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A method for acoustic monitoring of a mussel longline ground using vertical echosounder and multibeam sonar.

by

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ABSTRACT

Mussel aquiculture on longline along the French Mediterranean coast has become an important economic activity since the 90s. Moreover it has produced important changes in the structure of the ecosystem, and several fish species have changed their behaviour according to the availability of this new shelter and source of feeding. Recently predation of mussel by a sparid, *Sparus auratus* had an increasing negative effect on the mussel production activity. Monitoring such an ecosystem is uneasy, due to the presence of the longlines which prevent to achieve sampling of the fish by fishing and acoustic surveys. We present a method for monitoring such a complex area, by the use of both a vertical echo sounder and a multibeam sonar. The sonar allows one to map the area, to reconstruct in 3 dimensions the longline structure, and to observe and measure in 3 dimensions the fish schools. The vertical echo sounder is not usable alone as the echoes coming from the fish and the longline cannot be discriminated. But when used jointly with the sonar, echo sounding is able to provide TS and density values in the sectors where the sonar shows that no artefact is present. The paper describes the methodology, the results that can be expected, and give preliminary results on the fish populations around the mussel longlines.

RESUME

La mytiliculture sur filières est devenue une activité économiquement importante le long de la côte méditerranéenne française du Languedoc depuis les années 90. Par ailleurs elle semble avoir abouti à enrichir le milieu et plusieurs espèces de poissons se sont adaptées à ces nouveaux abris et à cette nouvelle source alimentaire. Récemment, la prédation des moules d'élevage par la dorade royale, *Sparus auratus* a augmenté de telle façon qu'elle met en danger l'activité aquacole. Il est difficile de suivre et gérer ce genre d'écosystème, du fait que la présence des filières et de leur gréement interdit l'emploi d'engins de pêche et d'instruments acoustiques. Nous présentons une méthode qui emploie conjointement un sonar multifaisceaux et un sondeur vertical. Le sonar permet de cartographier l'abondance des bancs de poissons et de reconstruire l'image en trois dimensions des filières et des bancs. Le sondeur utilisé seul ne permet pas de discriminer les échos provenant des poissons et des filières. En revanche, sur les zones qui ont été reconnues comme vierges de structures artificielles par le sonar, le sondeur fournit des informations sur les tailles des cibles (TS) et les densités en poissons. Les instruments et la méthodologie sont décrits, et des résultats préliminaires sur le champ de mytiliculture de Sète sont présentés.

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INTRODUCTION

The coastal ecosystems are submitted both to high human pressure (industry, agriculture, tourism, transports), and to heavy exploitation (fishing and aquiculture). These ecosystems are endangered in many areas, and there is a strong need for tools and methods able to monitor them. This is becoming more important even nowadays, as it appeared that such areas must be monitored in an ecosystem level, and that single survey on one of the elements forming these ecosystems are likely to give weak or unusable results.

In this paper we give a case study, on a mussel aquiculture ground in the French Mediterranean (south of Sète), which is suffering serious problems due to the recent predation by a Sparid, *Sparus auratus.* This mussel culture activity was initiated in the 80s, and this activity took rapidly a great economic importance. Moreover, this aquiculture is likely to have quite positive effects on the ecosystem. Indeed such sandy-muddy marine coastal areas are known to have a rather low natural productivity, especially compared to the rocky coast in the surroundings. The introduction of mussels was followed by an increase of fish densities. Particularly, the "*Daurade royale*" (*Sparus auratus*) began to feed and develop on the mussel grounds in 96. The total production reached 8000 tons in 1992, and 10000 tons in 1996. In 2000, 3000 tons were lost due to the predation by the Sparid, and the production was around 2000 tons in 2001 (Allèguède, 2001).

Such a high level of predation leads to two conclusions: first there is a strong need for monitoring this mussel ground, in order to maintain the production: the predation has reached such a level that the exploitation is almost unbalanced. The second point is that this predation is likely produced by an important biomass of sparids (Rosecchi, 1985), which were not present a few years ago and does not seem to be exploited, as there is no related n increase in the catch. Therefore one possibility could be that the mussel ground has allowed an important increase in the total fish biomass. Although there is not enough element to conclude, the idea that this kind of use of the Mediterranean shore could be a way to optimize the biological productivity seems fruitful. Here too, monitoring these ecosystems would allow to answer this type of questions.

It was thus decided to monitor the aquiculture ground and in a first stage, to evaluate precisely the biomass of predators and to study their behaviour (movements and migrations during the day, number of schools, spatial distribution in the mussel ground, etc.), in order to decide of an appropriate method to get rid of the predator problem. This monitoring appeared to be impossible with the conventional methods:

- fishing is impossible inside the ground, due to the great number of artefacts present in the area (mussel longlines and their rigging).
- direct observation by divers is useless for a general overview of the area, for it represents more than 2500 hectare.
- conventional underwater acoustics using echo sounders is not possible neither, for the same reason as fishing: too many artefacts in the water, which cannot allow to recognise the fish and school echoes from the longlines.

In order to overcome these points, a new methodology using multibeam sonar and echosounder was developed and is presented in this paper.

MATERIAL AND METHODS

The mussel longline ground

It represents 2754 hectares in total split in 348 concessions, from which around 50% are effectively used for mussel production by about a hundred exploitations (Sanguinède, 2001). The mussel ground is located between the depth lines 20 and 30 m, at around 3 miles from the coastline (fig. 1). Each concession represents a 300 m side square which can hold six longlines. The longlines (fig. 2) are also approximately 300 m long and the mussels are cultivated on usually five metres ropes ("cordes") suspended to the longline (Loste et Cazin, 1993).

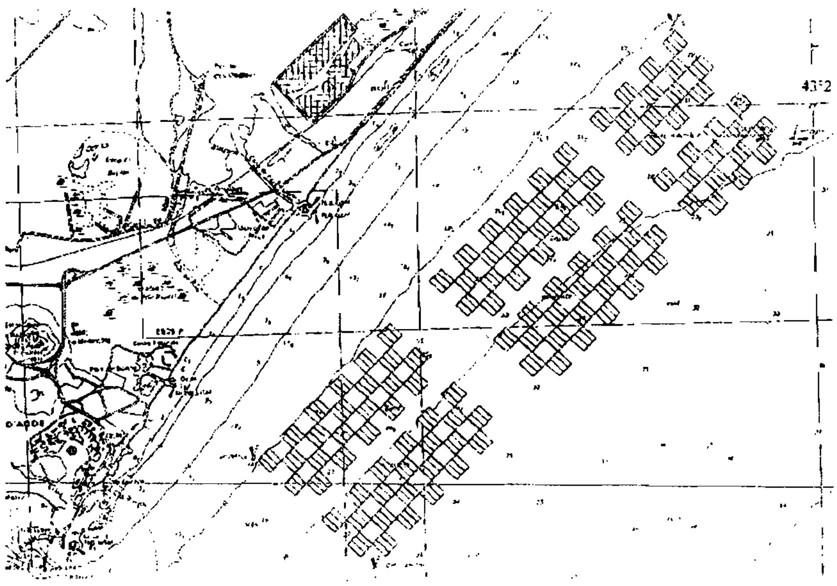

Figure 1. The mussel aquiculture ground, off Sète (French Mediterranean). The concessions are represented by the small squares, each one being constituted of a series of longlines (see fig.. 2)

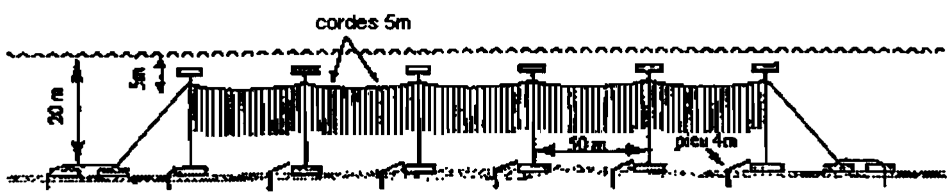

Figure 2. Schema of a mussel longline.

One longline gathers around 500 ropes, for an average production of 25 tons/year/longline.

The survey strategy is to sample the concessions and to survey a couple of longlines inside the sampled concessions. This was done by day and by night. Some difficulties may lead to changes in the selected samples: in some of them, navigation is dangerous due to the uncharted items present in the water. The samplings by day and by night are similar whenever it is possible (in some case the lack of buoys or signals makes difficult the navigation by night on a precise point). The longlines are sampled in two ways: parallel and perpendicular to the line. By day, when a school is observed with the acoustic devices, diving may be decided for fish identification.

Two experiments were performed: a preliminary observation in summer, 2000, and a series of surveys in spring, 2001 (Gerlotto *et* Brehmer, 2000). They followed the same sampling strategy with some marginal differences. In summer 2000 the survey was done aboard a professional vessel belonging to the exploitation, while in spring 2001 the vessel used was the R/V Chlamys (IFREMER)

Table 1 : Details of the summer survey, 24-26 August, 2000.

Type of activities	**Date**	**Hour**	**Nb of longlines surveyed**	**Nb digital sequences recorded**
Test	24/08/2000	13h00 to 17h00	0	0
survey day	25/08/2000	11h00 to 18h00	31	48
survey night	25-26/08/2000	22h00 to 02h30	16	25
survey day + divers	26/08/2000	13h00 to 15h30	7	7

Table 2. Details of observations in spring, 24-27 April (D1) and 16-17 May (D2) 2002

	Survey D1	**Survey D2**	**Survey D1, 2000**	**total**
Prospecting time	**6:24:03**	**1:00:08**	**5:16:55**	**12:41:06**
Nb longlines observed	**51**	**12**	**54**	**107**
Nb schools	**73**	**6**	**61**	**140**
schools on longline	**19**	**0**	**18**	**37**
schools open sea	**56**	**6**	**43**	**103**

The multibeam sonar

The sonar adapted is a RESON SeaBat 6012, with 60 beams of 1.5° covering a total sector of 90°. The system was adapted for school recording (Gerlotto *et al*, 1999; Fernandes *et al*, 1998) through a digital recording of all the images obtained. The settings of the sonar are presented in the table 1. The data are recorded during periods from a few seconds to more than one minute. Normally the digital recording is decided only when interesting features appear on the monitor. On the contrary, the recording of video images is permanent. This recording can be assimilated to and is used as an echogram. The digital recordings are processed using the software SBI Viewer (Hamitouche *et al*, 1999) for 3D echograms and school reconstruction in three dimensions. The sonar deployment is adapted from Gerlotto *et al* (1999), but the main axis of the 90° sector was set vertical during the first survey, and 45° during the second one. The survey method consists in a series of transects along the mussel longlines (fig. 1 and 2). In order to observe both schools and scattered fish, some transects were repeated day and night during the first survey. The second survey being exclusively devoted to school observation, no night survey was performed.

Table 3. Main characteristics and settings of the multibeam sonarSeaBat 6012 in summer, 2000, and spring, 2001

	2000	2001
Frequency	455 kHz	455 kHz
Nb beams	60	60
beam shape	1.5° * 15°	1.5° * 15°
TVG	20 log R	20 log R
Power	7-8	7-8
Gain	4-5	4-5
Zoom	1	1
Scale	linear	linear
Palette	Color	Color
Ping rate	7/sec	7/sec
Pulse duration	0.06 ms	0.06 ms
Range	50m	50/100 m
smoothing	Off	off
beam position	vertical	45°
Sound celerity	1500 m/s	1500 m/s
recording	video + digital	video
survey	day/night	day

The sonar provides us with two types of data: video images and digital data. The digital recording using "SBI Acquis", a specific software designed by RESON[4] was applied in 2000, while the video recording was done during all the surveys. The digital data are processed using "SBI Viewer", a specific software designed by ENSTB[5] (Lecornu et al, 1998; Hamitouche et al, 1995). The video images are digitised and processed as images in the laboratory. During the summer survey, the two methods were used, and a total of 80 sequences along longlines or in free water were recorded (table 1). In spring, 2001, only the video images were recorded and digitized using an ISV3 card (Brehmer, 2001).

The echosounder

Two different echosounders were used during the surveys: in summer 2000 we used a BIOSONICS[6] DT5000 Dual Beam echosounder, 130 kHz, and in spring 2001 we used a SIMRAD[7] EY500 split-beam echosounder, 70 kHz. Both systems were used in the same way. The transducer of the echosounder is fixed with the sonar transducer on a vertical pole on the side of the boat (fig. 3). The echosounder was mostly used during the first survey, and only results from this survey will be given. Therefore the table 4 only details the characteristics and settings of the echosounder used during the summer survey.

The echosounder allowed to record the echograms along the transects and the individual TS (using the dual beam function). The densities were recorded but could not be used for any realistic abundance estimate.

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[4] RESON A/S, Slangerup, Denmark. www.reson.dk
[5] Ecole Nationale Supérieure de Télécommunication de Bretagne, France. www.enst-bretagne.fr
[6] BIOSONICS Inc, Seattle, USA www.biosonics.com
[7] SIMRAD A/S, Norway www.simrad.no

Table 4. Main settings and characteristics of the echosounder used during the summer surveys

Echo sounder type	Biosonics DT5000
Frequency	129 kHz
Beam	dual beam
threshold:	-70 dB
Ping rate:	5 pps
range	40 m
ping duration:	0.4 ms
absorption coefficient:	0.00531 dB/m
salinity:	34 ppt
Water Temperature:	24 deg C
Sound Velocity:	1485.32 m/s

The TS collected were split according to three particular cases: TS collected by day, by night, and during some "lamparo[8]" experiments by night. They were studied separately, then compared.

The biological sampling.

No fishing was performed, both because fishing is officially forbidden in the longline ground, and would be extremely risky anyway. The biological sampling was done by scuba divers, who dived when a school was recorded on the sonar image. The summer survey allowed a rather good identification of the pelagic species, which was much more difficult in spring, due to the turbidity of the water.

RESULTS

The objective of this paper being to show the capability of the acoustic methods to monitor this kind of ecosystem, we will mostly insist on the different types of results that can be extracted from the methodology, and not on a description of the ecosystem itself.

The identification of the longlines.

- **Sonar**. The first point was to check whether the artefacts (lines, ropes, anchors, buoys etc.) could be discriminated from the biological targets. The figure 3 gives two different single images of a longline. The bottom depth in these cases was 25 and 30 m. The identification of the longline is extremely easy.

  The figure 4 shows a series of biological targets, near a longline or in free water. Here too, the identification of the biological target is quite easy, and the discrimination between artificial and biological target does not present any particular problem.

[8] the lamparo is a characteristic method of fishing with light used in the Mediterranean.

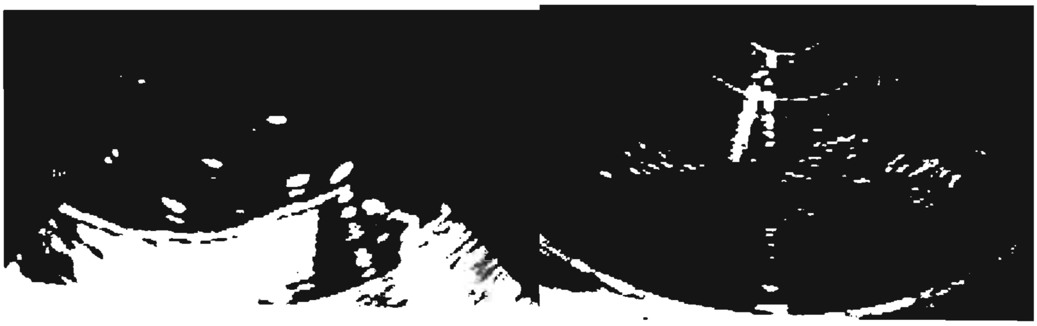

Figure 3. Two vertical observations of a longline. The image on the left shows a long line perpendicular to the transect, the image on the right a longline parallel to the transect. On this last image, two rope are visible, with the cut of the longline, an anchor line (vertical) and a buoy. On the first one, a large part of the longline is visible, with buoys, rigging, and a series of rope.

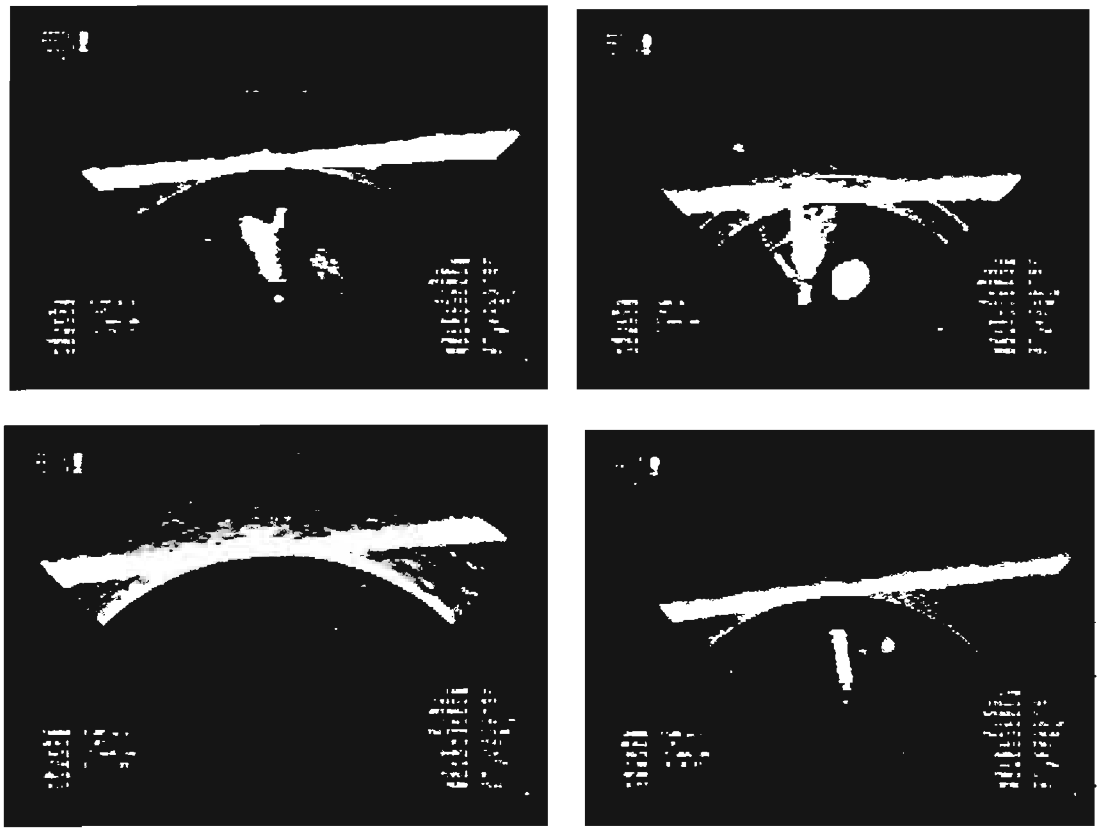

Figure 4. Four examples of biological and artificial targets observed in some sonar images (note that the images are the original ones provided by the sonar, and for an easier observation, the bottom -on the top of the image-should observed after a 180° translation,)..

These series of frames can be observed in full 3D , and represent a "3D echogram". The figure 5 gives an example of a complete longline recorded and processed using the software SBI viewer.

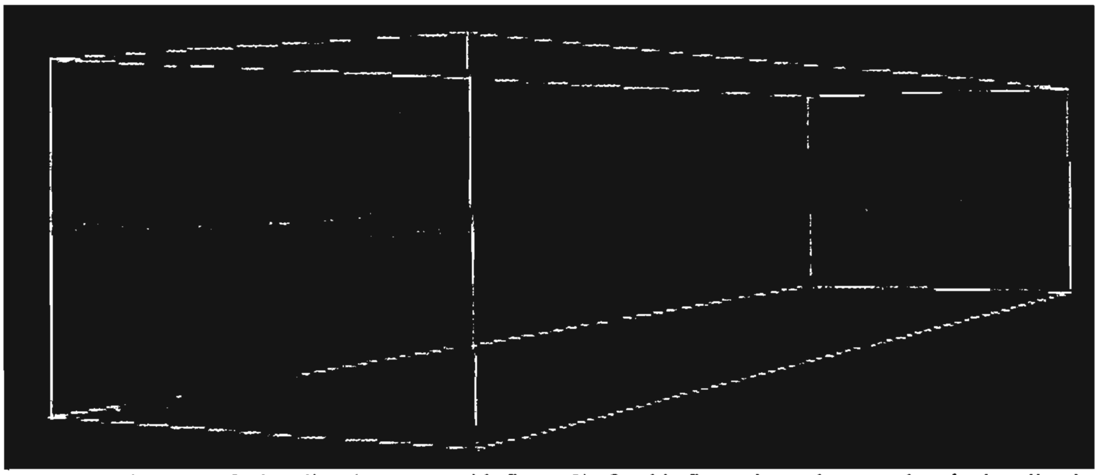

Figure 5. 3D echogram of a longline (compare with figure 2). On this figure it can be seen that the longline is not completely set with rope, which appear in 5 parts of the structure. On the last rope (right of the echogram), a small school can be observed at the depth of the top of the longline. The circles lines above and below the bottom are background noise coming from side lobes echoes and interference with the echosounder.

- **Echosounder**. Observing this kind of complex environment with an echosounder results to be practically impossible. The figure 6 gives an example of vertical echogram recorded on a longline.

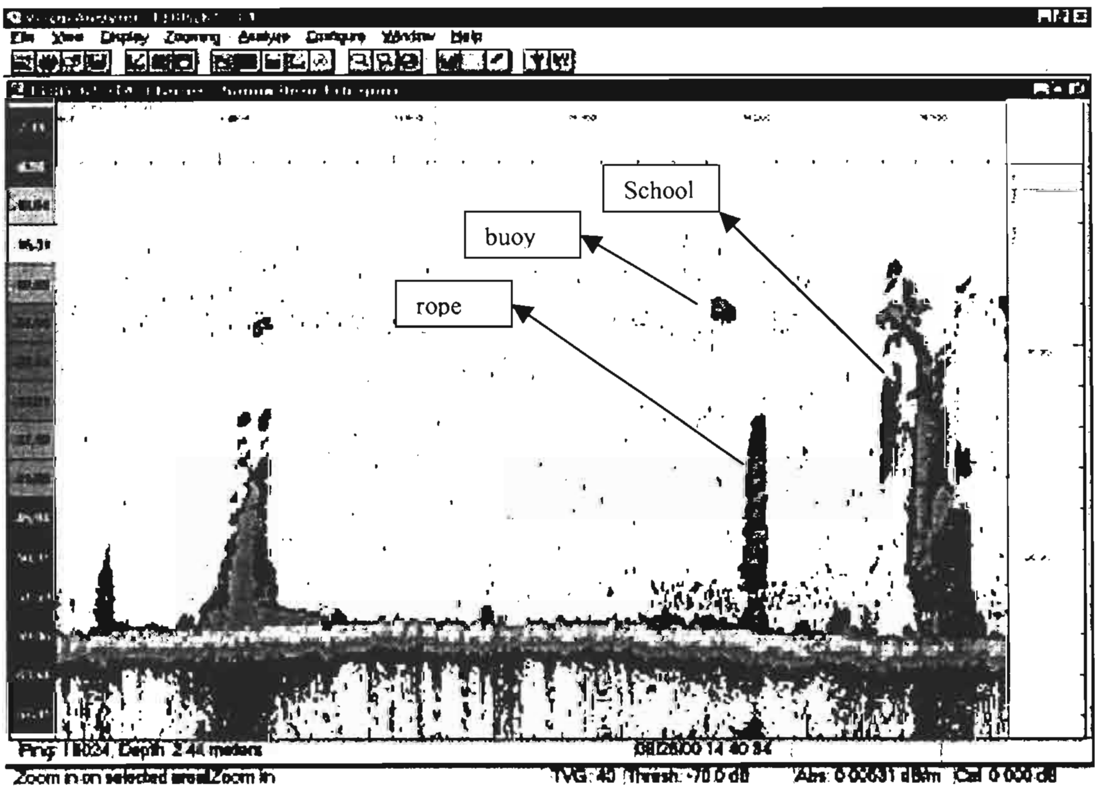

Figure 6. Vertical echogram obtained with the DT5000.

On this figure, the school that has been observed simultaneously with the sonar is impossible to discriminate from the echoes of the longline structures. Using vertical echosounder alone for school observation or density measurement is not possible in such an ecosystem.

On the contrary, when both instruments are used jointly, the echosounder data can be used, in the sectors where it has been observed that no artificial structure is interfering. In this case, the echosounder can be used in a conventional way.

The TS distributions

The figure 7 shows three echograms obtained under different TS measurement conditions: by day, by night and during a lamparo experiment by night.

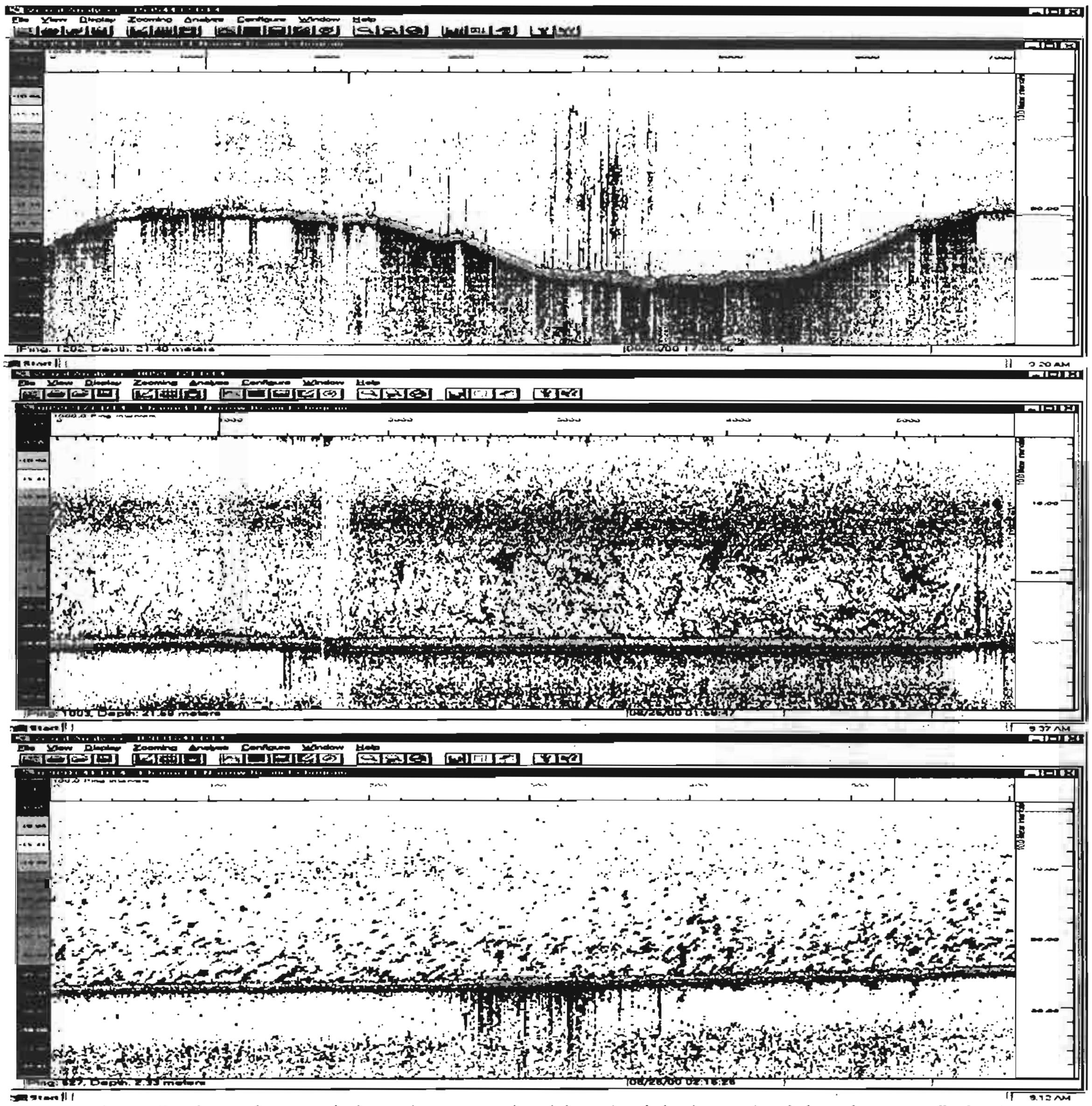

Figure 7. Three characteristics echograms: day (above), night (centre), night + lamparo (below)
Note that the day data could present some noise due to side lobe echoes on a longline. This kind of echo does not interfere with TS measurements.

The TS were calculated using the software DT Analysis, from Biosonics. The three histograms for the three sets of data are presented on the figure 8.

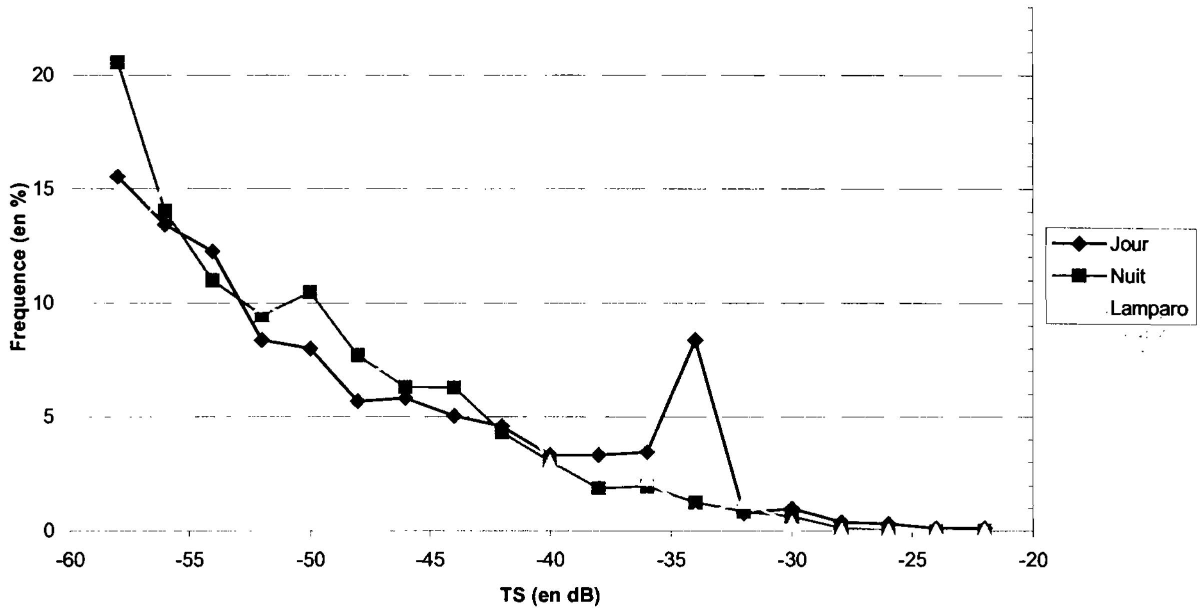

Figure 8. TS histograms. Jour = day; Nuit = night.

Table 5. TS distributions

TS (dB)	DAY	NIGHT	LAMPARO
-22	2	1	
-24	2	0	
-26	5	1	
-28	6	5	
-30	15	22	2
-32	12	30	8
-34	128	44	4
-36	53	68	14
-38	51	65	16
-40	51	106	18
-42	70	150	38
-44	77	218	56
-46	89	219	44
-48	87	267	42
-50	122	363	55
-52	128	328	60
-54	187	381	86
-56	205	486	91
-58	237	713	71

Although it is not the objective of this paper, it can be noted that there are typical differences between the three histograms, the day histogram presenting bigger targets than the night data, while the lamparo data show a shift towards large targets compared with the night data (table 5).

The school characteristics

Another interesting set of data was collected on the schools recorded. When using the digital recording, these school characteristics can be extracted using SBI Viewer. The figure 9 gives an example of such a data extraction.

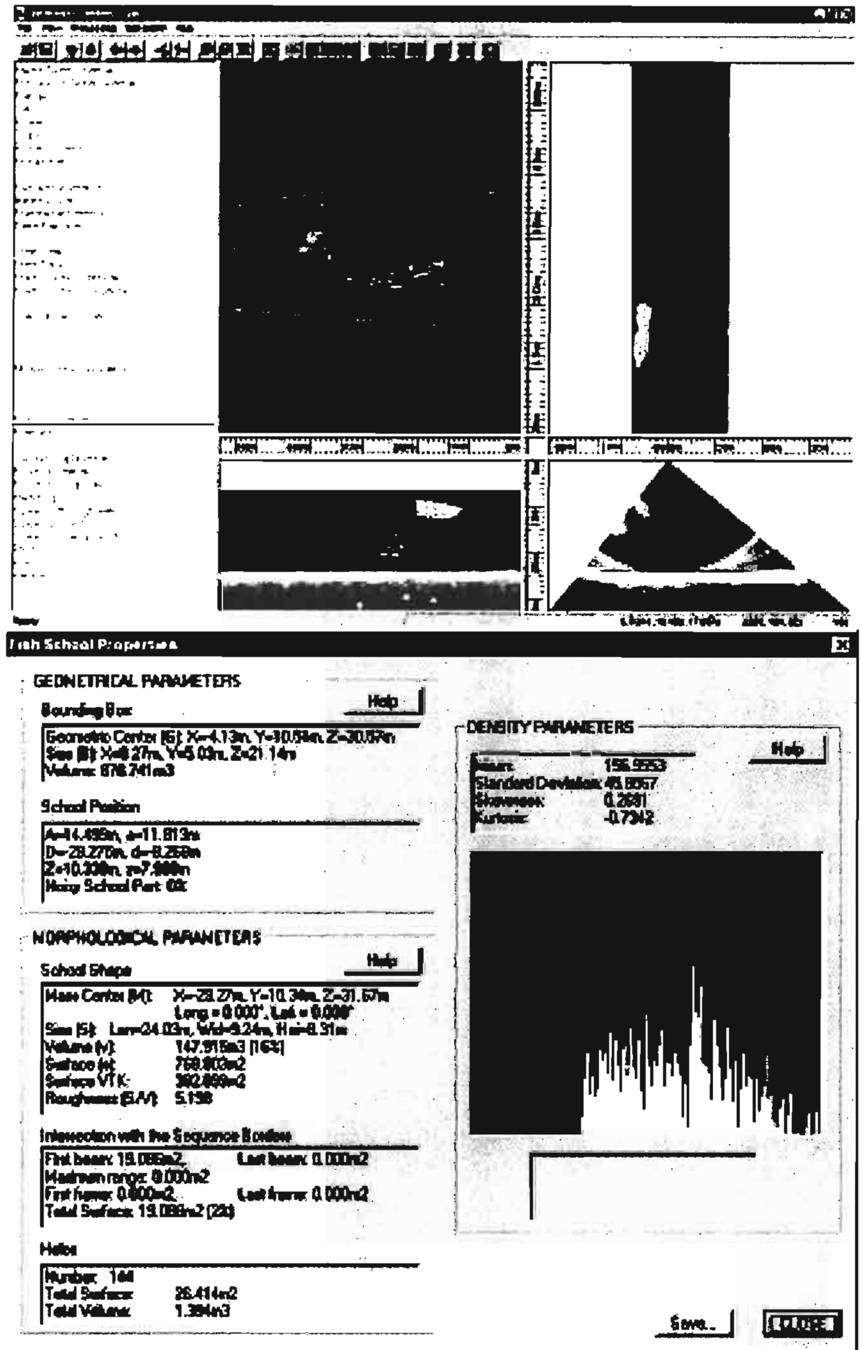

Figure 9. Example of school characteristics extracted from a 3D echogram using SBI Viewer.

During the spring survey, no digital recording was possible, and the same school morphological and geographical characteristics were collected from the video recording and digitisation. These results allowed to perform some statistics on the school data base, which are resumed in the table 6.

Table 6. Synthesis of the main morphological and geographical parameters of the schools recorded with the sonar during the Spring surveys.

	N	Mean	Median	Minimum	Maximum	Variance	Std err.	Assymetry
width	79	5.4	4.7	0.9	24.0	11.4	3.4	2.5
height	79	3.4	2.9	0.5	11.6	3.7	1.9	1.4
lenght	79	13.7	10.8	3.1	67.9	118.5	10.9	2.4
w_h	79	20.9	12.0	0.8	157.1	505.0	22.5	3.3
volume	79	360.7	132.7	2.4	2595.0	300361.0	548.1	2.5
altitude	79	7.9	6.2	0.4	24.9	33.7	5.8	1.3
bathymetry	79	27.0	28.0	20.7	32.7	10.5	3.2	-0.3
distance to vessel	79	35.4	30.4	8.0	93.8	314.3	17.7	1.4
distance to line	19	15.3	12.72	0.18	48	148.1	2.79	1.15

DISCUSSION AND CONCLUSION

The results we presented are a good example of what can be obtained from the use of modern acoustic equipment in complex ecosystems. A single tool may not give consistent data, while when using jointly different acoustic tools, a complete set of information can be obtained. This result is in agreement with Reid's (2000) description of the future of fisheries acoustics. The main results are the following:

- possibility to discriminate precisely the target according to their origin. This allows to consider reliable sets of data, such as TS distributions, schools characteristics, and even density values, where the noisy data can be eliminated from the data base.
- real time observation of the ecosystem. All the mechanisms that are organising the life in this longline ground can be monitored. Although the question listed at the beginning of this paper were not yet documented, they are likely to be answered after a series of appropriate surveys at the correct periods.
- monitoring of the human activity. A complete map of the mussel culture activity can be obtained, by a series of surveys on the longlines. The proportion of mussel production on each of them can be evaluated permanently. Also, the empty areas, the lost equipment, and the clandestine longline can be recognised easily.
- investigating the changes in the ecosystem. The first question presented in this paper: do the longlines produce some extra fish biomass by changing the flux of food in the area?" can be approached with these direct observations, as it becomes possible to observe the movements of the fish inside and outside the ground. After a series of observation, it would be possible to define whether the fish are growing only inside the ground or are "opportunistic predators", coming from other regions.

A few limitations still remain, and principally the difficulty for target identification. It has been noted that fish identification by diving is not at all easy, and could be more difficult even in colder or rougher countries. Nevertheless when the conditions are good, accurate identification can be achieved. During our experiments, only schools of small pelagic fishes (*Sardina pilchardus, Engraulis enchrasicholus, Boops boops, Trachurus trachurus*) have been precisely identified. Another strong limitation is the fact that these acoustic devices require a rather calm weather in order to give good results. In the Mediterranean for instance, when the north wind (Mistral) is blowing, no result at all can be expected. This reduces the applicability of the system to the only favourable periods. Such limitation means that the monitoring cannot be easily planned, and that the tools (acoustic, but also vessels) must be available at any moment when the conditions are good. Considering the ecological objective of the research, it has been concluded that further work would require some conditions.

- The first one is that longer surveys would be needed, in order to have time to explore and observe in details the Sparid schools. Some information from the fishers seem to indicate that there are very few large schools of Sparids, which makes them difficult to sample using a systematic grid.
- The second one is to be able to decide a survey at the appropriate moment, as it has been demonstrated that deciding in advance of a survey timing does not make sense: when the wind is blowing, no observation is possible; when there is an upwelling process, the Sparid are not feeding on the ropes; when the water is turbid, no identification is possible. This requirement makes indispensable the availability of the acoustic devices be permanent.
- The last one will be to add some behavioural research to the acoustic surveys, such as acoustic tagging and biological studies.

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