Estuarine and mangrove systems and the nursery concept : which is which ? The case of the Sine Saloum system (Senegal).

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ABSTRACT

The mangrove system of Sine Saloum in Senegal is characterized by the lack of permanent river flow, in the context of the sahelian drought which began in the 70's. The main environmental consequence is that Sine Saloum has turned to a so called "reversed estuary" with salinity increasing upstream and reaching 100 ‰ and more, with a mean salinity between 45-50 ‰.

A three years survey of the juvenile fish community was undertaken with the aim to verify if this environment was still suitable as a nursery for exploited fish populations. The main sampling gear in use was small fyke-net in addition with gillnet and a limited rotenone sampling. One of the 6 mangrove stations included in the survey clearly exhibits a higher species diversity. This station is the only one where salinity can reach as low levels as 25 ‰ at the end of the rainy season although salinity is much higher in the upstream region near this station. Such a low salinity is supposed to be due to an underground freshwater connection or underwater springs.

This observation gives an opportunity to deal with the respective importance of estuary and mangrove in the nursery function.

RESUME.

Une caractéristique de la zone de mangrove du Sine Saloum au Sénégal est l'absence de cours d'eau permanent, ceci dans le contexte de la sécheresse qui sévit depuis les années 70. La principale conséquence au plan écologique est que le Sine Saloum a évolué en un estuaire inverse dans lequel la salinité augmente vers l'amont jusqu'à atteindre des valeurs de 100 ‰ et plus pour des moyennes variant entre 45 et 50 ‰.

Un programme de suivi du peuplement de juvéniles de poissons a été mené pendant trois années dans le but de vérifier si le système continue de jouer un rôle effectif de nursery à l'égard des espèces exploitées. L'engin principal utilisé pour l'échantillonnage était la nasse complétée par des filets maillants ainsi qu'un échantillonnage limité à l'aide de la roténone. L'une des 6 stations que comportait le programme d'échantillonnage présente une diversité spécifique nettement supérieure. Cette station est la seule pour laquelle des niveaux de salinité relativement bas, jusqu'à 25 ‰, sont notés en fin de saison des pluies bien que les zones amont proches de la station présentent des salinités plus élevées. Une hypothèse pour expliquer ces salinités basses serait l'existence d'un affleurement de la nappe phréatique ou de sources sous-marines.

Une telle observation fournit l'opportunité d'examiner les rôles respectifs des estuaires et de la mangrove dans le contexte du concept de nursery.

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INTRODUCTION

The estuarine and mangrove systems are widely recognized as good nursery grounds for young fishes of exploited populations (Miller J. M et al.,1983; Ross and Epperly, 1985; Day and Deegan, 1988; Little et al., 1988; Blaber *et al.*; 1989; Potter *et al.*; 1990...). In most of the cases when mangrove is present, it is associated with "true" physico-chemical estuarine conditions, that is to say under conditions where freshwater is provided in such amount that the environment is brackish most of the time (Sasekumar et al., 1992; Tzeng and Wang, 1992). In such a situation, the respective roles of estuary and mangrove are far to be clear. Beside, estuaries without any mangrove formation can also be fairly good nurseries (Ruiz *et al.*, 1993). The Sine Saloum system exhibit a quite uncommon example of a mangrove system with little if no freshwater input except by direct rain or by ground water (Pagès and Citeau, 1990). The mangrove system is then the main feature of this "inverse estuary". The consequences on the diversity of fish populations in the inner mangrove creeks and especially the diversity of the young fish community are here described and discussed in the scope of the question : "What are the respective importance of the estuarine or the mangrove conditions in the nursery?"

THE SINE-SALOUM SYSTEM

The Sine Saloum is a mangrove system located in Senegal, West Africa. The main characteristic is the lack of freshwater inputs for a long time. This results in a so-called inverse estuary (Pritchard, 1967) with salinity usually greater than that of seawater (table n° 1.). The whole region is to 800 km² in area. Three main channels, Saloum, Diomboss and Bandiala (from north to south) cross this region from the sea in a northern-eastern direction (fign°1). Many small seawater creeks (locally named "bolongs") penetrate through the inner mangrove forest. The area near the sea (about one third of total surface) is covered with mangrove, mainly *Rhyzophora* and *Avicenia*, except on the northern bank of the Saloum channel. A detailed description can be found in Diouf (1996).

SAMPLING GEARS, STRATEGY AND METHODS

A two years survey of the young fishes community was undertaken, after a one year period of methodological and sampling gear adaptation. The main gear was a small fyke-net 2.5 m. long for a 0.40 m. in diameter. This net was provided with two small wings 1.5 m. and a 4 m. long leader (or wall) to conduct the fish to the trap. The mesh of the net was 6 mm (mesh side) for the leader, the wings and the first half of the fyke-net and 3 mm for the second half. The larger mesh for the first half was chosen to make the net less threatening for young fishes (after a personal observation on grey mullet fry).

After the testing period, it was decided to sample during flow at night as daytime fishing leads to unsuccessful catch, assuming that fishes enter the mangrove small channels at night with raising tide (Robertson and Duke; 1987 cited in Blaber, 1997). In order to control as much as possible the sampling conditions, only six nights per month are suitable because of everyday delay in time of full tide. This choice places the monthly sampling during the new moon phase.

It was decided to only sample the mangrove area with two other choice criteria : the distance to the sea and the northern-southern repartition according to the three main channels. (table n° 2. and fig. n° 1). Two successive sampling strategies have been used. During the first year, three sampling sites (Dioto, Juv1 and Juv3, see map) were fished during two successive nights with four nets, giving an eight samples set by site and month in an attempt to control sampling variability. This period was dedicated to the characterisation of the seasonal variations in juvenile fish community. The "next year", six sampling sites (adding Likitt, Mounde and Guilor, fig n°1) were sampled during one night with six nets. This second strategy was decided to obtain a more detailed approach of the spatial repartition of juvenile fish.

For each sampling date, temperature and salinity were measured around 8.00 am. Transparency was not measured according to the fact that it was frequently over the depth on sampling sites (i.e. over 1 meter)

The data from the entire list of species were used to calculate the diversity for each station during the two sampling seasons. Shannon's index was calculated for a prior approach of this question

For the multivariate analyses, species or groups were selected with an occurrence criterion of 1/10 of the sampling units (whole catch on a one night and site unit) in the overall original data (annexe table). This results in 34 taxonomic groups which were utilised for all the analyses even if some sampling dates and sites had to be remove in the successive stages of the treatment because of their excessive variability. The list of these selected "species" is given in table n° 2.

In order to get an even sampling effort for all sites, the sampling results for the February 1996- January 1997 period where all sites are represented, have been selected. The sample from Dioto on March 1996 was excluded because of an exceptional abundance of the LAR group (larvae are with high probability from *Pellonula leonensis*).. January, May and October, were devoted to rotenone sampling and do not appear in this analysis.

This set of data was processed by Factorial Analysis to describe the structure of the community and its spatial organisation. Then the same data set was submitted to a Canonical Correspondence Analysis or Factorial Correspondence Analysis on Instrumental Variables (Lebreton *et al.*, 1988) to look for the influence of variables. The explicative variables chosen are salinity, temperature, distance to the sea and bio-climatical seasons. As qualitative and quantitative variables are used at the same time, quantitative variables are distributed in classes, three classes for salinity, temperature and distance to the sea (table n° 4). The climatic seasons were added with a "bio-climatic season" which groups the October to December months. A previous analysis based on the monthly repartition of all sampling site except Dioto (in preparation), showed that the coldest months of January, February and March exhibit a particular community structure. The "new" season was qualified as the post-rainy season (PH). It is characterised by salinity and temperature of intermediate values. The community structure during this season is similar to that of the rainy season. The matrix of repartition of the variables was submitted to a Multiple Correspondence Analysis.

RESULTS

Hydro-climatical observations.

Here are reported the hydro-climatic data gathered in each sampling site during thestudy . Figure n° 2 gives an overview of the salinity and temperature seasonal variations.

Water salinity may vary between 25 ‰ and 50 ‰ from late rainy season (October) to the end of the dry season (April or May). There is a clear difference between Dioto and the other sampling sites as it exhibits the lowest salinity. It is the only site where values below sea water salinity are observed every year. The differences with the less saline station after Dioto are of 8.6, 7, and 7 ‰ in October 1994, October 1995 and November 1996 respectively. The absolute highest salinity measured in this station is 43 ‰ in May 1996, 7 ‰ under the maximum salinity noted at the same date.

The 10°C range of seasonal temperature variation can be of some importance for young or small fishes inhabiting those shallow mangrove creeks. Beside, this range of variation can affect the productivity and then have some consequences on the young fishes alimentation. No obvious difference can be noted between the different sampling sites.

The entire community

The table of the overall species sampled during the two years of observations showed 59 taxonomic units as fish (table in annexe). Some larvae, *Liza* and *Mugil* fry, *Gerres*, leptocephale larvae, young soleids were not identified at the species level. With some hypothesis on the possible identity of these unidentified fish, it can be assumed that 52 species were caught. The twelve most abundant taxa account for 90 % of the individuals caught. Most of these fish are juveniles (fig. n° 3 and table n° 2)

In first place, *Eucinostomus melanopterus* (Gerreidae) represents more than one third of the total. Almost all the individuals caught are juvenile fish with length between 9 and 80 mm (FL). *E. melanopterus* is classified as seaside spawner, owning to the Marine-Estuarine (ME) bio-ecological group according to the criteria from Albaret (1994). The presence of very young fry at some sampling places and the rapid appearing in all places are indices of a probable estuarine spawning in the particular ecological conditions of the Sine Saloum system. Elsewhere, in more classical estuarine ecological environment, *E melanopterus* is considered exclusively as a sea spawner (Albaret and Desfossez, 1988).

Following the dominant *E. melanopterus*, are found three species of similar abundance, between 11 and 8 % : *Pellonula leonensis* (Clupeidae), *Aplocheilichtys spilauchen* (Cypronodontidae) and *Sarotherodon melanotheron* (Cichlidae). *P. leonensis* is caught in both as juvenile and adult phases. It is an estuarine spawner but some populations in other parts of Africa can reproduce in freshwaters. For that reason *P. leonensis* belongs to the Estuarine from continental origin (Ec) bio-ecological group. *A. spilauchen* is a true estuarine species (Es), juvenile and adult phases are represented in the samples. *S. melanotheron*, a mouth-breeding tilapia, is very common in the mangrove area (probably under-estimated by the gear because of its great ability to avoid traps). This species is a member of the true Estuarine group (Es). *S.melanotheron* is frequently caught as adult except when some breeding male brings very young larvae in the net with it.

In the fifth position is found *Ethmalosa fimbriata* (Clupeidae), an estuarine spawner from marine origin (Em). The individuals caught are mostly juvenile fishes. Then come *Atherina sp* (Atherinidae) and *Psettias sebae* (Monodactylidae). The first is a typical estuarine inhabitant, the second is an exclusive estuarine inhabitant (Es) very characteristic of the estuarine and mangrove habitats.

In the general description of the young fishes community, the mullets (*Liza* sp. and *Mugil sp.*) appear not to be dominant species as one could expect. There is probably a gear effect as the species of that family can be frequently observed by eye. Nevertheless, the mugilid species appears between the 11'th and the 23'rd position in the list . Most of *Liza sp.* (12'th) could *be L. falscipinnis* or *Liza dumerilii* as *L. grandisquammis* fry are easy to identify. *Mugil sp.* (22'nd) could be *M.curema* (quite common) or *M. bananensis* (less common). *M. cephalus* is not frequent in the region.

The species diversity and the spatial characteristics of the environment.

The Species richness and diversity

Table n° 3 gives the values of species richness and I_{sh} for each sampling site.

Species richness takes into account the estimated identity of non-identified groups (LAR, LIZ, MUG, IND, GER). The sampling effort is greater on the Dioto, Juv1 and Juv3 sites. This could cause a slight difference in the species richness but probably does not change the highest richness for Dioto. Nevertheless, the species richness for the three less sampled sites, Likitt, Mounde and Guilor, is quite the same than that of Juv1 and Juv3. This indicates that the bias would not be so important. The species richness vary between 22 and 43 species. Dioto has the better richness. It is followed by Juv1 and Likitt, the two stations near the sea. The species richness for Mounde and Juv3 are just below that of the two preceding stations.

I_{sh} is obviously higher in Dioto. This cannot be attributed to the distance to the sea as the two other sites nearest to the sea, Juv1 and Likitt, show values similar to those of more inland stations. The main difference between this site and all the others sites is the lowest salinity which can be notice (Tab n° 1 and fig. n° 2).

Only eight species are exclusively found in Dioto, all are rare species occurring with no more than two individuals. These are *Engraulis encrassicolus*, *Butis koilomatodon*, *Blennius sp.*, *Engraulis encrassicolus*, *Hemiramphus brasiliensis*, *Pseudotholithus elongatus*,., *Sphyraena* sp. and one Eleodrid species. Nine species or groups are absent from Dioto and represented elsewhere *Gobionellus occidentalis*, *Pomadasys incisus*, *P. rogeri*, Leptocephale larvae, Caranx sp. *Arius latiscutatus*, *Cynoglossus senegalensis*, *Dasyatis margarita* and *Yongeichthys thomasi*. Most of these species, when present, are only represented by juvenile fish except for G. *occidentalis*, *A.latiscutatus* and *D.margarita*.

The Community structure

The matrix in use for this part of the study has 46 observations for 34 species.

The Simple Factorial Analysis of the fish community shows clear difference between Dioto and all the other sampling sites. This difference is confirmed all the year long (fig. n° 5a). In this analysis, *Sarotherodon melanotheron*, *Hemichromis fasciatus* and *Eucinostomus melanopterus* are associated with the first axis with *Liza grandisquamis* and *Bostrychus africanus* as secondary species (fig. n° 5b). All these species except *E. melanopterus* are relatively well associated with Dioto station. *E. melanopterus* is positionned near the other sampling sites in a mid position which reflects its relatively wide distribution. *A.spilauchen* is associated with the second axis and nearest to the inland sampling sites. The species closest to *A. spilauchen* is *Liza falcipinnis*.

The Factorial Analysis on Instrumental Variables applied on the same data set with the matrix of the variables described in the methods paragraph. Table n° 5 shows the correlation coefficient of each variable with the first three axes which explain 76 % of the overall variability.

The first axis does not exhibit a clear linkage with a definite variable except with season. In this method, the first axis is obtained by a combination of the explicative variables that maximise the species variance. The second axis shows a great signification for salinity and a lesser one with distance (fig n°6). Salinity and distance to the sea are linked as salinity increases in the landward direction (Diouf, 1996). So there is some redundancy between the two variables even if they probably act in different ways on the community structure. Nevertheless, the distance to the sea is not a good explicative variable for the structure of the data table examined . This is because the Dioto station has been classified as a mid-inland station, the two stations closest to the sea are Juv1 and Likitt (table n°6). The third axis is clearly linked to both seasonal and temperature variations. This reflect the originality of the cold season community structure as mentioned before. In most of the cases, their is a high variability (seasonal variability).

The repartition of the samples on the F2xF3 factorial map of the analysis is presented with the sampling site placed at the centre of their referring samples (fig. n°7). This figure reproduces the clear difference between Dioto and the five other stations, as seen before. The other stations seem to organise along a seaward-landward axis.

The relative position of single species is weakly explain by the variables used. This is not a surprising result as more of these species are quite ubiquitous. The best related species are *Eucinostomus melanopterus*, *Aplocheilichthys spilauchen*, *Hemichromis fasciatus*, *Liza grandisquamis*, *Pellonula leonensis*, *Strongylura senegalensis*, *Atherina sp.*, *Sarotherodon melanotheron and Gerres nigri.* This list includes mainly true estuarine species.

DISCUSSION.

The juvenile fish community inside the mangrove area, as seen through the fyke-net sampling, is dominated by young individuals from relatively small exploited species : *Eucinostomus melanopterus*, *Ethmalosa fimbriata*, *Pomadasys peroteti.* They share this habitat with true estuarine species which are also present as adults : *Pellonula leonensis*, *Atherina sp.*, *Monodactylus sebae.* The cichlid *H. fasciatus* is present and abundant everywhere with some individuals as large as 200mm or more (fig n°3). It is a very active predator which preys on young fishes, shrimps and crabs (Diouf, 1996). This does not agree with one of the characteristics of nursery area which are believed to offer reduced abundance of predators (Day and Deegan, 1988; Miller J.M. et al., 1991).

One noteworthy trait of this fish community is the relative species paucity of the gobbiid family with only four species : *Porogobius schlegelii*, *Gobionellus occidentalis*, *Yongeichthys thomasi* and *Periophthalmus barbarus.* This can be compare with other West African estuarine communities like in the Ebrie lagoon in Ivory Coast with 7 species (Albaret, 1994) or in the Fatala river in Guinea with 8 species (Baran, 1995). The low diversity of this very specific estuarine family can be interpreted as a sign of a depreciated environment.

The overall Sine Saloum fish community has 123 species identified from the present study (with additional gillnet and rotenone sampling), the data from Diouf (1996) obtained by purse seining in open waters area of the three main channels and additional observations from small-scale and game fisheries. Most of the new species added to the list by the juvenile sampling technics are small size species, mainly from the true estuarine group like *Gobionellus occidentalis* or *Bostrychus africanus*. This indicate that the estuary is not as poor as one could expect in the drought context. Diouf (1996) attributes this relative richness to the fact that nutriments are poorly exported to the sea. Nevertheless, this situation does not allow a great abundance and diversity of juvenile fish inside the mangrove even if the abundance and diversity in open waters seem better (Diouf, 1996). It is proposed that the mangrove "positive" influence cannot compensate for the lack of freshwater flow in the system at least in regard of the nursery function. One other complementary hypothesis is that the absence of strong run-off to the sea limits the larvae and newly hatched fishes to be driven to the estuary as many authors have already shown this run-off to play an important role in estuarine recruitment (Fortier and Leggett, 1983; Holt *et al.*, 1989; Neira and Potter; 1992; Castillo *et al.*, 1994; Whitfield, 1994).

Ethmalosa fimbriata is the first species in this juvenile sampling that is heavily exploited in the Sine-Saloum region, as referred by Bousso (1996). Individual caught are quite exclusively juvenile ones (fig. n°3). Other species identified as exploited by the small-scale fishery inside the estuary are *Eucinostomus melanopterus*, *Sarotherodon melanotheron*, *Tilapia guineensis* and the Mugilids. None of the main demersal species exploited at sea by the small-scale fishery (Samba; 1993, Caverivière; 1993) appears among the most abundant juveniles. It is noticeable that Sciaenids and Carangids are generally absent in the mangrove area including the Dioto station even if few individuals of some species were caught.

Dioto differs from the other stations more by its diversity as measured by the Shannon's index than by a lot of particular species. The species only found at the Dioto station are neither frequent nor abundant species. Nevertheless, they can be important ones like the Scianid *Pseudotolithus elongatus*, the barracuda *Sphyraena afra*, two important species for the small-scale fishery. The first belongs to a family very indicative of estuarine environmental conditions. The differences between Dioto and the other stations are clearly related to the probable presence of freshwater supply by the way of ground water. This fresh (or less saline) water causes the improvement of other related favourable conditions such as the better health and productivity of the mangrove forest but also a probably better overall productivity.

There is a slight seaward-landward organization from the Juv1 and Likitt stations to the Juv3 and Guilor stations as shown by the multivariate analysis. The influence of the sea does not result in a higher diversity index for the two stations near the sea when compared with the two inland stations. In regard of the nursery function, the proximity of the sea does not give a decisive advantage to the concerned sampling sites.

As a consequence of its environmental originality, the Sine Saloum estuary shows a more seasonal organisation of the reproduction and of the recruitment from the sea that one would expect in a tropical estuary. The model of the tropical estuarine fish reproductive strategy is a long spawning period lasting several months (Albaret and Diouf, 1994). In the case of the Sine Saloum system, appearance of very young juvenile fish seems to be more seasonal with, broadly, true estuarine fish which spawns just before the rainy season and the juveniles of sea spawning species that appear during the rainy season. The lack of freshwater inflow makes the rain amount more important for the environment as shown by Pagès and Citeau (1990). This is also true for the success of fish recruit as this is limited in space and time.

This community structure maintains during the post-rainy season. This similarity in the young fish and small species community in the rainy and the post-rainy seasons is important. The environmental conditions in P. H. S. (October to December), especially salinity, depends on the rain fall of the previous season in a moment where the young fishes have to succeed in their first growth before the cold season. So, if rain could be important during the rainy season to allow good settlement conditions, a second level of importance is located during the post rainy season to offer suitable growth conditions either as salinity or as productivity. The cold season that follows is the moment of ontogenetic changes in most of the young fish which migrates to deeper parts of the creeks, frequently with change in the diet. It must be kept in mind that this may be a fortuitous feature that these changes occur when the temperature decreases. Indeed, it had been frequently shown that temperature has little influence on the estuarine fish communities (Cyrus and Blaber; 1992).

It is evident that the presence of mangrove is not sufficient to compensate for the lack of freshwater inflow. The best estuarine site, Dioto, exhibits a far better diversity than that of the general community but not a greater abundance in juveniles, especially concerning the exploited species. The better condition of mangrove trees on this station is obvious, so the link between the quality of the estuarine environment, especially water quality, and the contribution of the mangrove to the nursery function seems clear though not direct. The role of the mangrove probably increases as the general environmental conditions improve. This point of view is consistent with the observation of Diouf (1996) who proposes to use apparent condition of the mangrove forest as an explicative variable for fish community diversity. The respective roles of the estuary and the mangrove are complementary but different. The estuary has a predominant position in providing good environmental conditions for the fish and the trees. Mangrove needs a good estuarine physico-chemical context to play a positive role in the nursery function of the estuary. It increases the available productivity by enhancing the nutriment turn-over and by providing support for epiphytic production and the related food web.

This can be summarized by saying that good estuarine conditions alone are sufficient for good nursery function but mangrove alone is not.

CONCLUSION

Estuaries are good nursery grounds when they receive sufficient amount of freshwater. If not, the nursery role can be depressed. The mangrove system alone cannot restore the nursery role when freshwater lacks. The consequences on the exploited fish population are important in those cases like West Africa where a drought situation prevails since the 70's.

This can also appear when river discharge is controlled (and reduced) by dam or utilised for irrigated agriculture. In these situations, lost of fishery resource would be integrated in the gain/cost computation of the whole environmental management. In this paper the only direct effect of the fresh water lack on the renewal of fish populations via the nursery function of the estuary is considered. This has to be added to the indirect effect of little if no export of nutriments to the coastal zone.

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Station	Geographic zone	Distance to sea	minimum T°	maximum T°	minimum Salinity (‰)	maximum Salinity (‰)
DIOTO	**Bandiala**	**23**	**19,5**	**29,2**	**25**	**43**
JUV1	**Diomboss**	**12**	**19,3**	**28,5**	**33**	**44**
LIKITT	**Saloum**	**18**	**20,3**	**28,3**	**40**	**45**
MOUNDE	**Saloum**	**27**	**21,0**	**29,4**	**38**	**48**
JUV3	**Baout**	**35**	**19,7**	**29,3**	**34**	**50**
GUILOR	**Diomboss**	**35**	**23,1**	**29,3**	**36**	**50**

Table n° 1 : Localisation and physico-chemical characteristics of the sampling sites

Tableau n° 1 : Localisation et caractéristiques physico-chimiques des stations.

code	Species	Family	LF min	LF max
GME	*Eucinostomus melanopterus*	Gerreidae	10	154
PSE	*Psettias sebae*	Monodactylidae	6	156
ASP	*Aplocheilichthys spilauchen*	Cyprinodontidae	9	96
PEF	*Pellonula leonensis*	Clupeidae	12	97
ASC	*Porogobius schlegeli*	Gobiidae	10	102
SME	*Sarotherodon melanotheron*	Cichlidae	11	220
HFA	*Hemichromis fasciatus*	Cichlidae	13	241
EFI	*Ethmalosa fimbriata*	Clupeidae	21	171
PPE	*Pomadasys peroteti*	Pomadasidae	15	285
EAE	*Epinephelus aeneus*	Serranidae	169	437
LFA	*Liza falcipinnis*	Mugilidae	33	231
SMA	*Strongylura senegalensis*	Belonidae	50	382
ATH	*Atherina sp.*	Atherinidae	11	53
LDU	*Liza dumerili*	Mugilidae	12	248
LIZ	*Liza sp.*	Mugilidae	9	80
TGU	*Tilapia guineensis*	Cichlidae	13	300
GNI	*Gerres nigri*	Gerreidae	10	190
IND	*(non déterminé)*		6	35
LGR	*Liza grandisquamis*	Mugilidae	13	214
PIS	*Pisodonophis semicinctus*	Ophichthidae	645	900
MCU	*Mugil curema*	Mugilidae	20	225
BLI	*Batrachoides liberiensis*	Batrachoididae	10	339
MUG	*Mugil sp.*	Mugilidae	9	66
PPA	*Periophtalmus barbarus*	Periophtelmidae	43	134
PJU	*Pomadasys jubelini*	Pomadasyidae	39	101
SEB	*Sardinella maderensis*	Clupeidae	21	88
PLM	*Plectorhinchus macrolepis*	Pomadasyidae	25	505
LAR	*Larves*		11	28
GDE	*Galeoides decadactylus*	Polynemidae	20	215
PBR	*Pseudotolithus brachygnathus*	Sciaenidae	91	284
LLA	*Lagocephalus laevigatus*	Tetraodontidae	20	37
IAF	*Ilisha africana*	Clupeidae	89	178
HAF	*Bostrychus africanus*	Eleotridae	57	159
CST	*Citarichthys stampfli*	Bothidae	47	182

Table n° 2 : List of the 34 more frequent taxonomic groups and their size range in the fyke-net samples

Tableau n° 2 : Liste des 34 espèces les plus fréquentes et gammes de tailles rencontrées lors de l'échantillonnage avec les nasses

Sampling site	Species richness	Shannon Index
DIOTO	43	3,89
JUV1	32	2,53
JUV3	28	2,92
LIKITT	30	2,71
MOUNDE	28	2,65
GUILOR	22	2,82

Table n° 3 : Species richness and Shannon diversity index by sampling site for the overall period of sampling,

Tableau n° 3 : Richesse spécifique et Indice de diversité de Shannon pour l'ensemble de l'étude, par station.

Variable	Modalities	Code
Distance to the sea		
	<20	D1
	20<d<30	D2
	>30	D3
Temperature		
	T°<22	T1
	22<T°<26	T2
	T°>25	T3
Salinity		
	S<40	S1
	39<S>43	S2
	S>43	S3
Season		
	Hot and dry Season	SC
	Hot and rainy season	HC
	Post rainy season	PH
	Cold and dry season	SF

Table n° 4 : Variables and modalities used in the CCA

Tableau n° 4 : Variables et modalités de l'AFCVI

Table n° 5 : Correlation coefficient of each variable with the three first axes of the ACC.

Tableau n° 5 : Coefficients de corrélation des variables avec les trois premiers axes de l' AFCVI

	axis 1	axis 2	axis 3
Distance	0.28178	0.41106	0.37966
Temperature	0.11463	0.02114	0.51275
Salinity	0.24419	0.70270	0.05025
Season	0.47456	0.01713	0.59875

Code	Species	Family	Number
GME	Eucinostomus melanopterus	Gerreidae	6362
PEF	Pellonula leonensis	Clupeidae	1833
ASP	Aplocheilichthys spilauchen	Cyprinodontidae	1421
SME	Sarotherodon melanotheron	Cichlidae	1261
EFI	Ethmalosa fimbriata	Clupeidae	862
ATH	Atherina sp.	Atherinidae	726
PSE	Psettias sebae	Monodactylidae	643
ASC	Porogobius schlegelii	Gobiidae	496
LAR	Larves (cf. P.leonensis)	Clupeidae	491
HFA	Hemichromis fasciatus	Cichlidae	361
LFA	Liza falcipinnis	Mugilidae	283
LIZ	Liza sp.	Mugilidae	265
PPE	Pomadasys peroteti	Pomadasidae	191
IND	Indéterminé X	Pomadasidae	169
LGR	Liza grandisquamis	Mugilidae	142
SEB	Sardinella maderensis	Clupeidae	132
TGU	Tilapia guineensis	Cichlidae	124
LDU	Liza dumerili	Mugilidae	106
SMA	Strongylura senegalensis	Belonidae	101
EAE	Epinephelus aeneus	Serranidae	96
GNI	Gerres nigri	Gerreidae	91
MUG	Mugil sp.	Mugilidae	49
MCU	Mugil curema	Mugilidae	48
PIS	Pisodonophis semicinctus	Ophichthidae	35
PPA	Periophtalmus barbarus	Periophtelmidae	34
PJU	Pomadasys jubelini	Pomadasyidae	31
IAF	Ilisha africana	Clupeidae	28
BLI	Batrachoides liberiensis	Batrachoididae	25
GER	Gerres sp.	Gerreidae	20
GDE	Galeoides decadactylus	Polynemidae	19
PLM	Plectorhinchus macrolepis	Pomadasyidae	19
LLA	Lagocephalus laevigatus	Tetraodontidae	17
PBR	Pseudotolithus brachygnathus	Sciaenidae	13
HAF	Bostrychus africanus	Eleotridae	10
OOC	Gobionellus occidentalis	Gobiidae	10
CST	Citarichthys stampfli	Bothidae	8
PIN	Pomadasys incisus	Pomadasydae	8
LEP	Leptocephale	()	6
MBA	Mugil bananensis	Mugilidae	4
POQ	Polydactylus quadrifilis	Polynemidae	4
CHL	Chloroscombrus chrysurus	Carangidae	3
PRO	Pomadasys rogeri	Pomadasyidae	3
SOL	Sole sp.		3
AGU	Engraulis encrassicolus	Engraulidae	2
BKO	Butis koilomatodon	Eleotridae	2
BLE	Blennius sp	Bleniidae	2
CAR	Caranx sp	Carangidae	2
ELA	Elops lacerta	Elopidae	2
HBR	Hemiramphus brasiliensis	Hemiramphidae	2
PEL	Pseudotolithus elongatus	Sciaenidae	2
ELO	Eleotris (à déterminer)	Eleotridae	2
SPI	Sphyraena afra	Sphyraenidae	2
AGA	Arius latiscutatus	Ariidae	1
CYS	Cynoglossus senegalensis	Cynoglossidae	1
DMA	Dasyatis margarita	Dasyatidae	1
SYN	Syngnathe	Syngnathidae	1
YTH	Yongeichthys thomaseï	Gobiidae	1
		Total =	16576

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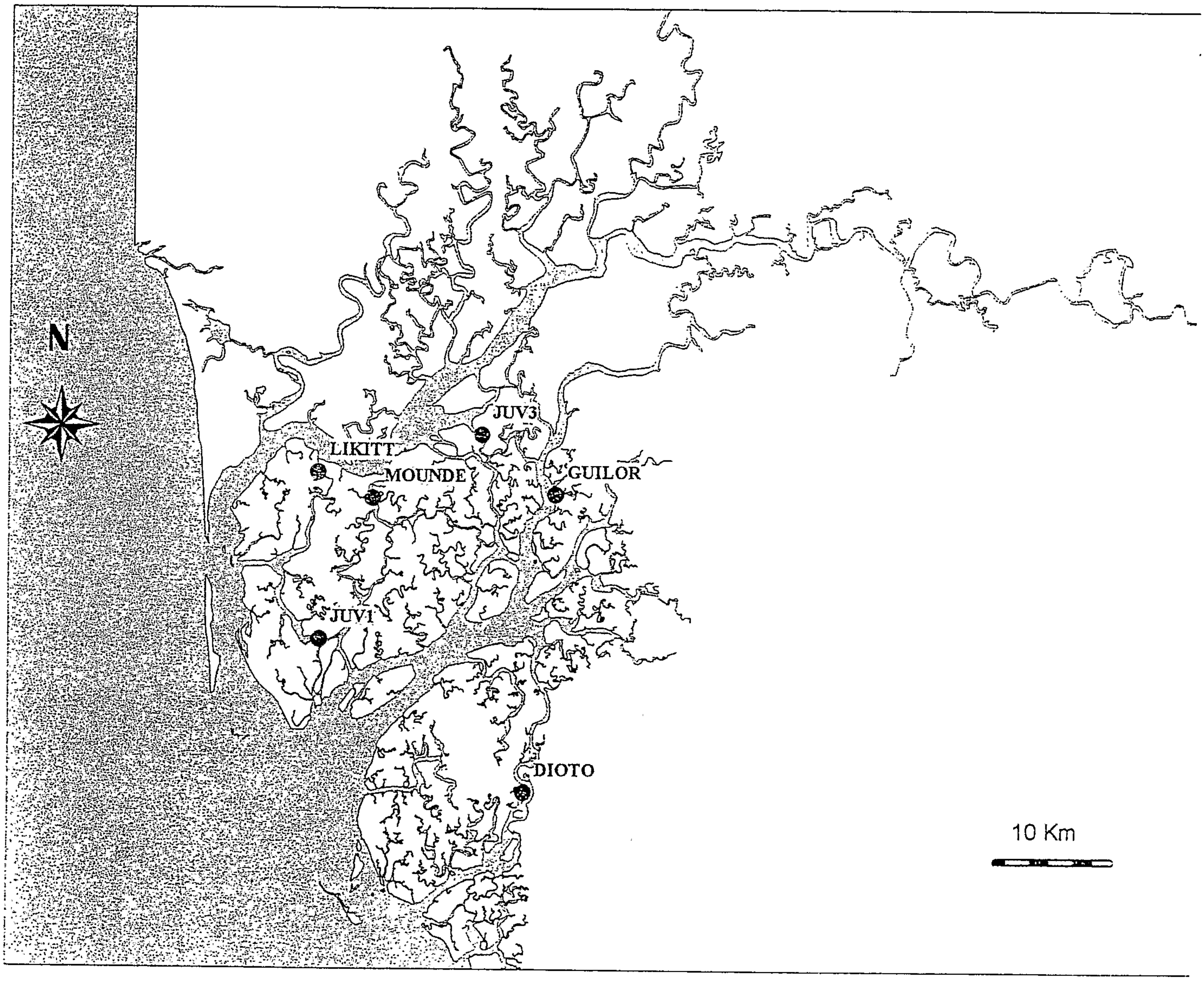

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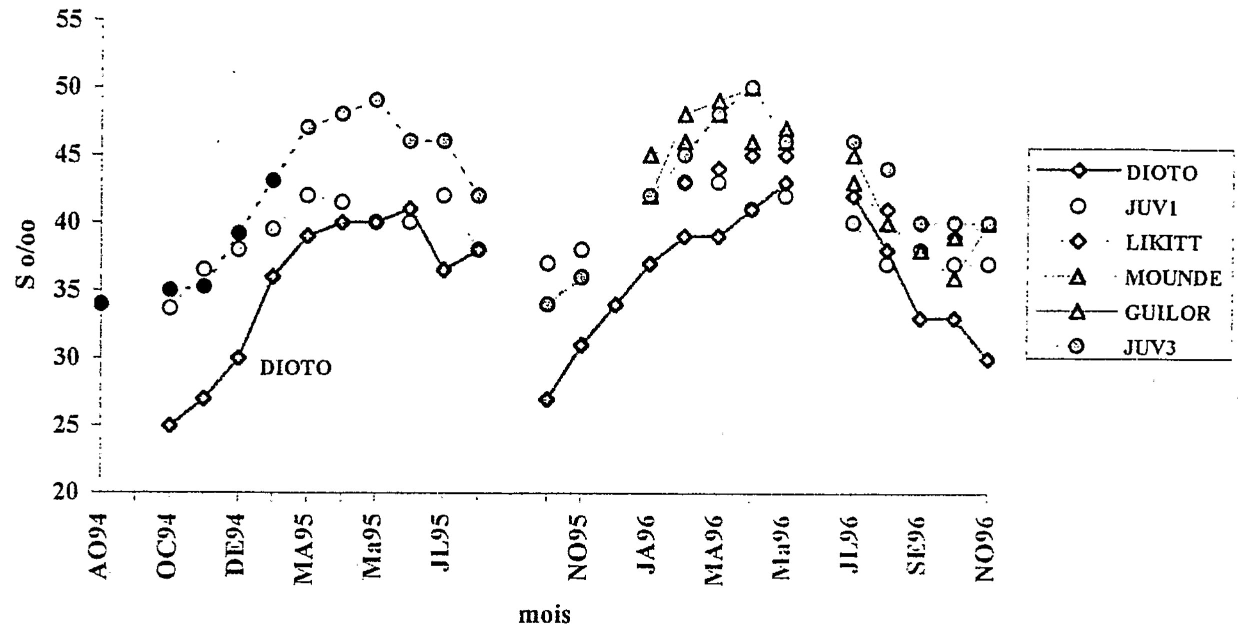
JUV3
LIKITT
MOUNDE
GUILOR
JUV1
DIOTO
10 Km



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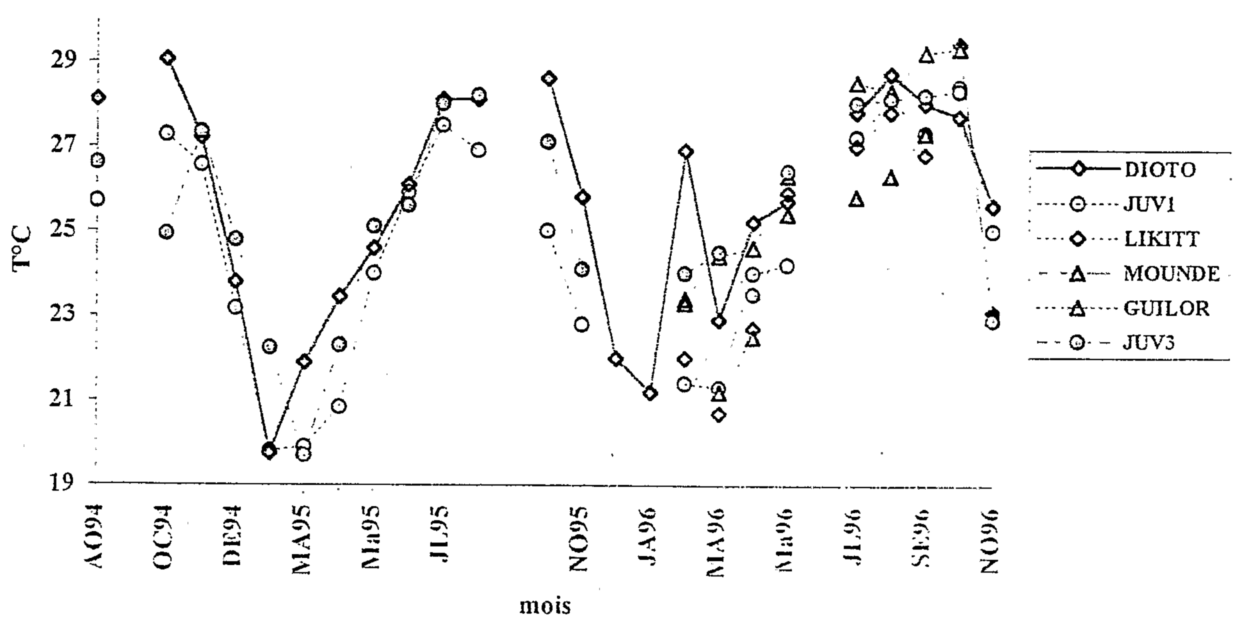
DIOTO
JUV1
LIKITT
MOUNDE
GUILOR
JUV3



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JUV1
LIKITT
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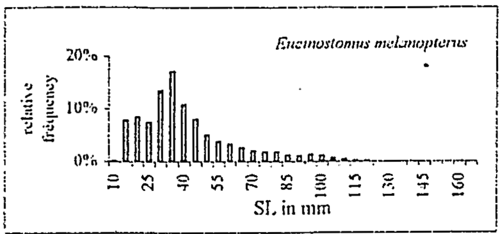
JUV3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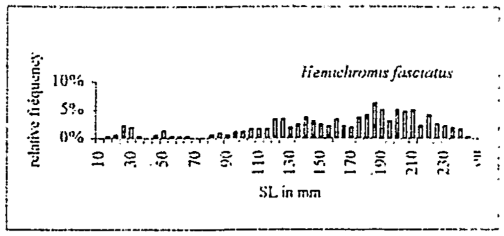
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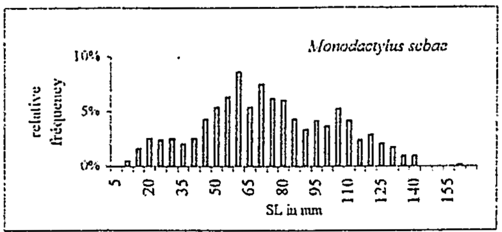
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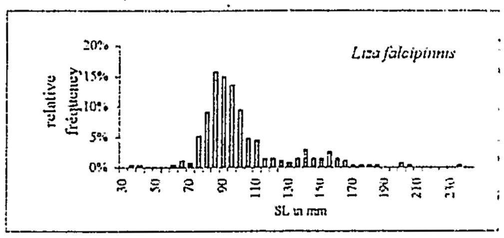
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relative fréquency
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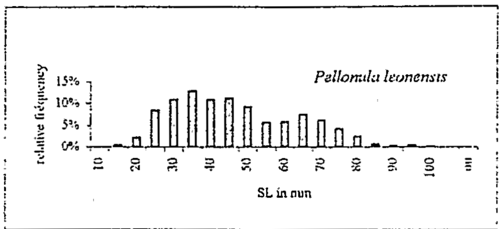
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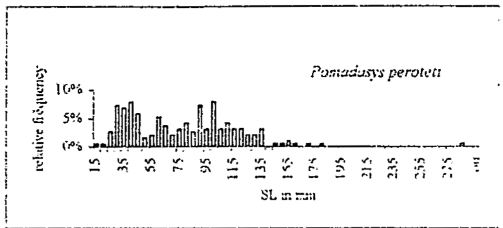
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relative fréquency
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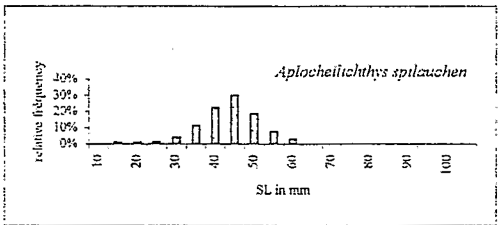
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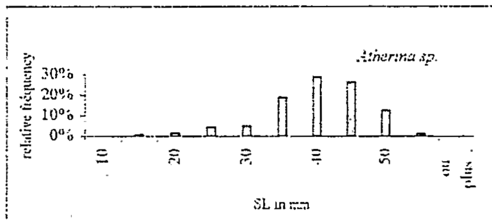
relative fréquency
40%
30%
20%
10%
0%
SL in mm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relative fréquency
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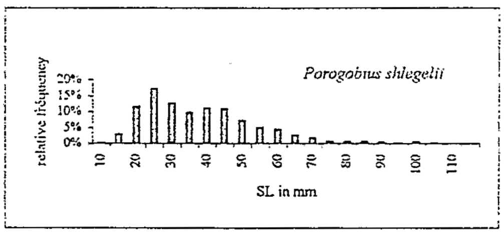
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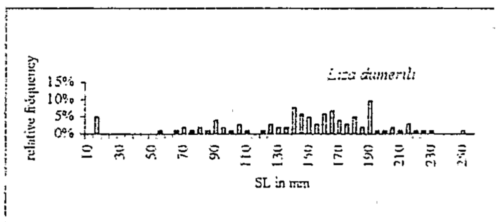
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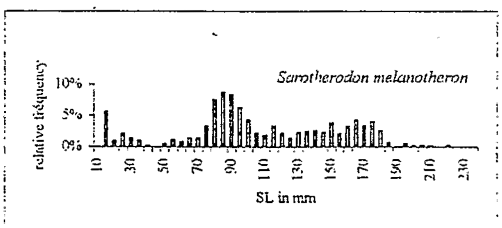
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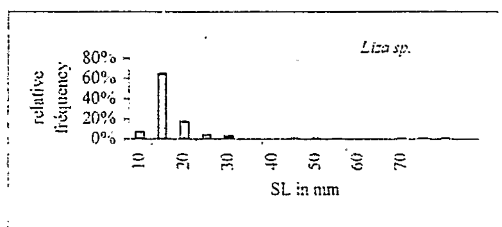
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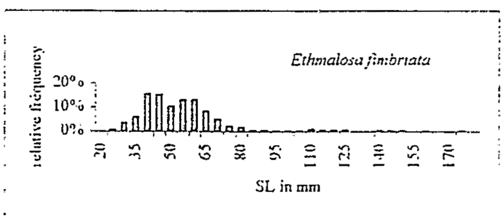
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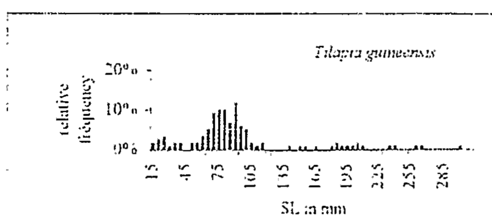
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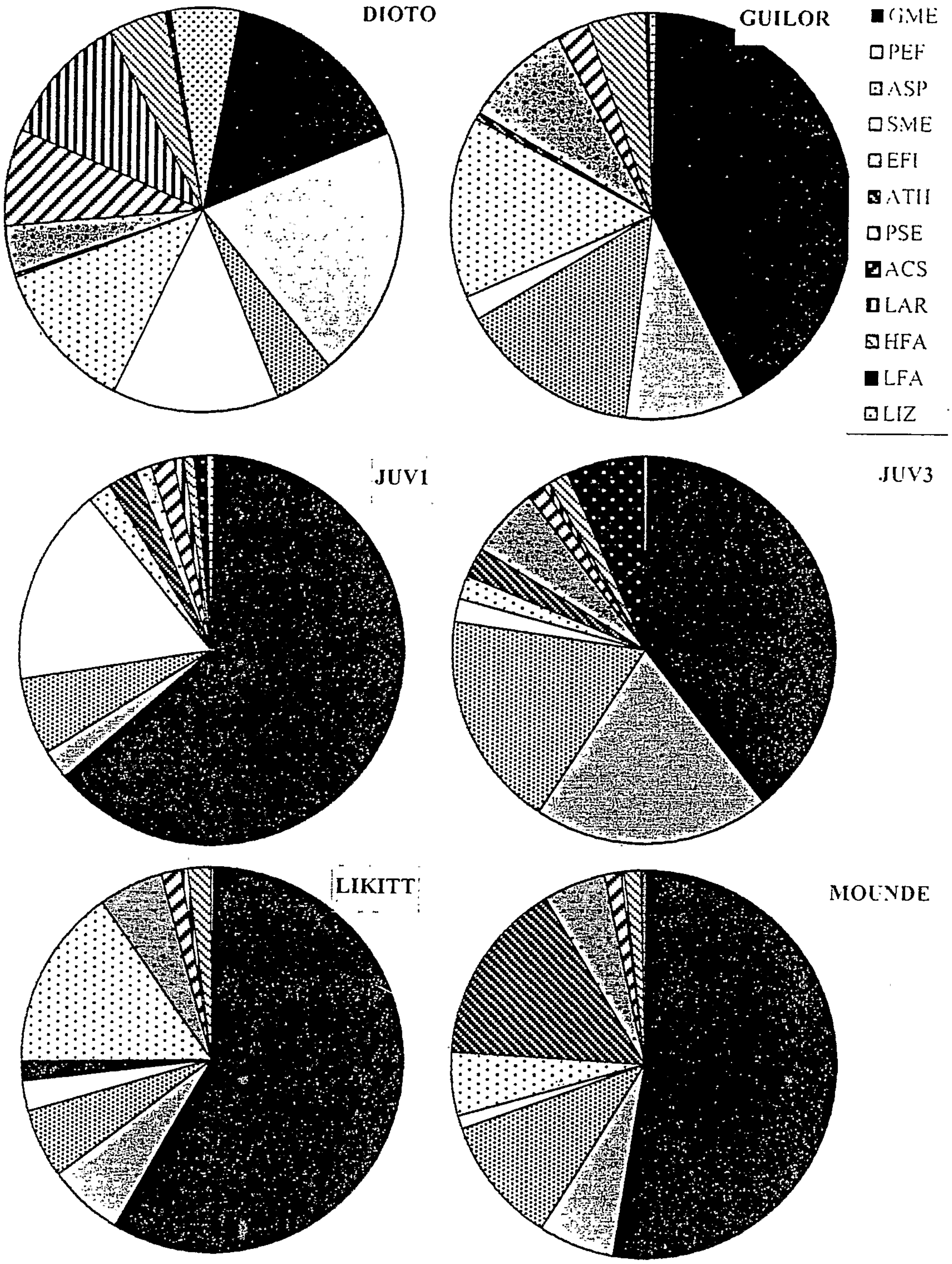
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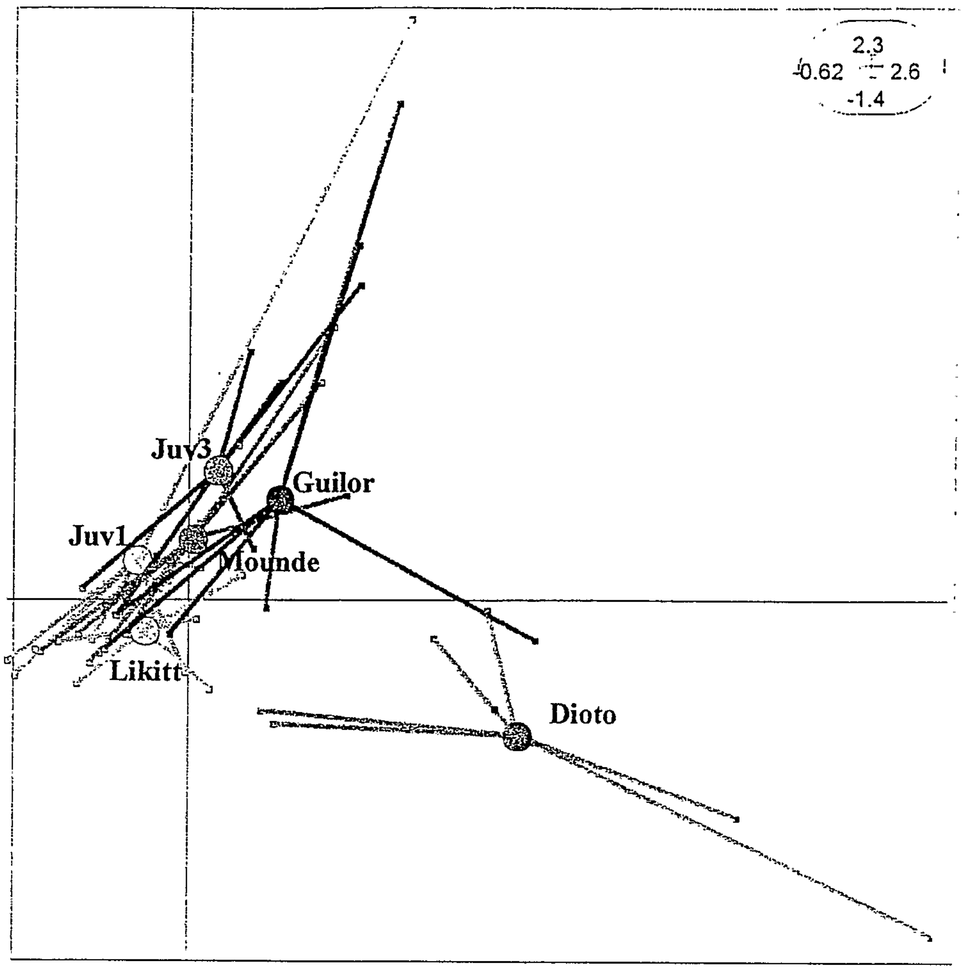
MOUNDE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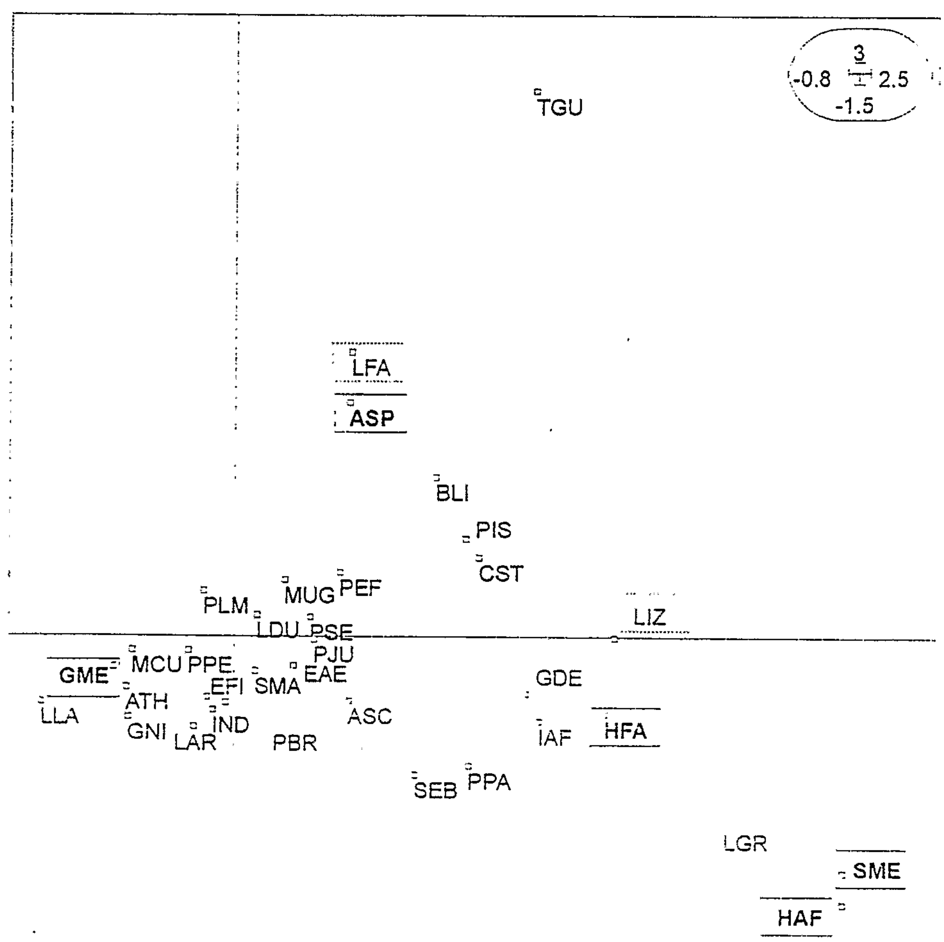
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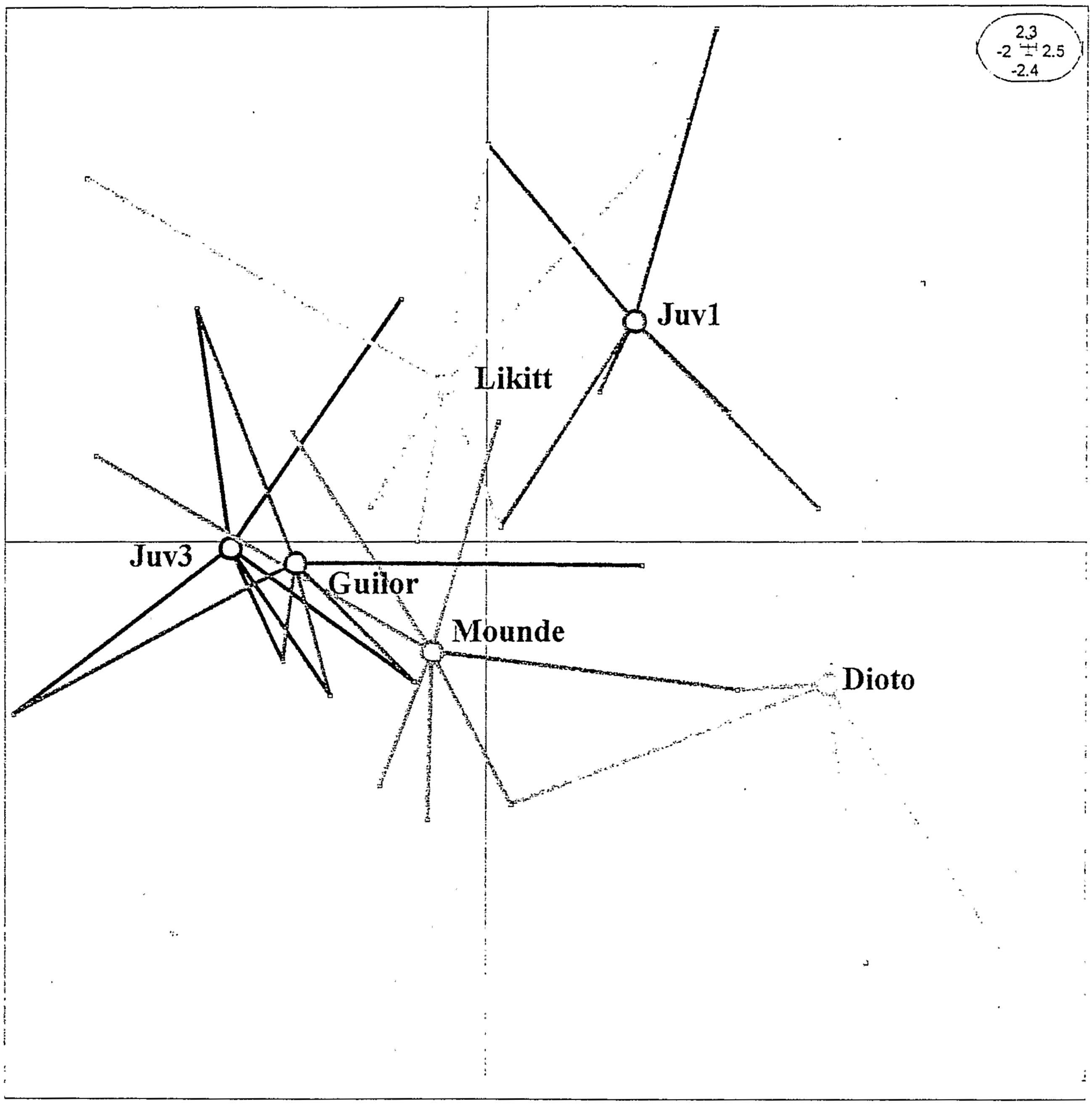
2.3
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