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Sensitivity analysis of school parameters to compare schools from different surveys: a review of the standardisation task of the EC-FAIR programme CLUSTER

by

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Echo traces seen on echograms contain a lot of information about the aggregation of fish in schools. But the acosutic image obtained with a vertical biomass assessment echosounder contains distorsions mainly due to the beam angle, the equipment settings and the school depth. When the acoustic image of aggregation patterns changes over the years or varies between stocks, it is important to know up to what extent biological interpretation is meaningfull. The present paper reviews the work performed by a group of scientist within the EC FAIR programme CLUSTER. Simulations were performed to correct school parameters. Digital data were replayed to assess the importance of these corrections. Charts were derived to limit biological interpretation of changes on the school acoustic images.

Keywords: Acoustics, Schools, Image analysis, Standardisation

Introduction

The EC-FAIR programme Cluster (1997-1999) has been developped to characterise and compare the spatial patterns of schools between different pelagic stocks under different environmental regimes and exploitation patterns (North Sea Herring, Atlantic Sardine, Atlantic and mediterrenean Anchovy, Sardinella from both sides of the Atlantic). The data at hand are the series of historical surveys in which significant variations of the stock abundance have been observed.

The spatial distribution of pelagic stocks is structured at a micro scale, the school and a meso scale, the cluster of schools. The number of clusters of schools, their spatial dimensions, their biomass and their average number of schools, and second, the biomass in the schools and the schools dimensions are major parameters both for the exploitation and the survey assessment. The Cluster programme aims at characterising these parameters and their inter-annual changes and relating these changes to the stock abundance level (density dependence of mesoscale clustering) and major environmental features (density independent factors of variation).

Each participating Institute is currently extracting from his echogram series of annual acoustic surveys a data base on schools. In 1997, we agreed on a list of primary school parameters we thought biologically significant for the Porgramme's objectives. The project participating Insitutes are: ORSTOM (France), IEO (Spain), IMBC (Grece), SOAEFD (Great Britain), IFREMER (France).

The present paper reviews the work done for the project to standardise (make comparisons more effective) school parameters obtained by different echosounders, different EchoIntegration thresholds, different school extraction protocols from the echograms.

1. Review of the Cluster School Data Base

1.1 Structure of the Data Base

The data base is made of two major files, the SCHOOL-file and the ESDU-file. The SCHOOL file contains primary parameters characterising school position, morphology and energy. It contains also reference to the ESDU file which can be used as a look up file. The ESDU file contains parameters characterising the immediate environment of the school ; morphological typology of echostructures (Dispersed, Schools, Aggregation, Layer, Other), species community, hydrography, bottom characteristics, strata, meteo. This file will enale to put back each school in its multidimensional environment. A STRATA file can be added when information on the environment is disponible at a larger spatial scale: temperature or upwelled waters obtained from maps, fishing effort by rectangles,...etc. The Strata file contains different partitions of space according to ancilliary information at a larger spatial scale than the Esdu.

It was advised that School, Esdu and Strata files be linked in a relational data base. The structure proposed is a simple structure with three tables: Strata, Esdu and School tables. Each stratum contains an ID which is repeated for each Esdu in the Esdu table. Each Esdu contains an ID which is repeated in the School table for each school. It is then easy to make queries or selecting those Esdus and Schools belonging to a given Stratum or those Schools which belong to a group of Esdus.

1.2. Protocols for extracting school parameters from echosounder echograms

Each project participating Institute has developped his own protocol for extracting school parameters: ORSTOM and IEO work on paper echograms, IMBC works on paper and digital echograms and SOAEFD and IFREMER work on digital echograms.

ORSTOM has extracted school parameters from paper echograms by a manual procedure. IEO has developed for this project a semi-manual procedure. Paper echograms are scanned. The digital images are then treated with a commercial image analysis software which allows to draw the school limits of by eye selected schools and take measurements of these objects using the mouse on the screen. SOAEFD has developed an image analysis procedure of the digital echogram based on the identification of objects by applying image analysis algorithms (constrast enhancement, blurring and erosion/dilatation) (Reid and Simmonds 1993). The algorithm has been implemented on Pc with a user friendly interface. IFREMER has developed an image analysis procedure of the digital echogram based on a ping by ping analysis of continuity (Weill et al. 1993). This is a commercial software named in its latest version Movies_Plus. IMBC has developed an image analysis procedure also based on a ping by ping analysis of continuity (Georgakarakos and Petarakis 1993). This is a software named School. For treatment of paper echograms in this project, IMBC has developed a quasi entirely automated procedure. Paper echograms are scanned. The digital images are then firt treated with a software called Scin which allows to separate interesting echogram portions from unwanted information on the image (lines in particular). Then the selected portions are treated using the software School. Except for Movies_Plus, the softwares are dependent on the echosounder output format.

2. Sensitivity of school parameters (standardisation)

Number of schools, length of school section and school density are of major ecological importance in the project. They are also dependent on equipment settings, depth of school and extraction protocols. The standardisation task contains theoretical and experimental work. The theoretical work is performed by simulating acoustic images which enable to study the sensitivity of school parameters to equipment settings and depth. The experimental work is performed by replaying digital data.

Beam refers here to twice the half beam angle (full beam).

The major results of the theoretical work are:
- justification of a common echointegration threshold at -60dB
- proposition of an algorithm to estimate real school size and density from echo-trace apparent parameters.

The major results of the data replays are:
- Good performance of the -60dB echointegration threshold: loss of small weak schools when increasing the echointegration from -70dB to -60dB.
- Small weak schools contribute little to the total energy but make the number of schools vary greatly. These are eliminated when increasing the echointegration threshold.

- Small schools not well sampled because of beam width at depth are few and contribute little to the total survey energy

2.1. Influence of equipement settings on school parameters

The beam angle defines the sampling volume (confusion volume) and is therefore used: (i) in the estimation of the school average volume backscatter Sv and (ii) in the corrections of the echotrace length at depth. The beam angle varies at each ping in a complex manner with the target strength of the schools, the Echointegration threshold and the school depth. Diner (1998) defines 3 beam angles (Fig. 1): the nominal angle θ defined by the theoretical 6dB attenuation, the detection angle B of the cone inside which are located the fishes contributing to the echo level and the "attack" angle A which is the angle of the first and last pings hitting the school. θ depends on the directivity function of the transducer, B on the difference between backscattered energy and echointegration threshold. The angle A varies in the most complexe way as it depends on the directivity, school density, echointegration threshold and how much of the beam is filled by the school. Correcting of the apparent length of the school requires the estimation of A and this requires simulations.

2.1.1. Arguments for a -60dB Echo-integration threshold

Echosounder directivity pattern and
difference between threshold (Tv) and school volume backscatter (Sv)

The 2-way directivity function of an echosounder and thus the width of the equivalent beam angle is defined by the difference of sound level (Δ in dB) coming from a point on the central axis and apart from it at the same distance from the receiver. The detection angle B varies with the difference Δ_v between echointegration threshold Tv and the real school volume backscatter Sv. The 2-way directivity function of an echosounder shows 3 regions (Fig.2). Region 1 (0<Δ<-10 dB) where the beam is small (less than 5 degrees) but where a small variation in dB has a large consequence on the beam. Region 3 (Δ<-30dB) where the beam angle is big and where the secondary lobe is active. The intermediate Region 2 (-25<Δ<-10 dB) is where the beam is relatively big but insensitive to variations of the Δ_v. Considering that the schools of interest have on average an Sv of -45dB, it seems reasonable to use a echointegration threshold of -60dB.

Orders of magnitude of packing density

-61dB at 38kHz corresponds to a density of 0.01 fish per cubic meter of length 20cm
-60dB at 120kHz corresponds to a density of 100 krill individuals per cubic meter
The fish school of interest for the Cluster program are a lot denser.

2.1.2. Diner's algorithm to estimate school length and density from apparent echotrace length and density

Diner (1998) has developped a simulator of schools insonification and backscatter and has proposed an algorithm to estimate school length and density from apparent echotrace length and density. Echotrace parameters extracted from echograms depend mainly on the following parameters: echosounder nominal beam angle, echointegration threshold, school density, school dimensions and school depth. Many situations were simulated. The corresponding echograms were processed with the software Movies (Weill et al. 1993). This was repeated with a range of different echointegration thresholds. A data base with more than 700 school situations was worked on. Regression charts between various parameters were derived by processing all simulated data. This will allow the estimation of the angles B and A (Figures 3, 4 and 5). The algorithm is iterative because we don't know the real school Sv when working on data (we only can estimate the echotrace volume backscatter from the acoustic image).

Phase1: the echotrace Sv is estimated (Esv) and its $E\Delta_v$ is deduced: $E\Delta_v$=ESv-Tv. This allows to estimate the detection angle B from the regression on Figure 3 based on the simulation results. This regression is analogous to an inverse transducers directivity function. The number of beamwidths Ne corresponding to the echotrace length Le at depth D is deduced: Ne=Le/(2Dtan(B/2)). Figure 4 shows the dSv that can be estimated using the regression on Ne which is obtained from the simulations. A first school Sv can then be estimated: Sv=ESv+dSv. So: Δv=Sv-Tv

Phase2: the "attack" angle A can now be estimated using the regression of A on Δv on Figure 5 based on the simulation results. School length Ls is finally estimated as: Ls=Le-2Dtan(A/2).

From here, Diner (1998) proposes to estimate a new value for Sv using the new value of the number of beamwidths that can be computed from Ls. The author also gives formulas for surface, perimeter and energy corrections. The school height is estimated by substracting $c\tau/2$ to the echotrace height (multiscattering effects inside the school are not taken into account).

2.2. Influence of depth on school parameters

Diner (1998) produce charts which show the increase of echotrace length with depth (Fig.6) and the decrease of Echotrace Sv, ESv (Fig.7). The increase of length is due to the "attack" angle and the decrease of ESv is due to « marginal » pings not fully occupied by the school when depth increases. The decrease is only of a few dB. Lines on the figures are for different values of Δ_v (difference between School Sv and Echointegration threshold Tv).

2.3. Influence of extraction protocols on school parameters

Same portions of echogram have been analysed by different extraction protocols. For dense schools, similar results were found with the manual and the Movies procedures (Fig.8) as well as for the Image analysis and the Movies procedures (Fig.9). Schools seen morphologically with a lot of heterogeneity inside lead to differences between eye oriented choices and automated definition of borders. All extraction protocols use the scientists subjectivity (expertise) because a selection of echotraces is needed at the final step.

2.4. Echotrace typology: can two scientists agree on the visual interpretation of echograms?

The coding of echotraces at the ESDU level in the categories Dispersed, Schools, Aggregation, Layer and Other is subject to the scientist's choices. In order to answer the question "can two scientists agree on the visual interpretation of echograms?", 75 ESDUs were coded by 2 different scientists (IEO and IFREMER) independently. When the ESDU contained an echotype, the scientist noted 1 in the corresponding category and 0 otherwise. PCA was applied on the matrix where the 75 lines are the ESDUs and the 6 columns are S1,A1,L1,S2,A2,L2. S,A,L stand for School, Aggregation and Layer. The index denotes each scientist. There was 100% agreement for the categories Dispersed and Other and these were not considered in the analysis. Results are shown on Figure 10. We see that there is good agreement for the categories Layer and Schools but not for Aggregation.

2.5. Replays of data

Assessment in the data sets of the importance of too small schools

These schools are sampled with too few pings to allow estimation of their length and Sv: their apparent length is smaller than the correction (one full nominal beam at depth). For IEO, these schools represent 0.5% of the all schools extracted sofar. For Ifremer, these schools represent 3% of all schools in the 1992 survey and represent 0.7% of the summed energy in all schools. But they represent 18% of all schools at depths between 60-120m depths. Marlab has performed an estimation by species: if the too small schools represent only 5% of the herring schools, they represent more for mackerel schools (Fig.11). For Orstom in Senegal, these schools represent also a small proportion of extracted schools but echogram objects considered as schools were relatively large (5m in height).

Performance of the -60dB Threshold

Marlab usually performs enchointegration with the threshold -70dB. Replays have been done on a selected portion of a survey to assess the consequences of using a threshold of -60dB.

In the IA Marlab algorithm of school identification (Reid and Simmonds 1993) an erosion/dilation is performed on pre-identified objects. Those which survive this pass are retained as potential school objects. With -70dB, 2 passes of erosion/dilation are necessary to pick objects adequate to what the eye is pleased with. With -60dB, only one pass is sufficient. Histograms of different object parameters (Sv, height, width, CV of distances from center to edge pixels) were computed to evidence the differences between the 2 procedures. In comparison to the -60dB with 1 pass, the -70dB with 2 passes adds schools that are smaller and less dense. The -60dB with 1 pass seems appropriate to select school objects relevant to the Cluster Programme. (Fig.12)

Allocation of the Energy in the schools as a function of the Threshold

Ifremer usually performs echointegration at -60dB. Replays have been performed on 2 selected portions of a survey where small schools were related with a near bottom diffuse layer, one at 50m and the other at 150m depths. Replays have been performed to study variations of school object parameters (Energy in the schools, number of schools, length of schools) over a long range of echointegration threshold values from -45dB to -65dB.

The school identification is performed with the software Movies developped by Ifremer which works on the continuity of ping values both horizontally and vertically (Weill et al. 1993). When decreasing the threshold and particularly between -55 and -65dB, the number of identified school objects increases greatly. These are evidenced to be small schools with little energy in them (Fig.13). This rises the question of the biological importance of small acoustic grains (schools) with little energy in them.

3. Conclusion

Simulations and data replays were complementary tools in this work. Corrections of echotrace size and density to estimate school size and density based on simulations provide charts for critical interpretation of the data. The major worry in the constitution of the data bases was that the sources of variations (visual interpretation at ESDU-level, extraction protocols of echotraces, influence of equipment settings on estimated school parameters) would produce data bases per country that would not be comparable. The results show solutions for making comparisons. Our objective is to be able to diagnose when it is meaningfull to make a comparison between schools acquired with different settings.

Ackowledgments:
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Weill A., Scalabrin C., Diner N., 1993, MoviesB: an acoustic detection description software: application to school species classification, Aquatic Living Resources, vol.6(3): 255-267.

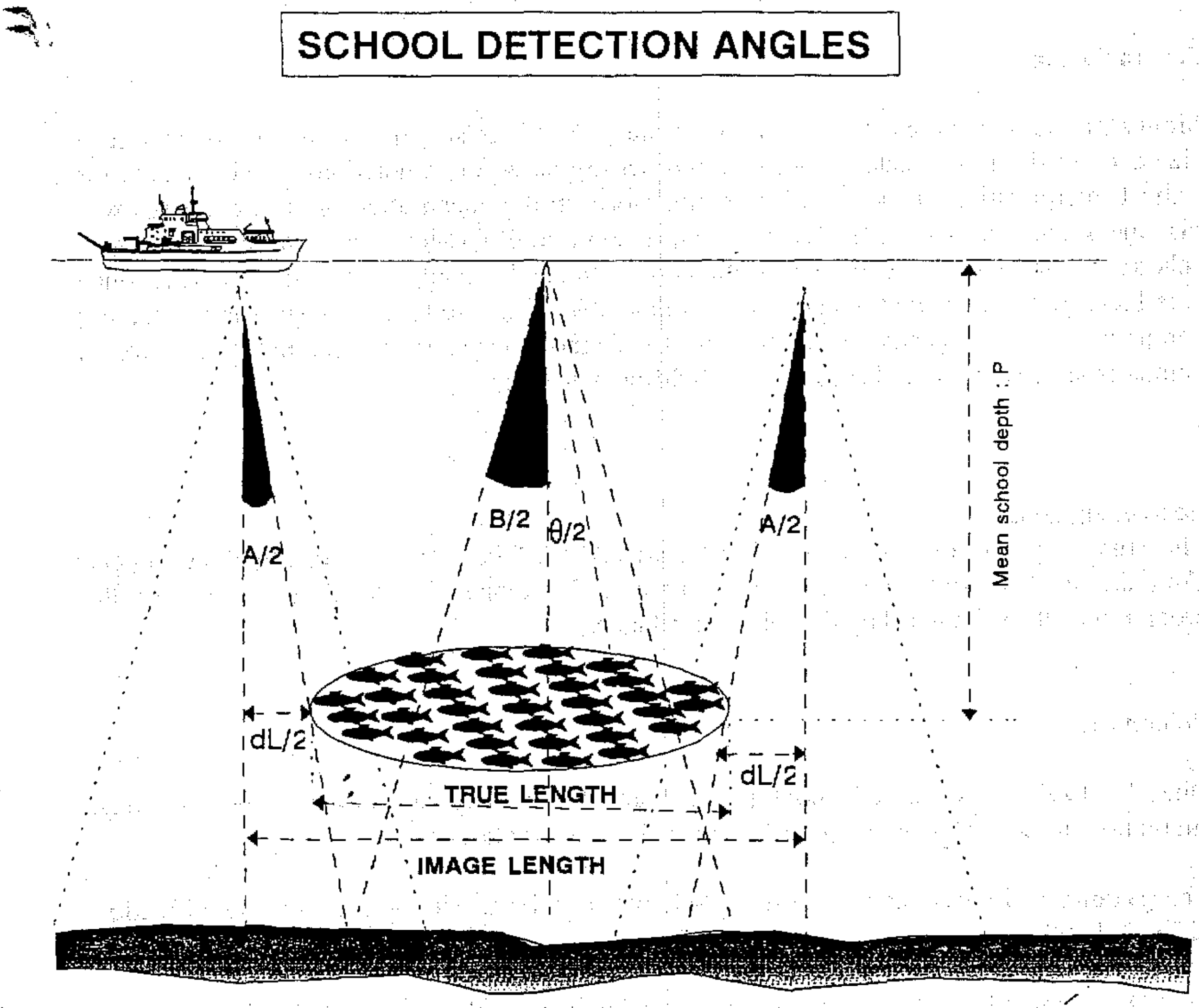

Fig. 1 : Different angles concerned by a school detection :

- θ : nominal angle defined by the 6 dB attenuation (two -away)
- B : detection angle fro the cone inside which are located all the fishes contributing to the echo level,
- A : ''attack'' angle which must be used for length correction of echo-traces :

$$dL = 2 \times P \times \tan(\frac{A}{2})$$

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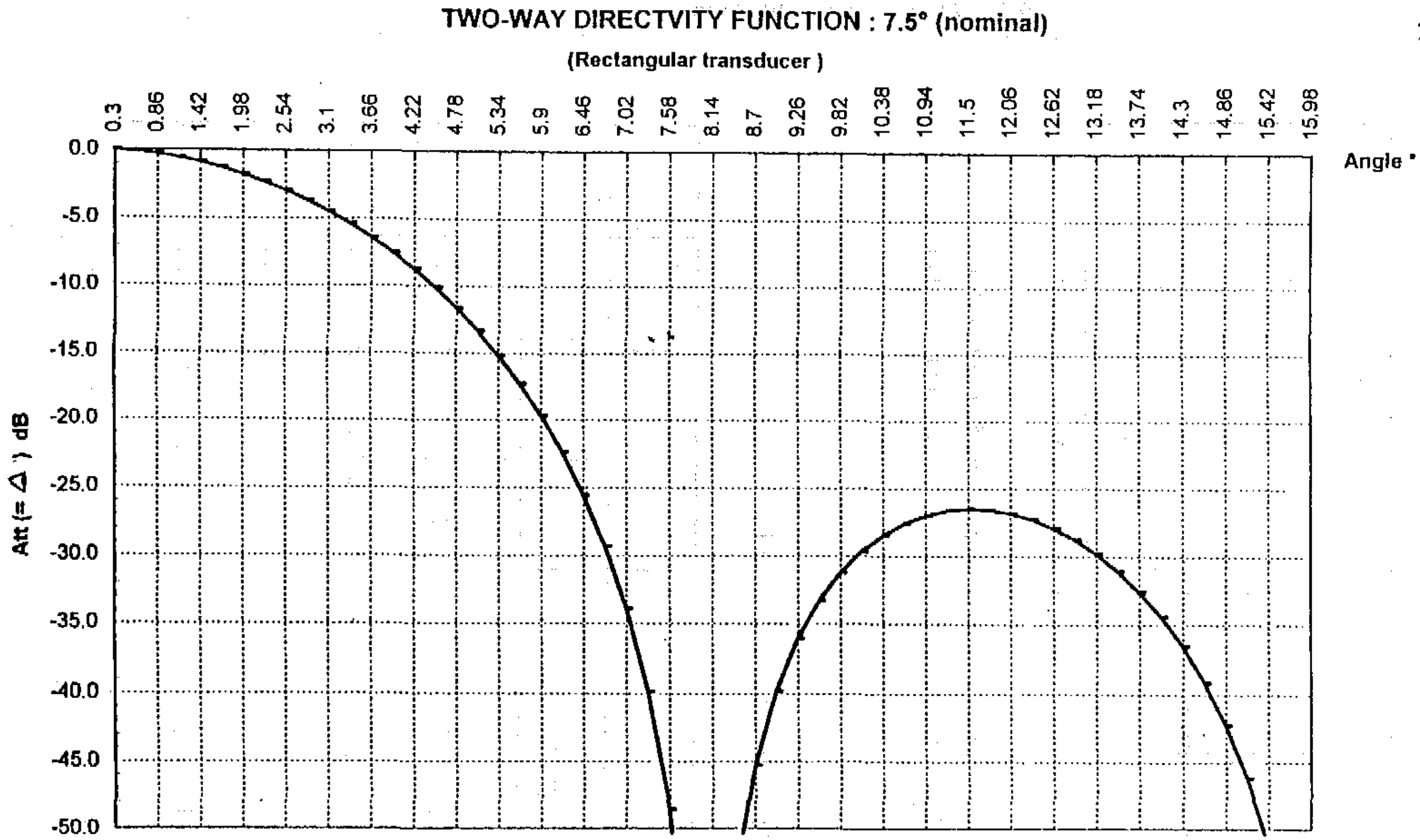

Fig. 2 : Two-way directivity function for rectangular transducer of nominal beam angle 7.5°.

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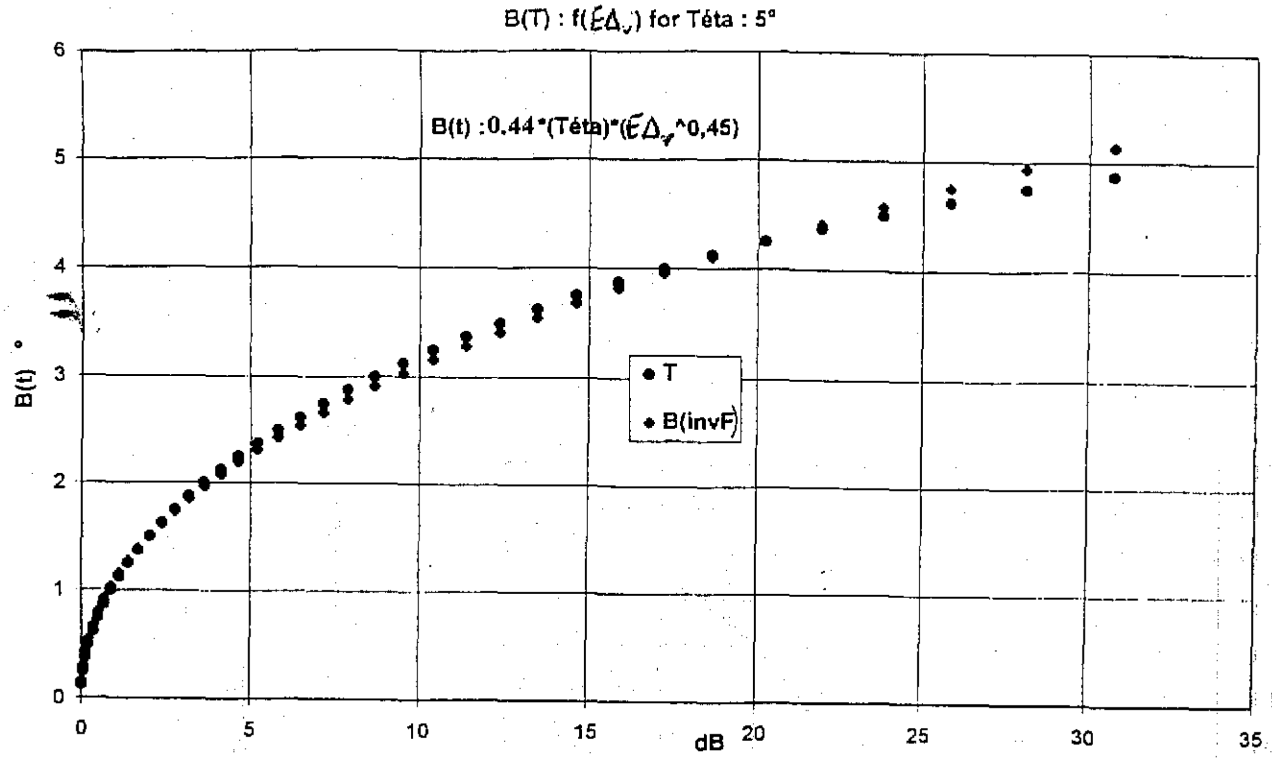

Fig.3 : Detection angle relation as an inverse function of transducer directivity function for a nominal angle 5°: • : true directivity function, ◆ : plot of the points of the function B(t).

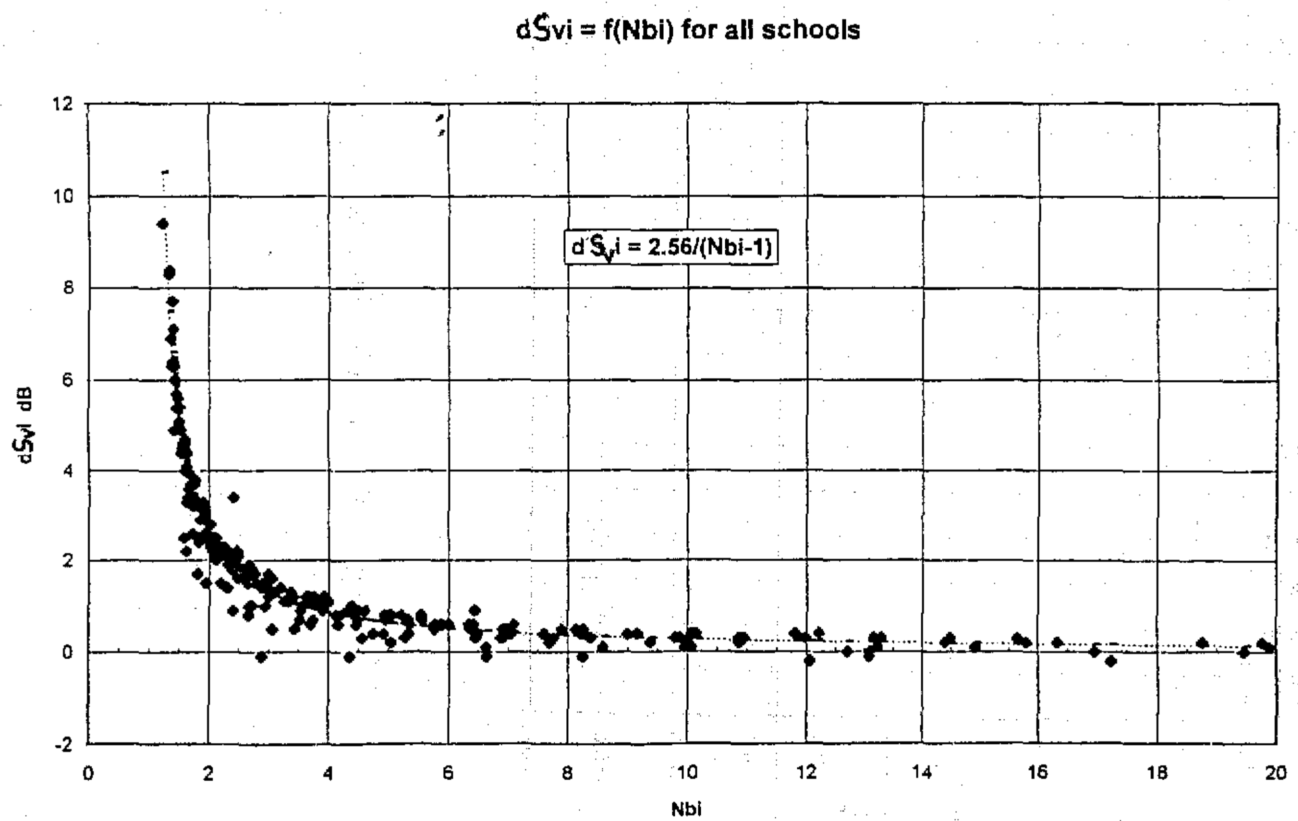

Fig. 4: Graph of dSvi versus Nbi. The function1 fits quite well with the points and allows the calculation of a first correction concerning the reverberation index of the echo-trace.

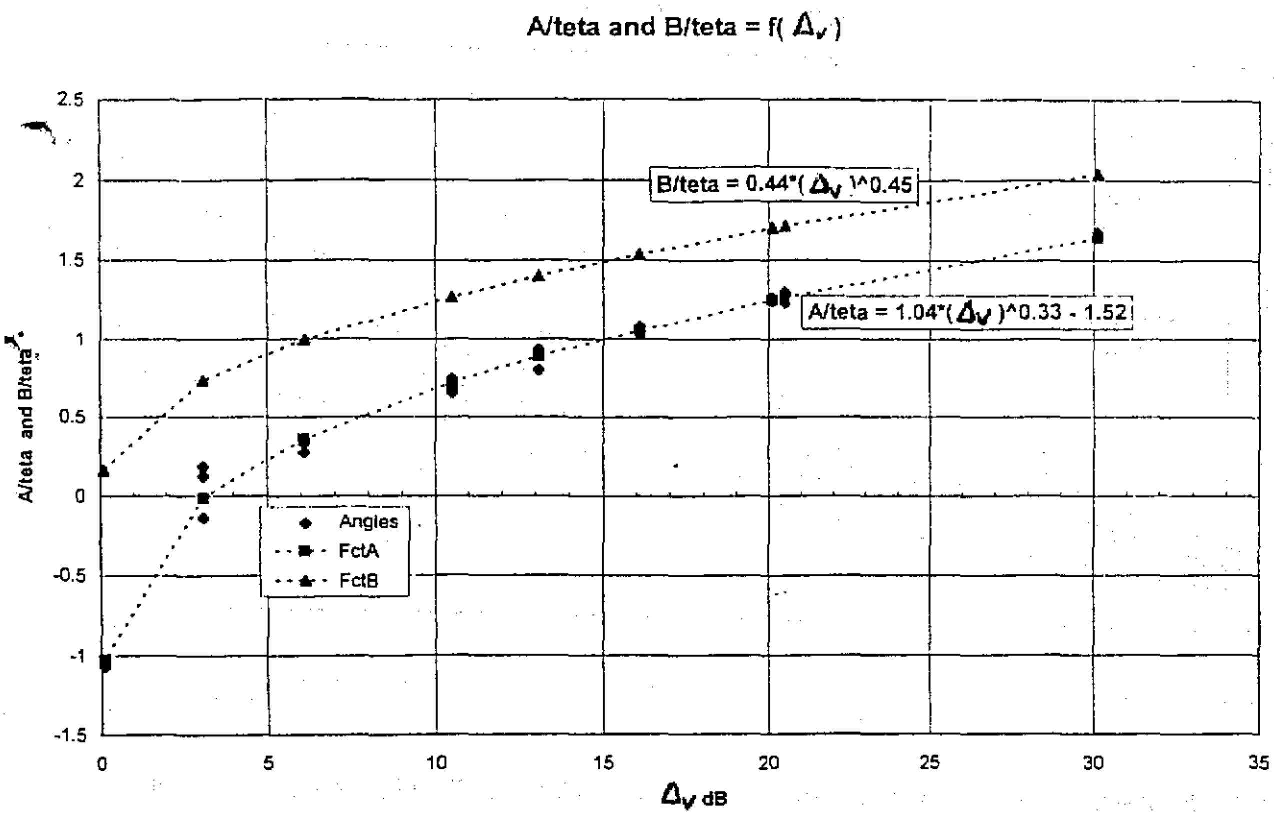

Fig. 5 . Graph showing the different ratios Attack angle, Ac, on nominal angle, θ, versus different Δ_v values. The function gives a mean relation between Δ_v and Ac/θ. The relation giving the ratio of the detéction angle, B, on nominal angle, θ, is plotted for comparison.

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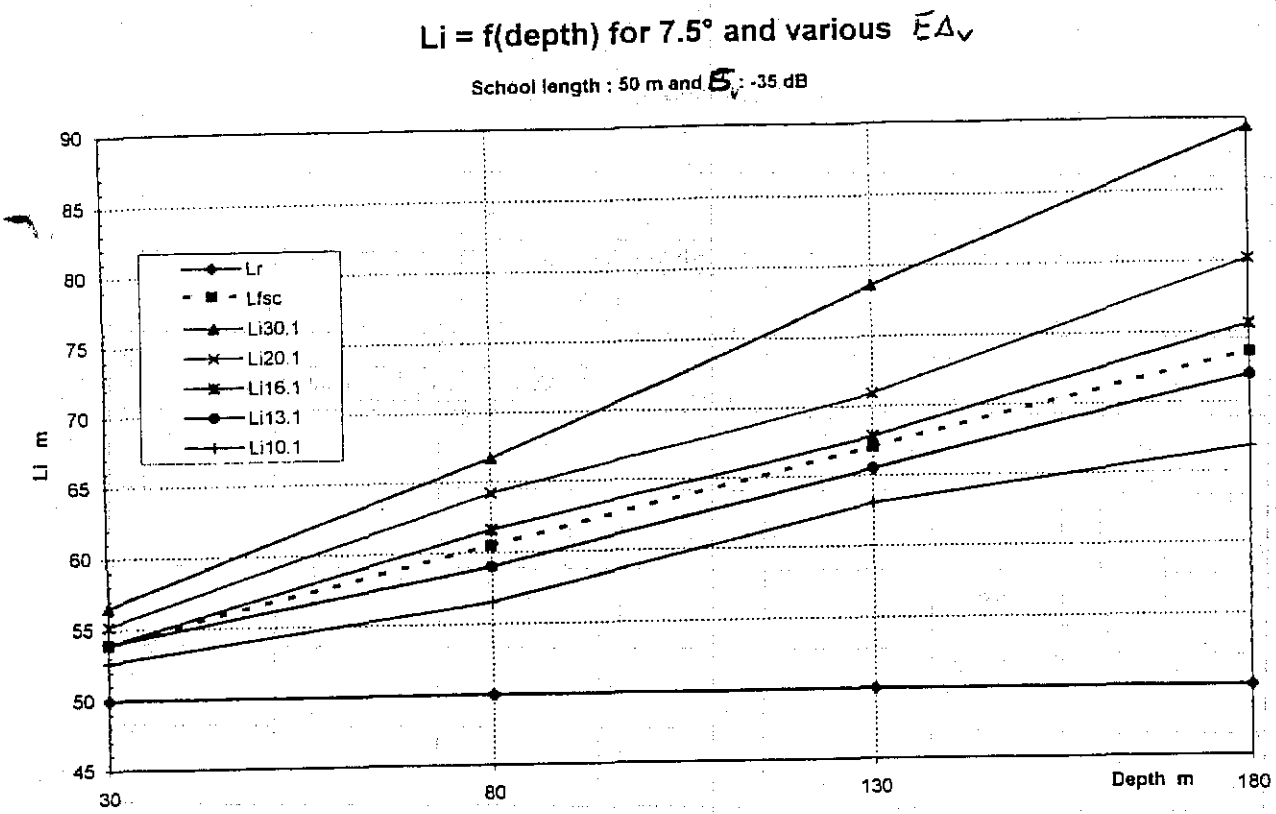


Fig. 6 : Echo-trace lengths for a school length 50 m and S_v -35 dB with various $E\Delta_v$ - 30.1, 20.1, 16.1, 13.1 and 10.1 dB :
versus mean school depth for a nominal angle of 7.5°,

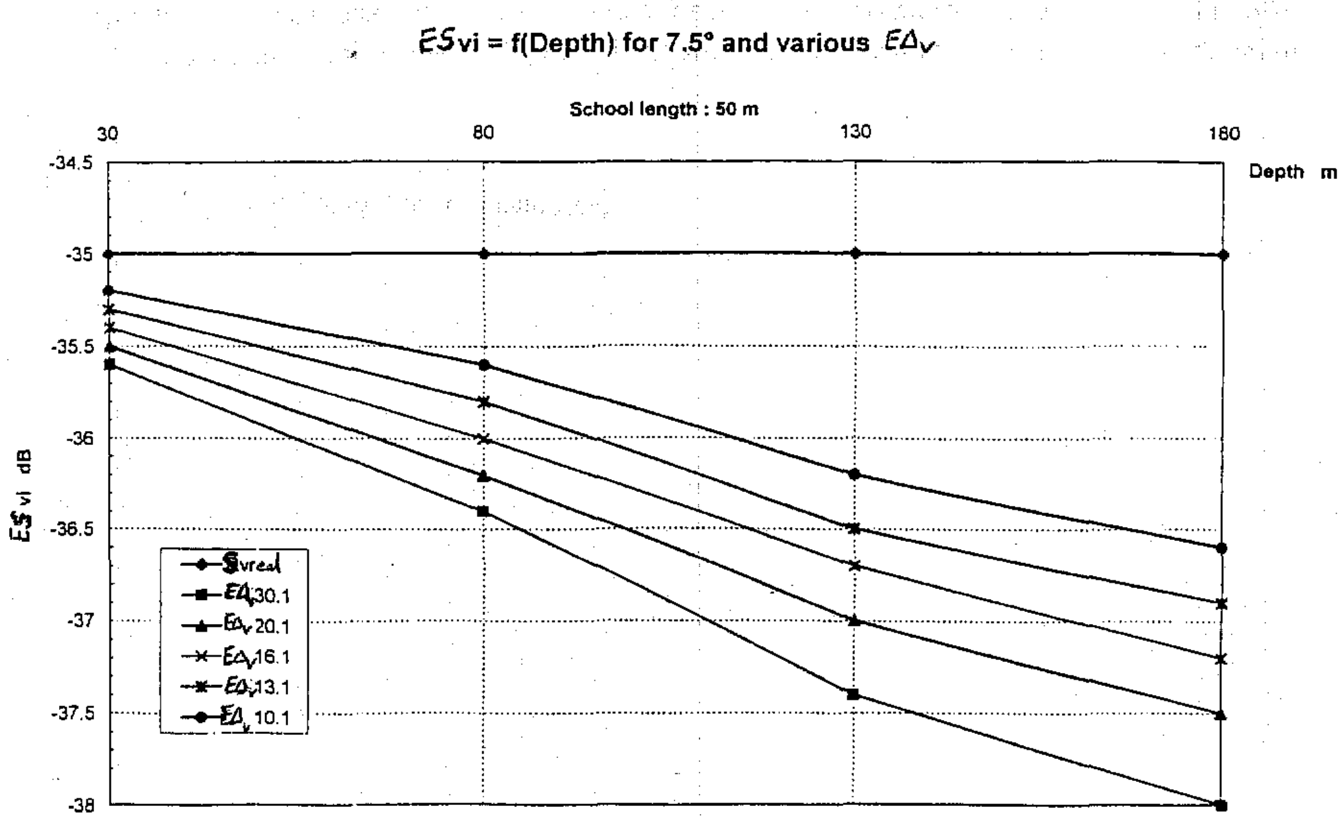
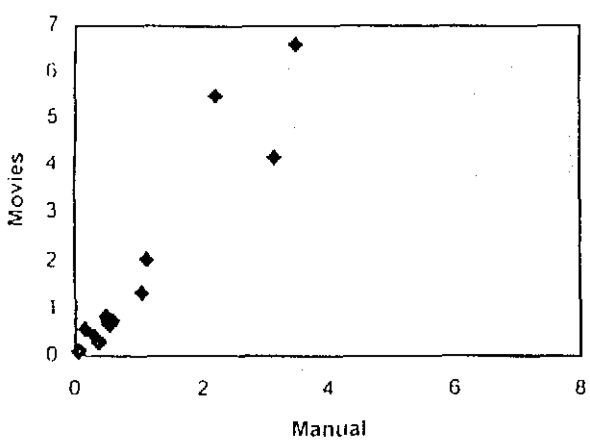


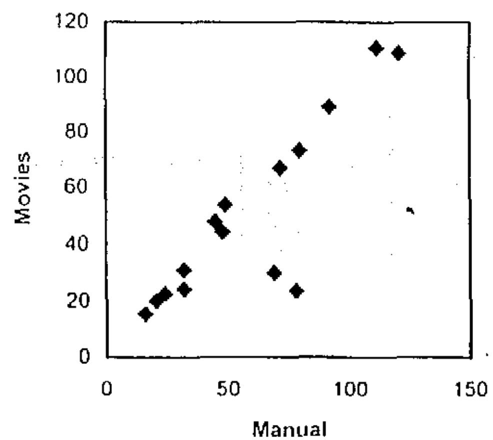
Fig. 7: Echo-trace volume reverberation index, ES_v, for the same school as Fig. 6 and same $E\Delta_v$:
versus mean school depth for a nominal angle of 7.5°

FIG.8: Comparison between automatic Movies_B school measurements and manual measurements on the same compact schools that stand alone in their ESDU
Digital 1997 survey of ORSTOM in Senegal
Packing density in the manual procedure is computed by allocating the total acoustic energy of the ESDU to the school rectangular section. The TS used is -35.4dB/kg

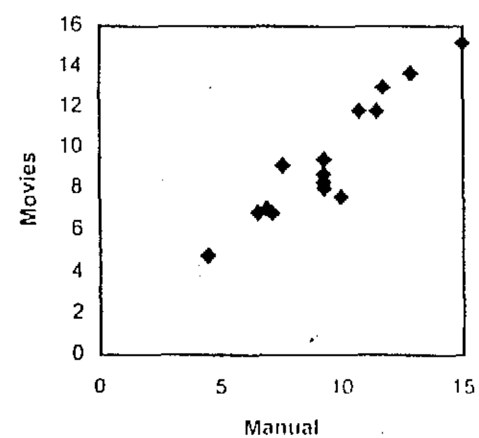
Packing density (kg/m3)



School length (m)



School height (m)



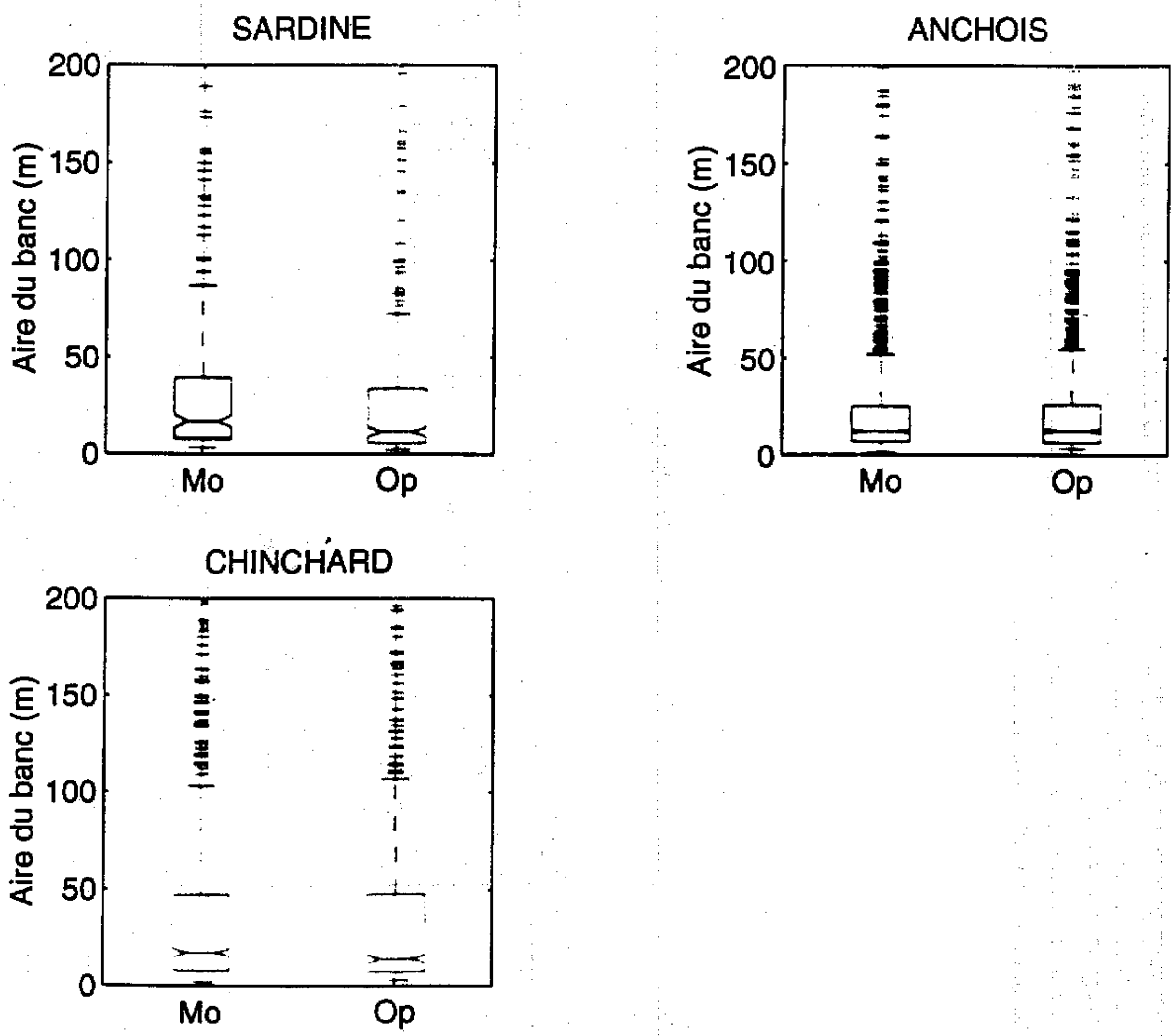
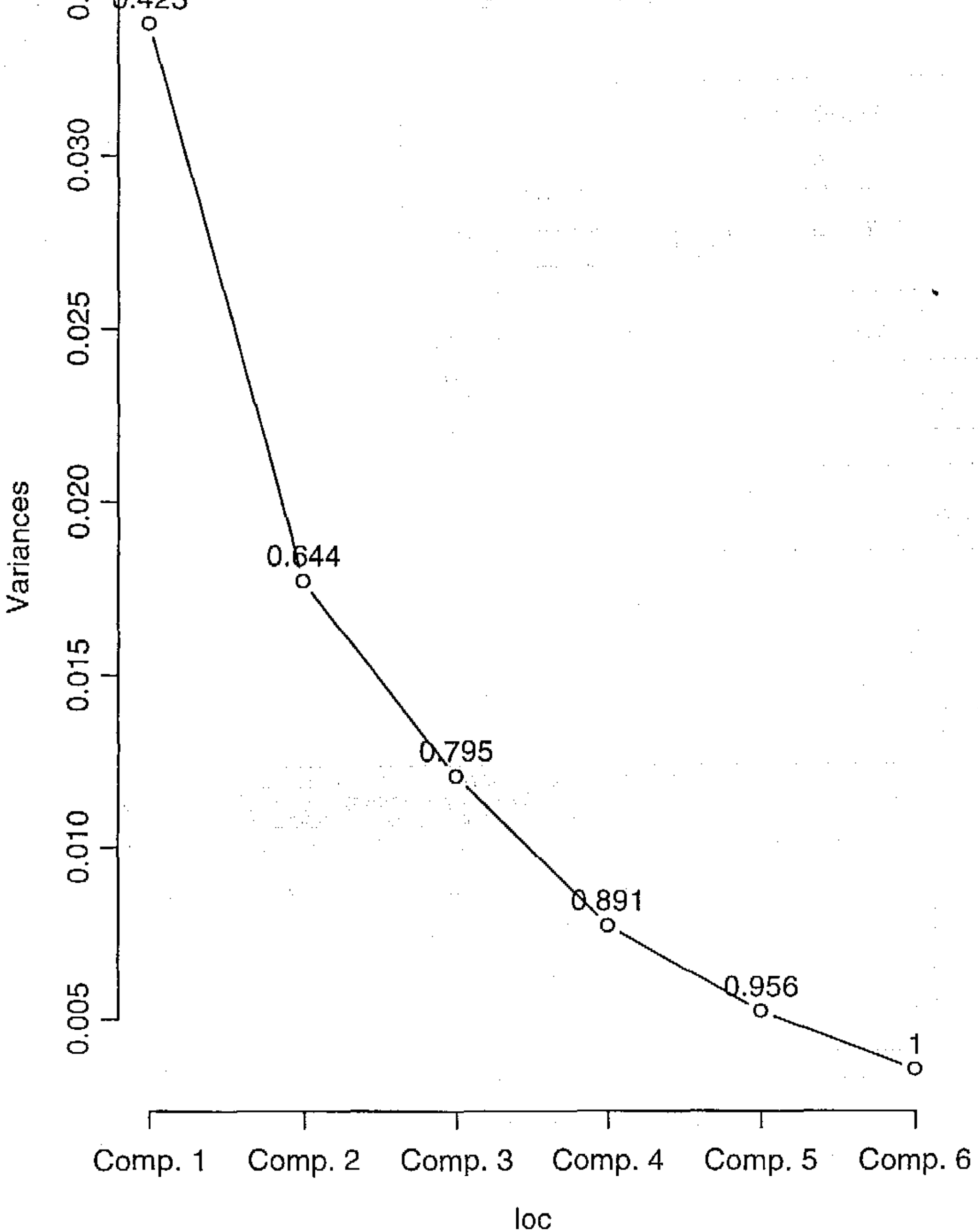
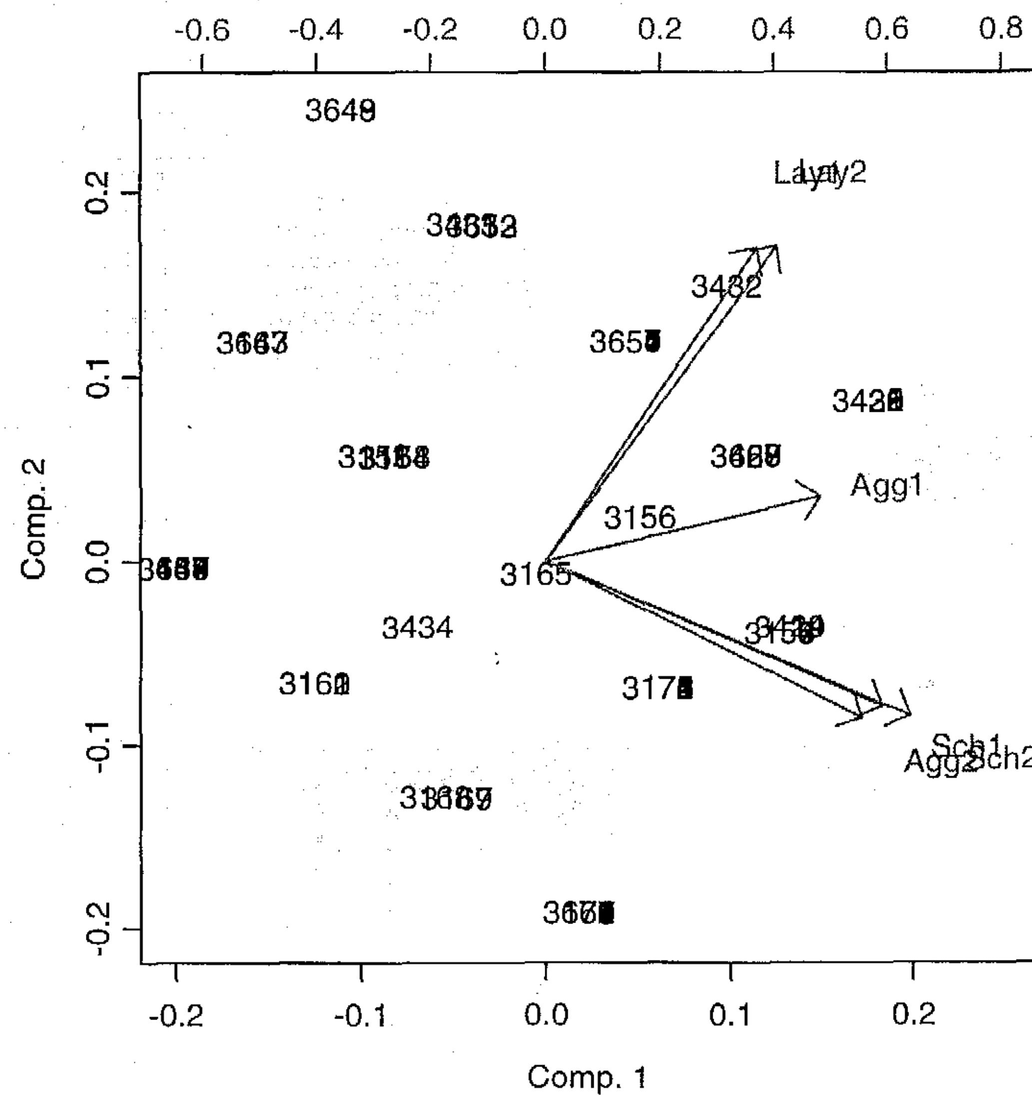
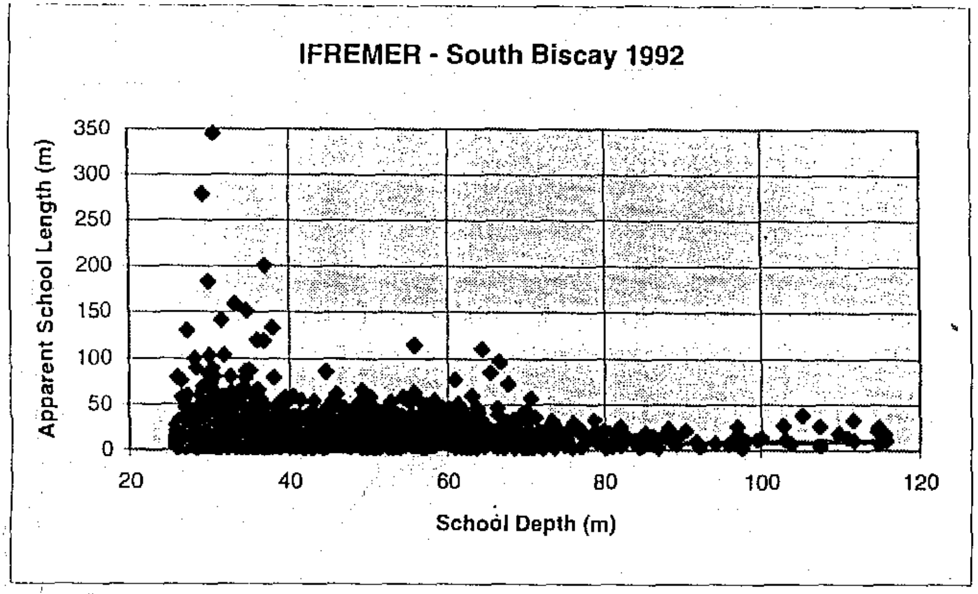


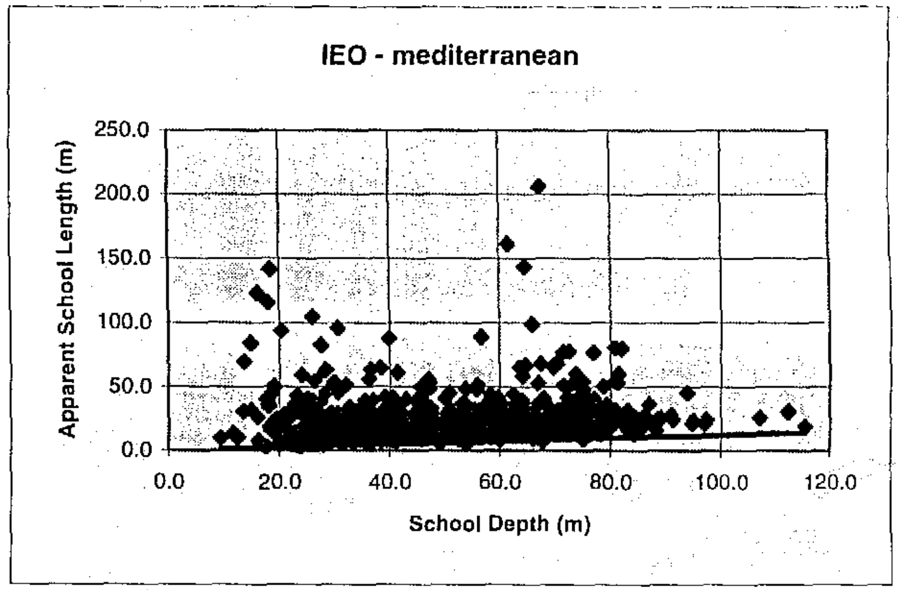
Figure 9: Comparison between Movies_B and Optilab estimates of echotrace area.

Figure 10: Results of PCA performed on table of abscence/presence. Two scientists (1 and 2) have coded echotraces along 75 miles of an acoustic survey in 3 categories: School (S), Aggregation (A), Layer (L).









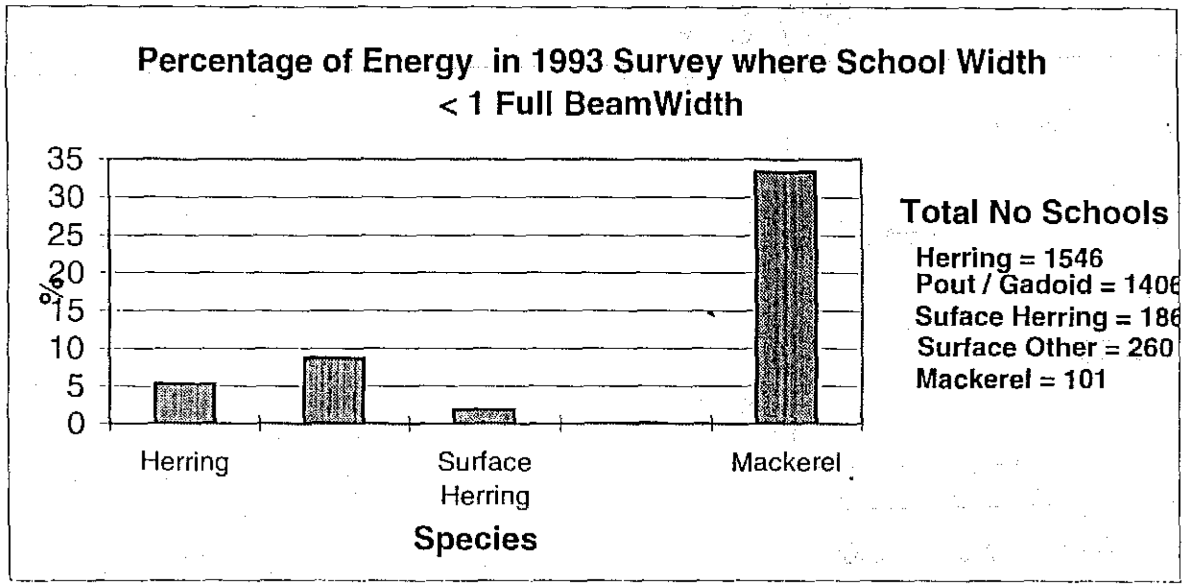


Figure 11: Echotrace length as a function of depth. The line shows the full nominal beam angle at depth, ie the "classical" correction applied.

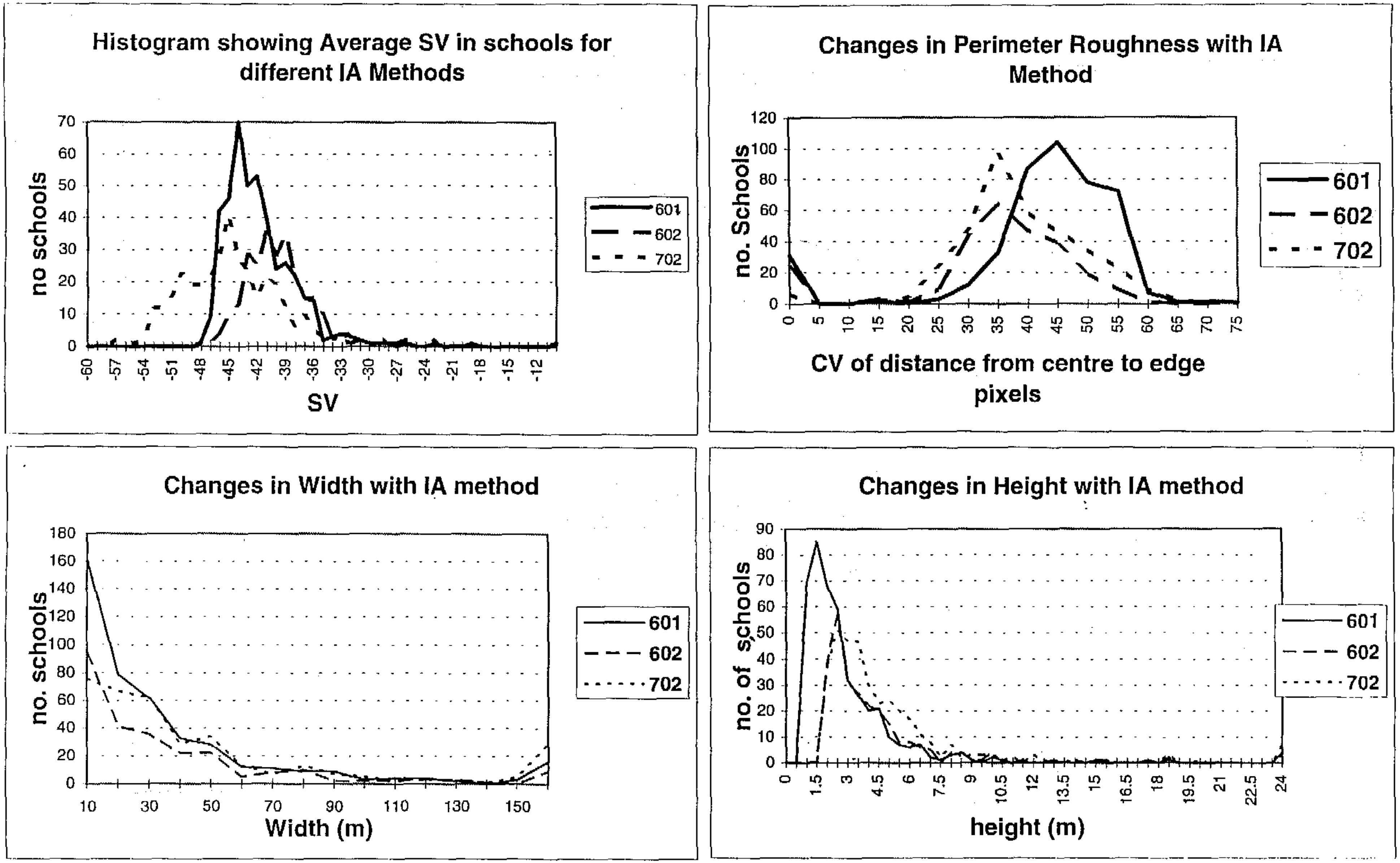


Figure 12: Variation of school parameters with threshold and Image Analysis algorithm. SOAEFD.

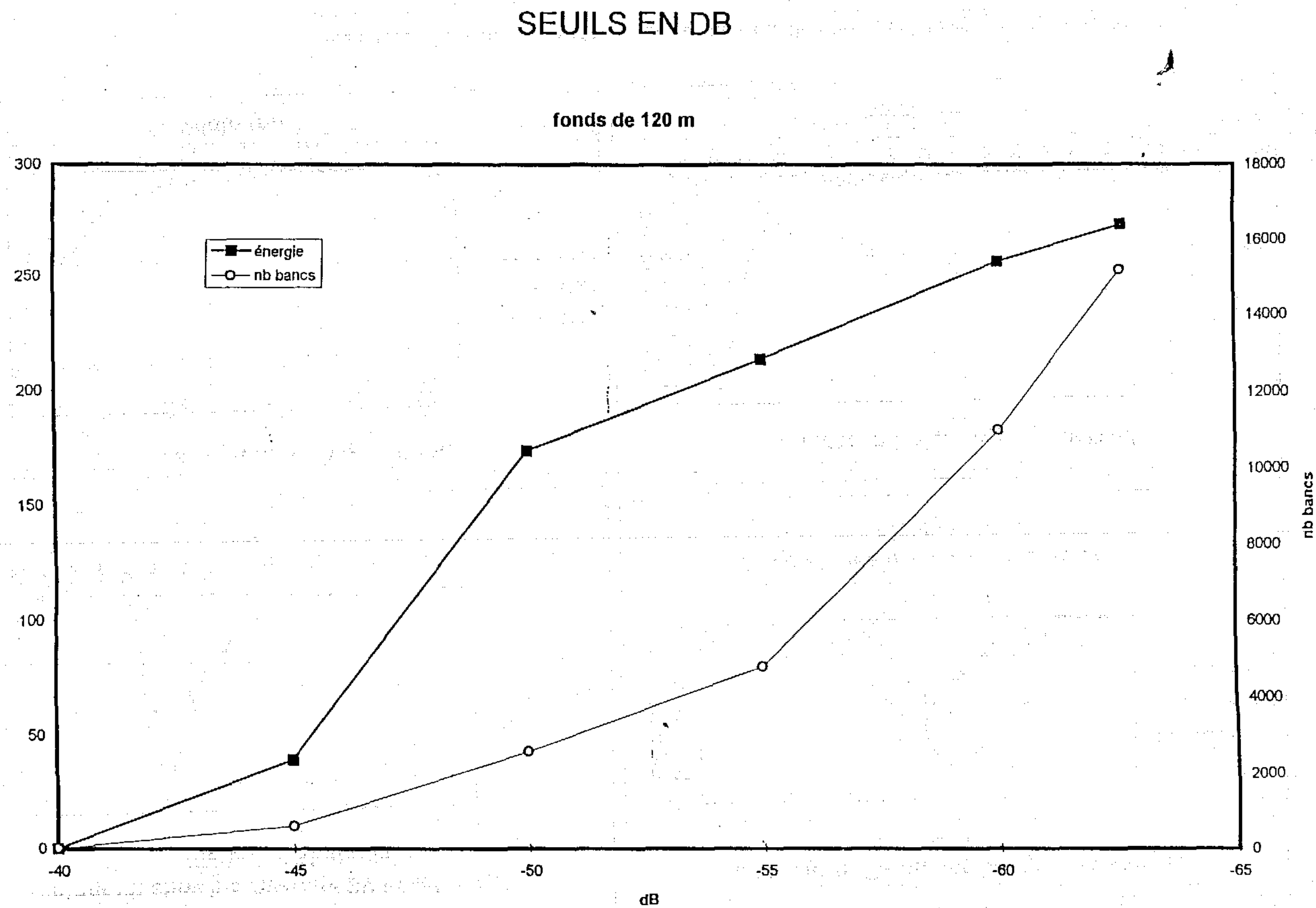


Figure 13: Energy in the schools and number of schools as a function of threshold over one Nm in Southern Biscay on bottoms of 120m. The schools are identified for when H>1.5m; L>2pings (2m). IFREMER.