Trophic niches in an Argentine pond as a way to assess functional relationships between fishes and other communities

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Abstract

The goal of this study was the identification of trophic niches of several fish species and, consequently, the differentiation of habitats in terms of to diet components, seen as an indirect way of linking predators as a function of prey to the various limnological communities.

Samples of digestive tracts from 11 fish species captured in 1992 at Güemes Pond (Azul, Argentina) were analysed. Fifty-four food items were identified, which were grouped as 18 variables. Multivariate techniques were used to analyse the data.

Four groups of samples were segregated on the basis of their associated communities:

- piscivorous species: *Hoplias malabaricus* and adults of *Oligosarcus jenynsii;*
- phytoplankton-periphytophagous species: *Bryconamericus iheringhi, Cheirodon interruptus* and *Cyphocharax voga*;
- zooplanktophagous species: *Odontesthes bonariensis*; and
- zoobenthiphagous species*: Rhamdia sapo, Astyanax eigenmanniorum*, juveniles of *O. jenynsii, Corydoras paleatus* (with incursions to the zooplankton), and *Loricarichthys anus* (with incursions to the phytoplankton-periphyton). *Cichlasoma facetum* exhibits a general, opportunistic diet.

Introduction

Traditionally, fishes were considered to be part of the nekton (Wetzel, 1975; Schäfer, 1985), even if they did not make up a functional entity. Although their swimming ability allows them to move throughout the environment, many fishes present morphological, physiological and behavioral differences which indicates that their niches are diverse (Ringuelet, 1975; Gatz, 1979; Hartney, 1989; Jachner, 1991; Winemiller, 1992).

As a way to decrease the interspecific competition for food, and related to the food supply, the segregation of trophic niches of the nekton species involves a differentiation of habitats based on the preyed-on community (Nilsson and Northcote, 1981; Flecker, 1992; Schiemer and Wieser, 1992; Dörgeloh, 1994). Their members establish stronger relationships with other aquatic communities, which allows building up links in ecological terms.

That would imply the disaggregation of the nekton community when looking at closer links between each species and the food-source community. Such a relationship is much more consistent than that given when comparing fishes in terms of typological similarities. The neotropical ichthyographic region, with its high diversity of species (Eigenmann, 1907; Ringuelet, 1975), appears to be a plausible scenario for testing the appropriateness of such a hypothesis.

The trophic niche of each species can be depicted by the identification and quantification of the diet components found in their digestive tracts. Fish diet features are usually studied by describing the food items found (up to the lowest taxonomical level attainable), by calculating the frequency of each item or the volume occupied, etc. (Hynes, 1950; Hellawell and Abel, 1971; Windell and Bowen, 1978; Berg, 1979; Hyslop, 1980; Bowen, 1984). In general, results were presented in a very descriptive manner using a simple statistical treatment, which hindered achieving an integrated view on how the system functions.

Given such shortcomings, multivariate analysis techniques are believed to be able to integrate the information of all variables belonging to the trophic niche (Hughes, 1985). Despite the loss of information embedded in those techniques, they set up an objective basis for the discrimination of the various functional groups of variables-samples clusters. Such techniques, many times used and discussed (Wartenberg et al., 1987; Peet et al., 1988; Jackson and Somers, 1991), have been employed in the analysis of fish diets (Graham and Vrijenhoek, 1988; Rice, 1988; Baltanás and Rincón, 1992, to note a few papers). By making use of multivariate analysis techniques, the sequential objectives of this paper are to identify the trophic niches of the eleven fish species found in a typical pond environment and to relate the predator to the prey community.

Materials and methods

The fish specimens were captured at Güemes Pond (36°50' S, 59°50' W), in Azul City, Argentina, which has a surface area of 2.5 ha with a mean depth of 1.5 m. Different gear was used (seine nets and gill nets) between August and November 1992, subsampling at least 10 specimens for each of the 11 species identified (Table 1). Season-dependent variations were not considered because the data were collected mostly during spring (September 21 to December 21 in the southern hemisphere). The digestive tracts were fixed in 5% formaldehyde. The contents of the tracts were spread over Petri dishes and identified/counted with either magnifying glass and/or microscope. The food items were determined at different taxonomic levels so as to assess the prey's original community (Table 2). The relative abundance was classified into six categories: very abundant, abundant, common, scarce, very scarce, and absent, which were coded from 5 to 0, respectively. The relative abundance is a variable that integrates the number and the volume of food items, thereby giving an idea about their importance with respect to the fishes' diet. Due to the high number of zero values, which hinders the statistical treatment (Baltanás and Rincón, 1992) and the noise that variables with low relative frequency introduce in the data matrix, the 54 originally identified food items were grouped and reduced to 18

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TABLE 1
SPECIES IDENTIFIED, NUMBER OF SPECIMENS (N) AND STANDARD LENGTH RANGE OF THE SAMPLES (SL)

Species	Number (N)	SL(mm)
Characidae		
Astyanax eigenmanniorum	10	41 - 61
Bryconamericus iheringi	10	48 - 56
Cheirodon interruptus	10	29 - 46
Oligosarcus jenynsii	10 (5*)	56 - 224
Cichlidae		
Cichlasoma facetum	16	33 - 101
Erythrinidae		
Hoplias malabaricus	10	283 - 356
Loricariidae		
Loricarichthys anus	10	279 - 367
Callichthyidae		
Corydoras paleatus	10	45 - 61
Pimelodidae		
Rhamdia sapo	10 (5*)	78 - 272
Atherinidae		
Odontesthes bonariensis	29	165 - 281
Curimatidae		
Cyphocharax voga	10	171 - 210

* juveniles of the species included.

variables (Table 2). Groups were defined by assuming that they belong to a given limnological community and keeping in mind their systematic affinity.

The above-mentioned data matrix was the input for correspondence analysis (David et al., 1977; Greenacre, 1984). In order to compare the results emerging from correspondence analysis (CA), Q-mode principal component analysis (PCA) was also used (Harman, 1976; Jeffers, 1978; Crisci and López Armengol, 1983).

Results and discussion

Correspondence analysis

The first factor (23.9% of variance explained) clearly separates those samples related to an ichthyophagic diet, where the 'fragments of fishes' variable is very well represented and mapped with an absolute contribution of 96% and a relative contribution of 99%. Specimens linked to such a diet correspond to *Hoplias malabaricus*, adults of *Oligosarcus jenynsii*, and - to a lesser degree - *Odontesthes bonariensis* (Fig. 1).

Factor 2 (14.32% of variance accounted for) defines the grouping of variables (Fig. 2) related to phytoplankton and periphyton (Table 2). Because of difficulties in trying to distinguish organisms which make up those communities, they have been considered as a functional unit of the ecosystem, with its predators labeled as primary consumers (although not exclusive ones). The inclusion of 'Rotifera' and 'Protista' in this functional unit was suggested by the relative contributions of Factor 1 and 2 to those variables. Samples related to this unit correspond to *Bryconamericus iheringi*, *Cheirodon interruptus* and *Cyphocharax voga*. At the other extreme of Factor 2, variables which clearly represent the zooplankton prevail, such as 'Bosminidae' and 'Copepoda', with associated samples of *O. bonariensis*. A variable linked to the neuston -'Diptera adults'- also contributes to the appearance of Factor 2.

Around the origin of the second factor there are several samples and variables which are desegregated by Factor 3 (10.61% of variance explained). This group is characterised by food items such as 'Chironomidae larvae' and 'Insecta fragments', which can be assigned to the benthic community. Samples related to such a group are not as clearly defined as those mentioned above. They could be taken as zoobenthiphagous, although with an ample trophic niche because of overlap with the zooplankton as well as with the phytoplankton-periphyton.

Therefore, in the space of Factors 2 and 3 (Fig. 2), samples and variables spread up in a U-shape. On one side, variables related to the phytoplankton-periphyton and primary consumers are plotted, whereas at the other extreme zooplankton which overlaps with the neuston are found. Variables associated with the benthos and zoobenthos species plot around the center zone. The dispersion of *Cichlasoma facetum* samples suggests a generalistic-opportunistic diet with a large trophic niche. The '*Coelosphaerium*' variable plots at the center of the Factor 2-Factor 3 space. This alga blooms recurrently in the pond and constitutes an important food supply to all species considered, except the piscivores, although its digestibility is largely unknown. It was not included with other 'Cyanophyta' as part of the phytoplankton-periphyton because that would mask the segmentation of the trophic niches postulated for the predator species.

Q-mode principal component analysis (CA)

This technique confirms the interpretation of the analysis presented above. The distribution of samples along the first three principal components does not differ significantly from that achieved by considering Factors 2 and 3 of CA.

Principal Component 1 (22.60% of variance explained) takes care of samples of *B. iheringi*, *Ch. interruptus* and *C. voga* and partly of *C. facetum*, whereas Principal Component 2 (19.84% of variance accounted for) isolates samples of *O. bonariensis* and *Corydoras paleatus* (Fig. 3).

Based on those results, a given diet type was assigned to those groups of samples: the first one refers to the primary consumers (phytoplankton-periphytophagous), whereas the second group corresponds to zooplanktophagous. The group of zoobenthiphagous species (samples of *Rhamdia sapo, Astyanax eigenmannorium, C. paleatus, Loricarichthys anus*, juveniles of *O. jenynsii* and some *C. facetum*) are segregated by Principal Component 3 (10.93% of variance explained), as seen in Fig. 3.

This sample grouping is in agreement with that obtained with CA: the isolation of *C. bonariensis* as the main zooplanktophagous species, the identification of phytoplankton-periphytophagous and zoobenthiphagous species, with incursions to the phytoplankton-periphyton (*L. anus* and *C. facetum*). Differences with results from CA are mainly given by the lack of segregation of specimens with an ichthyophagic diet, but with a better identification in the zoobenthiphagous group.

The conclusions drawn about the trophic niches of each species studied in some cases do not agree with those of surveys in other ponds in the region (Ringuelet et al., 1980; Escalante, 1982; 1983a; 1983b). That can be explained by reference to differences

TABLE 2
GROUPING OF FOOD ITEMS (VARIABLES: NUMBERED AND HIGHLIGHTED) FOUND IN THE DIGESTIVE TRACTS AND COMMUNITIES THEY HAVE BEEN ASSIGNED TO

	Phytoplankton-periphyton
1	**Protista**: *Paramecium* (Cl. Ciliata), *Phacus* and *Euglena* (Cl. Euglenophyceae), and *Peridinium* (O. Peridiniales - SubCl. Dinoflagellatae).
2	**Chlorophyta**: *Pediastrum, Kirchneriella, Oocystis, Scenedesmus, Crucigenia, Coelastrum, Tetraedron, Botryococcus, Ankistrodesmus, Dictyosphaerium, Actinastrum* (O. Chlorococcales), *Staurastrum, Closterium* and *Cosmarium* (Fam. Desmidiacea - O. Zygnematales).
3	**Cyanophyta**: *Chroococcus, Gloeocapsa, Aphanocapsa, Merismopedia, Microcystis* (O. Chroococcales), and *Spirulina, Phormidium, Anabaena* and *Calotrix* (O. Hormogoniales).
4	**Diatoms**: Cl. Bacillariophyceae.
5	**Algae of periphyton**: *Chamaesiphon* (O. Chamaesiphonales - Div. Cyanophyta), *Characium* (O. Chlorococcales), *Mougeotia* (Fam. Zygnematacea - O. Zygnematales), *Oedogonium* (O. Oedogoniales - Div. Chlorophyta), *Tribonema* and *Ophiocytium* (Cl. Xanthophyceae).
6	**Rotifera**: Cl. Rotifera.
	Benthos
7	**Plant rests**: seeds and fragments of macrophytes.
8	**Microcrustaceans of benthos**: Fam. Chidoridae (O. Cladocera), O. Harpacticoida (SubCl. Copepoda), and SubCl. Ostracoda.
9	**Acari**: O. Acari (Cl. Arachnida).
10	**Chironomidae larvae**: larvae of Fam. Chironomidae (O. Diptera - Cl. Insecta).
11	**Insecta larvae**: larvae of O. Odonata and O. Diptera (Cl. Insecta).
12	**Fragments of Insecta**: O. Hemiptera, O. Homoptera, elytrons and fragments of aquatic adult insects, except wings of O. Diptera (Cl. Insecta).
	Zooplankton
13	**Bosminidae**: Fam. Bosminidae (O. Cladocera - Cl. Crustacea).
14	**Copepoda**: O. Calanoida and Cyclopoida (SubCl. Copepoda - Cl. Crustacea).
	Neuston
15	**Diptera adults**: wings and adults of O. Diptera (Cl. Insecta).
	Others (see text)
16	**Coelosphaerium**: *Coelosphaerium* (O. Chroococcales - Div. Cyanophyta).
17	**Palemonidae**: Fam. Palaemonidae (O. Decapoda - Cl. Crustacea).
18	**Fragments of fishes:** fragments of Cl. Osteichthyes.

in the food supply (hence, food demand) at the various sites, as well as to the influence of the variety of species present and its population density (Boisclair and Leggett, 1989). Such a versatility is mirrored by the low trophic fidelity of the species considered (Destéfanis and Freyre, 1972).

Conclusions

The interpretation emerging from the multivariate techniques used applies only to the communities mentioned, whereas others less relevant at Güemes Pond get masked. That would explain the rather diffuse composition of the zoobenthiphagous group. Nevertheless, benthos, phytoplankton, zooplankton, neuston and macrophytes, from a functional viewpoint, make up the principal communities which drive the energy flux of the system.

Correspondence analysis and Q-mode principal component analysis played a central role in finding relationships among fish species and limnological communities.

Specific conclusions are as follows:

- *H. malabaricus* and adults of *O. jenynsii* have ichthyophagic diets (they should be linked to the respective preyed-on fishes);
- *B. iheringi, Ch. interruptus*, and *C. voga* are species related to the phytoplankton-periphyton;
- *O. bonariensis* is the main species preying on the zooplankton;
- zoobenthos is preyed on by *R. sapo, A. eigenmanniorum*, juveniles of *O. jenynsii, C. paleatus* (with incursions to the zooplankton), and *L. anus* (overlapping with the phyto-

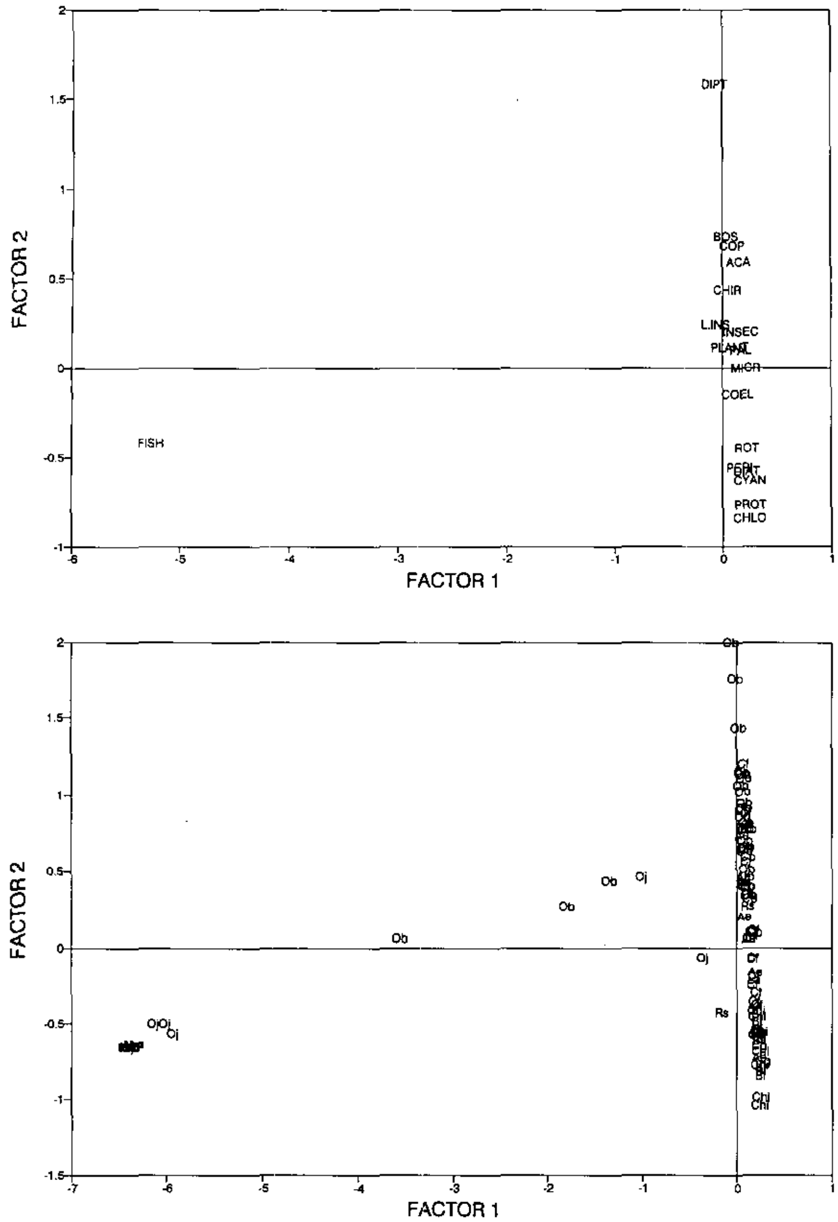

Figure 1
Results of correspondence analysis: distribution of variables (top) and samples (bottom) on Factor 1/Factor 2 space

plankton-periphyton);

- *C. facetum* behaves as a generalistic-opportunistic species;
- *O. bonariensis, H. malabaricus*, and *Ch. interruptus* are the species which have the most restricted trophic niche in Güemes Pond;
- *Coelosphaerium* sp., an alga that blooms frequently, is a food item common to most of the species considered, with the exception of the piscivores;
- the phytoplankton and the periphyton were not differentiated as different communities by the techniques employed;
- the nekton appears not to have identity as a community, given the much closer links among fishes and other communities of the ecosystem; and
- the trophic niche of each species varies as a function of the environment food supply.

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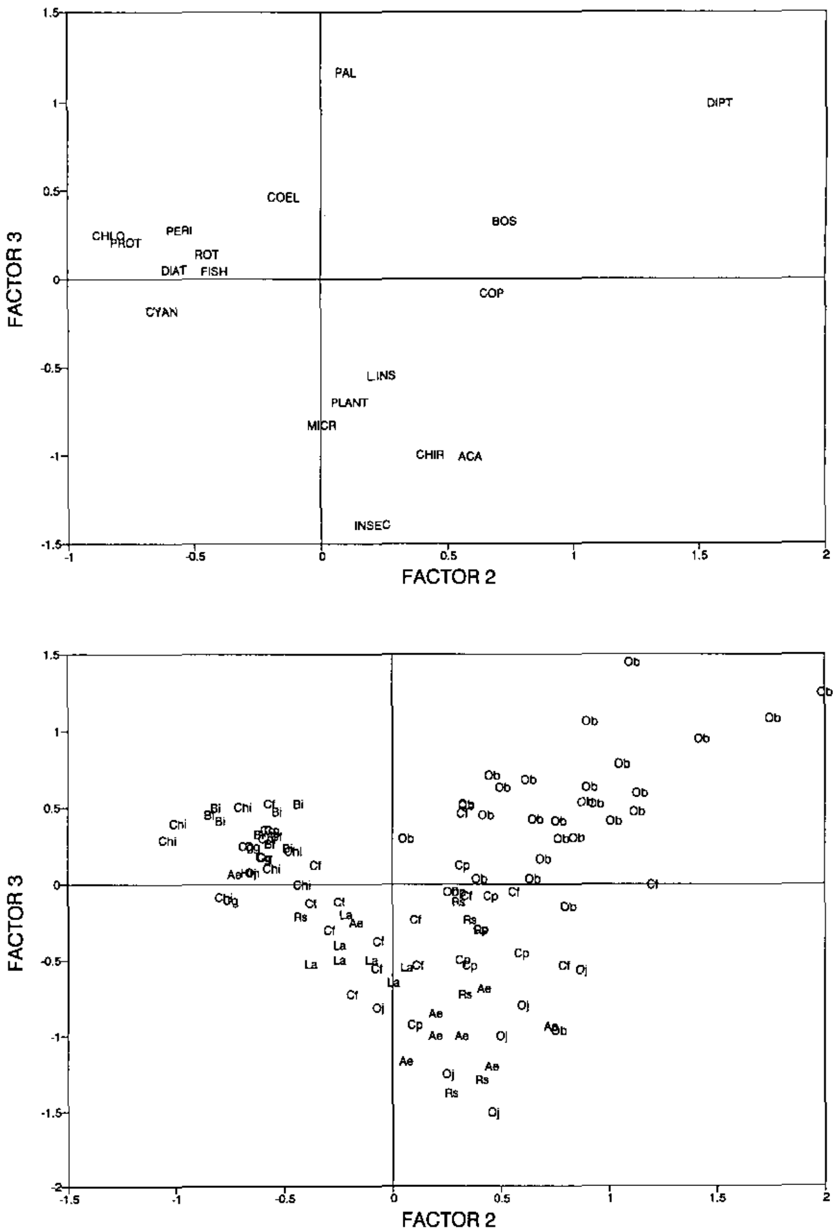

Figure 2
Results of correspondence analysis: distribution of variables (top) and samples (bottom) on Factor 2/Factor 3 space (note the U-shaped distribution)

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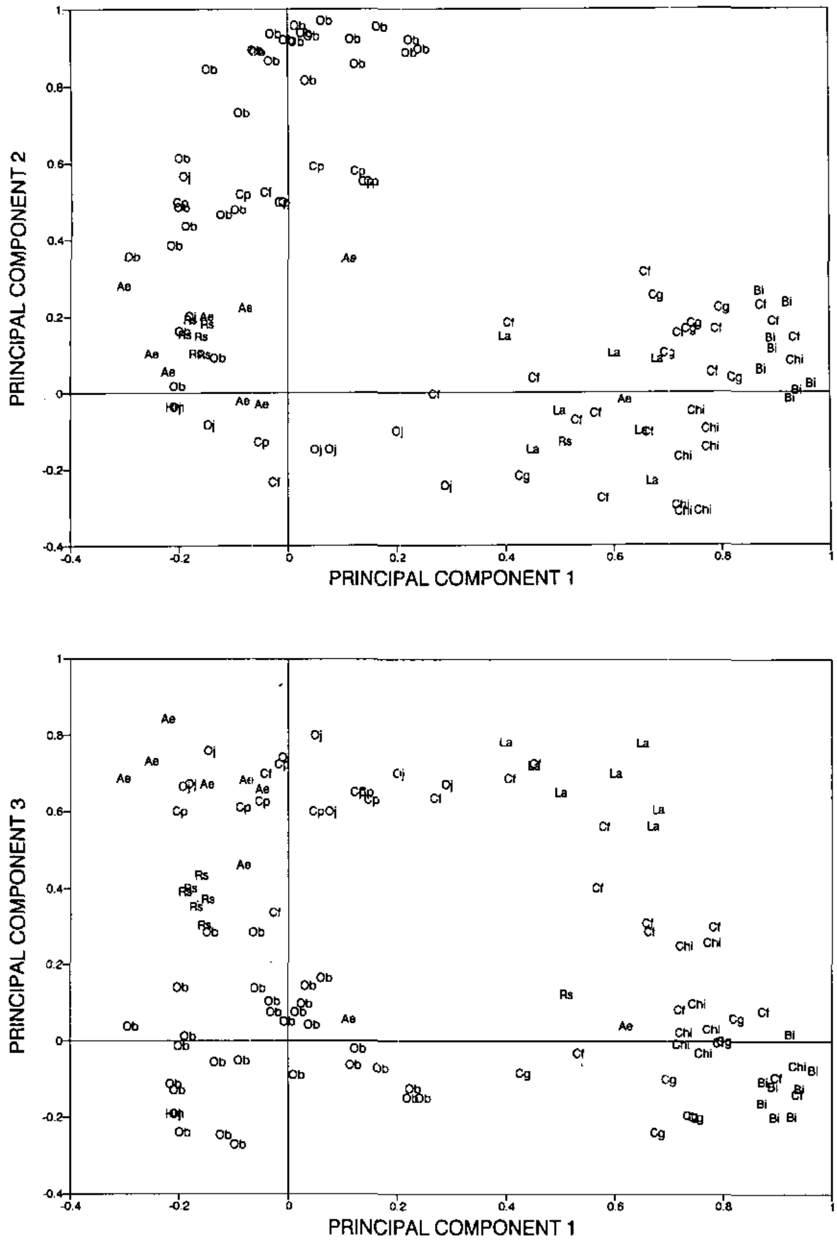

Figure 3
Results of Q-mode principal component analysis: samples on the Principal Component 1/Principal Component 2 space (top), and on the Principal Component 1/Principal Component 3 space (bottom)

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