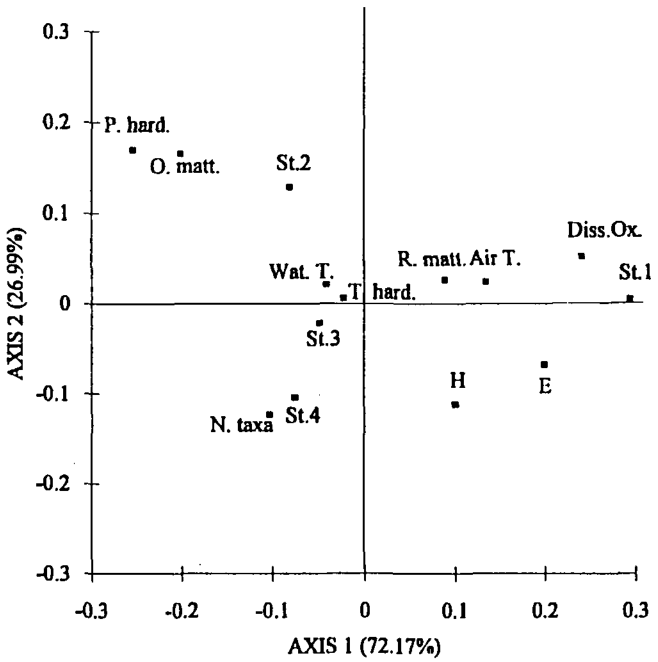

Fig. 6 - Correspondence analysis of the environmental parameters according to the first two axes.

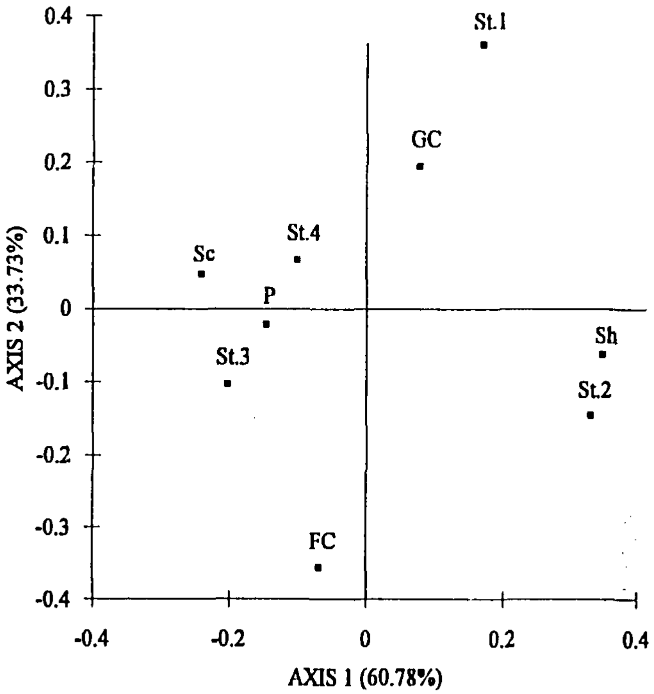

Fig. 8 - Correspondence analysis of the mean values of functional feeding groups and sampling stations.

highest QS and QS' similarity value (Figs 4, 5) reflects their shared fluvial typology (*metarhithral*). The identification of another fluvial typology (*epirhithral*) at station 2 (River Sordo) was due to its proximity to the source. Station 1 (source of River Nera) proved to be well distinguished from the other three stations, in that the biotic community included species that are typical of source environments (*crenal*) (Consiglio, 1971; Moretti & Mearelli, 1981), particularly: *Protonemura ausonia, Drusus camerinus* and *Catagapetus nigrans. Catagapetus nigrans* was also found together with *Chaetopteryx gesneri tomaszewkii*, another source taxon, at station 4 where the input of small springs gave rise to microhabitats with increase of species richness over that of other *metarhithral* zones. This interpretation is supported by the correspondence analysis reported in Figure 6 where it will be seen that in axis 1 there is separation between station 1 and the other stations, while in axis 2 there is separation between station 2 and stations 3 and 4.

Trophic relationship analysis on the basis of estimated abundance (Table IV, Figs 7, 8) revealed that, because of the large shredders component, station 2 once again differed from stations 3 and 4. The structural composition of station 2 biocenosis suggests that it is influenced by a greater trophic input of course particulate organic matter (CPOM) (Cummins *et al.*, 1984). The marked variations in the distribution of filtering collectors between station 1 and the others stations are probably accounted for by the paucity of the load of suspended fine particulate organic matter (FPOM) in the source biotope. There were no significant differences among the four stations for the trophic categories of gathering collectors, scrapers and predators. However, since they do not depend on the particulate size of the available organic matter, the mean value of predators remained reasonably constant at around 20%. These findings indicate that filterings, collectors and shredders define the trophic dynamics in this section of the basin, as they do in the upper basin of the River Tiber (Goretti *et al.*, 1995).

The changes in functional organization of macroinvertebrate communities from upstream to downstream in the River Nera watershed agree with the predictions of the river continuum model (Hawkins & Sedell, 1981).

Comparison between functional trophic analysis and fauna composition gives concordant results for the filtering collector category and, by inference, reveals a marked difference in the quantity of suspended FPOM in the *crenal* and *rhithral* zones. The analysis exposes a similar difference for shredders with respect to CPOM in the *rhithral* zone.

The application of the zonal and clinal patterns adopted in our investigations gives results that are not in contrast (Ward *et al.*, 1994). In fact, a weak upstream to downstream gradient is found even within single fluvial zones. As faunistic communities may vary significantly when the abiotic gradient changes suddenly, a discontinuity can be found even in contiguous tracts (Perry & Schaeffer, 1987).

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