SOURCES OF THE VARIABILITY OF ACOUSTIC RESPONSE OF CLUPEOIDS IN THE BALTIC

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Acoustic information, collected in the form of calibrated measurements of integrated echo energies, has been applied at the Sea Fisheries Institute since 1981 to examine the relationships between clupeoids distribution in the Baltic and the relevant environmental factors. Data were collected during different seasons for each elementary distance unit (EDSU) at standardised depth intervals and compared to the values of selected environmental parameters measured in parallel. Acoustic, biological and hydrological data were correlated temporally and spatially, then transferred to a comprehensive database, thereby enabling the 4D analysis of the factors characterising a wide range of fish behaviour. Selected characteristics describe the variability of environmental factors during the short- and long-term life cycles of clupeoids. Apart from the analysis of abiotic factors, specially prepared cross-sections of the herring in different stages of gonad maturity are presented. The aspects of variability have been described for their inclusion in the measuring and modelling herring and sprat target strength, particularly under the specific circumstances of the Baltic Sea.

INTRODUCTION

The functioning of the marine ecosystem is consisted from many processes, which are strongly dependent on environmental factors [2]. Adaptation of the fish to the aquatic habitat demands following the evolutionary process, optimizing its functioning in the ecotope [9]. In a consequence the fish strongly respond to the spatial and temporal variability of the environment. This response is adequate to the abiotic components. Biological cycle of fish life, mostly related to the astronomic year, has a parallel influence on fish reactions and physiology.

Coefficients applied to convert echo-integrator output into fish biomass need to precise the correlation of fish back-scattering cross-section σ to adequate variability of behavioural or physical factors [3, 4, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 24, 25, 27, 28]. Fish backscattering cross-section σ, being also known as a target strength (TS), represents the most important multiplier in such conversions. Definition of the target strength of fish given in [7] it is expressed by very simple formula:

$$TS = 10 \log \sigma / 4\pi \qquad (1)$$

where σ corresponds to the equivalent cross-section of the target. Correlating the acoustic measurements of TS to fish length is calculated with empirical formulas [7], based on regressions of series of results:

$$\langle TS \rangle = 20 \log l - A_i \qquad (2)$$

where <TS> - average TS of given fish species,

l – fish average fork length,

A_i – constant dependent on fish species.

The constant A_i is the most sensitive factor in the process of the conversion of the acoustic data into fish number or biomass. It is considered as characteristic for each fish species.

It is very important to underline, that all methods of measuring the target strength are based on acoustic systems, which are able to receive and identify echoes of single fish. This assumption is limiting the time of measurements to the night-time period, when the fish is dispersed and single echoes are able to distinguish. In a consequence the constant A_i is calculated for night-time situation only. Increase of the precision of acoustic stock assessment methods needs to the estimate the constant A_i for each moment of the day, according the final effect of the variability of abiotic and biotic factors, influencing the target strength.

Increasing number of experiments shows that the constant A_i is strongly variable with factors characterising the circumstances of acoustic measurements [10, 11, 12, 13, 14, 16, 18, 21, 22, 23, 24, 25, 28]. It can be easily predicted, that directional characteristics of the fish and its acoustical contrast depends on biological state, depth, depth history, seasonal and short term behaviour reactions, as mentioned in the papers cited.

The main task of this paper is to review variability of abiotic and biotic factors, which can play the most important role in forming a final acoustic response of the fish. The presentation of results and conclusions will be given for selected case studies, including experiment, clearly illustrating importance of such studies and showing the range of uncertainty of the fish biomass estimation. The studies were made for clupeoids in the southern Baltic in the period 1981-2006.

Each marine ecosystem is characterized by a number of static and dynamic factors playing an important role in forming its biotic and a-biotic functions. One of the most important and critical elements of the ecosystem is known as benthic habitat. This area represents the seabed and surrounding waters, together with populations of biological organisms [1, 3, 9, 17, 22, 24, 28, 29]. Due to special functioning of this zone its characterization has to related to static and dynamic features of the basic parameters. Spatial variability of those factors, expressed by gradients and radiuses of correlation, effectively influences the final distribution of biological organisms [1, 7, 10, 12, 14, 14, 18, 23, 24, 29, 30] . Taking this into consideration the author suggests to enhance the classification of the benthic habitat by

introducing acoustic transects as quasi-linear units of the spatial variability of the features of the ecotope.

Acoustic methods are very effective to recognize sea depth and seabed structure. They were applied in the Baltic sea for bottom classification since early seventies of the XX century [11, 15, 16, 18, 19, 25]. In 2005 the author [20, 21] introduced a new method applying acoustic information to distinguish seabed structure. The classification was provided by simple algorithm, based on normalized bottom echo length, extracted from acoustic bottom recordings collected during series of cruises (1995-2003). Results of those surveys, spatial statistical distributions of hypothetical effective angle of a bottom echo ($\theta'/2$ – called *theta*) together with scattering mode, layers indicator, volume scattering strength, percentage of cod and hydrological factors were used to provide nine parameter classification of the bottom habitat in the southern Baltic. It was shown [19, 21] that acoustic information collected within demersal zone can be effectively utilised to provide 4D description of this ecotope, by joining acoustic, environmental and biological information. The paper indicate the way of classification of the benthic habitat by multi-parameter spatial and statistical analysis, related to selected transects.

1. MATERIAL

During the period 1981-2006 ships of Sea Fisheries Institute in Gdynia (RV "Profesor Siedlecki" and RV BALTICA) carried out series of research cruises, collecting acoustic, biological and environmental data in the southern Baltic. Three cruises (July 1981, August 1983, 1988) were conducted during the summer, two cruises (May 1983, May 1985) during the spring. Since 1989 all cruises have been carried out during the autumn (October 1989, 1990, 1994 - 2006), being the part of international ICES programme of the Baltic pelagic fish stock assessment. Each cruise lasted approximately three weeks, and had a potential to collect data from 1-2 thousands nautical miles of acoustic transect. Samples were collected continuously, and integrated every one nautical mile, 24h a day. The time distribution of samples in relation to the whole period 1981-2006 was quasi-homogeneous what gave a good base to estimate 4D characteristics of clupeoids behaviour in the southern Baltic.
In early eighties EK 38 echosounder and QMkII echo-integrator were used. Since 1989 EK400 and a QD echo integrating system were applied with proprietary software. In 1998 an EY500 scientific system was introduced to fulfill international standards of acoustic measurements, enabling research to continue. Both systems were using a frequency 38 kHz and the same hull-mounted transducer of 7.2˚x 8.0˚ beam. Calibration has been performed with a standard target in Swedish fjords in 1994 to 1997 and in Norway from 1998 to 2006. Cruises were carried out in October and lasted 2 to 3 weeks, giving the possibility of collecting samples over 1 to 1.5 thousands of nmi (approximately 450 transmissions per nmi). Survey tracks of all cruises were on the same grid to obtain high comparability of measurements.

Biological samples were collected over the period from 1994 to 2006 by the same pelagic trawl, on average every 37 nmi. of the transect. Fish observed during all surveys were mostly pelagic, herring and sprat (*Clupeidae*). Valuable complement to the biological data was the series of photos of herring (male and females) cross-section in different stages of the maturity, collected in 2007 cruise.

Hydrologic measurements (temperature-T, salinity-S, and oxygen level-O_2) were made by a Neil-Brown CTD system. These were mostly at sample haul positions, with a similar biological sampling space density. Each hydrological station was characterized by its geographical position and values of measured parameters at 2m depth intervals (slices).

In the Fig. 1. it is given the map of all sampling units (EDSU) collected in the period 1995-2004. Most of them are overlapping from year to year, due to semi-regular grid of the transects.

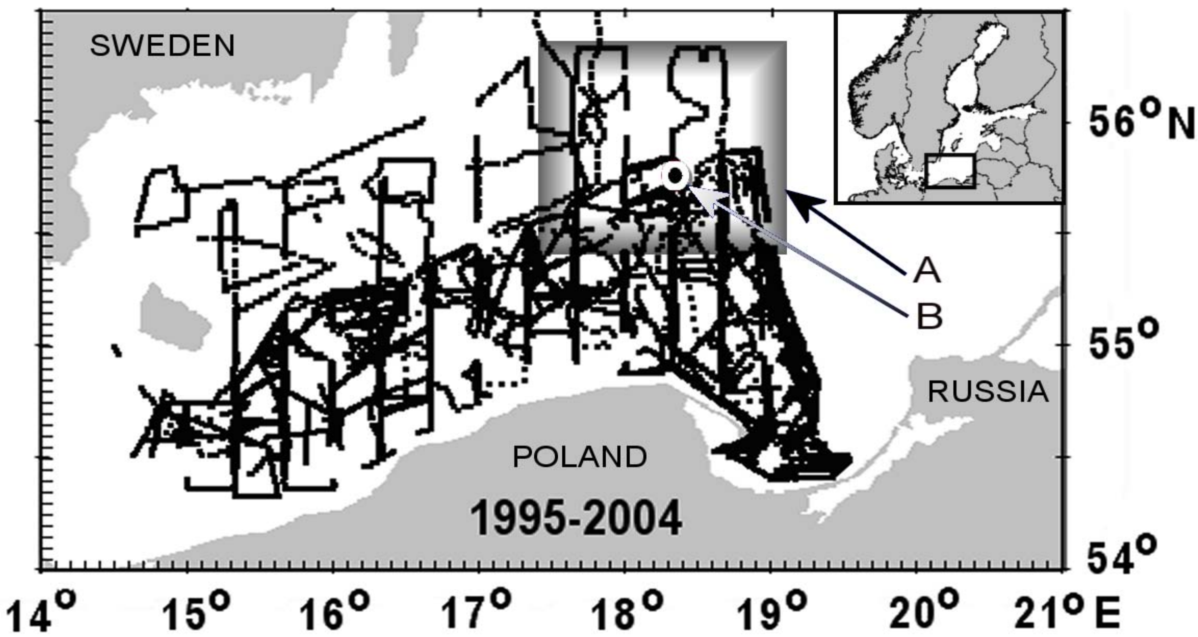

Fig.1 Area of research of RV BALTICA in October 1995-2005 taken into consideration in studies: A – sub-area of South Gotland Deep, B - sub-area of experiment carried out in October 2001

2. METHODS AND RESULTS

The method of extracting inter-disciplinary data from acoustic, biological, and hydrological measurements was described in [19, 23, 25]. Distance of one nautical mile was considered as an elementary unit (record) of the data base. For each record values of remain factors characterizing the biological and hydrological parameters were estimated. Enhancing the record length by depth structure of acoustic scattering Sv (z), biological and hydrological components, and by introducing time factor we can produce 4D data base, called 4D-ABO (A-coustic, B-iological, O-ceanographic), covering wide range of parameters. Due to limited possibilities of 2D sampling density of biological and hydrological parameters estimate of their values per each EDSU had to be done within some standardized statistical areas (ICES rectangles in the Baltic). Following parameters were measured or calculated for each EDSU:

- date, time, day- night time,
- geographic position,
- bottom depth,
- S_A, S_v values in the layered standard structure,
- depth of the upper (D_u), centre of gravity (D_f), and lower (D_l) limit of fish recordings,
- temperature, salinity, and oxygen level at D_u, D_f, D_l,
- % of the herring, sprat, and cod.

Data base was analyzed due to single cruises, blocks of cruises, and for determined geographical area (i.e. South Gotland Deep).

In October 2001 the special experiment on studying the diel fish behaviour cycle was carried out [24]. The aim of the experiment was to verify fish behaviour characteristics measured previously on a long timescale. It was also intended to estimate the dynamics of a fish behaviour in one separate diel cycle. The studies were based on a 24h per day continuous integration of fish echoes using an EY500 echo sounder at 38 kHz. Measurements were carried out by RV BALTICA traveling along the sides of a square equal to 4 nmi at a constant speed of 8 knots. The south Gotland Deep (Fig. 1) was chosen for the experiment due to the greatest amplitude there of fish vertical diel migrations within the Polish EEZ. Duration of the experiment was limited by deterioration of weather conditions but nearly 300 ESDU samples were collected. 3D distributions of echoes were correlated to the values of coincident environmental factors: time, depth, water temperature, salinity and oxygen level. Fish distribution vs. environmental factors has been described by different macrosounding visualizations, statistical, and mathematical models [19, 23, 24, 25].

2.1. BIOTIC FACTORS

Most of papers dealing with the measurements or modeling of the target strength of the clupeoids are taking into consideration only one element of the herring body – the swim bladder [7, 8, 13, 15, 18]. Due to Helfman [9]– maintaining location up of pelagic fish in the water column is energetically expensive. The need to regulate the volume of the gas bladder is a result of pressure as fish changes depth. It is considered, that the volume of the swim bladder is proportional to the fish length – what in effect provides to the constant value of the factor A_i appearing in the equation (2), applied to convert acoustic data into fish assessment procedures. If the swim bladder works as the regulator of the buoyancy [9] – its volume SBV has to be perfectly correlated to the average density of the fish body and to the present depth (pressure). In a consequence SBV has to be strongly dependent on fish biological state (maturity stages, stomach contain), depth, depth history, seasonal and short term behaviour reactions (i.e. migrations). It must be declared, that biological state of the fish strongly influences the structure of the body.

Herring individuals aboard the RV BALTICA are classified according to the Meyer's eight stages maturity scale [1]. During the last cruise in October 2006 we collected the photos of representative cross-sections of the *Clupea harengus* females and males, at different maturity stages, to show very significant changes in their body structure.

It is important to underline, that during the October cruise all stages of the maturity were found. There is no doubt that the fish body should represent very differentiated physical and chemical properties according to the maturity stage. In a consequence regulation of the buoyancy, for the same fish length, needs different SBV level for each stadium (see extreme stage IV). Also the body by itself represents different acoustic contrast. Those factors can be also connected with different fish behaviour (tilt angle). The factor of maturity can be considered as dependent on the year cycle – and the spawning season. But due to the phenomenon of time dispersion of the spawning, connected with the climatic instability, it can not be considered as the stable.

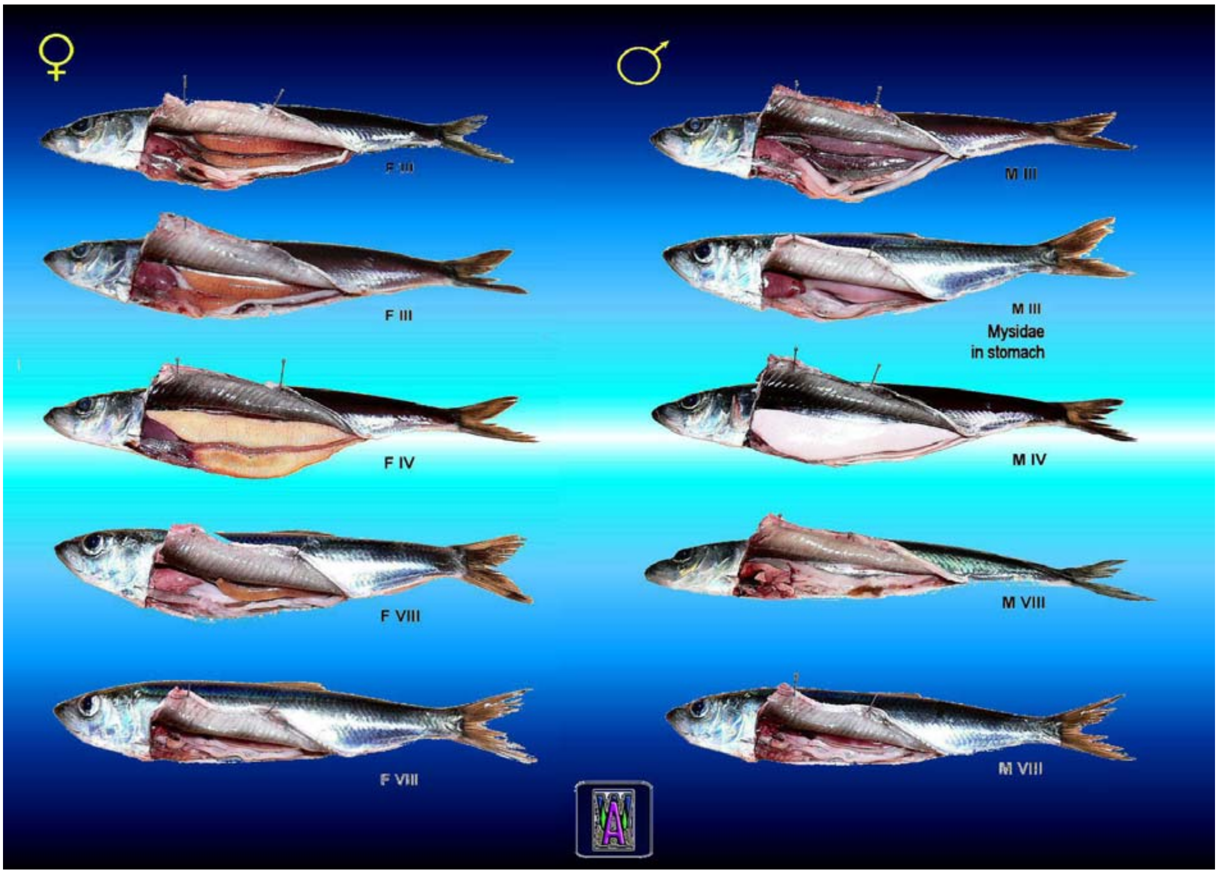

Fig.2 Cross-sections of the *Clupea harengus* females and males, at different maturity stages according to Mayer's scale (RV BALTICA, October 2006)

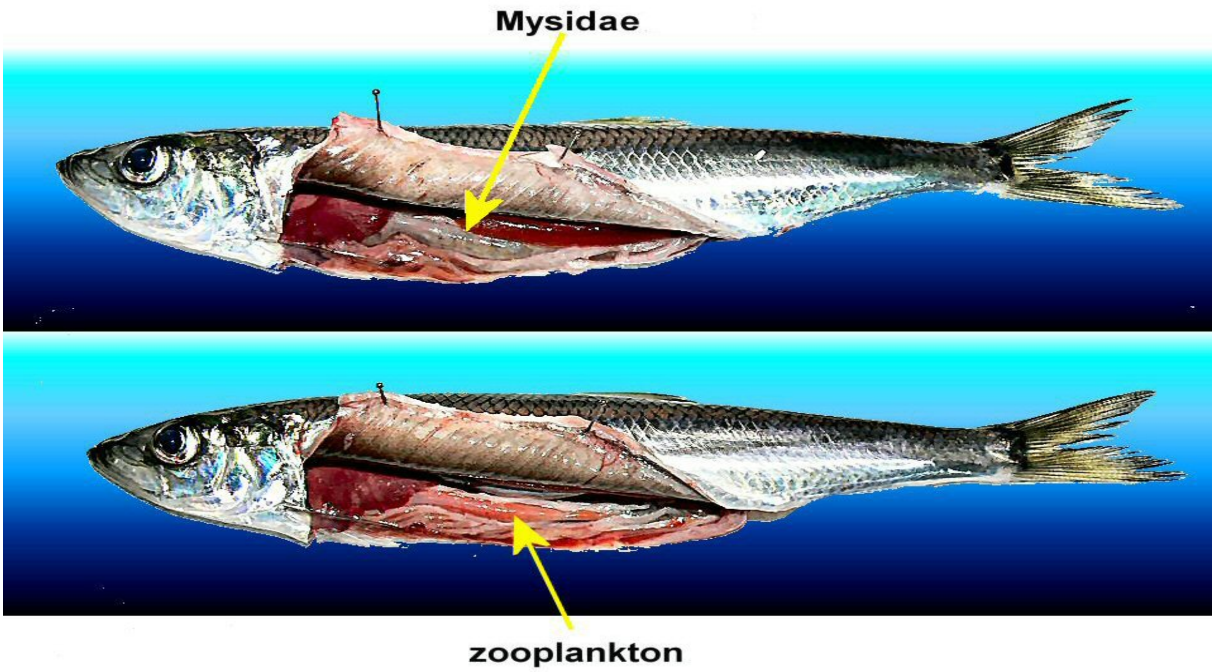

Fig.3 Examples of two different stomach contain for *Clupea harengus*

Some variability is also connected with the feeding process, influencing the factor of stomach filing. The degree of the filing of the stomach and the type of nutrition has the influence on final properties of the fish body. In many cases in our research the weight of the full stomach was exceeding 25% of the total fish weight. Two examples of herring with different stomach contain is shown in Fig. 3. Due to the diel cycle of the fish life - this factor can be considered as variable in time of the day.

2.2 ABIOTIC FACTORS

Variability of the abiotic factors in the life of the fish is closely connected with the aspect of seasonal climatic periodicity (one year period) and diurnal vertical migrations (24h period). In the first case, the environmental parameters, specially the temperature in the upper water column is strongly influenced by the elevation of the sun and the length of the day. In the second case, changes in environment are closely related to the fish actual depth due to the vertical structure of the basic water parameters. In the Baltic Sea, counted as the brackish water reservoir, the upper layer is slightly salted (less than 8 psu), while in the deeper layer (over 50m) the salinity is exceeding 9-18 psu. This situation produces strong vertical water density gradients, influencing the vertical distribution of the temperature and oxygen distribution [22].

In a consequence the fish vertical migrations are connected with conquering few environmental gradients (light, depth-pressure, temperature, salinity, and the oxygen content.

The year differences are mostly observed within the range of temperature at fish depth, corresponding to their vertical position during the diurnal cycle. In Fig. 4. we can observe clearly the differences in the diel fish depth (D_f - centre of gravity), and the average temperature (T_f) at fish depth time dependent models. The differences in the day- and night-time duration are significant too.

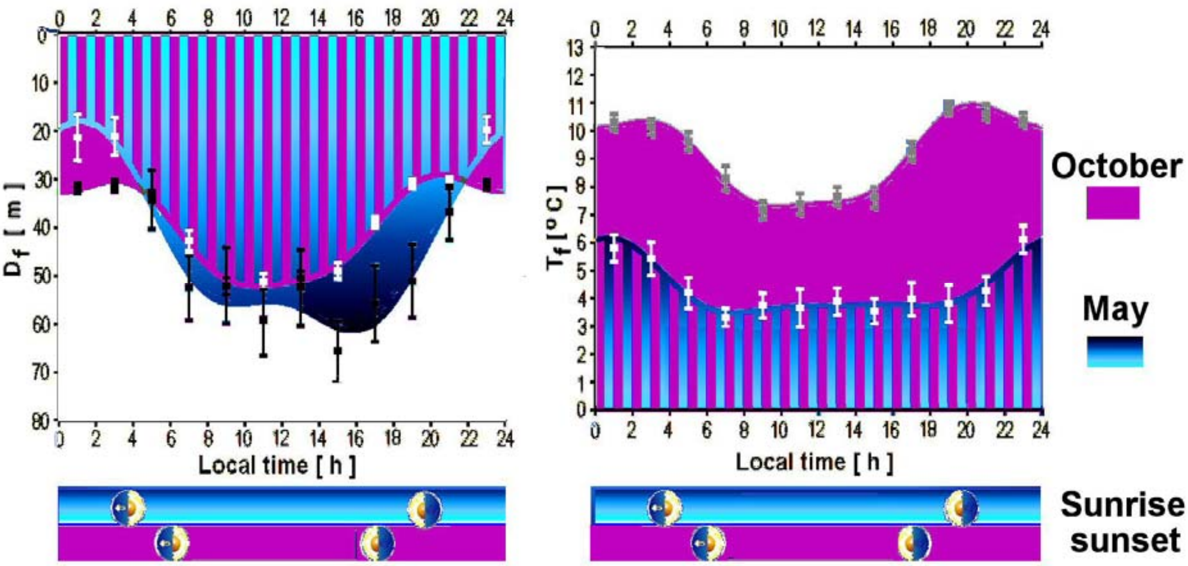

Fig.4 Polynomial models of Clupeoids vertical migration in southern Baltic during spring and autumn. Confidence intervals of average values within each statistical interval are shown

Acoustic assessment of fish resources in the Baltic (ICES international programme) is carried out each year in the autumn, so the main pressure in this paper will be given to characterize abiotic and biotic factors in clupeoids life cycle in this period. Diel cycle of fish is one of the most fundamental processes regulating fish biological condition [9]. During the autumn there is not so big difference between herring and sprat vertical distribution – so our description will be dedicated for both species together, as the Clupeoids representatives.
Diel cycle strongly effects fish behaviour and related vertical migrations causes significant changes of physical parameters of fish environment and physiology. In this paper the studies of diel cycle of the Clupeoids in the Baltic is made on the basis of data collected for the deepest area of the Polish EEZ – the South Gotland Deep (see Fig.1). The results are analyzed for the whole 1995-2004 period, and for special 48 hours experiment.
The experiment, described in detail by Orlowski [24], was made to verify fish behaviour characteristics measured in a long timescale. It was also intended to estimate the dynamics of a fish behaviour in one separate diel cycle. The studies were based on the 24h per day continuous integration of fish echoes using an EY500 echo sounder at 38 kHz. Measurements were carried out by RV BALTICA traveling along the sides of a square equal to 4 nmi at a constant speed of 8 knots (Fig.1). In the Figure 5 it is given the pattern of diel migration dynamics, shown by the macrosounding visualization. We can observe clearly the time dependent day- and night-time configuration of the fish recordings, separated by vertical migrations, synchronized with sunrise and sunset moments.
The process of the vertical displacement of the centre of gravity of S_v distribution was approximated by trigonometric polynomials (11th degree), and the vertical speed of the displacement was calculated [19]. The values of the speed were calculated for each 6 minutes intervals and are presented in the Figure 6.
Characteristics measured during the experiment were compared with calculated on the basis of all data from the surrounding area of the south Gotland Deep for the period 1995-2001. The comparison is given in the Figure 7.

The Fig. 8 shows basic characteristics of clupeoids diel cycle: limits and value of: depth of the centre of gravity, temperature, salinity, and oxygen level.. The comparison is made between the experiment 2001 area and its vicinity (over1995-2001).
More detail modeling was made for a longer period of 1995-2004, covering the same geographical area. Approximation, as in the previous case, was realized by trigonometric polynomials of 11th degree [19, 24].

The main analyzed factor is representing the average acoustic response of the fish - ($S_A(t)$). This magnitude is considered as proportional to the average acoustic response of the fish. Diel variability of this factor has to express the variability of the average acoustic cross-section of the fish in relation to the receiving transducer. Remain factors: T_f (t), S_f (t), $O_{2f}(t)$ characterize the environment at the fish depth $D_f(t)$. The degree of the polynomials was selected on the basis of minimization of the approximation error.
It is more reasonable to observe the relative variability of this factor ($S_A(t)/<S_A>$) during the diurnal changes of fish behaviour. The magnitude $<S_A>$ represents the average value of $S_A(t)$ per 24h. Having mathematical expression of the functions describing all factors analyzed ($D_f(t)$, T_f (t), S_f (t), $O_{2f}(t)$, and $S_A(t)/<S_A>$) it is possible to find the relationships between the value of $S_A(t)/<S_A>$ and each of these factors. This value can be calculated for the running value of time of the day, playing here the role of the parameter. The final results are shown in Figures 9, 10, 11, and 12.

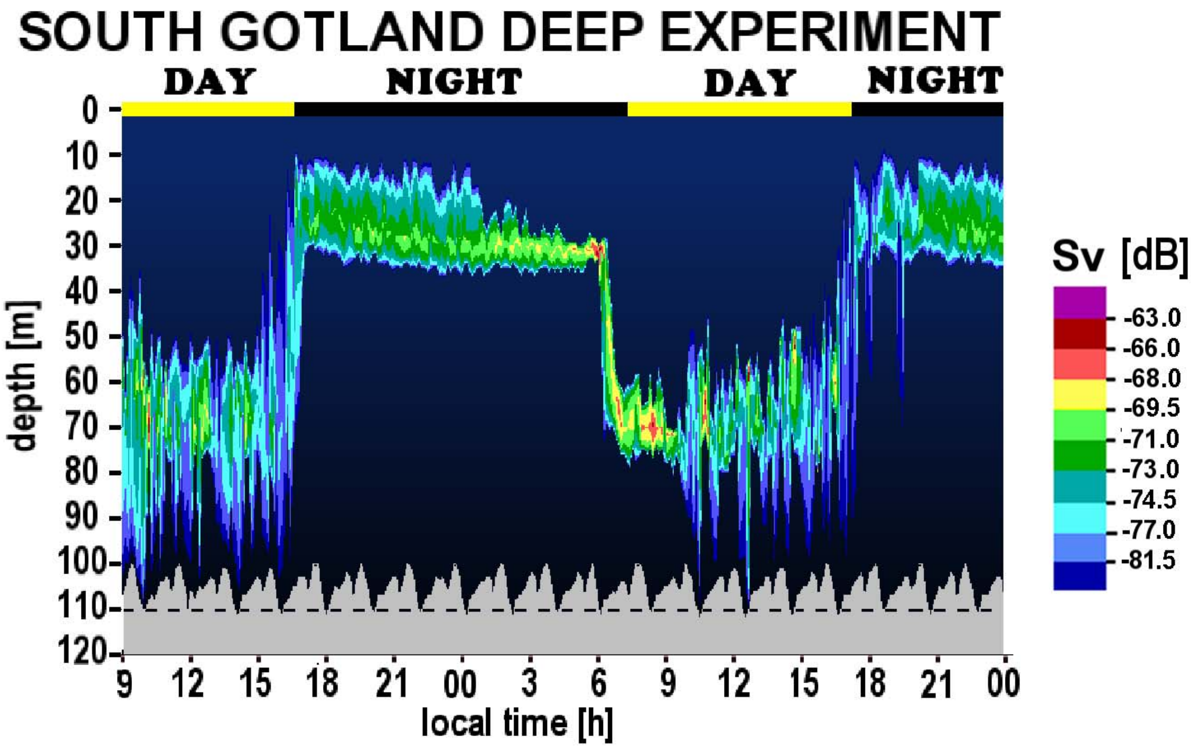

Fig.5 Macrosounding visualization of the clupeoids diel cycle observed during 48h experiment in October 2001 in south Gotland Deep

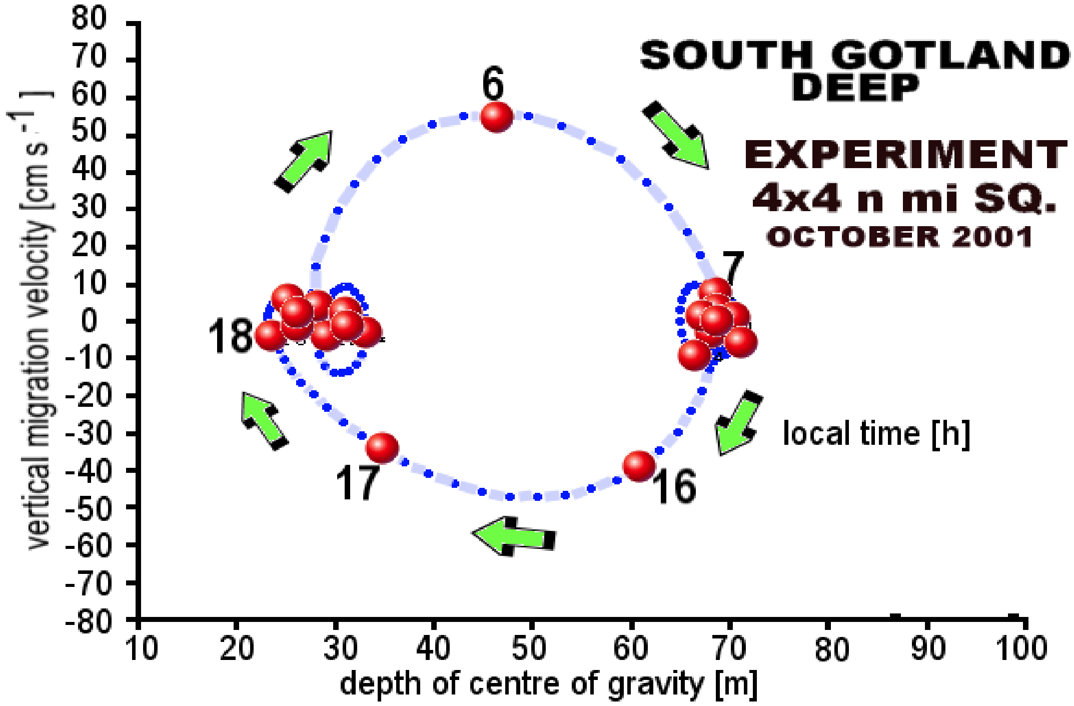

Fig.6 Diel variability of clupeoids vertical velocity in a function of depth and local time (acoustic experiment in October 2001 in south Gotland Deep)

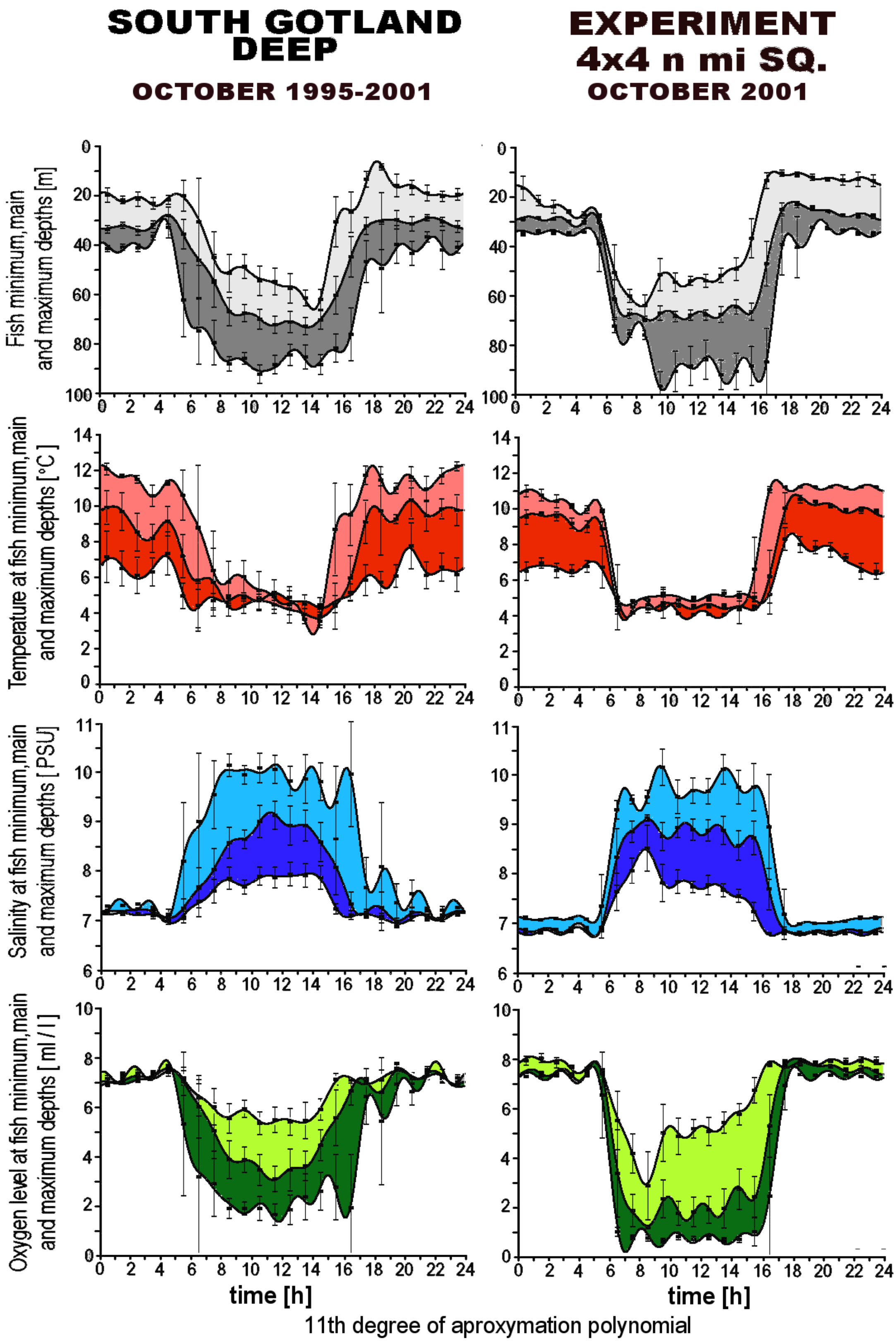

Fig.7 Comparison of basic diel characteristics of clupeoids diel cycle in autumn: limits and value of: depth of the centre of gravity, temperature, salinity, and oxygen level. The comparison is made between the experiment in 2001 area and its vicinity (1995-2001 period)

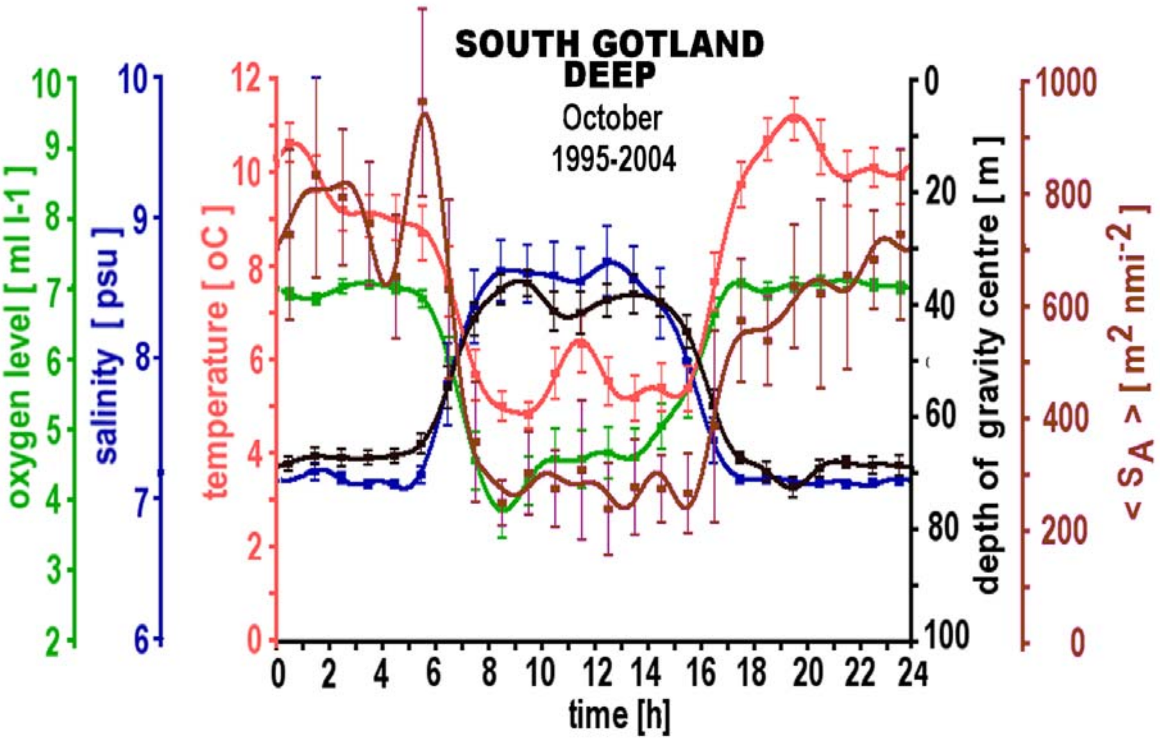

Fig.8 Diel characteristics of clupeoids diel cycle: depth of the centre of gravity, expressed by trigonometric polynomial approximations (11th degree). The comparison is made for the autumn cruises carried out in 1995-2001 period

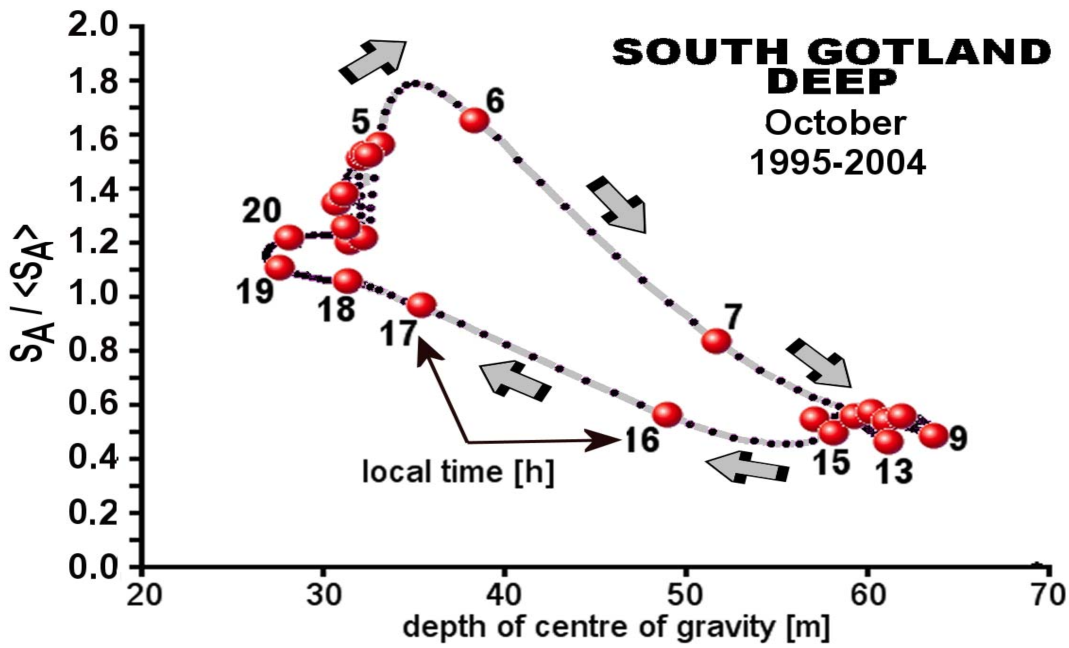

Fig.9 24h cycle of relationship between relative acoustic response of fish ($S_A(t)/<S_A>$), and depth of clupeoids centre of gravity in south Gotland Deep in October over 1995-2004 period

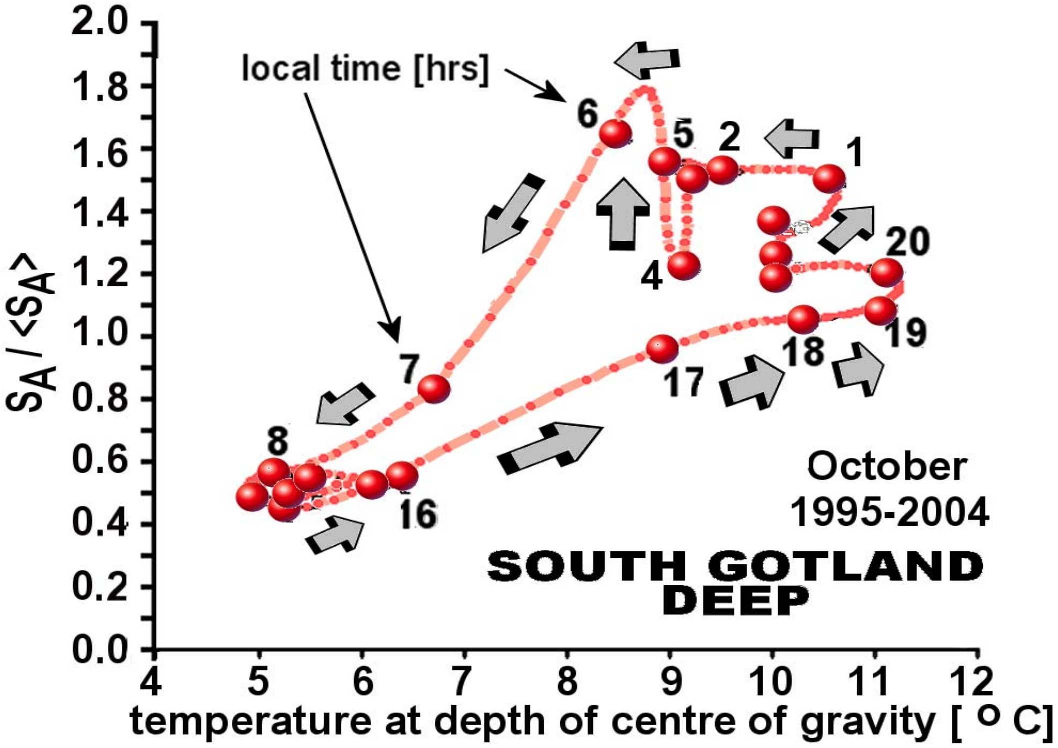

Fig.10 24h cycle of relationship between relative acoustic response of fish ($S_A(t)/<S_A>$), and temperature at depth of clupeoids centre of gravity in south Gotland Deep in October over 1995-2004 period

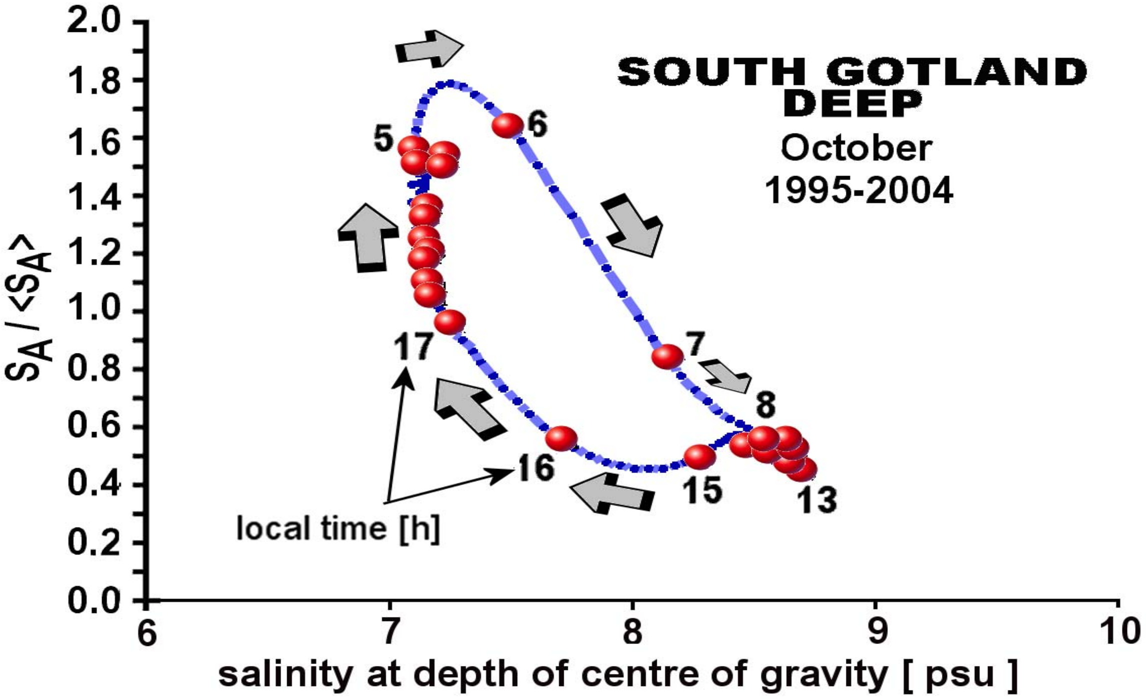

Fig.11 24h cycle of relationship between relative acoustic response of fish ($S_A(t)/<S_A>$), and salinity at depth of clupeoids centre of gravity in south Gotland Deep in October over 1995-2004 period

3. DISCUSSION

The paper presents results of studies of the factors, which could have a potential influence on the final acoustic response of the clupeoids, expressed by the target strength or acoustic cross-section (factor A_i in the formula 2). Variability of the factors was observed and analyzed in two different classes of factors: biotic and abiotic ones.

3.1. BIOTIC FACTORS

Most of works on biology of the fish indicate a strong differentiation of the fish specimen according to the different stages in the short-term and long-term life cycles [1, 3, 4, 9, 22, 28]. In the Figures 2 and 3 were given cross-sections of the male and females of the herring at the different maturity stages (III-VIII). The samples were collected during the October research cruise. It is evident, that the content of the fish body is strongly differentiated according to the stage of the maturity. The biggest difference is observed for the spawning fish (stage IV). It can be concluded, that the volume of the swimming bladder has to be matched to the fish body density. Total density of the fish body depends on the proportions of its structure and in a consequence the regulation of the buoyancy demands increase or decrease of the swim bladder volume. This phenomenon has a direct influence on the fish target strength and a final conversion factor of the acoustic data into fish biomass.

3.2. ABIOTIC FACTORS

One of the first variables taken into consideration to provide the correction of the fish target strength was the fish depth. The phenomenon of the variability of the target strength at different depth was reported by [7, 10, 13, 18, 21, 22, 24]. Primary solution for this problem was based on application of the Boyle's law, describing the relationship of the pressure and gas volume. This option was applied in the formulas given by [13, 18].

Average vertical diel migration of the clupeoids layers is variable in different seasons as it was shown in Fig.4. Generally the amplitude of migration is bigger, when the day-time is longer. The pattern of migration is also modulated by local structure of environmental gradients [22, 24]. Single pattern of migration (Fig. 5) is much sharp than the average, but the amplitude of them is very similar (Fig.7).

In Fig. 6. we can observe reconstruction of the dynamics of the clupeoids average diel migration, expressed by the values of the vertical velocity of the movement. It can be a big surprise to find such a regular pattern. The diel cycle of the fish behaviour can be easy divided into the static and dynamic periods. The first static period (0700-1500hrs - local time) corresponds to the day-time fish activities, while the second static period (1800-0500hrs) is associated with the night-time. The average fish displacement is negligible in that periods. The beginning of the diel life activities starts at 5hrs in the morning, about one hour before the sunrise. Maximum velocity of the vertical migration towards the deeper water is observed at 6hrs. The velocity in this moment is approximately 50cm/s. The period of the sunrise migration is closed between 0500-0700hrs. The sunset migration starts at 15hrs and stops at 18hrs. This period lasts longer that the sunrise one, besides its maximum velocity at 1630hrs is similar (approximately 50cm/s). In the Fig. 5 we can also observe slow night migration of the fish towards the bottom, associated with visible change of the vertical structure of the layer.

Comparison of all basic characteristics: $T_u(t)$, $T_f(t)$, $T_l(t)$, $S_u(t)$, $S_f(t)$, $S_l(t)$, $O_{2u}(t)$, $O_{2f}(t)$, and $O_{2l}(t)$ made for the experiment and calculated for the south Gotland Deep over period 1995-2001 shown in Fig. 7 shows very visible similarity of the diel clupeoids vertical migration cycle in all aspects analyzed. Taking this into consideration approximations of the main relationships ($D_f(t)$, $T_f(t)$, $S_f(t)$, $O_{2f}(t)$, and $S_A(t)$ were calculated for the south Gotland Deep for the period 1995-2004 (Fig. 8). The curves shows irregularities associated with non-linear structure of the hydrological factors (thermocline) vs. depth. The most visible irregularity is observed for the period 3-6hrs for the $S_A(t)$ curve. Fish acoustic response is decreasing in the at 3hrs and strongly increases after 6hrs. No significant changes of the remain factors are observed in the same time (Fig. 8-11). It can be directly considered that the reason of S_A can be correlated to clupeoids behaviour reaction. This decrease of S_A can be associated with tilt angle reaction, stimulated by the coming sunrise. After that a strong increase of the S_A is observed, and its value gain the maximum of the diel cycle ($S_A \approx 950^2 nmi^{-2}$). A significant increase of fish echoes during the sunrise period needs to find some logical explanation. In [9] we can find adequate comment: "When fish descend, the volume of the gas bladder decreases due to increasing pressure, the fish must add gas to maintain neutral buoyancy". We can say: it is also necessary to avoid a danger of squeezing the gas bladder and risk total lose of buoyancy. Using such a simple physical explanation we can interpret an increase of fish acoustic response by behavioural reaction, which goes ahead of the descending migration. The time of this migration is regulated by the astronomic factor, which gives a possibility of sufficiently early fish body adaptation for a longer period migration. Clupeoids as physostomes have better dynamic control of their gas bladder volume.

The phenomenon associated with fish vertical migration has to be present during the fish school also descending during the day. Instability of fish acoustic properties is closely related to fish vertical migrations and this is accepted by many authors [7, 12, 13, 18, 21, 22, 28].

Detail analysis of the characteristics given in Figs 9-11 indicate very substantial (around 400%) diel variability of the fish acoustic response, expressed by $S_A(t)/\langle S_A \rangle$. The pattern of $S_A(t)/\langle S_A \rangle = F(D_f(t))$ in Fig. 9 shows linear increase of the $S_A(t)/\langle S_A \rangle$ value during the sunset migration, what can be explained by Boyle's law effect. Next increase appears between 19hrs and 5:30hrs – this one is not correlated to the significant changes of the D_f factor. Those changes were discussed above. The migration towards the deep water after the sunrise (5:30-9hrs) is associated with decrease of the acoustic response joined with the Boyle's law effect only. Average acoustic response over the day was stable until the afternoon.

Due to the presence of the thermocline even small changes of the depth can strongly influence the values of $T_f(t)$.This phenomenon is visible in the Fig. 10 for the period between 20hrs and 6hrs. In relations between acoustic response and salinity and oxygen level changes of this factor in the period 5:30-9hrs are correlated with those factors. Salinity and oxygen level are constant within this period (Figs. 11-12).

4. CONCLUSIONS

All the aspects described above show a wide range of abiotic and biotic factors, which play important role in the year and diel clupeoids life cycle. The factors were mostly analysed from the point of view of their influence on the procedures of measuring and modelling the target strength of herring and sprat, particularly in the specific Baltic circumstances. It has to be underlined, that the following factors could strongly influence the final acoustic response of the fish:

- stage of the maturity,
- full consequences of the vertical migrations (including history of the vertical displacement),
- seasonal and diel behaviour,
- temperature, salinity, and oxygen conditions (including gradient structure).

It is important to estimate total uncertainty for survey-based abundance, associated with the described errors, not taken into consideration till now in calculating the conversion of acoustic data into the quantity of fish stocks.

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