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A METHODOLOGY FOR ACOUSTIC ASSESSMENT IN VERY SHALLOW WATERS (LESS THAN 8 M)

by

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RESUME

Une méthodologie de prospection acoustique et de traitement des données pour l'évaluation des biomasses est proposée pour les systèmes lagonaires tropicaux, à fond plat, profondeurs faibles (de 3 à 8 m) et houle réduite. Les méthodes de mesure de l'angle d'échantillonnage et de déconvolution des TS "in situ" sont adaptées de la littérature pour ce cas particulier. L'application de cette méthodologie au golfe de Batabano (Cuba) montre que les meilleures évaluations de biomasses sont obtenues par comptage, et que la précision des mesures dépend étroitement des conditions extérieures: prospection de nuit exclusivement, mer plate et absence de lune.

ABSTRACT

A methodology for acoustic assessment and data analysis is proposed for the case of tropical island lagoons, with flat and very shallow bottom (3 to 8 meters), and low swell. Methods of measurement of the sampling angle and TS "in situ" deconvolution have been adapted from the litterature for this particular case. The application of the methodology to the Gulf of Batabano (SW of Cuba) shows that the best biomass evaluations are obtained by fish counting, and that the precision of the results is directly depending on external weather conditions : prospection exclusively by night, no swell, no moon light.

INTRODUCTION

The shelf of tropical islands presents usually two kinds of bathymetric structures: on the one hand, a lagoon, with very shallow waters, with flat sandy bottom including in some places circular coral reefs, and limited by the island coast and on the peripheral by mangrove on small islands and long and thin coral reefs; on the other hand, a very narrow shelf from 10 to 500 meters, all around the island. Each of these systems presents particular ecological characteristics and different fish populations, which present usually the common particularity to have a rather low density, the fish being concentrated in a few places by day and very scattered by night (fig. 1).

As far as acoustic assesment is concerned, both types of fish distribution do not permit to apply conventional methods, and appropriate methodologies are required. We present in this communication the methodology that has been developped for the first ecosystem, through the example of a survey program of the Gulf of Batabano, SW Cuba.

1. CHARACTERISTICS OF THE AREA

The Gulf of Batabano is a flat area of more than 20 000 km^2, with a mean depth of 6 meters (EMILSON and TAPANES, 1971), limited in the north by the island of Cuba, in the SW by the Juventud Island, and in the S and SE by a line of keys (low island covered with mangrove) and coral reefs (fig. 2). The bottom consists generally of muddy sand covered with a phanerogame, Thalassia testudinum. In some places circular coral grounds may be found inside the gulf.

The fishery is exploiting several families: Lutjanidae, Serranidae, Pomadasyidae, some typical coral families and spiny lobsters.

The fish live in two main groups:

- group depending on coral reefs: the fish live around the coral reefs by day and are scattered all over the Thalassia bed by night. This group is formed of the families mentioned above.

- group depending on mangroves: the fish, mainly small Clupeids (Harengula spp, Opisthonema oglinum, Jenkinsia lamprotenia) and juveniles of the other groups, live inside the mangrove by day and move to the grass bed by night, where they may be found either scattered or in small schools according to the light of the moon.

The climatic conditions within the gulf may be found very favourable in some periods of the year (no swell, no wind, low currents, etc).

2. MATERIAL AND METHODS

The choice of the material will depend of the following constraints:

- survey in very shallow waters (3 to 8 m), making necessary:
    * use of a small shallow-draught boat;
    * sounder with small blind-zone and TVG useable in the first meters below the transducer
    * large-beam transducer, for obtaining the highest sampling

- use of small boat:
    * equipment with independent electric power-supply;
    * favourable weather conditions;
    * transducer to be put close to the surface.

- fish behaviour:
    * survey exclusively by night;
    * survey during new moon and complete darkness.

- work on large areas:
    * a rather big ship is needed for life and work base
    * need of a positionning system, include aboard the small boat.

We have used the following material:

- echosounder EY-M SIMRAD, 70 kHz, with 22° transducer (1);
- portable digital tape recorder DAT (Sony) (1);
- echo integrator AGENOR (2);
- computer Toshiba T 5100 (2);
- boats: a 6 meter plastic motorboat, with flat hull (draught less than 50 cm), and a 25 m research vessel (R/V Triton)

The survey grid was the following: the transects are performed at 4 knots aboard the motorboat, and only the echo sounder and the tape recorder are used. The position of the small boat is obtained by reference to the big one, which is placed in some pre-defined points. The recorded data are processed during the day aboard the big vessel.

The transducer is placed on the fore part ov the motorboat (fig. 3), and is fixed as close to the surface as possible according to wave noise.

3. PRINCIPLES OF THE EVALUATIONS

The fish are extremely scattered. In these conditions the only reasonable method for biomass evaluation is the fish counting, but the conversion of the densities in number of fishes per cubic meter in densities in tons per square kilometer needs two precise informations about:

- the sampled volume;
- the TS distribution "in situ".

A. Measurement of the sampled volume

Most of the methods existing (EHRENBERG, 1983; MARCHAL, 1983) and particularly the so-called "duration-in-beam" method (THORNE, 1988) use the number of echo received from a single fish, in order to determine the actual angle of the beam, according to the mean TS of the fishes and the threshold of the receiver. Unfortunately this kind of method is impossible to apply on our results, because usually the fish is too close to the transducer to give more than a single echo.

Therefore we have been oblige to adapt the usual method in the following manner:

the calibration standard sphere has been moved horizontally below the transducer at constant slow speed along a line that crossed the beam axis. This operation has been repeated several times, for each gain value of the echo sounder, in order to give curves of the relations between voltage response and beam angle for various TS values.

Once determined the mean beam angle, the sampling volume is easily obtained using classical calculations (FORBES and NAKKEN, 1972; JOHANNESSON and MITSON, 1982, for instance).

B. Correction of the TS "in situ" measurement

We have adapted a method derived form the "deconvolution method" presented by CRAIG and FORBES (1969). The principle is the same as described by these authors (see also FORBES and NAKKEN, 1972), but the equations have been slighty changed in order to eliminate the negative results.

We have used the directivity diagram of the large beam transducer of the EY-M sounder given by SIMRAD. The angle of the beam for each 1 dB step has been measured manually, and used in the equations in the following way.

Let us suppose for instance that we have three sets of TS values, **High**, **Medium** and **Low**, and that N_h is the number of high TS, N_m the number of medium TS and N_l the number of low TS, and three strata in the directivity diagram, for instance -30 dB (angle Θ_1), -20 dB (angle Θ_2) and -10 dB strata (angle Θ_3). N_l is the sum of the big fish in the -30 dB stratum plus the number of medium fish in the -20 dB stratum plus the number of small fish in the -10 dB stratum. N_m is the sum of the medium fish in the -10 dB stratum plus the big fish in the -20 dB stratum, and N_h is the number of big fish in the -10 dB stratum. In these conditions the total number B of big fish is:

$$B = \left[N_h \frac{A_1}{A_1} \right] + \left[N_m \frac{A_2 - A_1}{A_2} \right] + \left[N_l \frac{A_3 - A_2}{A_3} \right]$$

where A_i is the surface delimited by the angle Θ_i

Once B obtained, and after removing the number of big fish TS in each strata, it is possible to calculate the number of medium fish as:

$$M = \left[N_m \frac{A_2}{A_2} \right] + \left[N_1 \frac{A_3 - A_2}{A_3} \right]$$

Then, removing the medium fish TS in each strata, gives us the number of small fish S.

C. Absolute biomass estimation

This estimation is done using the following data:

- D_f, number of fish in the unit volume;
- W_f, mean weight of a single fish.

The evaluation of D_f is obtained using the actual volume sampled and the total number of echoes counted on the echogram:

$$D_f = N/V$$

The calculus of the mean weight needs the TS values of a fish to be converted in length; then we have to convert the length distribution in weight distribution.

We have very few informations on the TS of tropical fish (LEVENEZ, 1987; GERLOTTO, 1987), and according to the fact that the only data on the species distribution come from the fishery and ecological studies (CLARO *et al.*, 1990), we have assumed that the use of the equation of LOVE (1971) was the most adequate transformation method:

$$TS = 19.1 \log L + 0.9 \log \alpha - 23.9$$

where L = length of the fish, and α = wave length of the sounder.

The transformation of the length distribution in weight distribution has been achieved using informations coming from the Department of Ichtyology of the "Instituto de Oceanologia" of Cuba (CLARO *et al.*, 1990), which are detailed in the table 1.

For each length class the L/W relationship of the most common species has been selected as the most representative.

4. RESULTS

We have applied the methodology in 6 different places on the Gulf of Batabano, using either parallel or zig-zag transects. The mean depth of the areas observed varied between 3.9 and 5.5 meters and the number of fish counted between 2.66 and 11.04 per km (table 2).

The results of these surveys were employed to test the validity of the methodology (fig. 4).

A. Measurement of the beam angle

The results of the measurements for the large beam transducer of the EY-M echo sounder are presented on the figure 5. According to the threshold used in echo counting (.15 V rms), and to the TS values (from -30 to -50 dB), this gives a mean beam angle of 30 °. We have assumed that the beam pattern was regularly conical. At a speed of 4 knots (2.00 m/s) and a transmission ping rate of 3/s, the overlapping between two transmissions begins at a depth of approximately 1.15 m. As the blind depth of the sounder has been observed to be 1 m, that means that there is a non-overlapped layer of 15 cm at 1 m below the transducer. With a 30° angle, this represents a volume of $v = 0.027\ m^3$ per transmission. In these conditions we can calculate easily the actual sampling volume V knowing the mean depth H, the length of the unit distance L and the half beam angle α :

$$V = D \left[(v * 3) + (H^2 * tg\alpha - z^2 * tg\alpha) \right]$$

where H = total depth
z = superior limit of the overlapped sector (in this case, z is considered as a constant, and equal to 1.15 m)
D = total distance of the transect
α = 1/2 beam angle

In some cases an other correction has to be add : when the wave noise is present on the surface layers, it makes it impossible to recognise the echoes of the fish to those of air bubbles, and consequently the upper limit of the observed volume has to be lowered. In this case the overlapped zone disappears ($v = 0$) and z is increased in the above mentioned equation. This gave for the actual sampled volume of the 6 experiments the values presented in the table 2.

B. Distribution of TS

It is important, before to use the EY-M echo sounder for "in situ" TS collection, to measure precisely the TVG function. We [illegible] classical way from 100 to 1.5 m. Then, due to the fact that we need to know the values of the TVG in very shallow depth, we have measured it using a standard sphere, from 5 to 0.90 m. The results show that the TVG is efficient until 1 m depth, but the data are overestimated in small distances (fig. 6). As the TS are measured within these small depths, a correction factor should to be applied. An other way consists in measuring (SL+VR) at these low depths. We have obtained (SL+VR) at 3.5 m and assume that this value is useable for the small depths without corrections.

We may then calculate the TS distribution (fig. 7)

C. Biomass evaluations

The biomass evaluation has been used in this experiment to test the applicability of acoustic assessment to the Gulf of Batabano: the annual catch in this area is well known, and gives a good idea of the actual biomass (PAEZ COSTA, 1989). The mean catch is evaluated as around 0.8 metric ton/km²/year in this kind of ecosystem. Considering that the total catch is 75 000 t and that the MSY calculated is evaluated to 80 000 t, we may assume that the density in the Gulf would be between 1.5 and 3.0 t/km².

After deconvolution, the TS histogram has been converted in a length histogram. Although we did not calculate the mean weight using the mean length, it is interesting to note that this mean length is 17.2 cm, which correspond reasonably to the population structure of the area as known from cathc data. The calculus of the mean individual weigh gives 217 g.

It is then easy to calculate the densities of each area sampled (table 2). These densities vary between 541 and 1980 kg/km².

5. DISCUSSION

We can see that the densities calculated through echo counting and TS measurements are lower than expected, but fit in the (ordre de grandeur). Various points are to be taken into consideration.

- TVG measurements. We must measure with better precision this point, which may input errors in the TS values.

- Fish behaviour. The survey has been performed during full moon, and a strong avoidance reaction of the fish was suspected. The next surveys will be performed in new moon periods.

- Weather conditions. They were rather favourable at the beginning of the survey, but changed during the work, and obliged us to eliminate a part of the data. This point is also to be taken into consideration when performing a cruise.

- Finally we have surveyed a very small part of the gulf and a correct evaluation will necessitate a more general grid.

Nevertheless it seems that under these conditions an evaluation of the fish abundance would be possible.

An other point interesting concerns the equipment. The echosounder EY-M gives rather good results and its TVG seems good enough, but the echogram is very difficult to read and the discrimination between fish echo and other signals is not easy. It will be indispensable to use a scale magnifier to count in good conditions the total fish echoes.

CONCLUSION

The acoustic survey of fish biomass in very shallow waters may give useable results using echo counting, and under favourable weather, light and behavioral conditions.

The most difficult point is to obtain unbiased values of TS, especially when using single beam echo sounder. In any case, if the data are collected aboard a small vessel and recorded for further processing, it is absolutely indispensable to use digital recorder, the analog tape recorder qualities being too low for these measurements. It is clear too that the equation of LOVE would be replaced by the actual TS data of the observed fish.

A special attention must be paid in the transformation length-weigth: in areas with various species present, the best way is to calculate a different relationship between length and weigth for eack length class, according to the specific composition.

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Table 1. Distribution of the main species for each length class

Length class	Species	L/W rel.
2-4 cm	Jenkinsia lamprotaenia	x
4-12 cm	Harengula spp Haemulon spp (juv.)	x
13-20 cm	Haemulon spp Lutjanus synagris Lutjanus griseus	x
21-41 cm	Lutjanus griseus Caranx spp. Calamus spp.	x
> 41 cm	Lutjanus analis Caranx spp. Sphyraena spp. Scombridae	x

L/W rel. = length/weight relationship of the species considered as representative of the length class

Table 2. Biomass evaluation for each experiment Gulf of Batabano, october 1989

Exp	1	2	3	4	5	6
date	12/13	13/14	14/15	15/16	16/17	17/18
H	5.5	4.7	4.3	4.9	4.4	3.9
z	1	1	2	1	1	1
D	11112	44448	40744	20372	12408	33336
V	84556	241041	158192	120958	58212	119326
N	39	213	233	225	33	189
dens.	550	902	1330	1980	541	1340

H : mean total depth (m)
z : blind zone (m)
D : total distance (m)
V : total sampled volume (m^3)
N : number of fish
dens : mean density (kg/km^2)

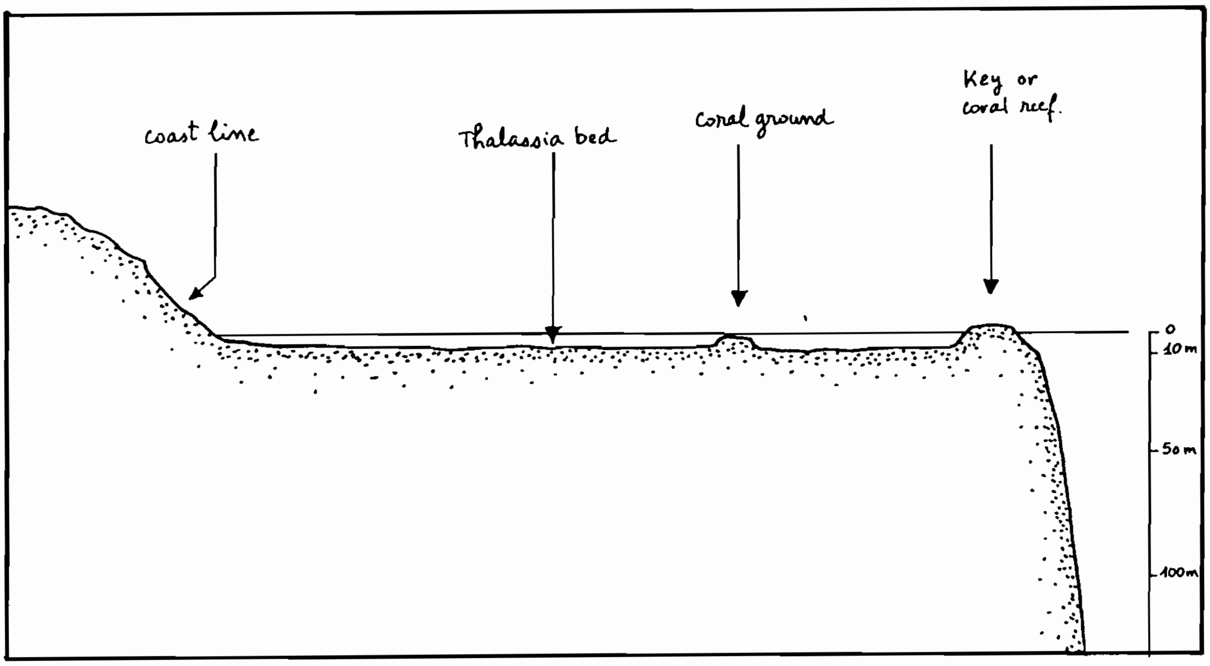

Fig. 1. Bathymetry of the Gulf of Batabano

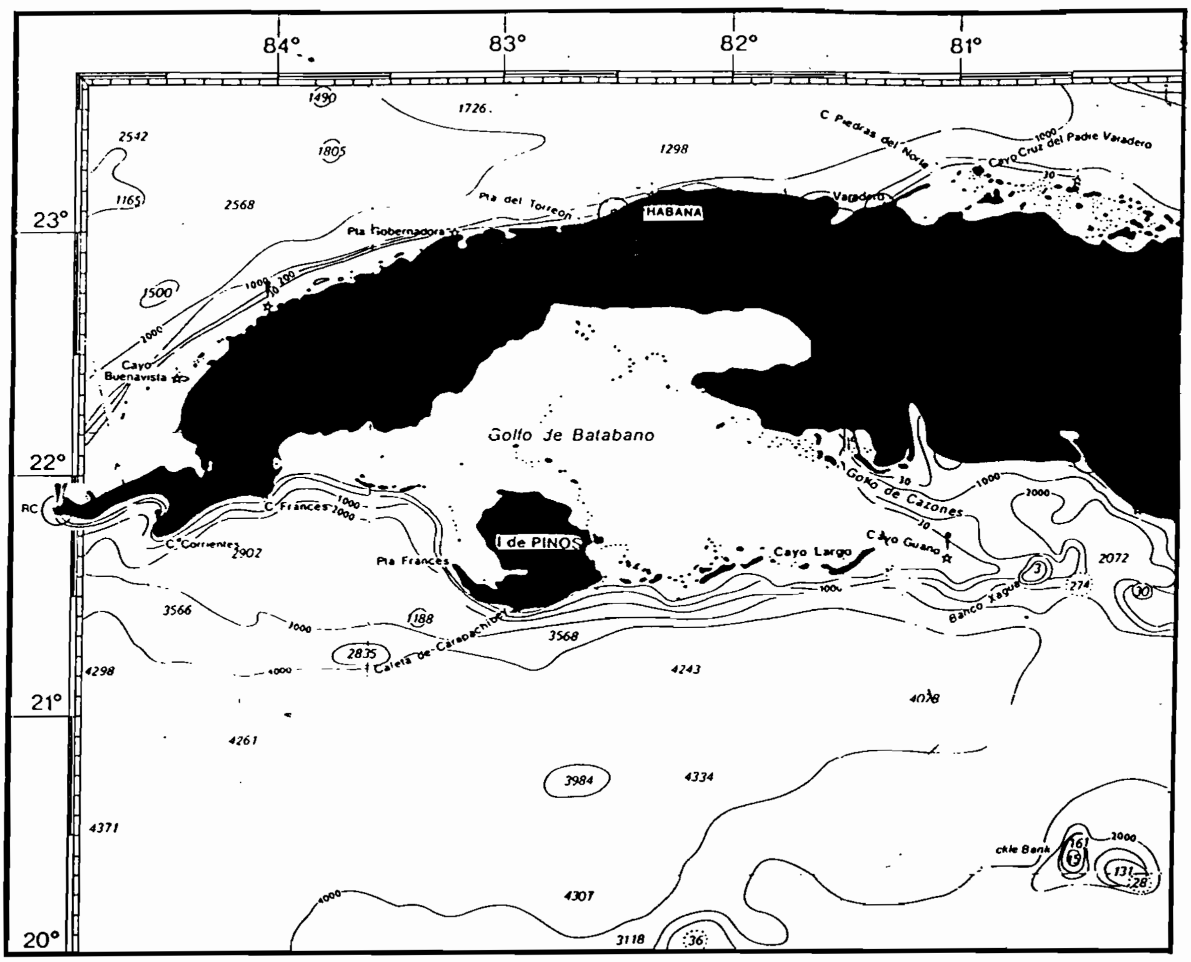

Fig. 2. The Gulf of Batabano (Cuba)

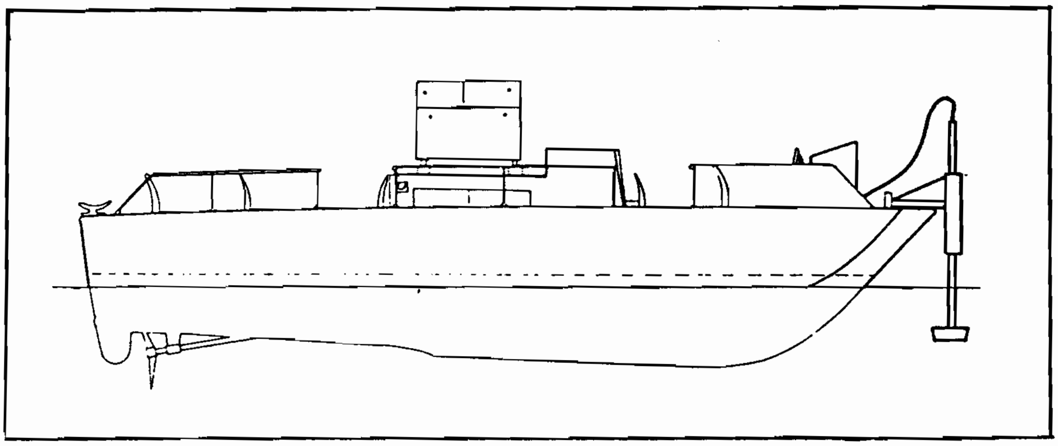

Fig. 3. Installation of the EY-M transducer aboard the motorboat

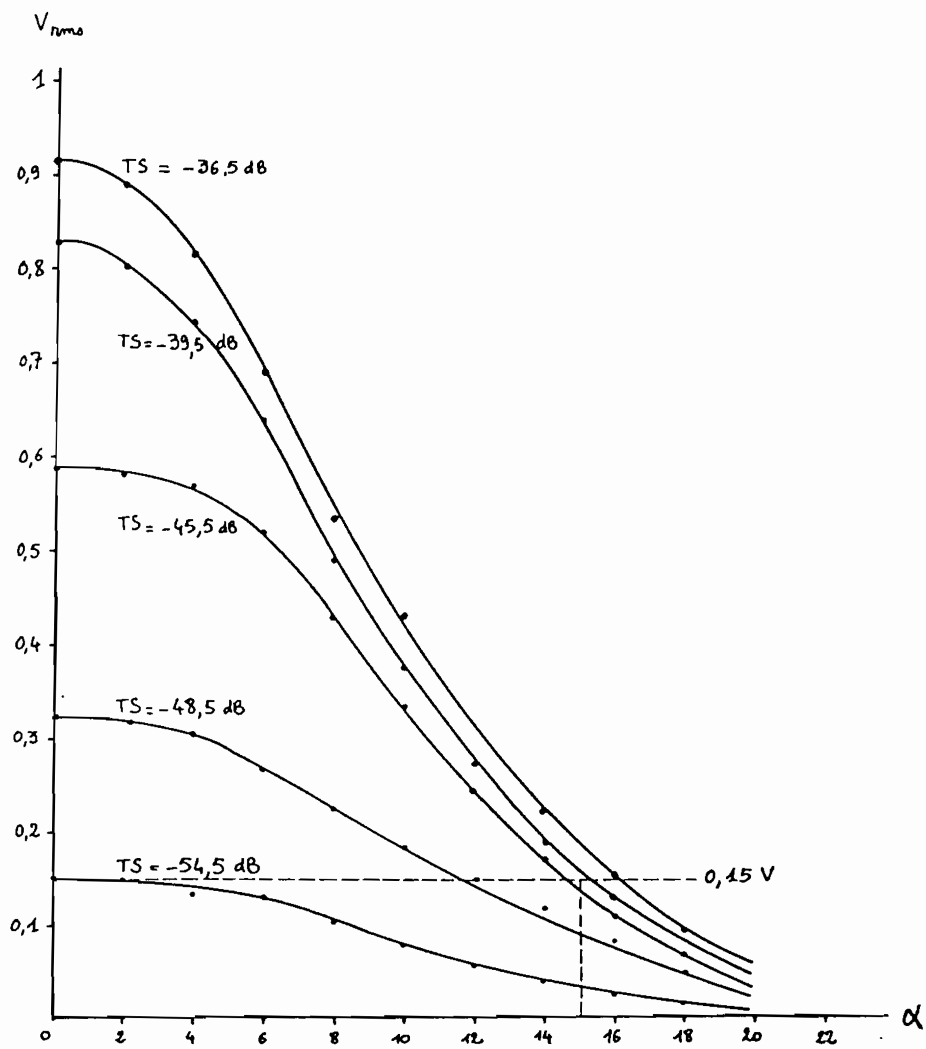

Fig. 4. Relation between beam angle and threshold for various TS