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PECULIARITIES OF SCOUTING AND ESTIMATING FISHES IN THE SOUTHERN OCEAN

V. A. Protaschuk

All-Union Research Institute of Marine Fisheries and Oceanography
17a Vekhnyaya Krasnoselskaya, Moscow B-140, USSR

INTRODUCTION

The main commercial objects of the Southern Ocean, besides Antarctic krill are are specimens of southern hemisphere fish (Nototheniidae) and white blood fishes (Channictydae). Scouting and especially estimating their biomass by acoustic methods presents a complicated problem. There are a number of reasons including their keeping close to the bottom, low reflectivity and distinct diurnal vertical migration. A no less important factor is the complex navigation and weather conditions of polar latitudes.

PROBLEMS

Let us dwell in detail on the peculiarities of registration of these fishes and, first of all, on those related to their close-to-the-bottom mode of life. Acoustic distance from bottom objects at extreme angles of the acoustic beam seems larger than the real depth of location. These objects are registered as if they were below the bottom, and in this case the so-called dead zone takes place. The size of this zone, as well known, depends on the width of directivity diagram of the transducer, length of transmission and the distance to the bottom. The smaller these values, the smaller the size of the bottom 'dead zone'. An additional contribution to this is naturally made by the unevenness of the ground. This unevenness, as known, is maximum at a stony bottom just like on the Antarctic shelf and the adjacent banks. Proceeding from the technical parameters of the main types of acoustic equipment installed on vessels and the nature of ground unevenness it can be said that the bottom 'dead zone' is in the order of 2-5 m.

On the other hand, it is known that bottom fish are distributed quite non-uniformly and the most dense concentrations are usually found 1-2 m above the bottom. The degree of their 'closeness' to the bottom is first of all determined by hydrological conditions and food (Antarctic krill, small jellyfish, ctenophora, and so on). If living conditions make fish stay in a smaller layer than the bottom 'dead zone' they will not be registered by echo-sounder. If the conditions are such that the vertical development of a concentration may exceed the size of this zone, some of the fish can be registered by echo-sounder. Therefore it is possible that with apparent absence of registration on the echo-sounder catches by bottom trawl are great. It follows that the method of calculation for determining the echo-sounder scale factor is in this case unacceptable. This method allows only the density of registered parts of a concentration to be determined. Since distribution of fish with depth is non-uniform it is not possible to distribute the obtained data on the whole concentration as the character of this distribution is unknown. The only acceptable method of calibration in this case is by trawl catch. Besides, as living conditions in different areas may vary, camouflage may vary as well. Therefore calibration by trawl catch should be made separately for each area with a maximum number of trawlings. Another peculiarity of the Southern Ocean is connected with the low acoustic reflectivity. Specimens of white blood fish and southern hemisphere fish have no swimbladder which normally makes the main contribution to the value of echo signal. Due to this, their target strength is one or two orders lower than that of swimbladder fish of similar length. Therefore acoustic signals from individual specimens become commensurable with the level of noise from the vessel and their successful registration is possible only with a high-powered echo-sounder.

METHOD

During the voyage of the research vessel "Khronometr" to the Antarctic part of the Indian Ocean in 1986 an attempt was made to measure target strength for a number of fish of both families. Measurements were made by two methods: in situ with the help of Simrad split-beam ES 400 echo-sounder, and a special diorama with restrained fish. In the latter case an echo-sounder EK 38S of the same manufacturer was used. Because, when the vessel was under way, the level of acoustic signal from individual specimens proved commensurable with the level of noise from the vessel, measurements in situ were made adrift with engines shut down. The procedure was as follows. The concentration detected with the help of a high-powered echo-sounder was fished with a trawl. If the catch was predominantly of one species the vessel drifted over this concentration. After that all vessel mechanisms and acoustic equipment except the echo-sounder ES 400 were switched off. While measuring, the averaging interval was chosen so as to allow the number of echo signals to exceed a thousand. As a result of this work it became possible to obtain several series of measurements with spiny icefish (Chaendraco Wilsoni) and grey rockcod (Notothenia squanmifrous). Averaging of these series of data is given in Table 1.

Table 1

Fish	Length, L (cm)			Mean weight (g)	Target strength 38 kHz TS (dB)			Target strength per kg TS kg (dB)
	min.	max.	mean		min.	max.	mean	
Spiny icefish	22	31	26.8	190	-56	-44.0	-50.6	-43.4
Grey rockcod	18	36	30.2	530	-51.5	-38.0	-44.6	-41.9

Measurements of fish target strength on a special diorama were mainly carried out to confirm the results obtained with the help of echo-sounder ES 400. A special structure was made for these measurements. It consisted of a frame with a transducer and two vertical lines with a load. The total length of the lines was 6 m. Fish were fixed in the middle between the transducer and the load at two points (near the head and tail) with lines, which in their turn were fastened to the main lines. When measuring, the whole structure was submerged in the water at a depth of 10-15 m. After 15-20 minutes measurements were made. It should be noted that the fastening of fish proved a success and individual specimens showed signs of life even after the operation was completed.

To increase accuracy, the method of substitution was applied and in the place of fixation the Standard Target Sphere was periodically fastened. The final calculation of target strength was made by the formula:

$$TS_f = TS_{sph} + 20 \log \frac{U_f}{U_{sph}}$$

where TS_f and TS_{sph} are target strength of fish and target strength of sphere; U_f and U_{sph} - output echo signal amplitude from fish and from sphere. This way of measurement was applied for target strength of spiny icefish (Chaendraco Wilsoni) and green rockcod (Trematomus Hansoni). Averaging of the results is given in Table 2.

Table 2

Fish	Length, L (cm)			Mean weight (g)	Target strength 38 kHz TS (dB)			Target strength per kg TS kg (dB)
	min.	max.	mean		min.	max.	mean	
Spiny icefish	29	32	30.2	200	-51.7	-46.9	-49.2	-42.6
Green rockcod	32	40	36.1	910	-37.4	-35.9	-36.4	-36.1

Comparison of these two tables shows similarity of the results. The same can be said if these data are compared with data obtained by other investigators. The same target strength per kilogram in mackerel icefish (Champsocephalus Gunnari) was determined by Polish scientists [1] at a frequency of 38 Hz; TS_{kg} = -43.1 ± 1.3 dB. The results obtained by scientific workers of AtlantNIRO [2] for striped-eyed rockcod (Notothemia Kempi) and marbled rockcod (Notothenia rossi) are TS = -38.3 ± 34.0 dB for fish 30-56 cm long. These measurements were also made with restrained fish at working frequency 29.8 Hz.

The above is additional evidence of low value of target strength in bladderless fish. Besides, the value of scatter of obtained data should be noted. This scatter exceeds similar scatter which usually occurs in measuring swimbladdered fish. It may be accounted for by the fact that in the latter the main contribution to formation of the echo signal is made by air. Therefore, general state of fish, degree of stomach fullness, as well as food composition for such fishes are not so important. In contrast, in bladderless fish the value of the echo signal is to a considerable extent determined just by these components. Therefore with these fishes great scatter of target strength value should be expected, especially if food objects contain air.

Another peculiarity of the detection of white blood and southern hemisphere fish is their clearly distinct diurnal vertical migration. As has been noted, in daylight fish keep close to the bottom in dense concentrations. At night they rise into pelagic strata, sometimes reaching upper layers and disperse. Thus, during the above voyage individual specimens of spiny icefish (Chaendraco Wilsoni) were seen several times in the upper 50 m layer.

DISCUSSION

The period of time when fish are dispersed varies depending on the season. For the same icefish in the middle of polar summer it is about 2 hours (from 3 to 5 am). Closer to autumn and in early autumn fish remain dispersed till 7-8 am and the beginning of their uprise is shifted to 11 pm. It may seem that at night the main mass of fish rises from the ground, it must be the most convenient time for scouting and estimation of biomass. However, while it is really convenient to undertake scouting at this time, carrying out an acoustic survey at this time is difficult because the period of time when fish are in this state is very short (especially in mid-summer) and varies during 24 hours. For example, the area of an individual bioproductive elevation of the shelf in the Sea of Cosmonauts comes to 70 sq. miles and a survey of one such elevation on an average takes 6-8 hours. If a night survey is carried out in mid-summer it takes 4-6 hours. During this period of time in polar latitudes there may occur considerable changes in hydrological and ice situations. This in its turn may result in incompatibility of initial and ultimate data. Closer to autumn when a survey of elevations may well be carried out in 24 hours complications related to navigation safety may occur. Weather condition in this period of time in polar latitudes deteriorate badly and to manoeuvre among obstacles of different kinds (icebergs, icefloes and loose pack) become difficult. Finally, low reflectivity of fish, commensuratibility of backscattering with the noise of the ship also affect the possibility of carrying out a survey. In this case it is necessary to have an echo-sounder of high-power and such equipment is not always available. Therefore acoustic surveys of the fish of the Southern Ocean are preferably carried out in daylight with the strict exclusion of vertical migrations. Calibration of echo-sounder scale should be made by trawl catch for a maximum number of trawlings. These trawlings should be made at the same time when the survey was carried out, for example, a day before or after survey. Finally, even with careful completion of all stages of survey, accuracy will not be great. More so, because some of the bioproductive areas may be packed with ice.

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[1] Orlovski, A. et al. Sprawordomie z v rejsu statku bodwcrego r/v Professor Siedleki na wody Oceanu Indyiskiego, Gdnania, MIR, 1975 r.

[2] Collection of works: Hydroacoustic methods in estimating marine organisms stock, Kaliningrad, AtlantNIRO, 1983 (in Russian).

DAYTIME DETECTED ABUNDANCE FROM ECHO-SURVEYS IN THE BAY OF BISCAY

J. Massé

IFREMER, rue de l'Ile d'Yeu, B.P. 1049, 44037 NANTES CEDEX 01

DAYTIME DETECTED ABUNDANCE FROM ECHO SURVEYS IN THE BAY OF BISCAY (1983 - 1987)

Since 1983 five acoustic surveys have been carried out in the Bay of Biscay on the continental shelf from the Spanish coast to 48°00 N. The main object of these surveys was to study the spatial distribution and the abundance of pelagic species between March and June. The relevant areas and periods are described in Table 1.

Year	Period	Prospected area	Depth
1983	17/3 - 3/4	* From the Spanish coast to 46°00 N	* 30 m - 500 m
1984	30/4 - 13/5	* From 46°00 N to 48°00 N * From the Spanish coast to 46°00 N	* 130 m - 500 m * 30 m - 500 m
1985	20/4 - 28/4	* From 46°00 N to 48°00 N * From 47°00 to 48°00 N * From 44°30 to 45°10 N	* 130 m - 500 m * 100 m - 130 m * 130 m - 500 m
1986	7/6 - 25/6	* From 46°00 N to 48° N * From 46°00 N to 48° N	* 120 m - 500 m * 30 m - 100 m
1987	7/3 - 4/4	* From 46°00 N to 48° N * From the Spanish coast to 45°30 N	* 140 m - 500 m * 30 m - 500 m

Tab. 1 - Periods and areas corresponding to each survey.

The deviations recorded during these surveys have been analysed and separated into two types (fig. 1).

- DP1 due to soft, scattered and cloudy detection , generally close to the bottom,

- DP2 due to sharp and dense detection , very often in the mid-water zone, and corresponding in any case to well separated schools.

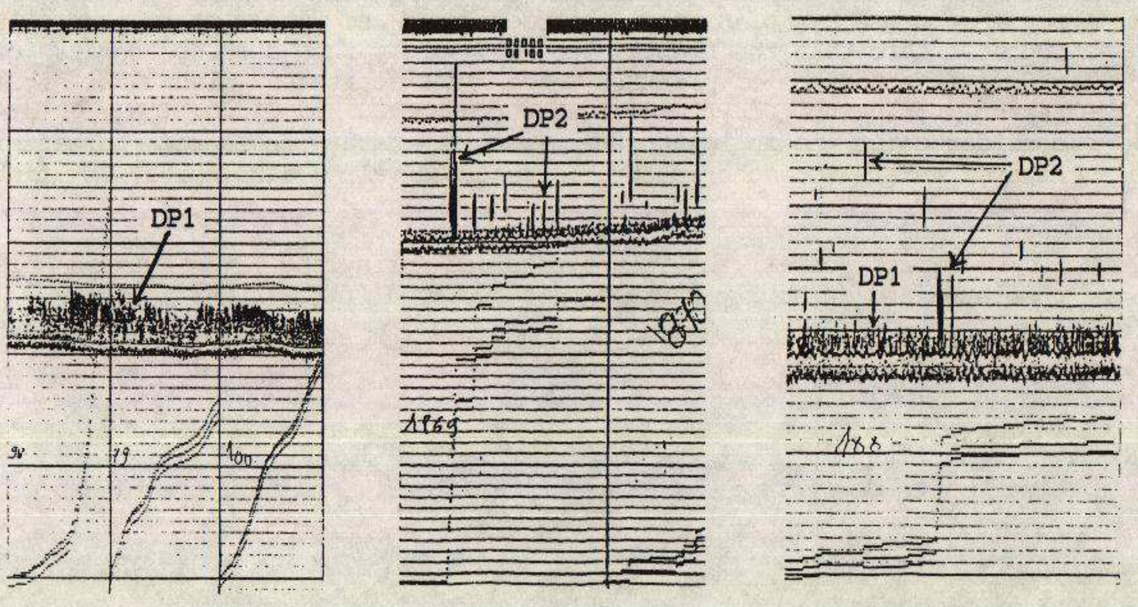

Fig. 1 - Examples of detection inducing DP1 and DP2 deviations.

The identification obtained with a pelagic trawl show that several species are generally mixed in each area, except in the south of the Bay of Biscay during March and April where anchovies are really predominant between the coast and 80 m depth. At present time, it doesn't seem possible to identify detections using objective criteria and the only sensible discrimination is based on fish behaviour, all the more as it concerns multispecies structures . On the whole, the detection corresponding to DP1 can be associated with horse mackerel and demersal species, and the detection corresponding to DP2 are more relevant to mackerel, pilchard, sprat and anchovy. As a matter of fact, these last species are usually observed, during day time, in mid-water and gathered in rather dense and well separated shoals.

Previous observations carried out with an omnidirectionnal sonar (DINER/MASSE,1987)[1] revealed frequent school avoidance reactions which result in acoustic stock under-estimates. To try and quantify these avoidance reactions, a selected rectangle was surveyed several times a day in two zones where high concentrations of fish were observed. The mean echo-integrated values per nautical mile showed great variations over a period of 24 hours.

As these experiments were realized in special conditions, it is now interesting to verify if such variations are observed within a larger area, and from year to year.

In the Bay of Biscay, between March and June, it is generally impossible to take the nightly recorded values into account, because of a great abundance of plankton which hides scattered fish. For this reason, only the daytime values between 6.00 and 22.00 (GMT+1) are considered in the following analysis. **The data considered hereafter always refer to echo-integrated recorded values attributed to fish only.**

First of all the values recorded during the five surveys are cumulated and an hourly average is calculated (fig. 2).

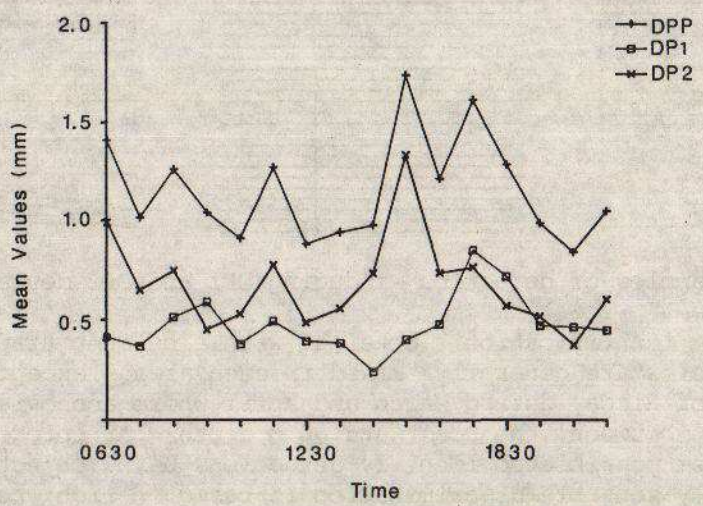

Fig. 2 - Hourly averages of values recorded during the five surveys.

Large variations occur during the daylight period, from 0.3 to 0.8 mm for DP1 and from 0.3 to 1.4 mm for DP2. When adding the values DP1 and DP2, the opposite effects are compensated in the resulting DPP. Despite this phenomenon we can observe great variations from 0.8 to 1.75 mm with two peaks at 15.30 and 17.30.

These surveys were carried out between March and June, which explain that a great lag may happen from year to year in the time of sun-rise or sun-set. To compensate this lag, moving averages are used in the following calculations. For example the average value attributed to 7.30 corresponds to the average of all values recorded between 6.00 and 9.00 , the 8.30 one to the values recorded between 7.00 and 10.00, a.s.o.

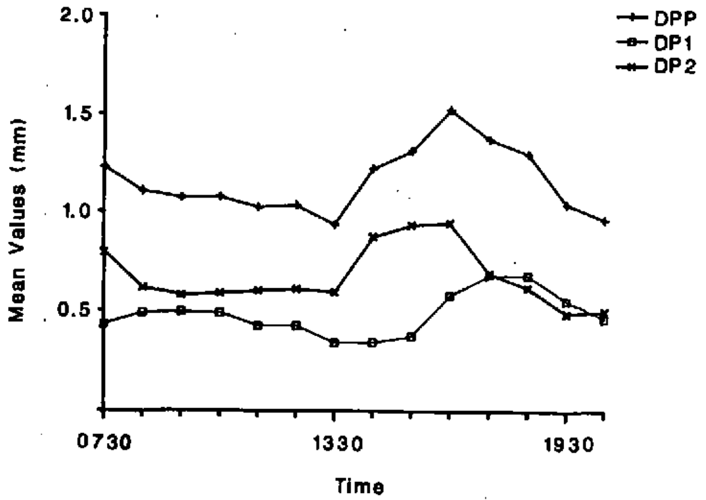

Fig. 3 - Moving averages calculated on 3 hours periods during the five surveys.

The curves in figure 3 are smoother with a small increase early in the morning and a more significant one during the afternoon.

Generally, during the surveys, most of the fish concentrations were located between the coast and 100 m depth, or between 150 m depth and the shelf break. A further selection makes it possible to do the same calculations for the values recorded at a depth less than 100 m (fig. 4) then at a depth greater than 150 m (fig. 5).

Data were checked to verify if no particular depth or time were privileged during this 16 hours period (6.00 to 22.00). It appears that data are generally well distributed except for 1985 when depth is less than 100 m and for 1983 and 1986 when the depth is greater than 150 m. For these latter situations, some gaps exist because of insufficient data.

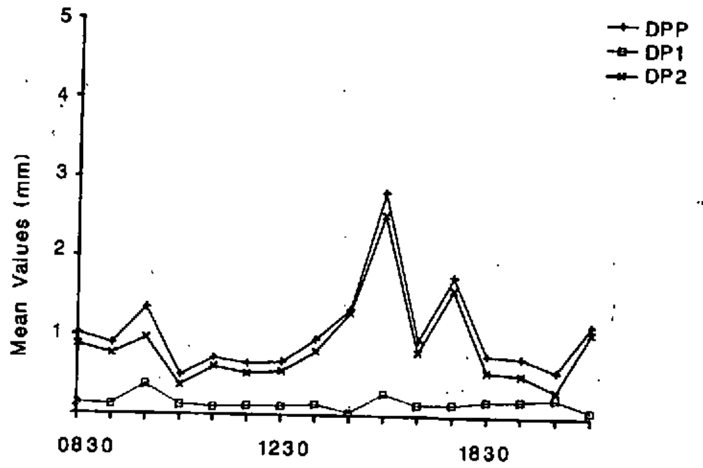

Fig. 4 - Hourly averages of fish echo-integrated values recorded during the five surveys when depth was lesser than 100m.

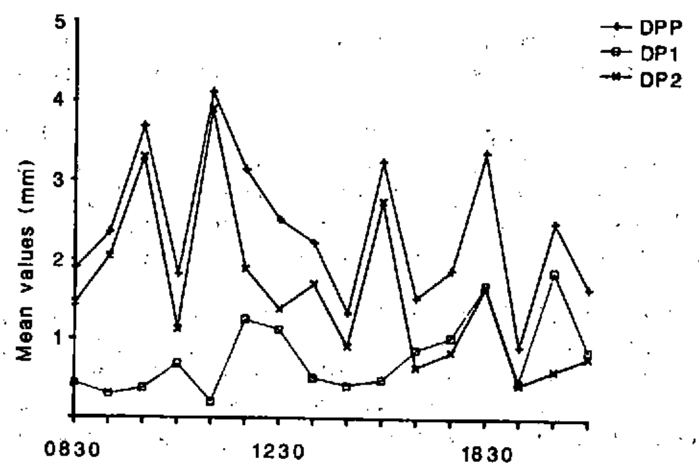

Fig. 5 - Hourly averages of fish echo-integrated values recorded during the five surveys when depth was greater than 150m.

We can stress the fact that the DP2 values are most of the time predominant, and greatly influence the DPP variations.

The average values were calculated for each representative survey and interpreted in percentage of the total abundance over the 16 hours period (fig. 6-7). The number of data considered are gathered in Table 2.

Year	Period	Nb of Nautical miles Depth < 100 m	Nb of Nautical miles Depth > 150 m
1983	17/4 - 3/5	1 160	–
1984	30/4 - 13/5	698	758
1985	20/4 - 28/5	–	299
1986	7/6 - 25/6	441	–
1987	17/3 - 4/4	299	175

Tab. 2 - Number of data considered for each year.

The fish echo-integrated values recorded in zones where the depth is less than 100 m show first a light decrease in the morning until noon, followed by a significant increase during the afternoon and finally a drop at a minimum level at dusk (fig. 6).

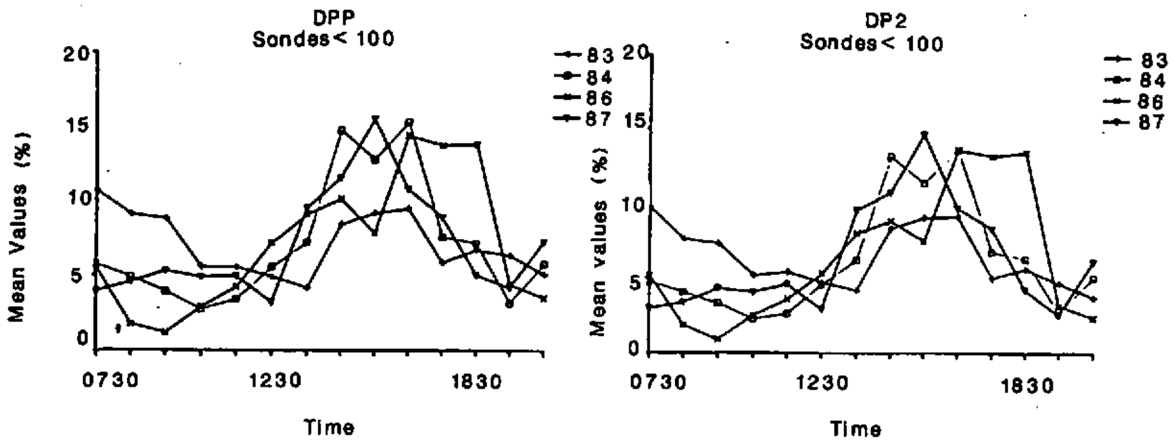

Fig. 6 - Moving averages (in percentage) at depths less than 100 m.

This regular evolution is not obvious in zones deeper than 150 m (fig. 7).

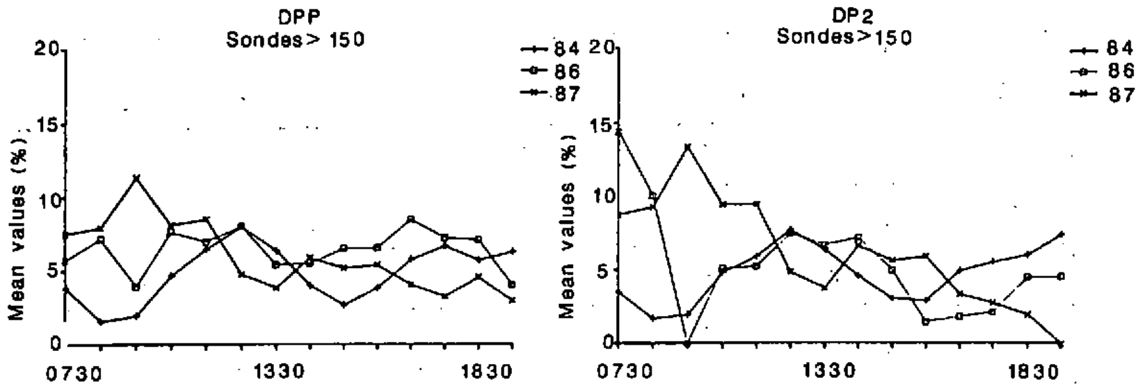

Fig. 7 - Moving averages (in percentage) when depth is greater than 150 m.

It is sensible to think that fish detected between 14.00 and 18.00 are also present the rest of the day, but are not detected by a vertical echo-sounder, in that case, two assumptions can be expressed :

- Fish is located very close to the bottom or in a thin layer close to the surface, two zones where the echo-sounder is inefficient.

- Fish is particularly lively in the morning and a lot of avoidance reactions induced by the surveying vessel occur at that moment.

This latter hypothesis seems to be plausible because most of the variations are attributed to species like mackerel, pilchard or anchovy which are known for their velocity and quick reactions.

In the present state of knowledge, it is impossible to put forward a definitive conclusion. Indeed these variations could result from the combination of several factors such as tide, luminosity or environmental conditions.

In any case, this analysis of data proves the variability of daytime detected abundance. Morever it is necessary to distinguish monospecies and multispecies communities.

As a matter of fact, in the case of clean single species structures, if such variations exist and have not been taken into account, the reliability of the absolute assessment of such stocks could be questionable. A preliminary analysis could induce to adjust the values recorded during the less abundant period with a correcting factor.

On the other hand, this is not feasible in the most frequent case where multispecies structures are concerned. Actually the values recorded may result from the combination of different behaviours therefore one cannot know which species causes an abundance variation. In such a case, even if echo-integration is the only usable method, the results may have been wrongly used by some assessment working groups, at least when these results are considered as absolute assessments.

As a conclusion, this analysis shows that thorough behaviour studies must be achieved before any acoustic stock evaluation.

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[1] DINER, N. and MASSE, J., 'Fish school behaviour during echo-survey observed by acoustic devices', Int. Symp. Fish. Acoust., Seattle, 1987, No. 30, 14 pp. mimeo.