Numeric analysis of planktonic spatial patterns revealed by echograms

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Abstract

Observations of acoustic images made along a transect perpendicular to the coast, off Villefranche-sur-Mer, allow one to recognize the hydrological zone corresponding to a surface density gradient characterizing the Ligurian Sea front (Mediterranean Sea). Combinations of statistical and geometrical parameters from the digitized echoes enable discrimination between different classes of patches in relation to the frontal structure during one transect recorded on December 20, 1990. Patch recognition is based on the extraction of the general trend of each column and each row of the digitized data matrix by Eigenvector filtering. Multivariate analysis (principal component analysis and discriminant analysis) run on a 650 patches × 19 variables matrix shows a high negative relation between statistic and geometric parameters of the patches. The two main discriminant parameters are shape and echo strength of patches. From the convergence of our results in the Ligurian front with those of previous works made in other frontal region, it is suggested that this method could be generalized for quantifying and standardizing studies of the patchiness of plankton.

Keywords: Echosounding, filtering, plankton, Ligurian front, Mediterranean Sea.

Analyse numérique des structures spatiales planctoniques observées sur les échogrammes.

Résumé

La visualisation des images acoustiques le long d'une radiale perpendiculaire à la côte, au large de Villefranche-sur-Mer, permet de reconnaître la zone hydrologique correspondant au gradient de densité de surface caractérisant le front de mer Ligure (mer Méditerranée). La combinaison de paramètres statistiques et géométriques des échos numérisés a permis la discrimination de différentes classes d'essaims en relation avec la structure frontale au cours d'une radiale réalisée le 20 décembre 1990. La reconnaissance des essaims est basée sur l'extraction de la tendance générale de chaque colonne et de chaque ligne de la matrice des données numérisées par la méthode de filtration dite des vecteurs propres. L'analyse multivariée (analyse en composantes principales et analyse discriminante) réalisée sur une matrice de 650 essaims × 19 variables montre qu'il existe une forte opposition entre les paramètres statistiques et les paramètres géométriques des essaims et que les deux principaux facteurs discriminants sont la forme et l'intensité des échos. La convergence des résultats observés au niveau du front Ligure avec ceux de travaux antérieurement réalisés dans d'autres régions frontales, suggère que cette méthode de traitement des échos pourrait être généralisée en ce qui concerne la quantification et la standardisation des études concernant les essaims de plancton.

Mots-clés : Détection acoustique, filtrage, plancton, front Ligure, Méditerranée.

INTRODUCTION

In all aquatic ecosystems, the animals are neither uniformly nor randomly distributed. Most of the time, they aggregate in patches whose size is quite variable depending on some physical and biological parameters. Plankton patches extend horizontally from tens to hundreds of metres (Wiebe, 1970; Haury and Wiebe, 1982). This type of distribution, although a main feature of the organization of marine populations, is difficult to assess using conventional sampling gear. Investigation of a large oceanic area with plankton nets requires a large amount of time and gives only mean conditions in one dimension of the water column. These are major drawbacks, especially in frontal regions where small-scale variability occurs (Ibanez and Boucher, 1987; Boucher *et al.*, 1987). Hydroacoustic assessment techniques can be used to give fine-scale biomass and distribution estimates of sound scatterers. The speed of recording and the high-resolution obtained in a two-dimensional field with echosounders have led work to focus on acoustics in the 20 past years. Although it is possible to study fine-scale patchiness of marine organisms by echo-soundings (Sameoto, 1983; Greenlaw and Pearcy, 1985; Richter, 1985), acoustical estimation of fishes and plankton still suffers from the difficulty of interpreting echograms and the inability to distinguish between the different target groups when the community is complex. However, fishermen are often able to identify commercial fishes or squid by a simple qualitative observation of echograms using some criteria acquired by experience. In the past few years, acoustic parameters contained in the digitized echoes have been used by various authors to automatically classify the populations ensonified by echosoundings using different methods and criteria (Souid, 1988; Rose and Legget, 1988; Reid and Simmonds, 1991; Scalabrin, 1991). Although the species composition still cannot be accurately determined by acoustical sampling alone, it is possible to characterize some fine-scale patterns of backscattered echoes and relate them to environmental parameters. The work of Nero and Magnuson (1989) is based on the estimation of patch parameters (geometrical and statistical ones). By running a Principal Component Analysis (PCA) using the same parameters, Nero *et al.* (1990) were able to recognize differences among patches in the scattering layers associated with water masses in the Gulf Stream.

The Ligurian front, located off Villefranche-sur-Mer, offers the possibility of studying the heterogeneity in plankton at meso and fine-scale. The front is characterized by a sharp surface density and haline gradient linked to vertical and horizontal motions of water, leading to a highly anisotropic distribution of planktonic communities (Ibanez and Boucher, 1987; Boucher *et al.*, 1988; Sournia *et al.*, 1990).

In this paper, we present the results of our patch-finding algorithm made on an acoustic data set acquired across the Ligurian sea front. The technique used for our acoustic images processing takes into account statistical and geometrical characters of the patches. We have calculated the same parameters as those found in Nero and Magnuson (1989). However, we used the smoothing method called Eigenvector Filtering (Ibanez and Etienne, 1991) to estimate the main background on both depth (vertical axis) and distance or time (horizontal axis) instead of taking an arbitrary threshold on both the vertical and horizontal axis calculated within a pre-determined window.

METHODS

Data acquisition

Data were collected at the end of December aboard the N/O Korotneff during one daytime transect (direction 123°) crossing the Ligurian front, off Ville-

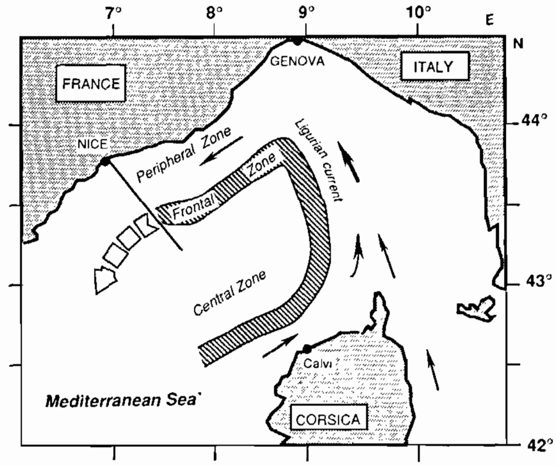

Figure 1. – Position of the transect made across the Ligurian front (solid line perpendicular to the coast) on December 20, 1990. The locations of the different hydrological zones of the front are indicated.

franche-sur-Mer (*fig.* 1). Acoustic data were recorded with a BioSonics model 102 echosounder using a 38 kHz transducer, towed at $2.5\ m.s^{-1}$ side away from the ship at depth of about 6 m. The sounder settings were constant with a ping rate of 4 s, a pulse duration of 5 ms, a beam angle (−3 dB) of 10° and a bandwidth of 1.25 kHz. Echo signals were digitized using 12 bits resolution in real-time over 1.5 m depth bins from the depth of the transducer to 600 m with an analogue to digital (A/D) converter and stored in arbitrary integer units suitable for data processing. The time varied gain (TVG) of the echosounder ($20 \log r + 2\alpha r$) was operating to a maximum depth of 255 m and data were corrected for spreading and absorption of sound in the water down to a depth of 500 m by software. In order to avoid statistical fluctuations, the data were horizontally averaged over 10 successive pings. The final horizontal inter-element distance was near 112 m, giving a matrix of 334 × 512 integer elements over the 50 km transect. The image was then reconstructed and displayed on the computer screen with colour ranging from blue to red (see *fig.* 4 *a*).

Acoustic results were compared with physical data collected during the return trip on the same transect using a SBE model 5 probe. Twelve casts were made from 3 to 30.5 miles, 2.5 miles apart. Temperature, salinity and depth were recorded continuously during the profiles at a scan rate of $2.s^{-1}$ and from 0 to 500 m. Considering the hydrographic structure of the studied area, acoustic patches were assigned to five different hydrological classes across the front (see Boucher *et al.*, 1988; Sournia *et al.*, 1990, for more details of the hydrographic structure): surface water ($\sigma_t > 28.40$), haline and thermal gradient ($28.40 < \sigma_t < 28.70$), winter water ($28.70 < \sigma_t < 29.00$), intermediate water ($\sigma_t > 29.00$). As the last class could not be defined by real specific hydrological characteristics, we have decided to distinguish it from the other four by its spatial position in distance (from 23 to 30 miles) and depth (from 200 to 500 m) (*fig.* 2).

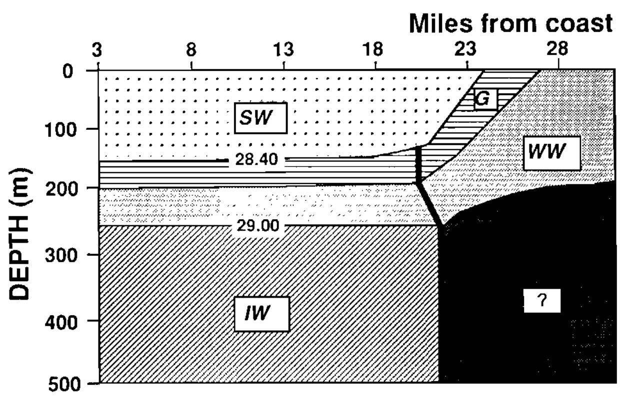

Figure 2. — Schematic representation of the hydrological structure of the Ligurian front with the position of the different water masses on 20 December 1990. SW = Surface Water, WW = Winter water, IW = Intermediate Water, G = Thermal and Haline Gradient, ? = zone without a simple hydrological structure. The thick vertical line is used to separate the horizontal part from the tilted part of SW and G water.

Patch identification

Echo patches may be defined as groups of echoes with intensities greater than the corresponding local average two-dimensional trend. Given the non-stationary nature and the absence of echoes in large zones (acoustic "hole"), the definition of the general trend of the echograms is not very easy. Instead of considering a trend surface of echo data, a patch will be defined as all adjacent echoes with intensities simultaneously greater than the global univariate trend on the corresponding axis of both depth and distance offshore. The determination of both depth (raw data of the matrix of the digitized echoes) and distance (columns of the matrix) trends is unique and corresponds to the smoothing method called Eigenvector Filtering (Ibanez and Dauvin, 1988; Ibanez, 1991; Ibanez and Etienne, 1992) and first applied in oceanograpphy by Colebrook (1978) to describe the major year-to-year changes in the abundance of the zooplankton of the North-East Atlantic and the North Sea. The Eigenvector Filtering is equivalent to a weighted moving mean and presents the advantage that no arbitrary choice is required regarding the shape of the trend. This method, using Principal Component Analysis (PCA), consists in taking as the general trend the first predicted series estimated from the first principal component alone extracted from the autocorrelation matrix of a data matrix whose successive rows contain the values of the original series shifted by one lag each time. For a random series, the characteristic scale — the scale from which the shifted series are independent of each other — corresponds to the interval of the first positive values of the autocorrelation function. Taking the medium value of this interval as the unique parameter for the filtering leads to define a general trend with periodicities greater than at least the main present cycles in the original series. In our case, the general trend was calculated for the whole acoustic map by considering each column and each row of the data matrix composed of the 334 × 512 elements as one series. The selected echoes were those with the intensity simultaneously greater than both the vertical and horizontal trends. An example of echo selection using this filtering is illustrated in *figure* 3 for one vertical series.

For each patch, a number was assigned and the coordinates of all points within the patch were stored for further processing. Instead of retaining all the patches extracted from the analysis, we preferred arbitrarly to retain only patches with a minimum number of 10 points.

Characteristics of the patches

Following Nero and Magnuson (1989), a series of 19 geometrical and statistical parameters were estimated for each of the patches. These parameters are listed in *table* 1.

RESULTS

Qualitative patch pattern

The echogram in *figure* 4 *a* represents the daytime distribution of 38 kHz echo signals with depth across

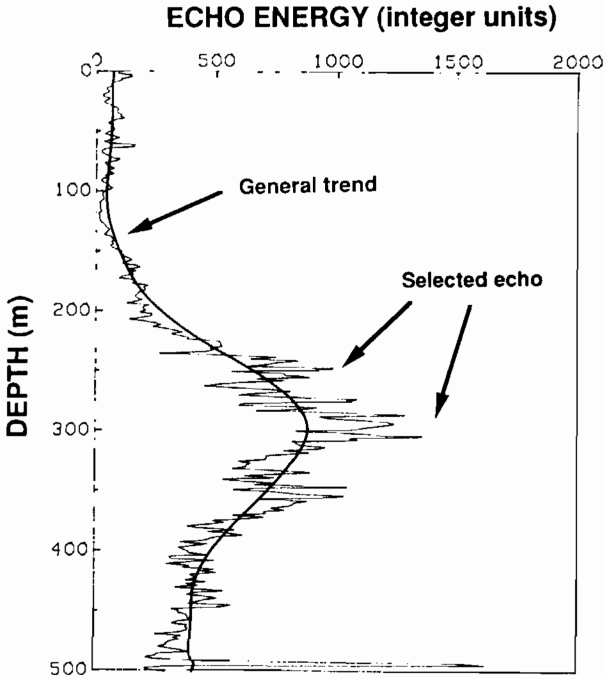

Figure 3. – Example of patch selection on one vertical axis only of the original 334 × 512 matrix. The same processing is done on the horizontal axis. The solid thin line represents variation of echo energy with depth as recorded by the acoustic system. The solid bold line gives the general trend calculated by Eigenvector filtering. The selected points are those with values greater than the general trend on both the vertical and horizontal axis.

the Ligurian front. Isolines of density are superimposed to the echogram. The frontal region is shown by a sharp surface horizontal density gradient and tilted isopycnals with depth between 20 and 23 miles offshore. From this figure, it is obvious that the higher biomass is found below 200 m whereas the shallower layers (surface water and vertical gradient) weakly scatter sound at the frequency used: near-surface echoes are diffuse with low intensity whereas the main deep scattering layer (MDSL), between 200 and 500 m, is denser with apparently uniform backscattering strength. As already shown by Baussant *et al.* (1992), differences in mesoscale patterns are observed in the scattering layers between the coastal and offshore part of the transect. The denser signals occur between 220 and 400 m where the upper part of the intermediate water lies, the higher biomass being located between 250 and 300 m. Large echo patches are found above the MDSL near 15 miles and at 200 m but are absent elsewhere on the transect. The scattering is lower and the acoustic patterns are different in the MDSL between 20 and 23 miles where the front occurs at the surface. In this region, the MDSL is deeper (upper limit at 350 m) and the patches seem to be more vertically elongated (20 m) than wide.

Quantitative patch pattern

Figure 4 *b* is the result of the two-dimensional filtering with the identification of the various patches plotted on the original echogram using the same colour scale. We have retained 650 patches with number of elements above or equal to 10. As a whole, the algorithm appears to isolate patches within the scattering layers where the backscattering strength was apparently of uniform distribution on the original echogram.

In order to visualize the correlations between the 19 patch descriptors, we ran PCA on the matrix composed of 650 × 19 elements. We added 5 supplementary variables: the coordinates X and Y (distance and depth) of the centroids of each patch and 3 measures of hydrology – salinity, temperature and density – estimated at the coordinates of centroids (*see* Legendre and Legendre, 1979, for more details on PCA). The results of PCA are given in *table* 2. The first three axes explained respectively 40, 32 and 11%, therefore 83% of the total variance. *Table* 3 gives the correlations of each of the variables for the first six axes. The first axis is mainly determined by morphological descriptors of the patches that are opposed to skewness and kurtosis which express the distribution of echoes within the patches. This axis, discriminating the small patches from the large ones, can be named the "size axis". The second axis is defined by descriptors of intensity and distribution of the echoes within the patches while the third axis is associated with the coefficient of variance and coefficient of horizontal rugosity which are both measures of patch internal acoustic variability. Note that, although representing respectively only 3.5 and 2.4%, axis 5 is correlated with angle and axis 6 with the distance between the patches. From the PCA, we have calculated a Euclidian distance matrix on the saturations and represented the proximity between variables by the dendrogram of *figure* 5. Taking a threshold distance of 1 has led us to select six different groups (G1 to G6). G1 and G3 groups are represented by geometric parameters. Note that the hydrological variables (salinity, density and temperature) and the variable "distance from coast" are found together in G1. The variable "depth" is close to intensity variables of group G2. This latter group is closer to G1 and G3 than to G4, G5 and G6 which concern statistical parameters. The representation of these variables on the first 3 main components of the PCA is given in *figure* 6. From this figure, a high negative relation is shown between the statistic characters and the geometric characters of the patches.

We have represented on *figure* 4 *c* the most correlated patches (= those with the higher negative or positive values) on component 2 using 10 different classes represented by 10 different colours. By plotting them on the original echogram, a spatial selection seems to occur between the patches regarding the frontal structure. The more positively correlated

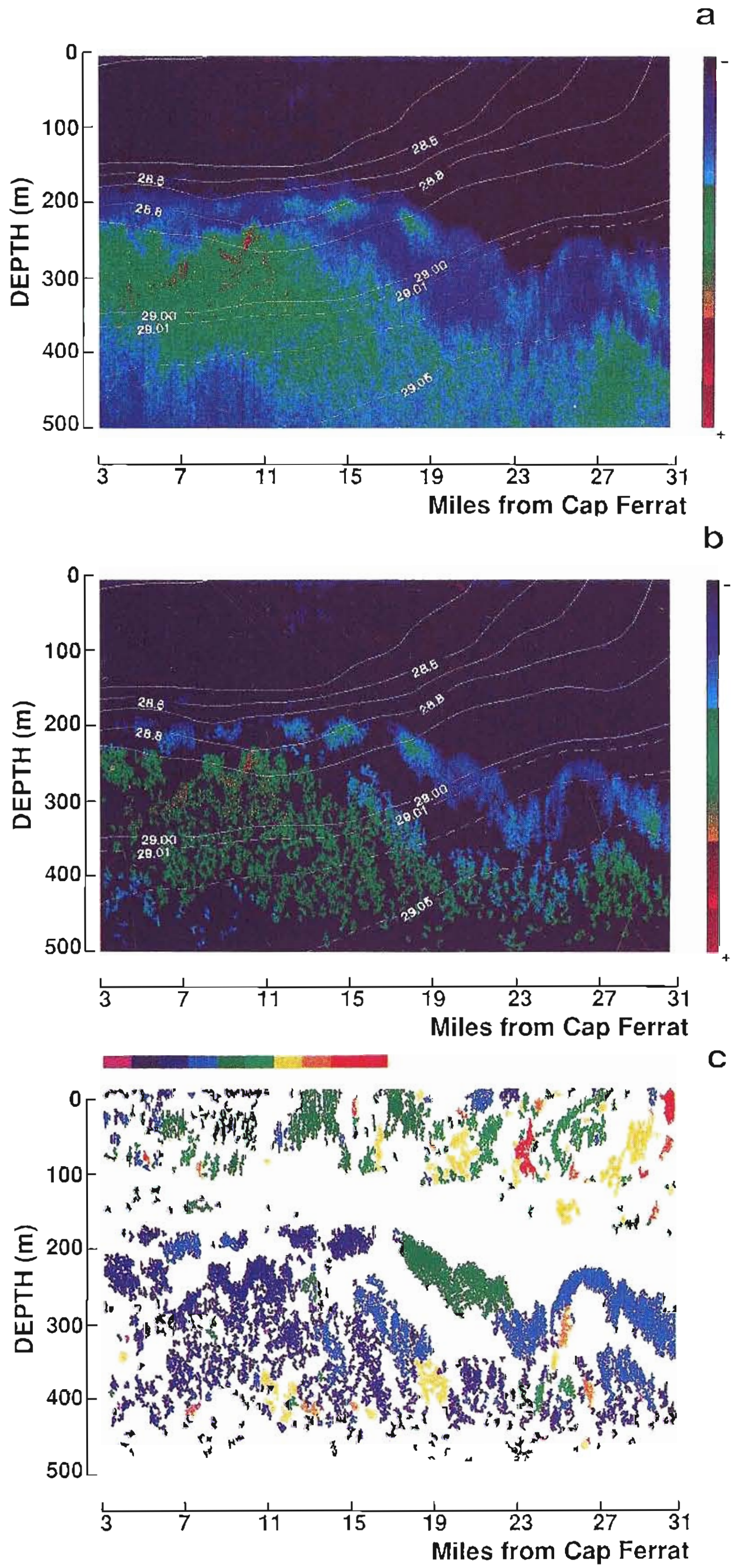

Figure 4. — (*a*) Colour echogram made from the digitized echo data of the 38 kHz acoustic transect from 0 to 500 m and from 3 to 31 miles offshore on 20 December, 1990. The colour scale on the right side represents echo strength (dark blue = no echo, red = strong echo). Isolines of density have been superimposed to the echoes, showing the position of the front where the surface density gradient is the highest (from 20 to 23 miles).
(*b*) Locations of the 650 patches retained and reprinted on the original echogram using the same colour scale. Isolines of density are the same as in figure 4 *a*.
(*c*) Representation of patch scores obtained from principal component axis two printed onto the original patch locations using 10 classes as the colours violet to red.

Table 1. – List of patch statistic and geometric parameters from Nero and Magnuson (1989). The abbreviations of the variables are in bold. The five following parameters have been added as supplementary variables: DIStance to the coast, DEPth of each patches and DENsity, SALinity, TEMperature estimated at the X, Y coordinates of the patch centroid.

Geometry	Statistic
1. AREa	1. MEAn intensity
2. PERimeter	2. MAXimum intensity
3. EXternal Width	3. VARiance
4. EXternal Height	4. Coefficient of VAriation
5. INternal Width	5. SKEwness
6. INternal Height	6. KURtosis
7. FRActal dimension	7. Horizontal RUgosity
8. Distance to the Nearest Neighbor	8. Vertical RUgosity
9. ANGle to the nearest neighbor	9. Coefficient of Horizontal Rugosity
	10. Coefficient of Vertical Rugosity

Table 2. – Percentage of variance explained by the first ten principal components from the principal components analysis (PCA) run on the 650 × 19 elements of the data matrix.

Component number	Percent of variance explained
1	40.1
2	32.0
3	11.1
4	4.1
5	3.5
6-10	8.5

patches are distributed offshore, near the front and at surface, whereas the more negative ones are situated nearshore and deeper in the intermediate water, IW.

A second type of analysis was made to estimate patch characters which best discriminate between the 5 hydrological zones illustrated on *figure* 2. We ran discriminant analysis on the matrix composed of 650 × 19 elements after log + 1 transformation except for skewness and kurtosis. Discriminant analysis is well suited for this approach because the different classes (here hydrological classes) are known *a priori*. After processing on the set of parameters using the MAHAL 3 program (Romeder, 1973), we have obtained the following results:

Variables	Abbreviations	Well-classified echoes
Fractal dimension	(FRA)	31%
Fractal dimension + Mean intensity	(FRA + MEA)	46%
Fractal dimension + Mean intensity + Variance	(FRA + MEA + VAR)	47%

By considering only fractal dimension, mean intensity and variance, we are able to classify and assign to the hydrological zones nearly 50% of the total set of patches. This result is not completely satisfying. However, shape and intensity of echo patches appear to be the two predominant discriminant factors in patch classification.

Table 3. – Variable weightings on the first six axes of the PCA of the 650 echo patches. Values greater than |0.5| are in bold. Abbreviations of the path variable names are those indicated in *table* 1.

Patch Variable	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
ARE	**+0.831**	+0.219	+0.472	−0.097	+0.039	+0.092
PER	**+0.907**	+0.214	+0.326	−0.045	+0.060	+0.059
EXW	**+0.820**	+0.175	+0.382	−0.170	−0.056	+0.084
EXH	**+0.859**	+0.229	+0.302	+0.036	+0.129	+0.062
INW	**+0.853**	+0.170	+0.235	−0.109	−0.103	+0.040
INH	**+0.862**	+0.201	+0.164	+0.117	+0.111	+0.028
FRA	**+0.869**	+0.119	−0.275	+0.157	+0.042	−0.118
DNN	**+0.751**	+0.160	−0.203	+0.200	0	**−0.531**
ANG	**+0.541**	+0.116	−0.337	+0.453	**−0.548**	+0.255
MEA	+0.450	**−0.757**	−0.423	−0.142	+0.077	+0.064
MAX	**+0.533**	**−0.751**	−0.335	−0.082	+0.080	+0.039
VAR	+0.113	**−0.963**	+0.063	+0.029	+0.083	+0.024
CVA	−0.216	**−0.630**	**+0.596**	+0.324	+0.023	−0.083
SKE	**−0.692**	**+0.534**	+0.272	+0.119	−0.025	−0.037
KUR	**−0.668**	**+0.618**	+0.196	−0.077	+0.040	−0.057
HRU	+0.079	**−0.912**	+0.093	−0.272	−0.218	−0.046
VRU	+0.067	**−0.960**	−0.012	+0.096	+0.157	+0.099
CHR	−0.188	**−0.616**	**+0.521**	−0.182	−0.445	−0.195
CVR	−0.299	**−0.664**	+0.431	+0.416	+0.164	+0.048

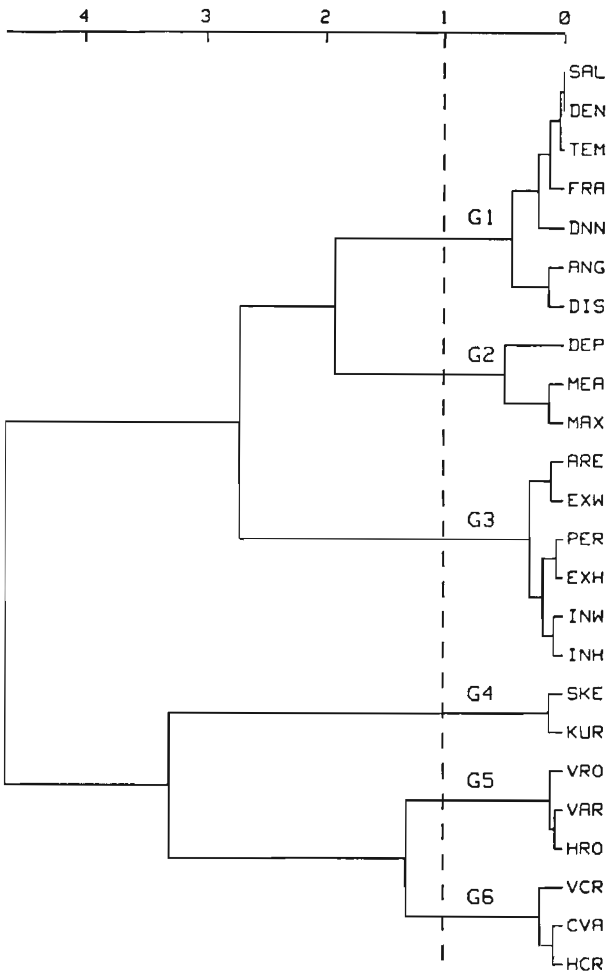

Figure 5. — Cluster analysis dendrogram of patch variables estimated from the PCA. The horizontal dotted line, at a distance of one, delineates the six different groups (G1 to G6) of variables. Abbreviations of variables as in *table* 1.

DISCUSSION

The main purpose of this paper was to develop an algorithm to classify echo patches after their recognition. Information in the digitized echo signal (envelope of signals) is sufficient to discriminate different groups of echoes. The selection of each patch descriptor is based on the shape and strength of echoes observed on the echograms. These are generally the main parameters that enable the discrimination of the different target populations ensonified by echosounding. Based on multivariate analysis (PCA and discriminant analysis), we showed that patch identification was mainly dominated by two descriptors, the morphology (shape) and echo energy, the former being predominant over the latter. Recent developments for the classification of echo detection are supporting our results. Nero *et al.* (1990) found the third

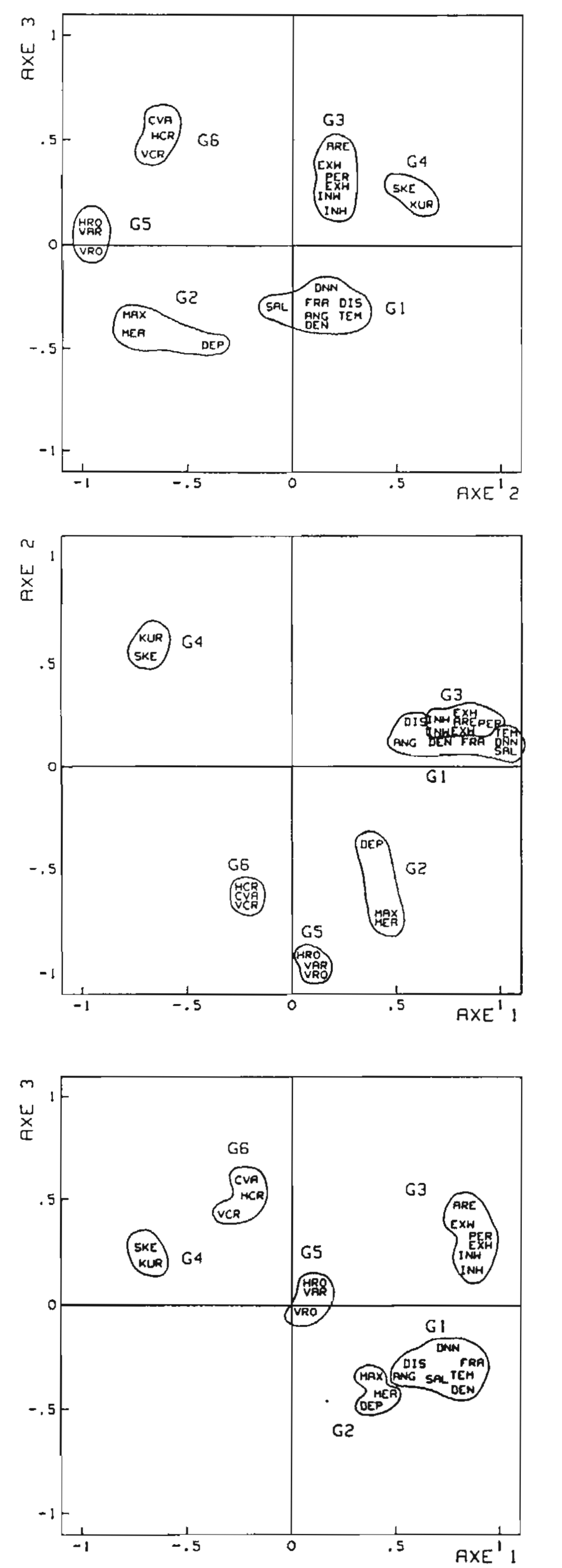

Figure 6. — Plots of the results of the principal component analysis (PCA), showing the locations of the 19+5 variables relative to the first three principal components. Abbreviations of variables as in *table* 1. The six groups (G1 to G6) are those obtained from the classification represented on *figure* 5.

component of the PCA made on the same set of descriptors to be the most important one. They interpreted this component as the most discriminant one between patches and between water masses. The results of our analysis are quite similar to those of Nero *et al.* but we found a better spatial discrimination of patches with the second component. However, there is a striking convergence of the results of this paper and that of Nero *et al.* (1990). The first 3 axes of the PCA express the same information as those of these authors. The similarity of results in two distinct but similar marine environments (the Gulf Stream front and the Ligurian Sea front) could suggest that animals causing the backscattering are responding in a similar way to the physical and biological gradients occurring in these two frontal regions. Nero *et al.* interpreted the difference in the distribution of "acoustic roughness" (coefficients of variance, roughness and skewness associated with the third components of their PCA) between the slope water and the Gulf Stream as a difference in the nature of animal and a more uneven spatial pattern of animals in the slope water than in the Gulf Stream. Concerning the biological composition of our echo patches, no data are available since no species identification by net sampling conducted simultaneously to our acoustic records were made in the front during this transect. In the site we studied off Villefranche-sur-Mer, results of *in situ* observations of animals during submersible dives and pelagic trawling made at the depth of the scattering layers during previous cruises have shown the occurrence of many populations of animals including decapods, euphausiids, gelatinous plankton as well as micronektonic fishes (Laval and Carré, 1988; Laval *et al.*, 1989 and J. Sardou, pers. comm.) that could be scatterers at 38 kHz. Recent works made with a Bioness sampler at 28 miles offshore Villefranche-sur-Mer, confirmed the abundance of zooplanktonic and micronektonic biomass where the 38 kHz MDSL is detected (Andersen and Sardou, 1992; Andersen *et al.*, 1992). Based on the frequency used, the organisms detected by our acoustic system are probably of about 2 cm in size and are assumed to be relativey mobile animals of micronektonic groups. Boucher *et al.* (1988) have shown that populations of mesozooplankton (mainly copepods) sampled near the surface were segregated by the discontinuities of the Ligurian front, some species always inhabiting the coastal zone. It is, however, unlikely that copepods scatter sound at the frequency used but the prey-predator relations could be modified in the front such that the type of distribution of the animals involved in the echoes would be altered. In this case, the difference suggested by our results across the front would not necessarily be due to a change in the target populations but could reflect a change in spatial distribution of the same animal population caused by different environmental conditions in the front. We think that the distribution patterns of animals could be influence directly or indirectly in response to the prevailing food supply. Recent studies in the Ligurian front support this hypothesis and have suggested downwelling of living particulate matter by frontal convergence as a mechanism responsible for the food supply of deep planktonic communities (Gorsky *et al.*, 1991; Laval *et al.*, 1992).

The classification of water masses by patch characters appears rather moderately successful when we run discriminant analysis (only 50% of well-classified echoes). This could suggest that animal populations are not exclusively linked to the characteristic of a water mass and hydrology of the frontal structure should not be the main parameter influencing the distribution of the patches. Rather, the animals could be influenced by some other parameters such as requirements for food or light that were not considered in the present study. On the other hand, the patchiness of plankton at fine-scale seems to result more from biological interactions than from the physical environment (Haury and Wiebe, 1982), but the physical processing occurring in fronts could be direct causative agents of the acoustic patterns observed, as suggested by the results of Arnone *et al.* (1990) and Nash *et al.* (1989) in the Gulf Stream.

We are not able to explain the rapid change observed in depth from 250 to 350 m of the MDSL between 20 and 23 miles by the simple analysis of our results. This observation was, however, often repeated on the acoustic images recorded in the front (Baussant *et al.*, 1992) and probably reflect some particular hydrologic conditions of this area that are not yet well understood.

Some care must be taken in considering our results since we only considered patches with a minimum of 10 points. The final horizontal distance between two elements was of 112 m and of 1.5 m on the vertical in our data. Thus, it is clear that the minimum length of our patches in the horizontal plane was of about 200 m and 3 m in the vertical plane. Sameoto (1983) found the most frequent length of euphausiid patches at 120 kHz to be 50 m with a mean of 125 m but the range of variation was from 25 m to 425 m. Backus *et al.* (1968) estimated a common diameter of myctophyd fish schools of about 25 m as displayed on the sonarscope of a submersible but they mentioned that considerable variation occurred. The small patches were arbitrarily not retained by the selection we made but they could have partly modified our final interpretation.

The convergence of our results with those of Nero *et al.* (1990) is more than encouraging, but surprising. Other studies concerning the discrimination of patches show that geometry together with intensity are the principal discriminant factors (Souid, 1986; Rose and Legget, 1988; Vray *et al.*, 1990; Scalabrin, 1991). However, most of these studies concern commercial fish and are applied in areas where the fish species are generally well known and well identified.

When one species is dominant over an area, identification is not a problem. Fishes are often aggregated in monospecific patches allowing easy discrimination between species. Planktonic communities are generally more diversified and complex. In the Ligurian sea, the community is truly complex and the difficulty of interpreting the results reflects the complexity of the interactions between physical and biological agents in a frontal area.

Our work calls for more knowledge about the nature of the scatterers. However, we think that the method proposed in the present paper is a valuable tool to help towards a better understanding of a marine biotope such as fronts. The development and use of sonar systems are now widespread in fisheries as well as in plankton studies. This type of method gives the ability to discern distributions of organisms in a two-dimensional field and at small scales. It could be generalized and applied to series of bioacoustic records made in other oceanic regions. By taking the best descriptors for patch characterization, we could reduce the processing time to the extent that near real-time patch characterization is possible.

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