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ACOUSTICAL SCATTERING PROPERTIES OF ZOOPLANKTON - ANALYSIS OF DIURNAL VARIABILITY

Joanna Szczucka
Institute of Oceanology, Polish Academy of Sciences
ul.Powstańców Warszawy 55, 81-712 Sopot, POLAND
e-mail: szczucka@iopan.gda.pl

The paper compares scattering properties of different types of fish and zooplankton inhabiting the Baltic Sea. They are modelled as elongated objects - prolate spheroids or bent cylinders. The knowledge of the target strength of various marine organisms is indispensable for their biomass estimation and for analysing the variability spatial and temporal in the aggregative behaviour. The dependence of the mean backscattering strength and the normalised moment of inertia on the depth of the centre of gravity, recorded in diurnally migrating Baltic biological layers, is analysed for two different seasons, for night and day separately. These relationships reflect the different vertical migration patterns typical of various seasons, connected with variable hydrological conditions.

INTRODUCTION

Acoustic scattering on the marine organisms is a key to the calculation of their abundance, estimation of their sizes, localisation of their habitat, searching for the migrations and investigation of their behaviour. Complicated field of the scattered sound carries the information that, if properly understood and interpreted, enables the biophysical parameters to be determined. The echo integration method for acoustic biomass estimation relies on an accurate knowledge of the species inhabiting the sea and their respective scattering properties. Target strength of any individual is a function of acoustic frequency and animal size, shape, spatial orientation, elastic parameters and morphology. It is a stochastic variable. Various mathematical models have been used to describe the sound scattering from fish and zooplankton [1,2].

1. SCATTERING PROPERTIES OF MARINE BIOLOGICAL OBJECTS

Acoustic scattering layers in the Baltic Sea comprise fish, mainly herring, sprat and cod, and various tiny species of zooplankton, mainly copepods and mysids. Target strength of typical Baltic individuals is shown in Fig.1 as a function of frequency. Fish tissue is described by the high-pass fluid-like prolate spheroid [2], with the ratio of the major to minor axis equal to 10. On the other hand, acoustic scattering by fish is dominated by the swimbladder that is modelled as a gas resonant prolate spheroid [1]. Elongation of the swimbladder increases the resonance frequency (in comparison with the spherical one), the surrounding tissue makes the Q-value much lower comparing to the free bubble case. Mysids, representative Baltic crustaceans, are several millimetres long. Their scattering is modelled by the fluid-like bent cylinder [2], with the length to radius ratio equal to 10.5. All calculations assume the broadside incidence. The sound speed and density contrasts between the scatterer tissue and sea water were taken after [2] as h =1.052 and g = 1.042.

The mysid is the smallest and the only non-resonant scatterer in Fig.1. All other are fishes of various type and size. For smaller objects the resonance peak of swimbladder moves toward higher frequencies and becomes lower and broader. It can be also seen that target strength of a large cod decreases in the frequency interval 30-200 kHz due to the weakening of the resonance effects. TS value at 30 kHz of a juvenile sprat (2cm long) and the adult one (8 cm long) differs by 10 dB. It means that 10 small fishes give the same scattering strength as 1 bigger fish and it can be impossible to distinguish those two sources of scattering. Analogous effect can be observed at 200 kHz in the case, when a singular fish is mixed with a big school of mysids. In the Rayleigh region the scattering properties do not depend on the shape, being only a function of size.

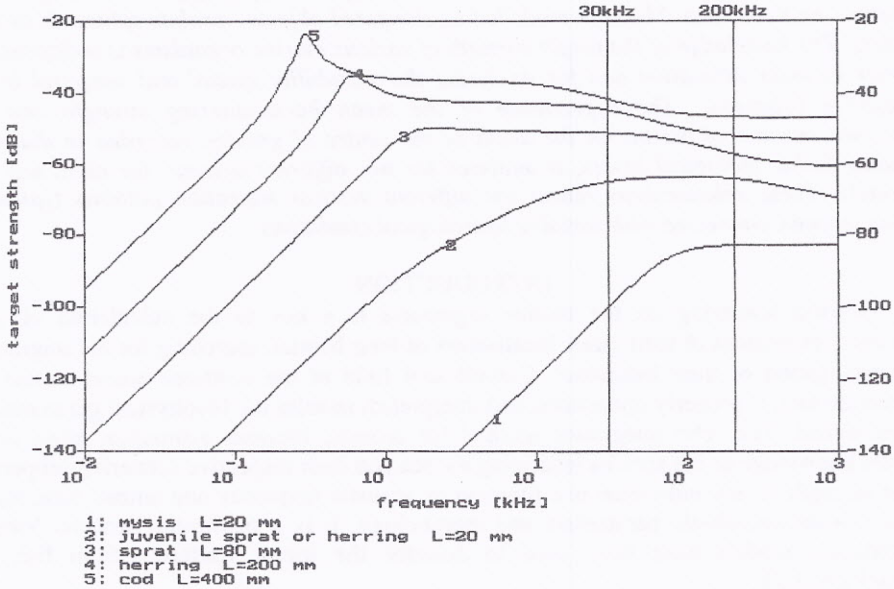

Fig.1. Target strength versus frequency for various individuals representing Baltic fauna

2. EXPERIMENTAL RESULTS AND DISCUSSION

In order to compare diurnal patterns of the vertical distribution of scattering layers, two series of stationary measurements have been analysed: 40-hour series performed in April'97 and 91-hour series performed in October'99. First of them is typical of the cold season, the second one - of the warm season. Both were recorded in the same point in the southern Baltic Sea (station P116; φ=54°40' N, λ=19°20' E ; depth 90 m).

The day-night differences in scatterers distribution in the water column are reflected inthe features of some specific parameters of the echo signal: the mean backscattering strength, the depth of the centre of gravity and the normalised moment of inertia (all averaged within the block of 64 successive pulses). The normalised moment of inertia is a measure of the dispersivity of the scatterers in the water column: the more disperse scattering objects, the bigger value of the moment of inertia. The gravity centre location determines directly the speed and direction of the scatterers movement. The mean backscattering strength reflects changes in the number of scatterers as well as changes in their scattering properties. Temporal variability of these parameters was analysed on the background of the condensed echograms for the different seasons [3, 4, 5] and showed the substantial difference in the total scattering level between day and night. Studying the interrelations between individual parameters can be another way of searching for the diel changes in the scatterers aggregative behaviour. Fig.2 shows the dependence of the mean backscattering strength on the depth of the centre of gravity, separately for day and night records, for both seasons. Firstly, it is evident that in both seasons biological objects occupy totally different areas of the water column: near bottom layer in April and upper layer in October. Secondly, it can be observed that during the day the mean backscattering strength value does not depend on depth. At night it decreases in a rate of -0.5 dB/m with deepening of the scatterers. It seems unlikely that the concentration of scatterers changes during 24 hours, so it means that either coherence becomes relevant in dense aggregations of organisms, or their target strength increases at night (when they move to the upper layer of the sea), or both. This problem still waits for solution!

Fig.3 shows the dependence of the normalised moment of inertia on the depth of the centre of gravity in an analogous way. The day situation is similar - almost no dependence is recorded. At night quite opposite trends are seen: In April (cold season) the value of the normalised moment of inertia falls with the deepening scatterers, whereas in October it rises.

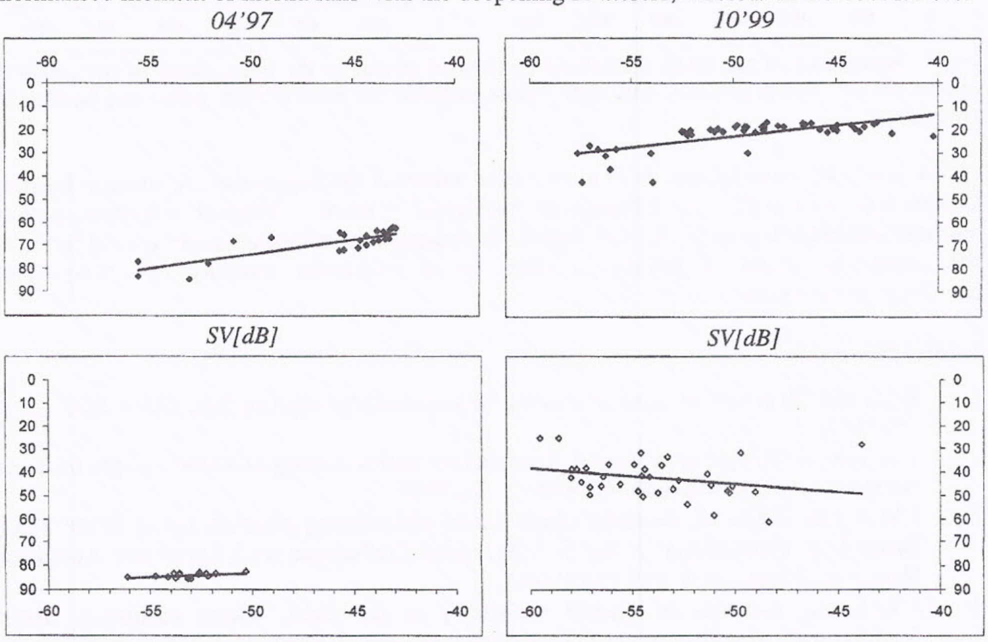

Fig.2. Dependence of the mean backscattering strength on the 1-hour depth of the centre of gravity for day (lower pictures) and night (upper pictures) for April'97 (left parts) and October'99 (right parts)

It means that in a cold season scatterers are concentrated in a relatively narrow layer close to the sea bottom, whereas in a warm season they concentrate mainly in the subsurface layer and some of them are dispersed in the deeper regions.

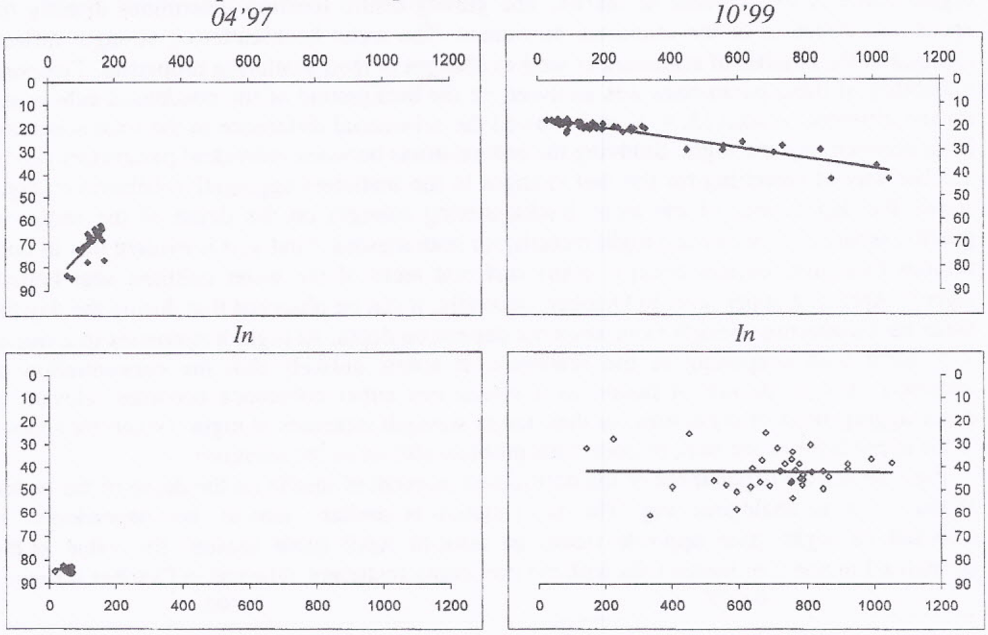

Fig.3. Dependence of the mean normalised moment of inertia on the mean depth of the centre of gravity for day (lower pictures) and night (upper pictures) for April'97 (left parts) and October'99 (right parts)

To conclude, it can be said that the measured values of the backscattering strength indicate a significant day-night redistribution of biological scatterers. Vertical migration pattern strongly depends on season. All the organisms constituting scattering layers are subjected to the continuous stress of having to adapt to an enormous diversity of time-variable hydrological conditions.

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