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APPLICATION OF ACOUSTIC METHODS TO CORRELATION OF FISH DENSITY DISTRIBUTION AND THE TYPE OF SEA BOTTOM

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ABSTRACT

The application of acoustic methods for research on living marine resources distribution in relation to environmental conditions has been developed at Sea Fisheries Institute at Gdynia for several years. The paper presents parallel use of acoustic methods to evaluate the type of sea bottom and determination of horizontal distribution of cod, herring and sprat. The methods were applied together during two cruises of R.V. "Profesor Siedlecki" in the area of the Polish fishery zone of Baltic. Geographical matrix of fish densities and bottom reflection properties was calculated and corresponding relationships were estimated. The correlation of distribution of fish densities and the type of bottom was found for cod, while for herring and sprat it was not observed.

INTRODUCTION

The sea bottom is one of the most important factors that influence static and dynamic characteristics of ecosystems. Bottom morphology determines water mass flows, that have an important impact on numerous environmental characteristics. One of them is a distribution of sediments. The bottom sediments stipulate local chemical, physical properties and detailed morphological structure of seabed. As it was shown [4][7], the bottom morphology has a significant role in forming of living resources distribution, even at bigger depths. Primary results of analysis of such relationships indicated the appearance of krill (Euphasia superba) swarms in the areas of characteristic bottom morphology [4] and a similar relationships for redfish (Sebastes mentella) from Reykjanes Ridge [7] were found.
This paper presents methods and results of parallel research on distribution of Baltic species and properties of the sea bottom. Both factors were determined by acoustic techniques.

METHOD OF ACOUSTIC BOTTOM CLASSIFICATION

To estimate the bottom properties (type of bottom)the method based on multiple echoes measurements, elaborated and described by Orłowski [5], [6] was applied. In the simplest case, when the planar wave is reflected by smooth surface, being the interface of two homogeneus media water-seabed, the acoustic pressure reflection coefficient depends on the difference of acoustic impedances of both media. As such properties are characteristic for different types of bottom sediments, the relation between the value of the reflection coefficient and the type of the seabed can

be expected.
Measurements of acoustic properties of the seabed were carried out by EK 38 echo-sounder, with wide beam 20° transducer and QM Mk II echo-integrator. The integrator was measuring and averaging the energy of multiple echoes, generated during reflection of the sounding pulse from the bottom and the water surface. Measurements of the relationship between the value of energy of II and I echoes from the bottom permits, under described in [5] and [6] conditions, to determine the reflecting properties of sea bottom VD thus enabling the evaluation of the type of sedimentation material.
The important complementation of the method, that allows for its practical use to interpret results of measurements of acoustic reflection properties, is the collection of VD empirical distributions for determined bottom sediments in surveyed area.

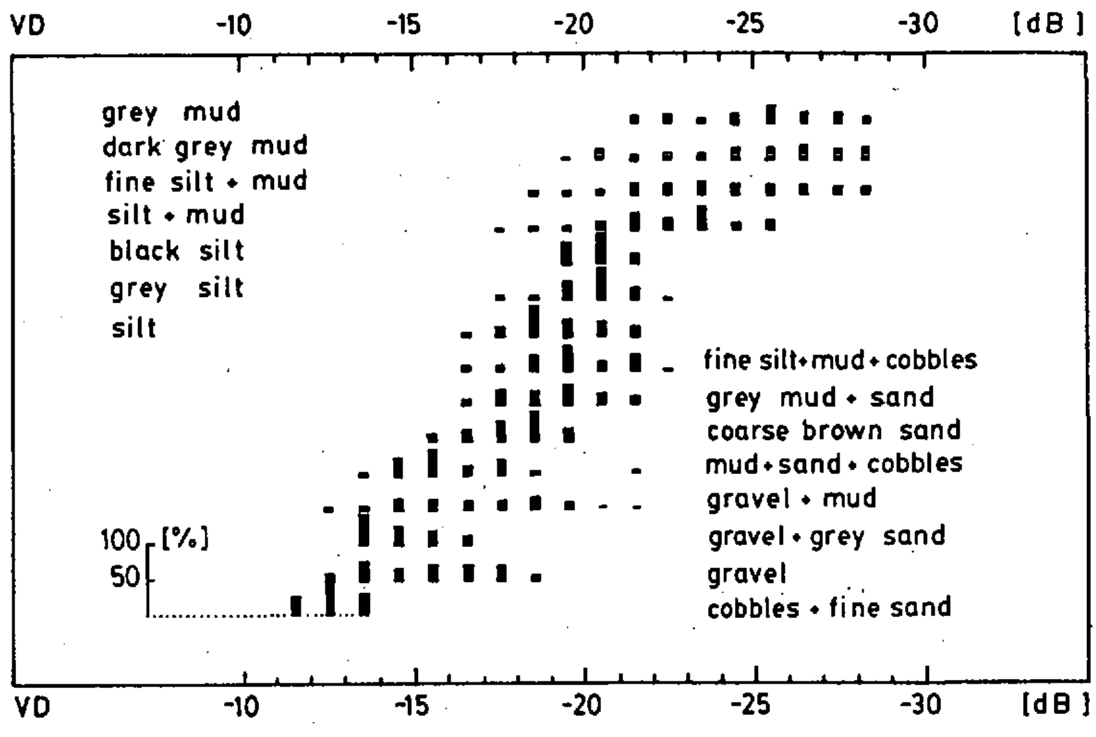
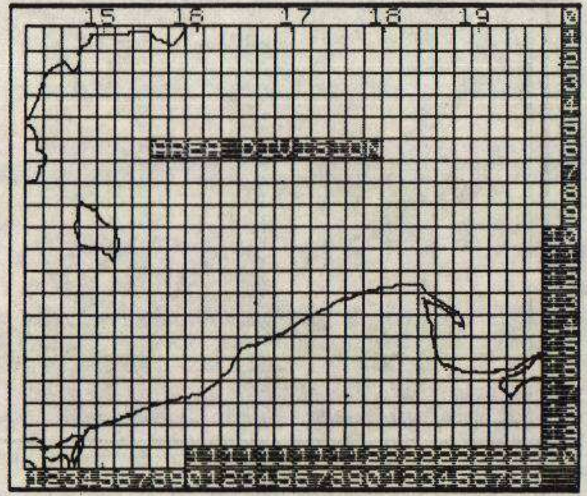


Figure 1 Distributions of values of acoustic reflection coefficients VD for determined bottom sediments in Polish fishery zone.

Figure 1 shows such distributions, collected during few cruises of R.V. "Profesor Siedlecki" in years 1981-1985, for different types of bottom in Polish fishery zone. The verification of sediments was made by direct probing of sediment material and by correlation with specialist charts. The classification of sediments was taken upon Rutkowicz and Klimaj [3]. The presented distributions are ordered according to increasing of bottom reflection properties. The Figure 1 shows the picture corresponding to approximately 700 independent measurements. Obtained spectra of VD values for individual sediments are different and it can be concluded, that those spectra are related to a local homogeneity of seabed, its vertical structure and morphology. The bottom sediment can not be determined by simple value of mean acoustical properties, but it can be more precisely estimated by anal sis of VD distributions. However the mean value of VD can be applied for rough determination of the class of bottom sediment.

ACOUSTIC CHART OF BOTTOM PROPERTIES IN POLISH FISHERY ZONE

As the first step to make possible geographical analysis of measured factors was to divide the whole surveyed area into 600 elementary squares, forming the matrix $\{a_{ij}\}$ of 30 columns and 20 lines (Figure 2). The side of each square amounted approximatly 7 nautical miles, what was closed between the mean distance of oceanographic stations 10n.m and the typical radius of autocorrelation of biomass density samples 5n.m, observed in the surveyed area. The measurements of acoustic reflection coefficient VD were



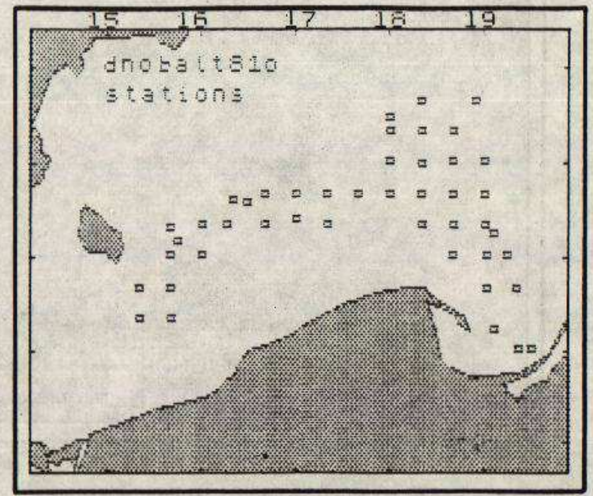


Figure 2 Division of surveyed area as $\{a_{ij}\}$ matrix of elementary squares.

Figure 3 Geographical distribution of measurements of acoustic reflection coefficient VD.

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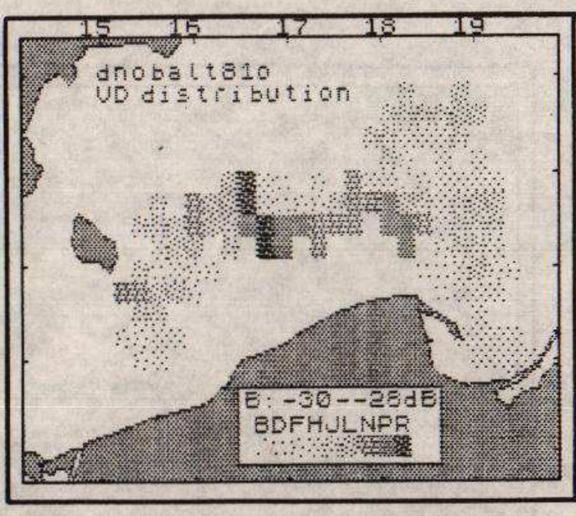
carried out on positions of standard oceanographical stations, shown in Figure 3, dislocated in semi-regular grid. The area of measurements was limited up to depths over 50m, where conditions taken under consideration in forming of multiple echoes were better fulfilled [5], [6]. For each elementary square of that area the mean value of VD was estimated by computer analysis of geographical positions of sample stations and extrapolation of neighbouring data. Calculated values of VD were located in the $\{a_{ijk}\}$ matrix. The final result as an approximate chart of bottom properties, corresponding to the matrix $\{a_{ijk}\}$, is shown in Figure 4. The values of VD were segregated into 2 dB classes. For each class graphical characters, with the number of dots proportional to the acoustical hardness of the seabed were used. The classification of the characters is showed in the lower part of the figure. Measured values of VD were closed between -11 dB and -29 dB. The strongest reflection properties appeared in the area of Słupsk Furrow, where the movement of in-flow waters is usually considerably higher.



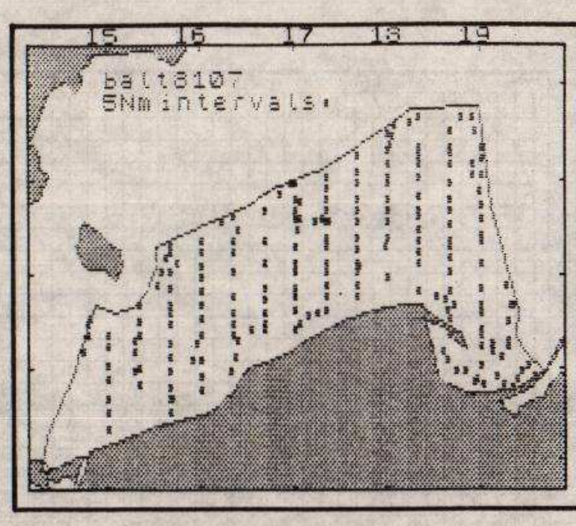


Figure 4 Approximate chart of acoustic properties of the seabed VD, determined by multiple echoes measurements: B= -30÷-28dB, D= -28÷-26dB,... R= -14÷-12 dB.

Figure 5 Routine survey track, presented by 5 n.m intervals along acoustic transect.

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DISTRIBUTION OF FISH IN RELATION TO TYPE OF SEA BOTTOM

The integration of fish echoes was conducted day and night in the layers of occurance of fish along vessel route. The route was regular and its picture is shown in Figure 5, by positions of 5 n.m intervals. The figure also presents the limits of Polish fishery zone, as the area of conducted surveys.
The EK 38 echo-sounder with transducer $4.5^o \times 5^o$ and QM Mk II echo-integrator were employed. The densities in tonnes per square nautical mile were determined by standard acoustic methods [1], [2] for all squares of the matrix $\{a_{ij}\}$ and located in the matrix $\{a_{ijk}\}$. For each 2 dB class of VD, by filtering the matrix $\{a_{ijk}\}$ mean surface densities of cod, herring and sprat $<\rho_s(VD)>$ were calculated in the area of depths over 50m. Calculations were made for July 1981 and May 1983 separately. For both cruises the models of linear, exponential and power regression were calculated and the quality of models was estimated by the comparison of correlation and random variation coefficients.
For herring and sprat, being typical pelagic fish, the correlation of their densities ρ_s and the type of seabed, expressed by VD, for all chosen models was not observed. Values of linear correlation coefficient r were as following: herring July 1981 r = 0.181, May 1983 r = -0.114; sprat July 1981 r = -0.090, May 1983 r = .060.

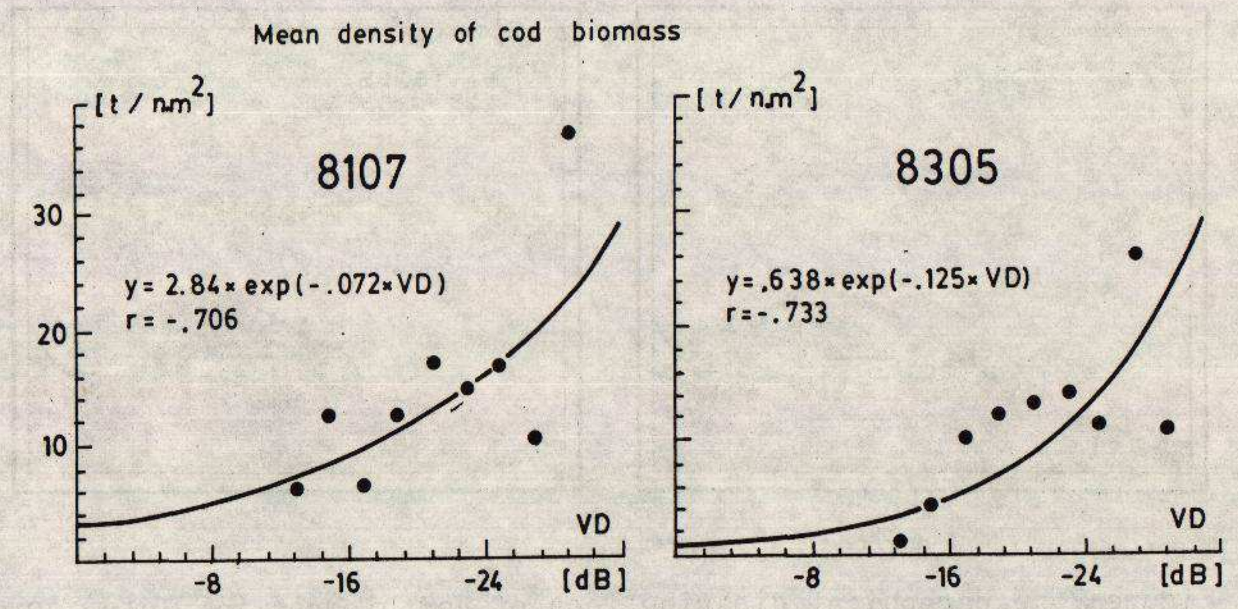

Figure 6 Values of mean density of cod biomass in t/n.m^2 for 2 dB classes of acoustic reflection coefficient VD.

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The same relation for cod had a significantly different shape. In Figure 6 are presented distributions of cod biomass densities for each classes of VD values. Maximum values of cod densities in July 1981 as well as in May 1983 appeared for the areas of acoustically softer seabed. Analysis of three models of regression of ρ_{cod} and VD showed, that the optimal approximation was done by exponential function $a \cdot e^{b}$ type. Coefficient of exponential correlation r amounted -0.706 for July 1981 and r = -0.733 for May 1983. In comparison with herring and sprat the cod showed essential and repeatable correlation of its distribution and the type of seabed during the both cruises.
Comparing the relation ρ_{cod} (VD) and distributions of VD for different types of seabed (Figure 6 and 1) we can notice, that the main stocks of cod were located during the surveys over the sea bottom consisted of sediments of higher porosity, as muds and silts. Taking under consideration relations between the porosity of sediments and exogeneous factors, it can be concluded, that the main stocks of cod were correlated with the areas of smaller flows of water masses. Comparison of geographical distributions of cod for both discussed surveys is given in Figure 7.

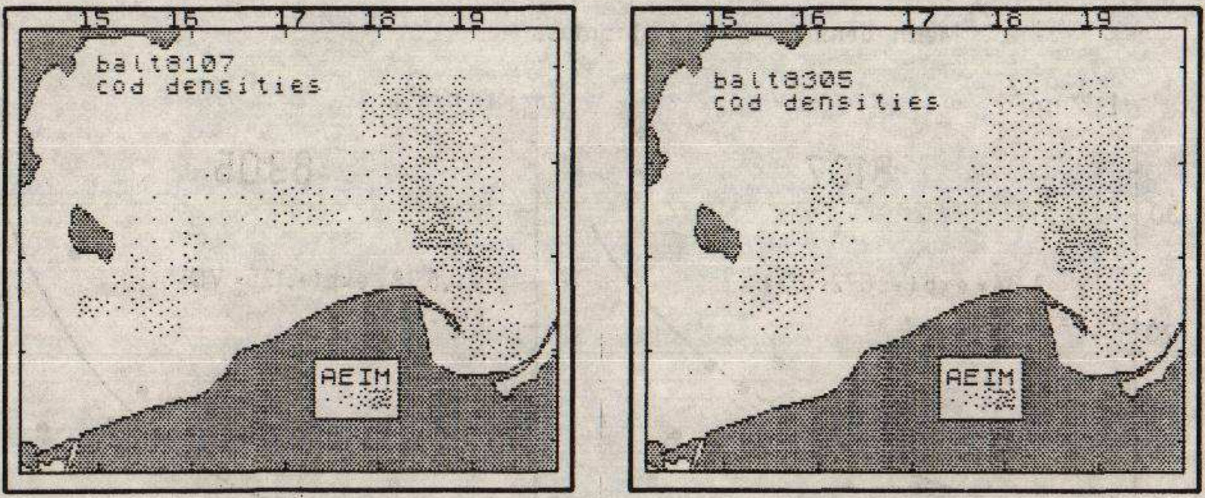

Figure 7 Geographical distributions of cod biomass in July 1981 and May 1983 in Polish fishery zone : A = 0÷4, E = 4÷14, I = 14÷40, M = 40÷120 tonnes per square nautical mile.

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CONCLUSIONS

The intention of the paper is to show the possibility of extension of application range of acoustic methods for developing research of marine ecosystems.

Basic advantage of presented method of correlation of fish stocks distribution and sea bottom properties lies in the ability of forming of numeral characteristics for both observed factors. As a consequence it allows correlation of both factors and to express relationship between them by standard mathematical and statistical methods.

Described relationships between the distribution of Baltic fish and the sea bottom properties have shown a practical result of putting the method into practice.

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