Describing distribution and density patterns of metamorphosed 0- and 1-group cod related to hydrographical conditions, physical frontal zones, and bottom topography using hydroacoustic and trawl sampling methods in the Central Baltic Sea

Nielsen, J. Rasmus; Lundgren, Bo; Lehmann, K.M.

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DESCRIBING DISTRIBUTION AND DENSITY PATTERNS OF META-MORPHOSED 0- AND 1-GROUP COD RELATED TO HYDROGRAPHICAL CONDITIONS, PHYSICAL FRONTAL ZONES, AND BOTTOM TOPOGRAPHY USING HYDROACOUSTIC AND TRAWL SAMPLING METHODS IN THE CENTRAL BALTIC SEA (Preliminary Results)

by

J. Rasmus Nielsen, Bo Lundgren, and Klaus M. Lehmann

ABSTRACT

Recent recruitment failures of the Eastern Baltic cod stock and changes in the spawning allocation as well as changes in the cod fry distribution and density patterns related to the hydrographical conditions in the Eastern and Central Baltic Sea (CBS) makes long term management difficult. There is a gap in knowledge and understanding about the recruitment patterns and the basic early life time events of the metamorphosed, pelagic and demersal stages of juvenile 0- and 1-group (Young Of the Year) cod in the CBS. A major problem has been to develop effective methods to distinguish, allocate, and catch YOY cod *in situ*. Several multi-task surveys have been performed from August 1994 to January 1997. A main objective was to map the horizontal and vertical distribution and density patterns of YOY cod by a combined hydroacoustic and trawl survey and to relate this to the physical environment, for example hydrographical features like current fields and frontal zones obtained from CTD and ADCP data, and bottom sediment structure and bottom topography obtained from Danish and Lithuanian sediment charts. Habitat characteristics, co-existing species diversities and densities, and location of nursery areas for these juvenile cod stages have been determined. Day and night repeated fishery on the same localities showed that the CPUE of juvenile cod was significantly higher during night. In depth stratified night fishery the juvenile cod were exclusively found in near bottom water layers. Analyses of stomach contents were carried out to establish whether these cod were feeding on pelagic or demersal food. The juvenile cod were found in all areas of the CBS with a varying density. They are mainly found at localities with bottom depths from 20 to 80 m with relatively high oxygen content, below the pycnocline when the water is stratified. No dense, aggregated occurrence or schooling behavior has been observed for juvenile cod in the CBS neither day or night. This indicates that the found distribution patterns and behavior of pelagic stages of juvenile cod in CBS is different from what has been observed in the North Sea as previously reported by Munk (1993), Munk et al. (1995) and Paulsen (1996, pers. comm.). This report is mainly based on data from the December 1995 and January 1997 surveys.

Key words: AIR Baltic CORE Project, bottom structure, Central Baltic Sea, combined trawl and hydroacoustic surveys, cod (*Gadus morhua* L.), fry detection methodology, distribution and density patterns, hydrography (CTD), metamorphosed 0- and 1-group cod, water current profiles (ADCP).

Address all authors: Danish Institute for Fisheries Research, Department of Fish Biology, North Sea Center, P.O. Box 101, DK-9850 Hirtshals. [Tel.: (+45) 33 963200, Fax: +45 33963260, email: rn@dfu.min.dk, bl@dfu.min.dk, kml@dfu.min.dk].

INTRODUCTION

Recent recruitment failures of the Eastern Baltic cod (*Gadus morhua* L.) stock and changes in the spawning allocation as well as changes in the cod fry distribution and density patterns related to the hydrographical conditions in the Eastern and Central Baltic Sea makes long term management difficult. There is a gap in knowledge and understanding about the recruitment patterns and the basic early life time events of the metamorphosed, pelagic and demersal stages of juvenile 0- and 1-group (Young Of the Year) cod in the Central Baltic Sea. (Bagge et al. 1994). Knowledge of the spatial distribution of cod in the Baltic Sea is important for modeling of the biological system. A major problem has been to develop effective methods to distinguish, allocate, and catch juvenile cod *in situ* in order to give biological advice and make forecasts on these life stages to be recruited to the fishery.

One possibility of obtaining estimates of the spatial distribution of juvenile cod not yet recruited to the fishery is to use trawl or combined acoustic and trawl surveys with research vessel as no commercial catch statistics or commercial CPUE data are available as alternative methods. When performing random stratified fishery and stratified acoustic integration, survey data can be treated as CPUE (Catch Per Unit of Effort) data and direct abundance estimates. Research vessel survey data has the advantage that precise and detailed information on fishing effort, fishing position, depth, and on the catch as number caught per age group is available.

As a part of the AIR Baltic cod recruitment (CORE) Project several multi-task surveys have been performed from August 1994 to January 1997 by R/V DANA in the Bornholm Basin and adjoining waters in the Central Baltic Sea. The purpose of these surveys has been to investigate the cod recruitment in the Baltic Sea as outlined in the AIR (EU) - Project: AIR2-CT94-1226 "Mechanisms influencing long term trends in reproductive success and recruitment of Baltic cod: Implications for fisheries management". The project covers research on all early life stages of cod including eggs, larvae, and 0- and 1-group metamorphosed juveniles. Major aims are to localize the juvenile Baltic cod and determine their distribution and relative density patterns. Another main objective is to develop further the methods to distinguish and uncover the acoustic patterns for juvenile cod in relation to physical and biological conditions in certain areas.

In August 1993 and August 1994, respectively, two pilot surveys with R/V Dana (DS0793 & DS0894) were carried out with the purpose of localizing young of the year (YOY) cod, to determine their distribution and get a fishery independent cod spawning stock biomass estimate, respectively. Three later surveys were carried out in October 1994 (DS1094), (a report to be found in Lehmann and Nielsen 1995), and in November-December 1995 (DS1195) and January 1997 (DS0197), respectively, (a report on which can be found in this paper for both surveys, and in Nielsen and Lehmann 1996 for the 1995-survey), to continue the search for YOY cod and to collect further information on the biology of these cod stages. This paper deals mainly with the surveys from 1995 and 1997.

MATERIALS AND METHODS

The two surveys with R/V DANA in the period November-December 1995 and January 1997 were performed in the Baltic Sea in ICES Subdivisions 24, 25, 26, and 28. The surveys covered multidisciplinary, intensive transects and combined hydroacoustic and trawl (demersal and pelagic trawling) surveying, respectively. (Tabs. 1,2,3 & 4; Fig. 1). Investigations was also directed towards those physical and biological environmental conditions in the Central Baltic Sea that might influence the distribution and density of juvenile cod. Among these conditions are the near bottom hydrography, localization of the pycnocline, and bottom structure (sediment type), as well as biological habitat features, such as relative density and diversity of other species and the density of larger cod which are potential predators of juvenile cod.

Biological trawl-sampling activities:
Sampling of juvenile cod has been performed with small meshed pelagic young fish trawl (IYGPT) and large demersal and pelagic trawls with small codend mesh size (EXPO), and to less extent with the small meshed pelagic MIK ringtrawl (Tabs. 1&2). The EXPO trawl is a combined pelagic and demersal trawl equipped with small bobbins. The stretched codend mesh size is 16 mm. The IYGPT trawl is a pelagic young-fish trawl without bobbins. Nearly all hauls with the EXPO- and IYGPT- trawls were performed as V-shaped hauls covering the pelagic water column and the sea bottom (actively fishing from surface to bottom, along bottom, and from bottom to surface). The active fishing time of a V-shaped haul was usually approximately 40 minutes of which 25 minutes were used to trawl along the bottom. The trawl gap varied from 6 m to 9 m. During pelagic trawling the gap was typically 8 m while only 6 (-7) m when at the bottom. The trawl width was between 90 m and 105 m (typically 100 m). A total number of 38 hauls in 1995 and 35 hauls in 1997 with the EXPO trawl was made. In 1995 also 4 hauls with the IYGPT trawl and 1 haul with the MIK trawl directed towards juvenile, metamorphosed cod was performed. (Tabs. 1 & 2; Fig. 2). In 1995 repeated depth stratified fishery during night and repeated day and night hauls, and in 1997 repeated day and night fishery at the same locality was performed. (Tabs. 1&2). At selected localities in 1995 where juvenile cod were found abundant isolated demersal and pelagic hauls (in specific water layers) were performed to identify vertical distribution patterns. The trawl sampling was not randomly stratified to estimate total abundance but directed towards catch of juvenile cod to localize these and compare with the acoustic data sampling. The sampling stratification and procedures from 1995 were repeated in 1997 at approximately the same time of the year and at the same localities as covered in 1995 to make the methodology and the results of the fishing operation for all hauls during both surveys directly comparable. Calm weather during both surveys also made that possible. (Tabs. 1-5). The fishing was performed with the same vessel, equipment, and skipper why the survey catchability and fishing power is assumed identical on both surveys.

Catch analysis on board and in laboratory:
Species and size compositions for total catch were recorded at all stations as number and weight by species. (Tabs. 1,2,6,&7; Figs. 7&8). Extensive individual analyses of the caught juvenile cod were carried out. This included measurement of total tail length distributions (Figs. 2&3), weight to milligrams (Fig. 4), age check by preliminary otolith examination (day-rings), and stomach contents analyses (Figs. 5&6; Tab. 9). Length distribution data and mean length of juvenile cod (0- and 1-group; TTL $\leq$ 11 cm) from catch in the CBS in the 1995 and 1997 surveys, and mean length of 0-group cod from Skagerrak, Kattegat and Western Baltic

Sea were compared and analyzed to identify juvenile 0- and 1-group stages of the Eastern Baltic cod stock in the present investigations (Tab. 11; Fig. 2&3). Furthermore, at localities where both juvenile and larger cod were found on both surveys stomachs of the larger cod were examined on board. The objective was to determine whether cannibalism occurred or not. (Not shown).

Hydroacoustic data sampling and analysis:
Acoustic split beam raw data were collected concurrent with trawling at all trawl stations (Ex. Fig. 9&10), and between stations standard acoustic integration were performed. The acoustic data collecting equipment consisted of a Simrad EY500 portable scientific echo sounder 120 kHz split beam system, and a Simrad ES400/EK400 scientific echo sounder system operating at 38 kHz split beam and single beam, respectively. Synchronous data sampling was performed with the two systems. Integration was performed using hull mounted transducers of the type ES120-7 120 kHz split beam with a 3 dB beamwidth of 6.9°, and a ES38 with 7.0° beamwidth. The hull mounted transducers are placed in 6 m depth from surface. Acoustic data sampling was performed with the EY500 version 5.2 data sampling system described by SIMRAD (1996a) and the ECHOANN system described by Degnbol et al. (1990) with the calibration parameters and parameter settings for the EY500 Version 5.2 system shown in Table 10. The acoustic systems were calibrated using the standard copper sphere technique (Foote et al. 1986; Degnbol et al. 1990). Raw data was sampled during the whole trawling transect at all trawl stations making replay of the acoustic data with different parameter settings possible. Replay output was station specific integration data and single target TS-values (single fish echo reflections). Replay in the SIMRAD EY500 Version 5.2 software of the here presented data was performed and TS- and Sv-data were analyzed in the EP500 version 5.2 echo processing and analysis system (SIMRAD, 1996a & 1996b). Analysis was performed for different water layers. The bottom echoes were excluded from the analysis field. Mean volume back scattering (Sv) and target strength (TS) distribution are presented for different layers covering the water column along the total trawl transect at two typical sampling localities. The presented examples in Figures 9 and 10 represents typical localities, one with well mixed water and one with hydrographically stratified water, respectively.

Acoustic Doppler current profile (ADCP) data sampling:
Acoustic Doppler Current Profile (ADCP) sampling was set to sample continuously with bottom tracking throughout the surveys to measure the water current profiles (Tabs. 3&4). The depth interval (bin length) was set to 2 m and the averaging interval to 5 minutes. This instrument is a RD Instruments VM ADCP System with a Narrow Band VM 600 kHz ADCP hull mounted transducer with 4 beams at angles 30° off perpendicular. With this beam arrangement the current profile can be measured from 2 m below the transducer located 6 m below sea surface to a depth corresponding to 85 % (cos 30°) of the distance between the transducer and the bottom because acoustic interference from the bottom limits the vertical measurement region. As an approximation it is assumed that the current velocity and direction can be extrapolated to actual near bottom current unless the pycnocline is located below the maximum profiling range. On that basis water current velocity and current direction near bottom, as well as maximum profiling depth, have been recorded at all trawling localities on both surveys.

Hydrographical data sampling:

On each trawl station a vertical CTD profile was taken with a SEABIRD SBE 911+ CTD with standard probes for pressure, salinity, temperature, and oxygen (Tabs. 3&4). The profiles covered the entire vertical water column including the near bottom water layer to measure oxygen, salinity, and temperature conditions in different depths at the sampling sites. The probes of the CTD was calibrated before start of the surveys. Calibration parameters for the oxygen probe are presented in Table 10. Furthermore, cross checking of the probes has been performed using a GO rosette sampler during up-cast. Water sample values were compared with the *in-situ* CTD measurements. The oxygen profiles have been corrected by linear regression factors obtained by Winkler titration of the water samples. (Not shown). The CTD data has been used to localize the pycnocline and determine the near bottom oxygen concentrations on the trawling localities.

Bottom sediment data:

Bottom sediment data on the trawling localities (Tab. 5) has been obtained from Danish topographical bottom sediment charts covering the western CBS, and from legends of Lithuanian sediment charts covering the eastern part of the CBS. The latter includes sediment data contributions from neighbor Baltic countries. These maps was made available for the present purposes from DGS (Danish Geological Survey) in 1997. (DGS et al. 1992; Anon. 19?).

Geographical areas covered in the Central Baltic Sea:

The Central Baltic Sea is in the present context subdivided into the following areas: the Western Baltic Sea on Rønne Bank, Adler Ground and Oder Bank (Area 1); the area around Stolpe Bank in the southern part of the Central Baltic Sea (Area 2); the northern area of the Central Baltic Sea around Hoburg Bank, the Midsjo Banks and in Hano Bay (Area 3). (Tab. 1-4; Fig. 1).

GLM MANOVA test on juvenile cod density (CPUE) data:

SAS Version 6.12. (SAS, 1990) Generalized Linear Models (GLM) procedure from the SAS statistical computer package was used to perform a parametric multivariate analysis of variance (MANOVA) to test the variance structure and to identify significant dependent variables of density of small cod (Tab. 8). The GLM MANOVA was used as this procedure can handle unbalanced data, i.e. where the number of observations vary by cells. Logarithmically transformed catch rates (CPUE = Catch Per Unit of Effort as number caught per trawl hour) as dependent variable was used. The original model was given by the equation:

$$\log(CPUE) = Y + L + A + D + O + Y*L + Y*A + Y*D + Y*O + L*O + A*D + A*O + \epsilon$$

where Y=year, L=light (night time / day time), A=area, D=depth strata, O=oxygen, and ϵ=epsilon, error term (residuals). * represent interaction terms. All potential first order interactions were tested where empty cells did not occur, i.e. where observations are available. The above variables (and their first order interactions) has been included of the following reasons:

Year: Density patterns of juvenile cod are expected to vary with year.

Light: Catch rates are obviously dependent of the light conditions (present results).

Area: Catch rates are expected to be different in different areas of the CBS.

Depth: To test if there is a depth dependence in density and distribution of juvenile cod.

Oxygen: To test the significance of the dependence of near bottom oxygen concentrations with juvenile cod occurrence and density.

Categories of potential dependent factors (classes) used in the MANOVA:
Year classes: 1995 and 1997.
Area classes: 1, 2, & 3 (see geographical area description).
Depth classes: 1: $\leq$ 50 m and 2: > 50 m average bottom depth.
Oxygen classes: 1: $\leq$ 3 ml/l and 2: > 3 ml/l oxygen concentration near bottom.
Light classes: N:night and D:day.

The reduced model is given by the equation:

$$\log(CPUE) = Y + L + A + O + Y*A + \epsilon$$

which include the statistical significant dependent factors on the 5 % level (Tab. 8).

To avoid taking the logarithm of zero 1 cod/hr was added to all the catch rates. Only catch rate data from EXPO trawl hauls performed as V-hauls or at bottom are included in the multivariate analysis of variance on log(CPUE). Also all hauls where the trawl was torn were excluded from the analysis. The variance structure of the model residual was analyzed by the SAS Univariate procedure (SAS, 1991) to test for normal distribution and equal variances, i.e. to test the null hypothesis that the input data values are a random sample from a normal distribution (Tab. 8; Fig. 11) which are preconditions for the use of the parametric statistical GLM test.

RESULTS

Size at age analyses and stock affiliations of the juvenile cod:
Figures 2 and 3 presents the size distribution(s) of the juvenile cod in the selected areas: The Western Baltic Sea by Rønne Bank, Adler Ground and Oder Bank (Area 1); the area around Stolpe Bank in the southern part of the Central Baltic Sea (Area 2); the Northern area of the Central Baltic Sea around Hoburg Bank, the Midsjo Banks and the Hano Bay (Area 3). (Tab. 1&2; Figs. 1,2&3). The juvenile cod from the present investigations range in size distribution from 3-9 cm (TTL) in 1995 and 3-11 cm (TTL) in 1997. The smallest juvenile cod that was caught was 36 mm (Area 3) and the largest one 98 mm (Area 2) in 1995, and the smallest juvenile cod caught in 1997 was 33 mm (Area 1). The majority of the cod that were caught were between 4 cm and 6 cm, and the modal length was approximately 5 cm in all areas in 1995. In 1997, the majority of the cod were between 4 cm and 7 cm with a modal length at 5 cm in area 1, and 6 cm in area 2 and 3. (Figs. 2&3; Tab. 11).

The juvenile cod analyzed in the present investigations originates from the eastern Baltic cod stock which is indicated by comparative analyses of the mean length at age of juvenile cod originating from several areas and stock components in the Central Baltic Sea, Western Baltic Sea, Kattegat, and Skagerrak, respectively, in the periods December 1995, summer 1996, and January 1997 (Tab. 11). The mean length at age of the Central Baltic Sea juveniles range from 4.9-5.2 cm in 1995 and from 5.4-6.6 cm in 1997 divided by the subareas here. Mean length for juvenile cod is, thus, quite equal in the 3 areas in both years, however, there seems to be a slight tendency towards smaller mean length in area 1 compared to the mean length in area 2 and 3 both years. (Tab. 11). By comparing the mean length at age of the juveniles from the Central Baltic Sea with the mean length at age of juvenile 0-group cod from the other areas (Tab. 11; Paulsen, 1997, pers. comm.), which range from 6.9-7.5 cm in the Western Baltic Sea, from 6.7-7.4 cm in Kattegat, and 8.7 cm in Skagerrak, respectively, it is obvious that the juvenile cod from the present investigations do not belong to the spawning patches or spawning peaks of cod in the Western Baltic Sea or the other areas taking into consideration the growth in the 4 month period from August to December. The cod caught in the Central Baltic Sea has approximately the same mean length at age in December and January as the mean length of age from the juvenile 0-group cod from other areas have in July-August. (Tab. 11; Paulsen, 1997, pers. comm.).

Similar indications of stock origin (as well as spawning time) could be found from examinations of otolith microstructures. Preliminary analyses of otolith microstructure of a selection of the juvenile cod caught in the Central Baltic Sea in December-January were carried out in order to determine the age of the cod (these analyses are not presented in this paper). The analyses comprehended samples from all the cod size spectrum from 3 cm to 11 cm (TTL) including the largest and smallest juvenile cod that were caught. The largest were approximately 8-9 months old. It follows that these juvenile individuals had been spawned in the period from April to May. In December 1995 the smallest individuals that were caught were about 2 months old, and so they had been spawned in the period from the end of August to the beginning of September 1995. Consequently, the analyses strongly indicate that all the individuals with a size less than 11 cm (TTL) did belong to the 0-group cod in the November-December period in 1995 and to 1-group cod in January 1997 in the Central Baltic Sea. These findings also indicate that the spawning period for adult cod in the Central Baltic Sea is prolonged and stretches from April/May to August/September. No cod larvae were found during DANA surveys DS1195 and DS0197 in November-December 1995 and January 1997. Further evidence of a prolonged spawning period can be found in previous observations of mature cod in spawning condition in August during the pilot surveys under the Baltic Core Project (AIR 2) that took place in 1993-1994 (not presented in this paper). Furthermore, the analyses of the otolith micro structures indicate that the smallest cod that were about 2 months in age had not yet settled. Settling structures were, however, observed in the otoliths of the older cod around 8-9 months old. (Not presented in this paper).

The mean weight per cod length group (TTL) is presented for the three geographical areas in Fig. 4. The figure demonstrates that there were no geographical differences between areas in terms of size for the juvenile cod in both 1995 and 1997. Furthermore, there are no differences in mean weight at length between 1995 and 1997. The average relationship between length and the weight of the juvenile cod follows, as could be expected, a power function. The cod in the smallest size groups (35 mm to 40 mm) weigh less than ½ gram, and the juvenile cod with an modal length of 50 mm weigh approximately 1 gram. The juvenile cod with a size around 65 mm weigh 2 grams, those with a size of 70-75 mm 3 grams, 78-80 mm 4 grams, and 83-85 mm 5 grams, respectively. (Fig. 4).

Density patterns of juvenile cod in the CBS:

The density patterns of juvenile cod in the Baltic Sea were analyzed with a parametric multivariate analysis of variance (MANOVA) to test the variance structure and to identify significant dependent effects of density of small cod in the CBS. The dependent variable in the test was log(CPUE). Table 8 shows the GLM and Univariate descriptive test statistics and the estimated parameters from the GLM MANOVA. Fig. 11 shows a schematic box plot, and a normal probability plot as a quantile-quantile plot of the residuals from the GLM MANOVA. The results of the Univariate test indicate that it was reasonable to assume equal variances on the logarithmically transformed data and that the input data values are a random sample from a normal distribution on the 5 % level, i.e. the null hypothesis described in the materials and methods section can not be rejected on the 5 % level (Tab. 8; Fig. 11). Of all effects and first order interaction effects on mean density of juvenile cod (log(CPUE)) tested only the main effects year, daytime (light), geographical area, oxygen concentration at bottom, and a first order effect between year and geographical area has shown to have significant influence on juvenile cod density. This results in a reduced model given by the equation:

$$\log(CPUE) = Y + L + A + O + Y*A + \epsilon,$$

which include the statistical significant dependent factors on the 5 % level (Tab. 8).

Geographical density patterns of juvenile cod in different areas of the CBS:
The mean catch rates of cod per trawl hour, MCPUE, of the juvenile cod were ≈ 17 in 1995 and ≈ 109 in 1997 for area 1, 2 and 3 in total in the CBS (Tabs. 6). During the December 1995, DS1195, survey with R/V DANA nearly 400 YOY-cod in the size group 3-10 cm (TTL) were caught in small meshed EXPO- (and IYGPT-) trawl(s) in the CBS, and during the January 1997, DS0197, survey more than 2000 juvenile cod in the size group 3-11 cm were caught (Tabs. 1&2; Figs. 2&3). Juvenile cod were found in all surveyed areas of the Central Baltic Sea (Tabs. 1,2&6; Fig. 1), which show that all these areas are nursery areas for pelagic and demersal stages of juvenile cod in the size group 3-11 cm (TTL). No dense, aggregated occurrence or schooling behavior has been observed for juvenile cod in the CBS. The MANOVA shows that the difference in density between the different surveyed areas is statistically significant (Tab. 8). Highest densities were found in area 2 both years, i.e. in the area around Stolpe Bank in the southern part of the CBS, and at the localities west of Stolpe Bank in particular. In 1997 much higher density was found in area 2 than in 1995, and to a less extent higher densities in area 1 in 1997 was found compared to 1995. (Tab. 6). This difference accounts for the significant first order interaction effect between year and geographical area found in the MANOVA and explains the estimates of the GLM model. (Tab. 8). The density in area 3 was at the same level in 1995 and 1997 (Tab. 6&8), respectively.

The surveys in the Central Baltic Sea did not sufficiently uncover the relationship between trawling fishery and actual occurrence of the juvenile cod as the trawl sampling was not randomly stratified (geographically and depthwise stratified) to estimate total abundance, but the surveys was directed towards catch of juvenile cod to localize these and compare with the acoustic data sampling. The present analyses only cover distribution and density patterns of juvenile cod (0-group and 1-group) and do not cover older life stages. The sampling stratification and procedures from 1995 were repeated in 1997 to make the results from the two surveys directly comparable. (Tabs. 1-5). The survey catchability and fishing power is assumed identical on both surveys so the observed differences in densities and size distributions express actual population and environmental related effects rather than survey related effects.

Year difference in juvenile cod density:
The MANOVA finds that the difference in density between years is significant, however, this

difference should be related to the occurrence of the significant first order interaction effect between year and geographical area and shall as such be considered with caution. Table 8 shows that the isolated estimated year effect as difference in density between 1995 and 1997 is not significant and much less in value than the standard error of the estimate which indicates a relatively weak year effect. The mean density of juvenile cod shown in Tab. 6 only takes account for year, area, and depth strata effects while the GLM model further classifies the density into oxygen concentration and daytime effect classes which should be taken into consideration when comparing the values in Tab. 6 with the results in Tab. 8.

Depth stratified occurrence of juvenile cod related to bottom depth:
Juvenile cod are both in 1995 and 1997 found at localities with bottom depths ranging from 16 m to 87 m (Tabs. 1&2), i.e. they have been found to be present at all depths surveyed. The MANOVA shows that juvenile cod density differences with bottom depth is not significant when considering 2 depth classes: over and under 50 m bottom depth, respectively (Tab. 8). This indicates that the distribution of juvenile cod in the size group 3-11 cm (TTL) in the Central Baltic Sea is not exclusively located to either shallow water areas or to deep sea areas, but rather uniform in relation to the two depth strata and types of localities. The present limited number of data does not allow for more detailed depth stratification analyses of variance than actually performed. However, the mean catch rates divided by depth strata shown in table 6 is divided into more detailed depth groups than operated with in the MANOVA. The catch rates divided by year, area, and depth shown in table 6 does not show any consequent tendencies related to depth stratified density dependence for any of the years. This is to be related to a approximately equal geographical survey coverage the two years. But in area 2 there might be a tendency towards decreasing density with increasing bottom depth at localities with bottom depths on 50 m and deeper. There always seems to be relatively low density of juvenile cod at bottom depths deeper than 70 m.

Hydroacoustic data has been analyzed in order to examine the distribution of juvenile cod, in particular the vertical distribution through the water column has been an object for study. (Fig. 9&10). Figures 9 and 10 present echograms, target strength (TS) distributions, mean volume back scattering (Sv), number of fish tracked in acoustic single fish tracks, and the number of targets found (density) per volume and area unit, divided by dB class for different layers covering the water column along the total trawl transect at two typical sampling localities with typical acoustic distribution patterns. Each figure shows data for three different water layers at each locality. The left vertical axis on the figures indicate the depth in meters from the hull mounted transducer in the direction towards the sea bottom. The hull mounted transducer is located 6 m below sea surface. The depth range in meters of each water layer analyzed is written in the left side of the TS distribution scale. The examples in Figures 9 and 10 represent typical localities, one with well mixed water and one with hydrographically stratified water, respectively. Furthermore, the depth stratified TS distributions show a very typical pattern for each prototype locality which covers the general picture for all sampling localities where cod were caught in larger numbers.

There is no well established *in situ* target strength (TS) algorithm for 38 kHz and 120 kHz for free swimming juvenile cod (Nielsen, Lundgren and Stokholm, 1997). Because of the scattered distribution and frequent overlapping occurrence with sprat and small herring it is complicated to isolate *in situ* measured good quality TS-distributions of juvenile cod as these other co-existing fish groups have similar TS-distributions the small cod (Nielsen & Lehmann, 1996). That sprat and small herring has TS reflection values in the same range as what is expected for juvenile cod has been shown by Lassen and Staehr (1985) which has established a TS algorithm for Baltic clupeoids and by Foote et al. (1986) and by Nakken and Olsens (1977) TS-algorithms (cod algorithm based mainly on larger cod). Preliminary results of recent *ex situ* TS measurements on free swimming juvenile cod in the size range 7-10 cm indicate a TS-distribution which range between -59 dB to -47 dB for these size groups (Nielsen, Lundgren & Stokholm, 1997). Olsen and Nakken (1977) finds TS values between -47 dB and -50 dB for fixed juvenile cods in the size group between 7 cm to 9 cm. On basis of the results from the above mentioned experiments it is assumed that juvenile cod in the size group 3-11 cm found in the present investigations mainly shows TS distribution within the range of -59 dB to -47 dB.

At the locality of activity 7 where no sprat and small herring was caught and where juvenile cod were found in relatively large numbers TS values within the expected range TS distributions for juvenile cod have been observed within that TS range (Fig. 9). At locality 11 where also sprat was found together with large numbers of juvenile cod TS values within the range -59 dB to -47 dB have been observed (Fig. 10). At the typical locality with stratified water, activity 11, only very few targets within that TS distribution range was observed in the upper water layer from 0-42 m depth from sea surface(when taking the placement of the transducer into consideration, 36+6 m) above the pycnocline in 1997 (Fig. 10). At this locality the TS values within the expected TS range for juvenile cod were only observed in high number in the layer below the pycnocline situated in the depth around 46 m. In the nearest bottom water layer at this locality from 50-58 m also very few targets with TS values between -59 dB and -47 dB were found indicating that the cod juvenile cod in the size range from 3-11 cm is not located in very close association with the bottom based on the hydroacoustic data (Fig. 10; Tab. 4).

At the typical locality with well mixed water, activity 7, targets within that TS range was found in all the examined water layers. Thus, on basis of the hydroacoustic data the juvenile cod can potentially be distributed in all water layers and not exclusively distributed in the near bottom associated water layers. No sprat and small herring were found at that locality where the catch consisted of small and large cod (17.5 kg), large herring (26.5 kg), flounder (10 kg), turbot (6.6 kg), and plaice (1.5 kg).

On both the well-mixed and the stratified localities there are found relatively more targets within the TS range from -50 dB to -47 dB than targets in the TS value range from -59 dB to -50 dB in the most bottom near depth layer compared to the TS value distribution observed in the depth layer just above the most bottom near depth layer. This indicates that the smallest stages of the juvenile cod might be more pelagically distributed than the largest size groups of the juvenile cod which have a possibly more demersal distribution in the bottom layer. This picture is especially clear for the typical deep water locality with stratified water where the near bottom oxygen concentration is relatively low.

The pelagic distribution of juvenile cod in the water column was also examined by the aid of depth stratified fishery in areas in which juvenile cod had been found to some extent in V-hauls (Tabs. 1&2). When V-haul fishery through the whole water column was carried out, and when individual hauls were made in the bottom water layer, the mid-water layer and the surface layer, respectively, the juvenile cod were only caught in hauls in which the whole water column was included or in the bottom layer hauls. No juvenile cod were caught when hauling in the mid-water layer or in the surface water layer only were carried out. (Tab.

1&2). This indicates that the distribution of juvenile cod in the size group from 3 cm (TTL) is concentrated in the near bottom water layers during the night in the Central Baltic Sea, i.e. associated to the bottom environment. However, the exact location of the juvenile cod in the water layer up to around 6 m above the bottom can not be determined from the trawl fishery investigations related to the EXPO trawl gap around 6 m, when fishing at bottom. Pelagic or semi-pelagic life is possible for the small cod within that depth range.

The depth stratified fishery at target localities was carried out during the day as well as the night. Juvenile 0-group cod were nearly only caught during night, and the CPUE of juvenile cod catches were significantly higher during the night. (Tabs. 1,2&8) compared to day catches.

Hydrography and hydrographical clines (oxygen, salinity, temperature) related to juvenile cod density and stratified distribution:
The Central Baltic Sea waters are stratified on deeper localities (Tabs. 3&4; Fig. 10). During the December-January (Winter) period in 1995 and 1997 a relatively low density surface and upper water layer was observed with low salinity around 7-8 psu both in 1995 and 1997 and with low temperature on 5-8 C in 1995 and on 2-4 C in 1997. The density, i.e. the temperature and salinity was rather constant in the entire vertical water column on localities with well mixed (not stratified) water. On deep localities with stratified water layers, i.e. with the presence of thermo-, halo-, and oxycline, the water layer below the pycnocline had a relatively high density with salinities up to 17 psu both in 1995 and 1997 and with temperatures up to 10-11 C in 1995 and up to 9 C in 1997 near bottom. (Tabs. 3&4). Localities with well mixed water had relatively high oxygen concentrations at the bottom which approximately equals the oxygen contents of the near surface water. Both years near bottom oxygen concentrations vary from near saturation at localities with well mixed / not stratified water down to very low (0-1 ml O_2/l) near bottom oxygen concentrations at deep localities with stratified water layers. In the nearest few meters to bottom the oxygen concentration reached near zero values at these localities. However, the oxygen concentration was only that low in these nearest few meters above bottom as the oxygen concentration in general had a continuos and gradual decline through the water column from the oxycline down to the bottom. The pycnocline, the thermocline and the halocline, but also the oxycline, has in the presently covered areas of the Central Baltic Sea most often been located at depths between 45-55 m from surface (typically 47-48 m depth) in both years in December-January. Very seldom the pycnocline has been located in 60-68 m depth from surface. (Tabs. 3&4). Pycnoclines has been observed on the more shallow water localities at 20-30 m depth from surface which do not show as big gradients in the temperature, salinity, and oxygen concentration as the more deep located pycnoclines (not shown).

Juvenile cod were found both at stratified and well mixed localities (Tabs. 3&4; Fig. 9&10). The MANOVA finds the difference in density of juvenile cod at localities with high and low oxygen contents in the near bottom water layers significant (Tabs. 3,4&8). The density at a localities with near bottom oxygen concentration on ≤ 3 ml/l is significantly lower than the density at localities with oxygen concentrations > 3 ml/l. Thus, the oxygen concentration in near bottom waters seems to have a significant influence on the distribution of juvenile cod in the CBS.

Stomach content analyses related to habitat and depth stratified occurrence of juvenile cod:
A number of analyses of stomach contents of the juvenile cod were carried out in order to

determine whether they were feeding on pelagic or demersal food items. The results are presented in Figures 5&6 for 1995 and 1997, respectively, split by geographical area. The explanation of labels to the figures is given in Table 9.

Figs. 5&6 show that the predominant food items were pelagic (copepods) and intermediary (mysids) for all sizes of juvenile cod up to 10 cm in total length both years in all areas except for cod in area 2 in 1997 where also benthic food items became an important food group for size group 58 mm and larger. However, also for area 2 in 1997 the pelagic (copepods) and intermediary (mysids) food items are in general very dominant for the smaller size groups. In all areas the pelagic copepods were the predominant diet for the smallest size groups of the juvenile cod (3 cm to 5-6 cm TTL) in both years, and for the cod larger than 55-60 mm in total length copepods ceased to be an important diet. In the stomach contents of the cod size groups from about 40 mm and up the mysids, as bentho-pelagic (intermediary) food items, were found in all areas in 1995 and 1997. In area 1 and 2 mysids were an important part of the diet for the cod size groups from 45-55 mm. In area 2 in 1995 the mysids turned out to be important for all the larger size groups whose stomach contents were analyzed up to those of 10 cm in total length, however in 1997, benthic food items also begin to become very important diet for the size groups from 61-70 mm and larger. The predominant diet for the size groups from 45-55 mm and all larger size groups (up to 92 mm TTL) in area 3 was mysids both years. In area 3, however, mysids were already an important part of the diet for the cod size groups from 40-45 mm in total length in 1997.

On basis of these findings it seems that there is a tendency towards a shift from copepods to mysids as the predominant diet for the cod size groups from 55-60 mm. This is indicated by the fact that only a relatively small number of juvenile cod larger than 60 mm did actually have copepods in their stomach contents. A diversity of benthic food items were found in the stomach contents of the juvenile size groups already from about 50 mm in all areas both years except for area 3 in 1997 where mysids are dominant diet. For cod larger than 10 cm benthic food becomes more and more dominant diet in general, however, mysids as intermediary diet is still found in the stomach content of 15 cm long cod. (Figs. 5&6). This may indicate that the juvenile cod gradually shifts to intermediary and benthic food items in the size group around 5-6 cm and larger.

However, it seems that juvenile cod smaller than 10 cm (and 15 cm), in general, do not 100 % adapt to a diet of benthic food items, a fact that may lead to the question whether permanent settling has taken place within these stages. Thus, it follows that a total and distinctive shift in diet has not occurred within all of the juvenile cod size groups from intermediary food items (mysids) and pelagic food items (copepods) to diverse benthic food organisms (Figs. 5 & 6) within the cod size range 3-10 cm in total length.

Cannibalism and density patterns related to occurrence of larger cod:

The juvenile cod were (nearly) always caught together with larger cod, mostly between 25-80 cm (Tab. 7; Figs. 7&8). Examinations of the stomach contents of all larger cod (> 15 cm TTL) that took place on board during the surveys in which individuals from hauls containing adult cod as well as juvenile cod showed no traces of juvenile cod within the diet of the adult ones, except for one finding of 1 juvenile cod eaten by a larger cod in 1997. This was the remains of a small cod with size 5-6 cm found in the stomach of a 45 cm long cod. In general the stomachs of the larger cod was full or half full and typically with the remains of herring and sprat. Thus, there seems to be no important cannibalism on small cod by co-existing adult cod in the areas in which the smaller cod were found in the Central Baltic Sea. In Figures 7&8 juvenile cod density has been plotted against large cod density, and there seems to be no trends or relationship in the mutual density pattern between them. The possible lack of intraspecific density dependence and the low level of cannibalism indicate a low suitability of small cod as diet for larger cod.

Juvenile cod occurrence related to the occurrence of other fish species:
Juvenile cod has been caught together with 21 other species (Tab. 7) of which herring, sprat, flounder, plaice, and turbot are the most important. In figures 7 & 8 the juvenile cod density has been plotted against species diversity and overall fish species densities for all localities surveyed. There can be found no tendencies in the relationship between juvenile cod density and overall species density. Also the juvenile cod density does not seem to be related to overall species diversity, however, the highest densities of juvenile cod are found at localities where the highest number of species have been caught, i.e. where the species diversity is highest.

Cod density related to near bottom water current conditions:
In Tables 3 and 4 current conditions in the near bottom water layers are presented as current velocity in cm/s and current direction in degrees from northwards direction, i.e. the direction vector. Furthermore, the depths from surface and above bottom in which the current measurements has been made are given. The current conditions have been compared to the CPUE of cod and there seems not to be any correlation between the current direction and the catch rates of cod neither in 1995 or 1997. It should be mentioned that the current velocities and directions in the table for many localities both years are only valid for the water layer above and down to the pycnocline. The measured current velocities are all low in both years, usually less than 15 cm/s. The highest observed current speeds observed in the present investigations are approximately 30 cm/s, i.e. much less than 1 knot (≅ 50 cm/s). Except for the fact that juvenile cod has only been found at localities with relatively low speed current conditions there seems to be no correlation's between current speed and cod occurrence based on the present preliminary investigations.

Cod occurrence related to bottom sediment type:
The bottom sediment type has been identified at all trawl stations, i.e. at all localities where there have been found juvenile cod (Tab. 5). Cod were found on localities with a variety of bottom sediment types, however, the predominant bottom type of all areas covered is the gIII type, which is glacigenous deposits consisting of rubbly loam and sandy loam. No obvious correlation between cod occurrence and bottom sediment type could be found based on the present tabulation of cod density against bottom sediment type

DISCUSSION

The investigations of juvenile cod distribution and density patterns in the Central Baltic Sea using combined hydroacoustic and trawl sampling methods ware initiated based on the attempt to develop adequate methods to be able to test the following expectations and null hypotheses related to these patterns:

H0a: Juvenile cod shows in the life stages from metamorphosis, during the following pelagic life stage, and into the first part of their demersal life stage schooling behavior and patchiness in their spatial occurrence. This hypothesis was based on findings for small pelagic life stages of juvenile cod (2-3 cm in modal length) in the North Sea (Bromley & Kell 1995; Munk 1993; Munk et al. 1995) and on catches of large patches of 5-6 cm juvenile cod in modal length by the Danish Institute for Fisheries Research in the North Sea in June 1996 (Paulsen, 1996, pers. comm.)

H0b: Juvenile cod are in the pelagic life stages distributed in the surface water layers above the pycnocline.

H0c: Juvenile cod are in all stages distributed in well aerated waters with relatively high oxygen concentrations.

H0d: Patchiness in the distribution of juvenile cod during day time will during dusk dissolve into a more disperse, scattered distribution which will be observed during night time until daybreak.

H0e: The distribution pattern of juvenile cod are not correlated with intraspecific densities of co-existing larger cod.

Juvenile cod was found in all areas (1,2,3) of the Central Baltic Sea at localities with a bottom depth ranging from 16 m to 87 m, and the present investigations indicate that their distribution was scattered. The juvenile cod analyzed in the present investigations originates from the eastern Baltic cod stock which is indicated by comparative analyses of mean length at age of juvenile cod originating from several areas and stock components in the Central Baltic Sea, Western Baltic Sea, Kattegat, and Skagerrak, respectively, in the periods December 1995, summer 1996, and January 1997, and which also is indicated by comparative analyses of otolith microstructure. Furthermore, these analyses indicate a prolonged spawning period of this cod stock. Consequently, all three areas can be characterized as nursery areas for pelagic and demersal stages of juvenile cod in the size group 3-11 cm (TTL) originating from the eastern and central Baltic cod stock. No significant correlation between juvenile cod density and bottom depth could be found, which indicate that the distribution of juvenile cod is not limited to either shallow water or deep sea localities in the Central Baltic Sea, but the distribution seems to be rather even related to depth. Even though the juvenile cod are distributed in all surveyed areas there was found a significant difference in their density between the different areas. Both in 1995 and 1997 highest densities of juvenile cod were found in area 2 and relatively low densities were observed in area 3, while the densities in area 1 did not show a consequent pattern for the two years as much higher densities in area 1 was observed in 1997 compared to the densities in 1995. Thus, even though all of the surveyed areas 1, 2 & 3 seems to be nursery areas for juvenile cod then area 2, however, seems to be the most important nursery area for juvenile cod in the size range 4-9 cm in December-January both in 1995 and 1997 in the Central Baltic Sea. The mean length for juvenile cod and the mean weight at length did not vary much between areas for both years. Only the mean length in area 1 seems to be slightly smaller compared to mean length in area 2 and 3 both years. No area and year differences could be found in mean weight at length for the juvenile cod.

The present investigation of juvenile cod distribution patterns was made on the null hypothesis that the pelagic stages of juvenile cod are distributed in schools associated to the horizontal physical clines in the Central Baltic Sea (H0a & H0b). These expectations was based on findings of juvenile cod distributions in the North Sea (Bromley & Kell, 1995; Munk 1993; Munk et al. 1995; Paulsen 1996, pers. comm.). Originally it was expected that the juvenile cod distribution would be highly dense in certain isolated areas (with schooling behavior), but unlike the findings in the North Sea this seems not to be the case. No schooling behavior for juvenile cod distribution was observed for either pelagic or early demersal life stages within the size group 3-11 cm, as the several surveys performed during the latest years in the search for juvenile cod and the present analyses has not been able to reveal occurrence of any large patches of any stages of juvenile cod in the Central Baltic Sea during late summer, autumn and winter time which could have confirmed the H0a null hypothesis. On the contrary, the present results indicate a scattered distribution of juvenile cod in the size group 3-11 cm in all areas of the Central Baltic Sea at localities at all bottom depths in the Central Baltic Sea which speak in favor of rejecting the H0a null hypothesis.

The intention was to localize these patches of juvenile cod and develop hydroacoustic methods to estimate the density and abundance of these stages of Central Baltic cod in order to approve the recruitment estimates to be used in the forecast for the eastern Baltic cod stock. This to be seen in light of that it until now only has been possible to obtain good quality and covering survey estimates of 2-group cod, while the yearclasses of 0- and 1-group cod have not been fully and sufficiently covered in the Baltic young fish surveys (BYFS) up until today, and that recruitment estimates of 2 year old cod is quite late estimates related to stock management as the cod from the eastern Baltic cod stock already recruits to commercial fishery as 3-year old fish. The scattered distribution of the juvenile cod complicates the accomplishment of this aim. This should also be seen in light of the near bottom distribution (H0b) complicates identification of specific acoustic patterns for juvenile cod as acoustic signals from other near bottom species as flatfish, of which the acoustic reflection (target strength) is not known, interact and disturbs the species and size specific acoustic target reflection from juvenile cod. If dense occurrences of juvenile cod in schools could have been found in the pelagic water layers of the open sea area in the Central Baltic Sea without too much spatial overlap of sprat and small herring, which are the most important pelagic species in the Central Baltic Sea, as origianally expected acoustic measurement of juvenile cod would have been a much more simple task to perfom than it actually is related to the observed more scattered, bottom near distribution of the juvenile cod.

The pelagic stages of 2 cm long juvenile cod has not yet been localized even though the Central Baltic Sea has been surveyed thoroughly in all periods of the year and areas where these life stages are likely to occur. This might be due to gear selectivity. The only area, where possible distribution of these stages could be found which has not yet been surveyed thoroughly is in the near coastal and shallow water areas. So far it has not been possible to survey these areas with large research ships with multi-disciplinary survey equipment on board. This task will demand surveys performed with smaller research vessels equipped with more limited levels of advanced technical survey equipment. However, if large patches of juvenile cod is to be found near coastal in shallow water areas, i.e. in depths less than 15 m bottom depth, they probably already would have been found and observed by fishermen. Another point is that these very small cod if occurring in near coastal areas have to perform a relatively extensive migration to the deeper sea areas, where we find them as 3 cm long juveniles, within short time. This extensive horizontal and vertical migration we will question to be possible within such a short period. Another argument, that we doubt this near coastal distribution of juvenile cod, is that it would not be in accordance with our H0b null hypothesis which state that these early pelagic stages somehow are distributed related to the localization of the pycnocline which is the only hydrographical frontal zone occurring in the Central Baltic Sea. This should be related to the pycnocline is located much deeper than at depths between 20 and 0 m bottom depth, i.e. there are no pycnocline in shallow water areas during late summer, autumn, and winter.

The analyses of the depth related acoustic TS distribution patterns in 1997 and the depth stratified trawl fishery during night in 1995 and 1997 indicate a bottom associated distribution of the juvenile cod in the size group from 3 cm as no juvenile cod were found when fishing exclusively in mid-water and surface layers. The acoustic data indicate that for localities where the water column is stratified, i.e. where a pycnocline does occur, the juvenile cod show a bottom associated distribution. Consequently, the present localized juvenile cod seems to have a distribution related to the pycnocline when such one exist. However, in contradiction to our H0b null hypothesis, that the juvenile cod in the pelagic life stages are distributed in the surface layers above the pycnocline, we have found both pelagic and demersal stages of juvenile cod in the size group 3-11 cm (TTL) to be near bottom associated below the pycnocline at localities with stratified water. Thus, it seems that the juvenile cod are distributed below the pycnocline rather than above the pycnocline. Furthermore, these juvenile cod stages are not always found to distributed related to the localization of a pycnocline, i.e. in or in association with a frontal zone, as they are found abundant at localities with well mixed water without presence of a pycnocline.

As juvenile cod are found in near bottom water layers also at localities where the pycnocline is located much higher in the water column with large depth range down to the bottom the present investigations indicate that the pelagic stages of cod are not associated with the pycnocline but rather with the bottom when taking the trawl gap into account. This is for example observed related to activity 28, 32, 74, 76, and 80 in 1997 and also at all other relevant localities in both 1995 and 1997 where the pycnocline is located high in the water column way above the bottom. However, the juvenile cod can have been fished near the pycnocline as most activities has been V-hauls in the present investigations, but the results from the depth stratified fishery and the analyses of the acoustic data do not indicate that. The exact distribution of the juvenile cod in the near bottom water layer up to around 6 m above the bottom can not be determined from the trawl fishery investigations related to the EXPO trawl gap around 6 m, when fishing at bottom. Pelagic or semi-pelagic life is possible for the small cod within that depth range. Thus, these stages of cod are not as originally expected found in surface or midwater pelagic water layers associated to the pycnocline neither day or night but are rather associated with the bottom environment. This leads us to reject the H0b null hypothesis for the larger stages of pelagic juvenile cod.

Juvenile cod were found at localities with both stratified and well mixed water. Based on the analyses of hydroacoustic data and on assumptions for the TS-value range for these juvenile cod stages, the acoustic data from the present analyses also indicate a depth stratified distribution in the vertical water column of juvenile cod at typical localities with stratified water, where the found juvenile cod seems to be distributed below the pycnocline which typically is placed in the depth around 47-48 m depth m below sea surface. The analyses of the acoustic data from typical localities without stratified water, i.e. at localities with well mixed water, can not distinguish depth stratified distribution of the juvenile cod found here, as the expected TS values for juvenile cod (-47 dB to -59 dB) was measured frequently in all depth layers of the vertical water column, which shall be related to that no sprat and small herring with overlapping TS values were found here. On both prototypes of localities there are found relatively more targets within the TS range from -50 dB to -47 dB than targets in the TS value range from -59 dB to -50 dB in the most bottom near depth layer compared to the TS value distribution observed in the depth layer just above the most bottom near depth layer. This indicates that the smallest stages of the juvenile cod might be more pelagic distributed than the largest size groups of the juvenile cod with a possible more demersal distribution in the bottom layer. This picture is especially clear for the typical deep sea locality with stratified water where the near bottom oxygen concentration is relatively low. These observations follow our expectations for the juvenile cod vertical distribution pattern.

Juvenile cod occurrence was tested based on the H0c null hypothesis that they are in all life stages distributed in well aerated waters with high oxygen concentrations. Juvenile cod were found at some deep localities with bottom oxygen concentrations down to 0.5 ml O2/l. When testing for density dependence of juvenile cod related to oxygen concentrations near sea bottom it was based on the expectation that both pelagic and demersal stages of the juvenile cod in the CBS would be less abundant at localities with low near bottom oxygen concentrations than at localities with well aerated bottom waters. The MANOVA shows that juvenile cod densities are generally higher at localities with near bottom oxygen concentrations over 3 ml/l than at localities with concentrations below 3 ml/l which leads us to accept the H0c null hypothesis. It is expected that when cod are found near bottom at localities with that low oxygen concentrations down under 3 ml O2/l in the lowest few meters over the bottom then the cod stay most of the time in waters just above this water layer and then make short trips down to the bottom for eating.

The found statistical significant difference in catch rate and density of juvenile cod between night and day, i.e. related to light conditions, indicate some diurnal migration of juvenile cod in the found size groups between 3-11 cm. It was expected that the pelagic stages of juvenile cod would show patchiness in their distribution during daytime (H0d) and during dusk disperse into a more scattered distribution through the night time concurrent with sprat and herring schools disperse and the mysids seek up in the pelagic layer during night. As nearly no juvenile cod has been caught during daytime this null hypothesis can not be thoroughly tested based on the present combined trawl sampling and hydroacoustic data.

The present feeding analyses indicate that the caught cod in the size groups 3-11 cm comprise pelagic life stages which comprise the juvenile cod from 3 cm up to the size around 4-5 cm (TTL), as these juvenile cod has been found to exclusively feed on pelagic copepods. Also there seems to be a tendency towards a shift from copepods to mysids as the predominant diet for the cod size groups from 55-60 mm, i.e. the juvenile cod seem gradually to shift to intermediary and benthic food items from exclusively pelagic food in the size group around 5-6 cm (and larger individuals). However, it seems that juvenile cod smaller than 10 cm (and 15 cm), in general, do not 100 % adapt to a diet of benthic food items, i.e. on basis of these analyses no clear size specific shift to full benthic diet which can be related to settling of the pelagic cod stages, could be distinguished. A fact that may lead to the question whether permanent settling has taken place within these stages. Thus, it follows that a total and distinctive shift in diet has not occurred within all of the juvenile cod size groups from pelagic food items (copepods) and intermediary food items (mysids) to diverse benthic food organisms within the cod size group 3-10 cm (TTL). This result should be related to the above discussion of the near bottom distribution of juvenile cod, from which it appears that the results of the different types of investigations are in good agreement with each other.

Density-dependent habitat selection related to other physical parameters such as near bottom current conditions and bottom sediment type has not been revealed from the present investigations. The current conditions at all examined localities showed relatively low speed (less than 30 cm/s), and the juvenile cod, which was always found within these general low speed current conditions, did not show any correlation in their density with the current speed within the relatively small current speed range found near bottom in the Central Baltic Sea in December-January. However, this result should be seen in light of the methodological difficulties with getting good quality near bottom current estimates at some localities where the pycnocline was located deeper than the average depth of the current measurement (Tabs. 3&4). Even though cod was found most often at localities with the gIII bottom type (glacigenous deposits consisting of rubbly loam and sandy loam) no obvious correlation between cod occurrence, cod density, and bottom sediment type could be found based on the present tabulation (Tab. 5). Conclusively, the only physical factors the juvenile cod has been found to correlate to in their occurrence and density-dependent habitat selection have been the oxygen concentrations near bottom and the localization of the pycnocline when present in stratified waters.

Of biological factors examined which might influence density-dependent habitat selection for juvenile cod only the species diversity seems to have some effect on the occurrence of juvenile cod based on the present investigations. Even though there is found no obvious relationship between juvenile cod density and species diversity, the results indicate that the highest densities of juvenile cod are found at localities where the species diversities have been measured highest. The juvenile cod were most often caught together with larger cod (mostly between 25-80 cm), herring, sprat, flounder, plaice, turbot and jellyfish. Density of larger co-existing cod and overall species density of all species caught together with juvenile cod show no obvious correlation with juvenile cod density. Juvenile cod was nearly always found together with larger cod both years. Examination of the stomach content of larger cod caught together with juvenile cod indicate very low predation (cannibalism) and predation preference on juvenile cod by larger co-existing cod. The possible lack of intraspecific density dependence, even though always found co-existing, and the low level of cannibalism indicate a low suitability of small cod as diet for larger cod when juvenile cod and larger cod are co-existing, and it also indicate independent habitat selection of juvenile cod related to occurrence of larger cod. These results indicate, thus, that the H0e null hypothesis, which says that the distribution pattern of juvenile cod are not correlated with intraspecific densities of co-existing larger cod, should be rejected.

CONCLUSION

The results from the present investigations contribute with knowledge about juvenile cod spatial distribution and their density dependent habitat selection related to some physical and biological factors and related to time of day.

The present investigations gives some information about the nursery areas and the recruitment biology of pelagic and demersal stages of juvenile cod found. Nursery areas have been located for juvenile cod in the size group 3-11 cm in the Central Baltic in the present investigations. However, information about delimitation of the nursery areas can not be revealed from the present analyses.

It can be concluded that the GLM model of the catch rates of cod in the trawl surveys in the Central Baltic Sea give knowledge about the spatial distribution of juvenile cod, and the model can not be rejected due to known gaps or bias in the basic data. Furthermore, the model appears sensible as regards the parameters considered in the GLM model and the variance structure in the data.

The results should be used in the planning process of cod recruitment (e.g. BYFS) surveys in the Baltic Sea as these stages of juvenile cod now have been located. It has been shown that the catchability of the juvenile cod is highest during night time compared to night time. The present results can, thus, help us in the attempt to obtain better recruitment estimates of 0-group and 1-group cod in the Baltic Sea to supplement the existing recruitment estimates which only covers the 2+ age groups.

The results will contribute to the establishment of an acoustic target identification catalogue with acoustic split beam measurements of single fish echo reflections (target strength (TS)) patterns of pelagic and demersal stages of juvenile cod in relation to larger cod and other co-existing (important) fish species frequently found in the Central Baltic Sea. In the present analyses acoustic signal patterns indicative for the presence of juvenile cod has been identified. This is also to be seen in the light of the results obtained from the *ex situ* TS measurement experiments with free swimming juvenile cod performed by Nielsen, Lundgren and Stokholm (1997). However, because of the scattered and bottom near distribution of the juvenile cod within the size group 3-11 cm and because of the overlapping occurrence of sprat and small herring, that probably have overlapping TS-values with juvenile cod, it is more complicated to use hydroacoustic methods to make abundance estimates of juvenile cod in the Central Baltic sea than if the juvenile cod had been distributed in isolated patches in the pelagic water layers above the pycnocline in the Central Baltic Sea as originally expected.

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Table 1. Locations, pelagic coverage, and time for trawling activities directed towards juvenile cod, and light conditions during trawling, related to juvenile cod density (CPUE = number caught per trawl hour). December 1995.

Activity number	Activity Type	Start Latitude	Start Longitude	End Latitude	End Longitude	Geograph. Area	Pelagic Coverage	UTC Time	Light	CPUE of 0-Group Cod
73	EXPO-trawl	54.35.70N	14.20.53E	54.38.19N	14.21.71E	38G4 (1)	V-haul	set 04.28	N	2
76	EXPO-trawl	54.37.78N	14.13.81E	54.40.33N	14.12.73E	38G4 (1)	V-haul	set 06.27	N/D	0
77	IYGPT-trawl	54.35.35N	14.20.09E	54.37.84N	14.21.34E	38G4 (1)	V-haul	set 09.13	D	0
79	EXPO-trawl	54.48.21N	14.31.92E	54.48.48N	14.35.88E	38G4 (1)	V-haul	set 11.39	D	0
81	EXPO-trawl	54.41.95N	14.30.77E	54.44.13N	14.32.82E	38G4 (1)	V-haul	set 13.48	D	0
82	EXPO-trawl	54.55.92N	14.53.71E	54.54.57N	14.49.37E	38G4 (1)	V-haul	set 04.14	N	7
85	EXPO-trawl	54.53.49N	14.46.23E	54.52.44N	14.43.70E	38G4 (1)	V-haul	set 05.57	N	2
86	IYGPT-trawl	54.56.08N	14.55.38E	54.55.14N	14.51.54E	38G4 (1)	V-haul	set 07.44	D	0
87	IYGPT-trawl	54.54.88N	14.47.99E	54.53.04N	14.45.22E	38G4 (1)	V-haul	set 09.02	D	0
88	EXPO-trawl	54.56.05N	14.54.32E	54.54.82N	14.50.33E	38G4 (1)	V-haul	set 10.42	D	0
90	EXPO-trawl	54.46.83N	14.41.00E	54.44.54N	14.39.65E	38G4 (1)	V-haul	set 12.50	D	0
91	EXPO-trawl	54.31.57N	15.21.25E	54.34.38N	15.20.00E	38G5 (2)	V-haul	set 02.18	N	19
93	EXPO-trawl	54.32.96N	15.21.10E	54.35.96N	15.18.67E	38G5 (2)	V-haul	set 04.07	N	16
95	EXPO-trawl	54.32.66N	15.26.59E	54.35.01N	15.25.35E	38G5 (2)	V-haul	set 06.31	N/D	0
97	EXPO-trawl	54.32.83N	15.20.98E	54.34.93N	15.19.42E	38G5 (2)	V-haul	set 08.16	D	0
99	EXPO-trawl	54.45.83N	15.53.11E	54.43.56N	15.50.94E	38G5 (2)	V-haul	set 12.08	D	0
100	EXPO-trawl	55.01.90N	16.20.01E	54.59.83N	16.14.41E	39G6 (2)	V-haul	set 23.31	N	0
102	EXPO-trawl	55.04.31N	16.22.50E	55.08.02N	16.23.32E	39G6 (2)	V-haul	set 01.47	N	2
103	EXPO-trawl	55.10.80N	16.28.30E	55.08.91N	16.25.08E	39G6 (2)	V-haul	set 04.01	N	7
105	EXPO-trawl	54.32.55N	15.21.09E	54.35.09N	15.19.44E	38G5 (2)	V-haul	set 17.19	N	59
107	EXPO-trawl	54.31.35N	15.21.59E	54.33.60N	15.20.71E	38G5 (2)	Bottom layer	set 19.26	N	78
109	EXPO-trawl	54.32.00N	15.21.56E	54.34.30N	15.20.21E	38G5 (2)	Midwater layer	set 21.23	N	3
110	EXPO-trawl	54.31.59N	15.21.61E	54.34.30N	15.19.50E	38G5 (2)	Surface layer	set 22.54	N	2
111	EXPO-trawl	54.31.57N	15.21.59E	54.33.80N	15.20.20E	38G5 (2)	Bottom layer	set 00.40	N	90
112	IYGPT-trawl	54.31.96N	15.21.71E	54.34.42N	15.19.61E	38G5 (2)	V-haul	set 02.47	N	9
114	MIK-ringtrawl	54.35.42N	15.17.11E	54.36.06N	15.15.58E	38G5 (2)	V-haul	set 04.16	N	0
115	EXPO-trawl	55.26.58N	18.17.92E	55.28.13N	18.14.74E	39G8 (2)	V-haul	set 18.30	N	3
118	EXPO-trawl	55.30.47N	17.57.47E	55.30.33N	17.53.64E	39G7 (2)	V-haul	set 21.11	N	11
119	EXPO-trawl	55.22.28N	17.38.08E	55.22.18N	17.34.09E	39G7 (2)	V-haul	set 23.30	N	0
121	EXPO-trawl	55.30.03N	17.28.63E	55.29.35N	17.25.28E	39G7 (2)	V-haul	set 01.49	N	26
123	EXPO-trawl	55.30.10N	17.29.17E	55.29.29N	17.25.60E	39G7 (2)	V-haul	set 03.39	N	48
124	EXPO-trawl	56.28.36N	18.36.88E	56.30.27N	18.39.17E	41G8 (3)	V-haul	set 17.23	N	59
126	EXPO-trawl	56.27.08N	18.37.24E	56.28.91N	18.39.47E	41G8 (3)	V-haul	set 19.22	N	6
128	EXPO-trawl	56.23.33N	18.30.66E	56.25.23N	18.32.89E	41G8 (3)	V-haul	set 21.42	N	17
130	EXPO-trawl	56.14.42N	17.51.53E	56.16.30N	17.54.20E	41G7 (3)	V-haul	set 01.15	N	0
132	EXPO-trawl	56.06.82N	17.38.57E	56.04.94N	17.36.80E	41G7 (3)	V-haul	set 03.39	N	3
134	EXPO-trawl	55.57.13N	17.13.76E	55.57.34N	17.09.98E	40G7 (3)	V-haul	set 17.17	N	0
136	EXPO-trawl	55.53.40N	17.09.27E	55.53.60N	17.05.12E	40G7 (3)	V-haul	set 19.07	N	0
138	EXPO-trawl	55.51.74N	16.39.68E	55.49.62N	16.40.06E	40G6 (3)	V-haul	set 21.45	N	11
140	EXPO-trawl	55.48.92N	16.20.91E	55.46.70N	16.20.61E	40G6 (3)	V-haul	set 03.02	N	6
142	EXPO-trawl	55.52.76N	16.00.11E	55.53.39N	16.04.32E	40G6 (3)	V-haul	set 19.28	N	0
144	EXPO-trawl	55.47.62N	15.44.30E	55.46.05N	15.47.20E	40G5 (3)	V-haul	set 22.13	N	21
146	EXPO-trawl	55.47.60N	15.14.65E	55.48.78N	15.17.75E	40G5 (3)	V-haul	set 01.15	N	14

Table 2. Locations, pelagic coverage, and time for trawling activities directed towards juvenile cod, and light conditions during trawling, related to juvenile cod density (CPUE = number caught per trawl hour). January 1997.

Activity Number	Activity Type	Start Latitude	Start Longitude	End Latitude	End Longitude	Geograph. Area	Pelagic Act. Coverage	UTC Time	Light	CPUE of 1-Group Cod
2	EXPO-trawl	54.38.31N	14.13.47E	54.36.04N	14.15.71E	1 (38G4)	V-haul	set 20.24	N	60
5	EXPO-trawl	54.38.77N	14.22.88E	54.36.56N	14.20.80E	1 (38G4)	V-haul	set 22.38	N	227
7	EXPO-trawl	54.43.71N	14.31.98E	54.41.19N	14.30.08E	1 (38G4)	V-haul	set 01.08	N	195
9	EXPO-trawl	54.48.28N	14.35.20E	54.48.22N	14.30.66E	1 (38G4)	V-haul	set 03.24	N	23
11	EXPO-trawl	54.35.22N	15.22.17E	54.32.82N	15.23.55E	2 (38G5)	V-haul	set 17.43	N	983
13	EXPO-trawl	54.35.24N	15.22.14E	54.33.98N	15.22.86E	2 (38G5)	V-haul	set 20.49	N	914
17	EXPO-trawl	55.02.28N	16.20.75E	55.00.70N	16.17.04E	2 (39G6)	V-haul	set 17.40	N	500
21	EXPO-trawl	55.09.79N	16.27.06E	55.11.68N	16.29.20E	2 (39G6)	V-haul	set 23.29	N	12
22	EXPO-trawl	55.01.07N	16.17.67E	55.02.44N	16.20.98E	2 (39G6)	V-haul	set 02.07	N	86
24	EXPO-trawl	55.05.18N	16.22.64E	55.07.31N	16.23.26E	2 (39G6)	V-haul	set 03.47	N	13
26	EXPO-trawl	55.29.46N	17.25.31E	55.29.58N	17.28.40E	2 (39G7)	V-haul	set 17.46	N	9
28	EXPO-trawl	55.22.18N	17.32.24E	55.22.21N	17.36.82E	2 (39G7)	V-haul	set 20.10	N	20
30	EXPO-trawl	55.30.15N	17.51.80E	55.32.24N	17.54.36E	3 (40G7)	V-haul	set 22.40	N	0
32	EXPO-trawl	55.21.04N	18.03.64E	55.22.88N	18.07.00E	2 (39G8)	V-haul	set 02.15	N	13
34	EXPO-trawl	56.27.66N	18.36.36E	56.29.84N	18.38.81E	3 (41G8)	V-haul	set 17.34	N	12
36	EXPO-trawl	56.27.55N	18.38.06E	56.29.82N	18.40.81E	3 (41G8)	V-haul	set 19.51	N	0
38	EXPO-trawl	56.24.40N	18.37.15E	56.26.69N	18.39.47E	3 (41G8)	V-haul	set 23.19	N	0
40	EXPO-trawl	56.24.59N	18.38.82E	56.26.87N	18.41.08E	3 (41G8)	V-haul	set 02.13	N	1
42	EXPO-trawl	55.53.68N	17.04.98E	55.53.35N	17.09.52E	3 (40G7)	V-haul	set 17.18	N	6
44	EXPO-trawl	55.57.63N	17.07.14E	55.57.14N	17.11.63E	3 (40G7)	V-haul	set 19.15	N	61
46	EXPO-trawl	56.03.02N	17.35.55E	56.05.42N	17.37.22E	3 (41G7)	V-haul	set 21.53	N	23
48	EXPO-trawl	55.54.45N	17.44.40E	55.56.79N	17.45.70E	3 (40G7)	V-haul	set 00.44	N	15
50	EXPO-trawl	56.14.32N	17.51.52E	56.16.29N	17.54.40E	3 (41G7)	V-haul	set 03.32	N	25
52	EXPO-trawl	55.47.93N	15.15.60E	55.49.28N	15.19.23E	3 (40G5)	V-haul	set 17.33	N	0
54	EXPO-trawl	55.47.11N	15.45.82E	55.45.12N	15.47.95E	3 (40G5)	V-haul	set 20.26	N	0
56	EXPO-trawl	55.53.05N	16.02.44E	55.53.04N	16.06.72E	3 (40G6)	V-haul	set 23.28	N	4
58	EXPO-trawl	55.46.45N	16.40.97E	55.44.09N	16.41.26E	3 (40G6)	V-haul	set 02.29	N	6
74	EXPO-trawl	55.05.61N	16.05.60E	55.07.86N	16.04.00E	2 (39G6)	V-haul	set 17.30	N	6
76	EXPO-trawl	55.04.29N	16.06.21E	55.02.10N	16.08.70E	2 (39G6)	V-haul	set 21.24	N	16
78	EXPO-trawl	54.34.68N	15.22.70E	54.33.31N	15.25.01E	2 (38G5)	V-haul	set 07.38	D	0
80	EXPO-trawl	54.33.29N	15.23.19E	54.35.62N	15.21.94E	2 (38G5)	V-haul	set 09.14	D	3
81	EXPO-trawl	54.34.86N	15.22.45E	54.32.58N	15.23.66E	2 (38G5)	V-haul	set 10.32	D	12
82	EXPO-trawl	54.33.45N	15.23.19E	54.35.62N	15.21.98E	2 (38G5)	V-haul	set 11.54	D	9
84	EXPO-trawl	54.33.71N	15.23.00E	54.36.10N	15.21.66E	2 (38G5)	V-haul	set 17.20	N	145
86	EXPO-trawl	54.56.07N	15.24.48E	54.57.10N	15.28.88E	2 (38G5)	V-haul	set 21.35	N	0

Table 3. Juvenile cod density (CPUE = number caught per trawl hour) related to average bottom depth and physical environmental factors (hydrographical clines, bottom oxygen conc., and water current near bottom). December 1995.

Activity number	Area	Aver. Bottom Depth	Halocline Depth (m)	Thermocline Depth (m)	Oxycline Depth (m)	Oxy. Conc., Near Bottom (ml/l)	Aver. Depth, Current Meas. (m)	Ave. Bott. Dist., Current Meas. (m)	Current Speed (cm/s)	Current Direction (Deg. from North)	CPUE of 0-Group Cod
73	1	28.7 m	(19)	(19)	(19)	7.3	20.2	8.2	17.09	173	2
76	1	30.3 m	(19)	(19)	(19)	7.3	21.0	9.3	13.93	173.68	0
77	1	27.6 m	(19)	(19)	(19)	7.3	19.4	8.1	14.07	174.52	0
79	1	16.5 m	None	None	None	7.6	11.2	5.0	4.9	242.1	0
81	1	37.3 m	None	None	None	7.6	28.1	9.4	4.7	246.75	0
82	1	36.1 m	None	None	None	7.7	26.0	10.5	16.19	197.96	7
85	1	16.6 m	None	None	None	7.6	11.0	5.7	9.87	160.78	2
86	1	37.1 m	None	None	None	7.6	25.4	9.6	13.58	192.2	0
87	1	13.2 m	None	None	None	7.6	10.4	2.8	12.92	187.24	0
88	1	36.8 m	None	None	None	7.6	27.0	10.1	13.49	197.1	0
90	1	46.1 m	None	None	None	7.3	34.0	12.3	3.48	39.65	0
91	2	51.2 m	47	47	44	6.5	38.2	13.3	9.3	66.36	19
93	2	54.3 m	47	47	50	4.2	41.0	13.5	9.48	40.04	16
95	2	58.9 m	51	51	53	3.3	43.5	15.3	6.15	337.4	0
97	2	53.5 m	51	51	53	3.3	40.8	13.1	12.27	37.42	0
99	2	56.9 m	47	47	47	1.0	42.3	14.8	14.73	262.98	0
100	2	59.9 m	47	47	47	1.0	44.2	15.8	11.88	197.35	0
102	2	61.9 m	48	48	48	2.1	47.0	15.6	4.64	241.72	2
103	2	59.2 m	48	48	48	2.1	42.1	13.9	14.9	298.74	7
105	2	53.4 m	50	50	51	6.4	40.8	13.1	12.36	343.77	59
107	2	51.1 m	51	51	51	6.9	37.8	13.5	6.41	0.59	78
109	2	52.9 m	51	51	51	6.9	40.1	12.9	9.85	348.97	3
110	2	50.8 m	51	51	51	6.9	40.0	13.0	9.45	346.91	2
111	2	50.5 m	51	51	51	6.9	39.5	12.6	8.81	348.41	90
112	2	53.0 m	51	51	51	6.9	40.3	13.1	9.23	336.26	9
114	2	54.6 m	51	51	51	6.9	41.0	13.8	11.38	334.29	0
115	2	86.0 m	50	50	50	3.0	65.9	20.3	6.69	230.44	3
118	2	68.7 m	50	50	50	5.2	51.4	17.0	1.73	277.47	11
119	2	77.8 m	60 (- 66)	54 (- 66)	60	1.0	59.0	17.3	5.94	191.81	0
121	2	34.8 m	None	None	None	7.9	24.5	11.0	11.83	75.28	26
123	2	34.4 m	None	None	None	7.9	24.5	10.4	10.19	69.2	48
124	3	51.0 m	48	48	48	6.9	39.0	12.1	6.53	44.71	59
126	3	64.7 m	53	53	53	6.1	50.6	14.3	1.6	306.12	6
128	3	41.1 m	None	None	None	7.8	30.8	10.6	1.6	170.88	17
130	3	44.4 m	None	None	None	7.7	33.0	11.4	2.04	110.6	0
132	3	50.9 m	None	None	None	7.8	39.6	11.7	3.11	44.91	3
134	3	46.0 m	44	44	44	7.2	34.1	12.1	10.02	5.2	0
136	3	47.9 m	44	44	44	3.1	36.3	11.9	3.67	70.53	0
138	3	45.3 m	None	None	None	7.9	34.0	11.5	2.58	93.96	11
140	3	59.7 m	55	55	55	2.2	45.3	14.2	5.85	353.09	6
142	3	51.9 m	None	None	None	7.7	39.3	12.6	24.25	61.97	0
144	3	53.1 m	(30-40)	(30-40)	(30-40)	7.7	40.8	12.6	9.35	351.41	21
146	3	55.1 m	50	50	52	2.5	42.7	12.2	13.84	353.3	14

Table 4. Juvenile cod density (CPUE = number caught per trawl hour) related to average bottom depth and physical environmental factors (hydrographical clines, bottom oxygen conc., and near bottom water current). January 1997.

Activity Number	Area	Aver. Bottom Depth (m)	Halocline Depth (m)	Thermocline Depth (m)	Oxycline Depth (m)	Oxy. Conc., Near Bottom (ml/l)	Aver. Depth, Current Meas. (m)	Aver. Bott. Dist., Current Meas. (m)	Current Speed, (cm/s)	Current Direction (Deg. from North)	CPUE 1-group cod
2	1	26	None	None	None	8.7	19.0	7.9	3.98	284.28	60
5	1	30.5	None	None	None	8.6	22.1	9.1	12.42	332.44	227
7	1	36.9	None	None	None	8.8	27.5	9.8	11.13	260	195
9	1	16.9	None	None	None	8.8	11.1	5.3	16.08	210.91	23
11	2	56.9	48	47	49	3.3	43.5	13.8	3.74	187.2	983
13	2	57.1	48	47	49	3.3	43.5	13.9	3.19	195.08	914
17	2	60.5	48	45	48	3.8	44.8	13.6	8.56	211.73	500
21	2	54.7	52	52	52	4.6	43.0	11.9	29.39	269.2	12
22	2	57.9	52	52	52	4.6	44.6	13.7	8.82	219.39	86
24	2	63.3	49	49	50	4.2	49.4	14.0	11.82	236.47	13
26	2	35.9	None	None	None	8.0	25.6	10.3	3.55	223.33	9
28	2	78.9	59	59	59	2.9	53.4	25.8	18.19	161.39	20
30	3	77.4	68	68	68	3.1	41.4	35.7	3.42	193.01	0
32	2	81.9	65	65	65	3.5	63.0	18.8	15.36	101.76	13
34	3	53.7	None	None	None	9.0	39.0	13.6	5.36	10.42	12
36	3	66.4	53	53	53	3.5	50.6	16.2	14.48	37.33	0
38	3	78.4	47	47	47	2.6	60.3	18.0	9	114.99	0
40	3	85.1	50	50	50	2.3	63.9	19.8	6.27	66.22	1
42	3	48.5	None	None	None	8.9	37.0	11.9	3.85	188.17	6
44	3	45.6	None	None	None	9.0	34.4	11.5	4.13	171.83	61
46	3	46.8	None	None	None	8.7	35.2	11.8	3.48	233.76	23
48	3	62.8	50	50	50	6.1	46.8	16.2	4.1	90.97	15
50	3	43.6 (slope)	51	51	51	8.4	33.2	11.6	5.65	276.12	25
52	3	55.2	47	47	47	4.2	42.6	12.6	4.28	128.14	0
54	3	54.5	50	50	50	3.9	41.0	13.4	17.4	107.02	0
56	3	51.9	49	49	49	5.4	39.6	12.8	2.34	147.19	4
58	3	53.5	48	48	48	8.0	41.2	12.7	2.63	228.35	6
74	3	86.8	52	52	52	0.5	56.8	28.7	6.97	258.34	6
76	3	76.3	52	52	52	1.1	54.8	21.5	7.87	292.18	16
78	3	57.8	49	49	49	2.2	44.6	13.4	7.92	234.44	0
80	3	57.4	48	48	48	4.0	44.0	13.4	8.6	227.15	3
81	3	56.9	48	48	48	4.0	43.4	13.8	5.05	210.15	12
82	3	57.2	48	48	48	4.0	43.7	13.8	5.75	215.4	9
84	3	57.7	48	48	48	1.9	43.9	13.9	1.23	341.69	145
86	3	79.4	48	48	48	1.2	55.3	23.8	9.05	38.49	0

Table 5. Bottom sediment type and code related to juvenile cod density. December 1995 and Januarry 1997.

Activity No	Juvenile cod CPUE	Sediment Code	Sediment type
1995			
73	2	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
76	0	(yellow/orange)	Sand, locally gravel and coarser materials / Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
77	0	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
79	0	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
81	0	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
82	7	(yellow)	Sand, locally gravel and coarser materials
85	2	(yellow)	Sand, locally gravel and coarser materials
86	0	(yellow)	Sand, locally gravel and coarser materials
87	0	(yellow)	Sand, locally gravel and coarser materials
88	0	(yellow)	Sand, locally gravel and coarser materials
90	0	(yellow)	Sand, locally gravel and coarser materials
91	19	gIII	Glacigenous deposits. Rubbly loam and sandy loam
93	16	gIII and L,mIV	Glacigenous deposits. Rubbly loam and sandy loam and Lacustrine and marine deposits undifferented. Sand, aleurite
95	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
97	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
99	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
100	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
102	2	gIII	Glacigenous deposits. Rubbly loam and sandy loam
103	7	gIII	Glacigenous deposits. Rubbly loam and sandy loam
105	59	gIII	Glacigenous deposits. Rubbly loam and sandy loam
107	78	gIII	Glacigenous deposits. Rubbly loam and sandy loam
109	3	gIII	Glacigenous deposits. Rubbly loam and sandy loam
110	2	gIII	Glacigenous deposits. Rubbly loam and sandy loam
111	90	gIII	Glacigenous deposits. Rubbly loam and sandy loam
112	9	gIII	Glacigenous deposits. Rubbly loam and sandy loam
114	0	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
115	3	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
118	11	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
119	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
121	26	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
123	48	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
124	59	gIII	Glacigenous deposits. Rubbly loam and sandy loam
126	6	gIII and lgIIIb	Glacigenous deposits. Rubbly loam and sandy loam. - and - Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
128	17	gIII	Glacigenous deposits. Rubbly loam and sandy loam
130	0	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
132	3	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
134	0	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
136	0	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
138	11	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
140	6	gIII	Glacigenous deposits. Rubbly loam and sandy loam
142	0	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
144	21	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
146	14	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
1997			
2	60	(yellow/orange)	Sand, locally gravel and coarser materials / Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
5	227	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
7	195	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
9	23	(orange)	Lag Deposits/ Till, locally with a thin cover of sand, gravel or stones< 1m.
11	983	gIII	Glacigenous deposits. Rubbly loam and sandy loam
13	914	gIII	Glacigenous deposits. Rubbly loam and sandy loam
17	500	gIII	Glacigenous deposits. Rubbly loam and sandy loam
21	12	gIII	Glacigenous deposits. Rubbly loam and sandy loam
22	86	gIII	Glacigenous deposits. Rubbly loam and sandy loam
24	13	gIII	Glacigenous deposits. Rubbly loam and sandy loam
26	9	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
28	20	gIII	Glacigenous deposits. Rubbly loam and sandy loam
30	0	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
32	13	gIII	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
34	12	gIII	Glacigenous deposits. Rubbly loam and sandy loam
36	0	gIII and lgIIIb	Glacigenous deposits. Rubbly loam and sandy loam - and - Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
38	0	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
40	1	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
42	6	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
44	61	L,mIV	Lacustrine and marine deposits undifferented. Sand, aleurite
46	23	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
48	15	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
50	25	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
52	0	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
54	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
56	4	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
58	6	lgIIIb	Limnoglacial deposits of the Baltic Ice Lake. Clay, aleurite, sand
74	6	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
76	16	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
78	0	gIII	Glacigenous deposits. Rubbly loam and sandy loam
80	3	gIII	Glacigenous deposits. Rubbly loam and sandy loam
81	12	gIII	Glacigenous deposits. Rubbly loam and sandy loam
82	9	gIII	Glacigenous deposits. Rubbly loam and sandy loam
84	145	gIII and mIIVlt+lm	Glacigenous deposits. Rubbly loam and sandy loam - and - Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite
86	0	mIVlt+lm	Marine deposits. Limnea and Litorinabeds. Mud, aleurite, sand, sapropelite

Table 6. **Mean density of juvenile (=< 11 cm) cod (MCPUE) in December 1995 and January 1997 divided by area and depth strata.**

Area	Depth Strata	MCPUE 1995	MCPUE 1997	N 1995	N 1997
Average All Ar.	All Depths	17	109	30	31
Average Area 1	All Depths	3	126	4	4
Average Area 2	All Depths	23	209	14	13
Average Area 3	All Depths	11	11	12	14
Average Area 1	< 30 m depth	2	42	2	2
	30-40 m	3	211	2	2
Average Area 2	30-40 m	37	9	2	1
	50-60 m	34	428	8	5
	60-70 m	6	257	2	2
	> 70 m	2	11	2	5
Average Area 3	40-50 m	5	29	5	4
	50-60 m	17	4	6	5
	60-70 m	6	7	1	2
	> 70 m		0		3

Table 7. **Community description of small cod in the Central Baltic Sea. List of species caught together with small cod divided by year.**

Species name	Dec. 1995	Jan. 1997	Species name	Dec. 1995	Jan. 1997
Atl. Cod	X	X	Horse mackerel		X
Plaice	X	X	Anchovy	X	X
Flounder	X	X	Cutling	X	X
Turbot	X	X	Stickleback, 3-s.	X	X
Dab	X	X	Whiting	X	X
Herring	X	X	Pollack	X	
Sprat	X	X	Sandeels		X
Salmon		X	Sculpins	X	X
Sea trout	X	X	Lumpsucker	X	X
Smelt	X	X	Eel	X	X
Mackerel		X	Fourbeard rockling	X	X

Table 8 The descriptive statistics of the GLM and estimated parameters from the GLM MANOVA. The sum of squared deviations (s. of sq.) for the various dependent effects are of type III s. of sq. (SAS, 1990), which are independent of the order of the effects in the model. Finally, descriptive statistics of the test of normality.

Descr. statistics:					
Error source	**d.f.**	**s. of sq.**	**F**	**Probability > F**	**r^2**
Model	7	20.77	8.18	0.0001	0.48
Error	63	22.85			
Corrected total	70	43.62			
Error source	**d.f.**	**s. of sq.**	**F**	**Probability > F**	
Year	1	4.06	11.19	0.0014	
Daytime (light)	1	4.98	13.74	0.0004	
Area	2	6.55	9.03	0.0004	
Oxygen	2	4.09	11.29	0.0013	
Year * Area	2	3.13	4.31	0.0176	
Est. Parameters:					
Parameter	**Group**	**Estimate**	**T for H0 Par.=0**	**Pr. > |T|**	**s.e. of estimate**
Intercept		0.772	4.74	0.0001	0.163
Year	1995	0.073	0.31	0.7602	0.237
	1997	0			
	D	-0.873	-3.71	0.0004	0.236
	N	0			
	1	1.182	3.45	0.001	0.342
	2	1.017	4.47	0.0001	0.228
	3	0			
Oxygen	1	-0.606	-3.36	0.0013	0.180
	2	0			
Year*Area	1995 1	-1.262	-2.71	0.0086	0.466
	1995 2	-0.637	-2.02	0.0478	0.316
	1995 3	0			
	1997 1	0			
	1997 2	0			
	1997 3	0			
Test of normality:					
Variable	**N**	**W:Normal**	**Pr < W**		
Residuals	71	0.9594	0.0629		

Table 9. Habitat specific grouping related to food items (pelagic, demersal, intermediary) for juvenile cod in the Central Baltic Sea. Based on stomach content analyses. Explanation of labels to Figure 5 and 6.

Food / Habitat Number	Food / Habitat Type
0	Vomitted fish
1	Pelagic (Copepods)
2	Benthic (Diverse Benthic Food Items)
3	Intermediary between Pelagic and Benthic (Mysids)
4	Empty or not possible to identify
5	1 + 3
6	1 + 2 + 3
7	1 + 2
8	2 + 3

Table 10. Calibration parameters and parameter settings for the SIMRAD EY500 Vers. 5.2 mobile echosounder system in Dec. 1995 and Jan. 1997, and for the SEABIRD SBE 911+ CTD Jan. 1997.

SIMRAD EY500 Vers. 5.2	PARAMETER SETTINGS	SIMRAD EY500 Vers. 5.2	PARAMETER SETTINGS
Ping mode, Operation Menu	Replay	Mode, Log Menu	Ping
Ping Interval, Operation Menu	0.0 sec (I.e. as quickly as possible)	Ping Interval, Log Menu	1500 (= 1/2 nm with speed 3 knots).
Range	100 m	Super Layer	Layer 1
Range Start	0 m	Type, layer 1	Pelagic
Bottom Range	10 m	Range, layer 1	100 m
Bot. Range Start	7 m	Range Start, layer 1	0 m
Bot. Range Pres.	Lower	Margin, layer 1	1.0 m
Sub. Bottom Gain	0.0 dB/m	Sv Threshold, layer 1	-80 dB
Presentation	Normal	Min. Value, TS-detect.	-65 dB
TVG	20 log R	Min. Echo Length	0.8
TS Colour Min.	-65 dB	Max. Echo Length	1.5
Sv Colour Min.	-70 dB	Max. Gain Comp.	4.0 dB
Mode	Active	Max. Phase Dev.	4.0
Transducer Type	ES120-7	Log	On
Transd. Sequence	Off	No. of Main Val.	250
Transducer Depth	0.00	No. of Bot. Val.	75
Absorption Coef.	38 dBkm	Sound Velocity	1500 m/s
Pulse length	Medium		
Bandwidth	Wide		
Max Power	63 W		
2-Way Beam Angle	-20.9 dB	**SEABIRD CTD SBE 911+**	**PARAMETER SETTINGS**
Sv Transd. Gain	26.1 dB	Calibration date	3. January 1997
TS Transd. Gain	26.1 dB	M	1.0043000E-05
Angle Sens. Along	21.0	B	-3.8162000E-08
Angle Sens. Athw.	21.0	Soc	8.2800000E-02
3 dB Beamw. Along	6.9° (at temperature 19°C)	Boc	-2.8100000E-02
3 dB Beamw. Athw.	6.9° (at temperature 19°C)	Tcor	-3.3000000E-02
Alongship Offset	0.00 dg	Pcor	1.5000000E-04
Athw.ship Offset	0.10 dg	Tau	2.0000000E+00
Minimum depth, Bottom	3 m	Wt	8.5000000E-01
Maximum Depth, Bottom	100 m	K	6.5059000E+00
Minimum Level, Bottom	-50 dB	C	-1.8668000E+00

Table 11. Size at age (mean length) for juvenile cod found in different areas (Baltic Sea & adjacent waters) in different months during the period from December 1995 to January 1997.

OBS.	AREA	MONTH	YEAR	AGE	MEAN L	MODAL L	MIN. L	REFERENCE
1	Area 1, W. Balt. Sea	Dec.	1995	0-group	4.9 cm	52 mm	48 mm	Nielsen & Lehmann 1996
2	Area 2, Centr. Balt. Sea	Dec.	1995	0-group	5.0 cm	49 mm	36 mm	Nielsen & Lehmann 1996
3	Area 3, Centr. Balt. Sea	Dec.	1995	0-group	5.2 cm	50 mm	38 mm	Nielsen & Lehmann 1996
4	Area 1, W. Balt. Sea	Jan.	1997	1-group	5.4 cm	5 cm	3 cm	Present results
5	Area 2, Centr. Balt. Sea	Jan.	1997	1-group	6.6 cm	6 cm	3 cm	Present results
6	Area 3, Centr. Balt. Sea	Jan.	1997	1-group	6.2 cm	6 cm	4 cm	Present results
7	W. Balt. Sea, SD 24, E. Rugen, Sassnitz	Aug.	1996	0-group	6.9 cm	X	X	Paulsen (DIFRES)
8	W. Balt. Sea, SD 24, Kieler Bay	Aug.	1996	0-group	7.0 cm	X	X	Paulsen (DIFRES)
9	W. Balt. Sea, SD ?, E. Gedser	Aug.	1996	0-group	7.4 cm	X	X	Paulsen (DIFRES)
10	W. Balt. Sea, SD 22, Langeland Belt	Aug.	1996	0-group	7.5 cm	X	X	Paulsen (DIFRES)
11	W. Balt. Sea, SD 22, N. Bogense	Aug.	1996	0-group	7.0 cm	X	X	Paulsen (DIFRES)
12	Kattegat, SD 21 / SA IIIa S., E. Øster Hurup	Aug.	1996	0-group	7.4 cm	X	X	Paulsen (DIFRES)
13	Kattegat, SD 21 / SA IIIa S., Læsø Rende	Aug.	1996	0-group	7.0 cm	X	X	Paulsen (DIFRES)
14	Kattegat, SD 21 / SA IIIa S., NE Hirsholmene	Aug.	1996	0-group	6.7 cm	X	X	Paulsen (DIFRES)
15	Skagerrak, SD 20 / SA IIIa N., Hirtshals	Jul. / Aug.	1996	0-group	8.3 cm	X	X	Paulsen (DIFRES)

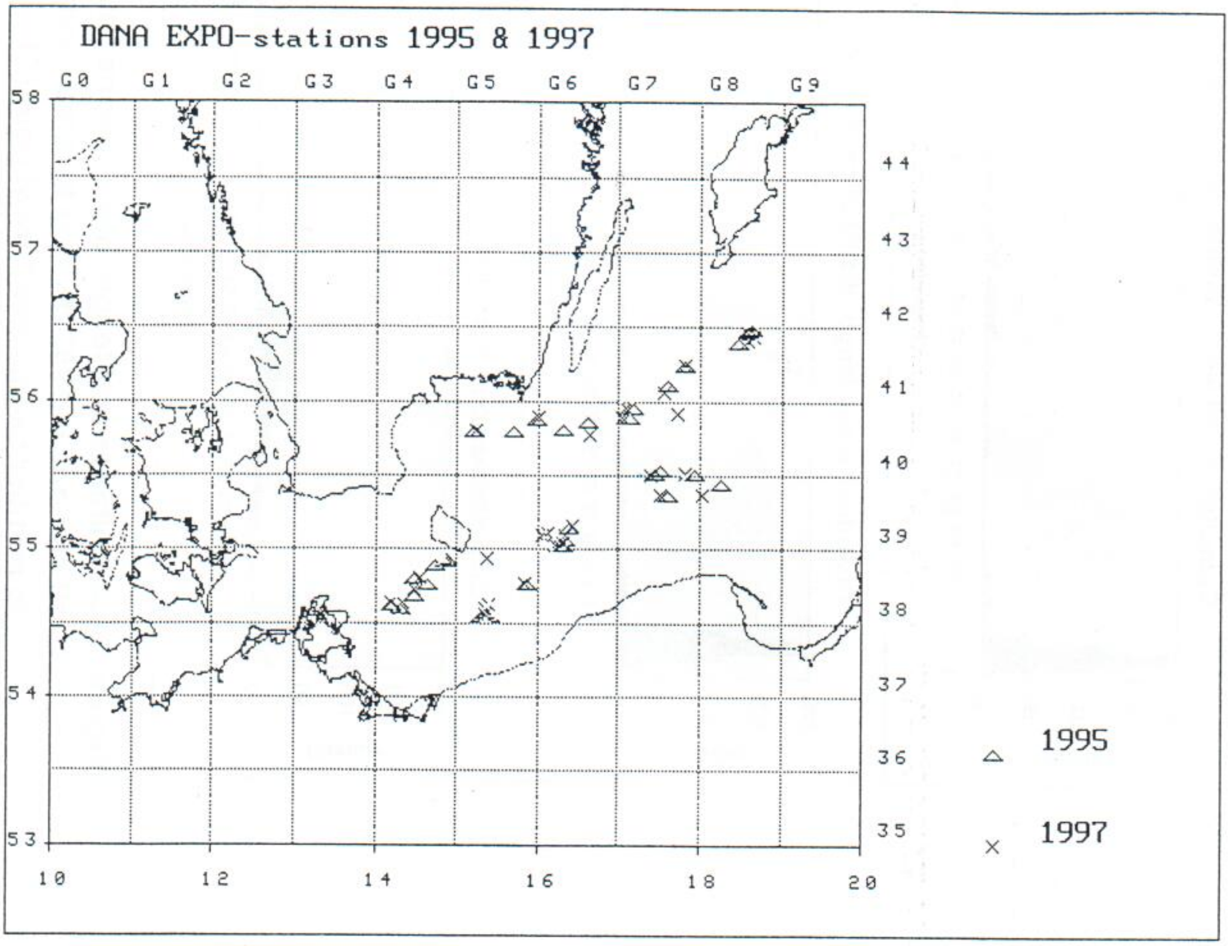

Figure 1. Geographical map over the study area where combined hydroacoustic and trawl survey sampling methods were used to map distribution and density patterns of juvenile cod in the Central Baltic Sea. Location of EXPO-trawl stations in December 1995 and in January 1997, respectively, are plotted on the map.

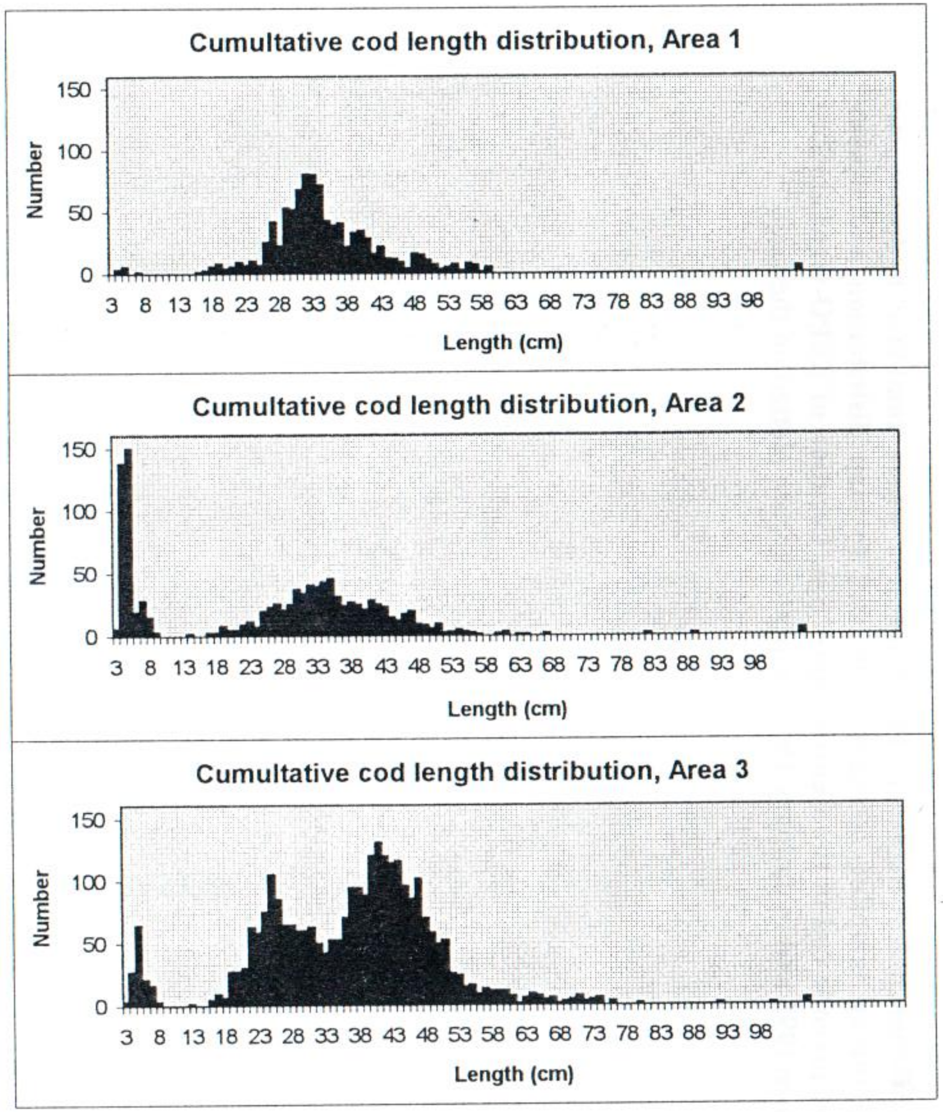

Figure 2. Cumultative cod length distributions caught at all stations in 1995 divided by area. Normalized to number caught per 1 trawl hour (CPUE) for all stations and all length groups.

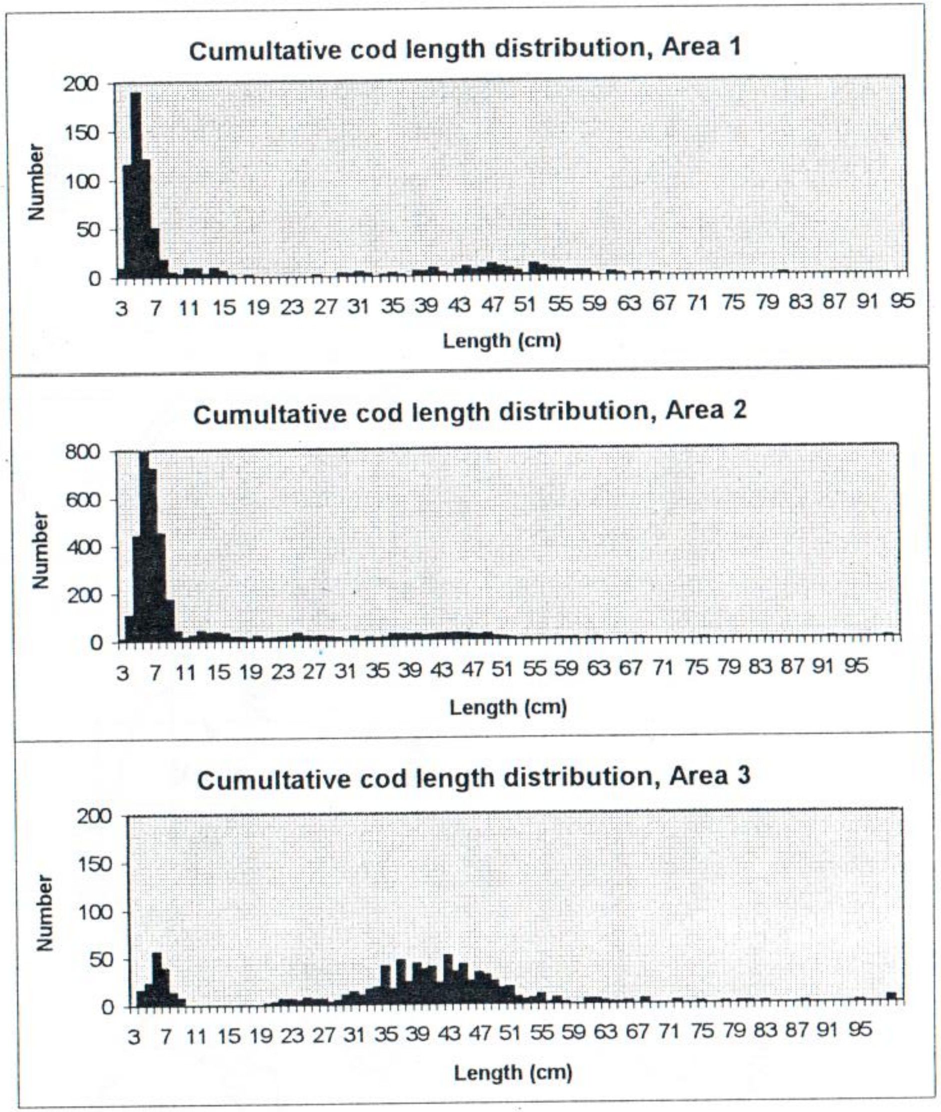

Figure 3. Cumultative cod length distributions caught at all stations in 1997 divided by area. Normalized to number caught per 1 trawl hour (CPUE) for all stations and all length groups.

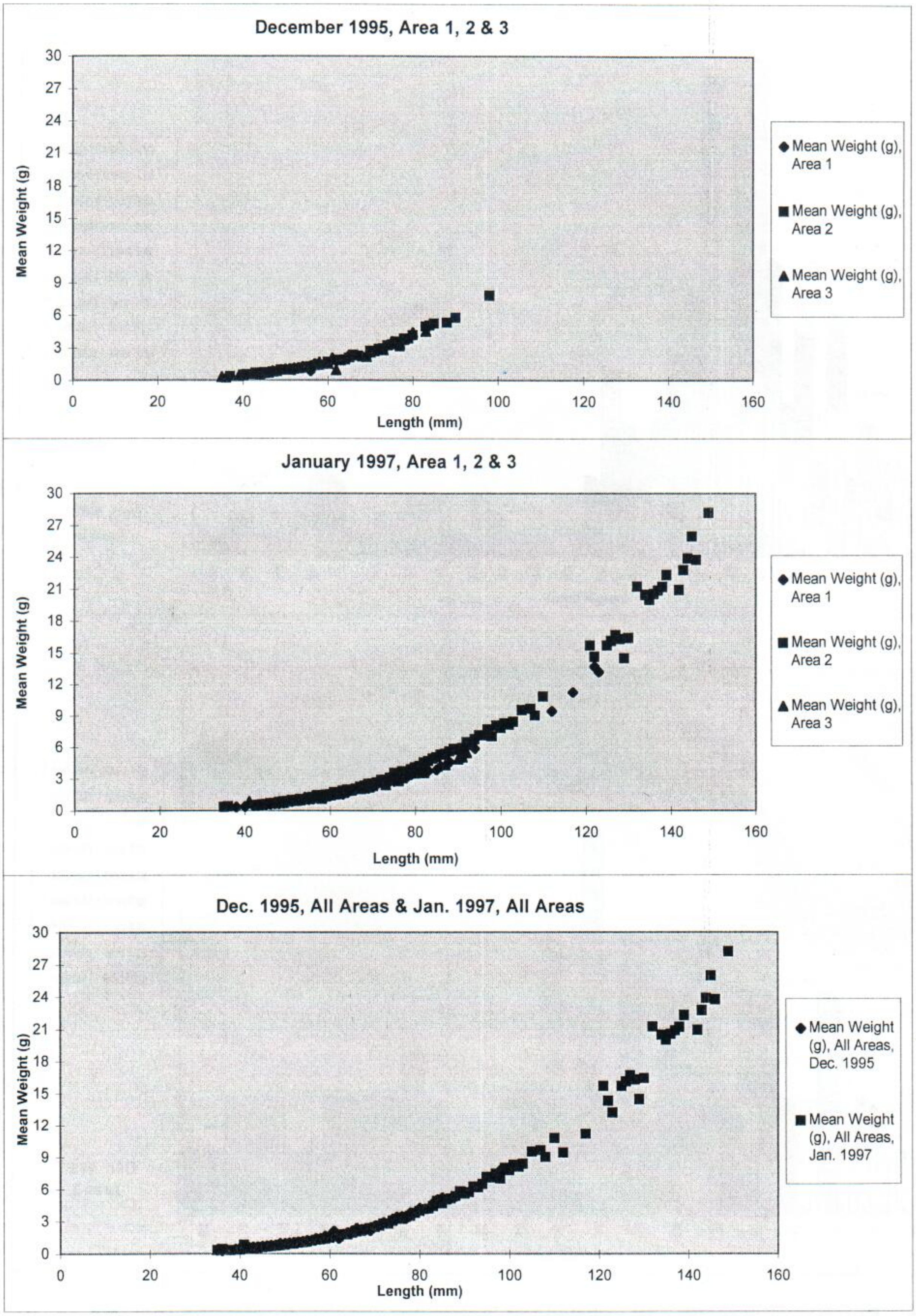

Figure 4. Mean weight in grams per 1 mm length group divided by geographical area of juvenile cod caught in the Central Baltic Sea.

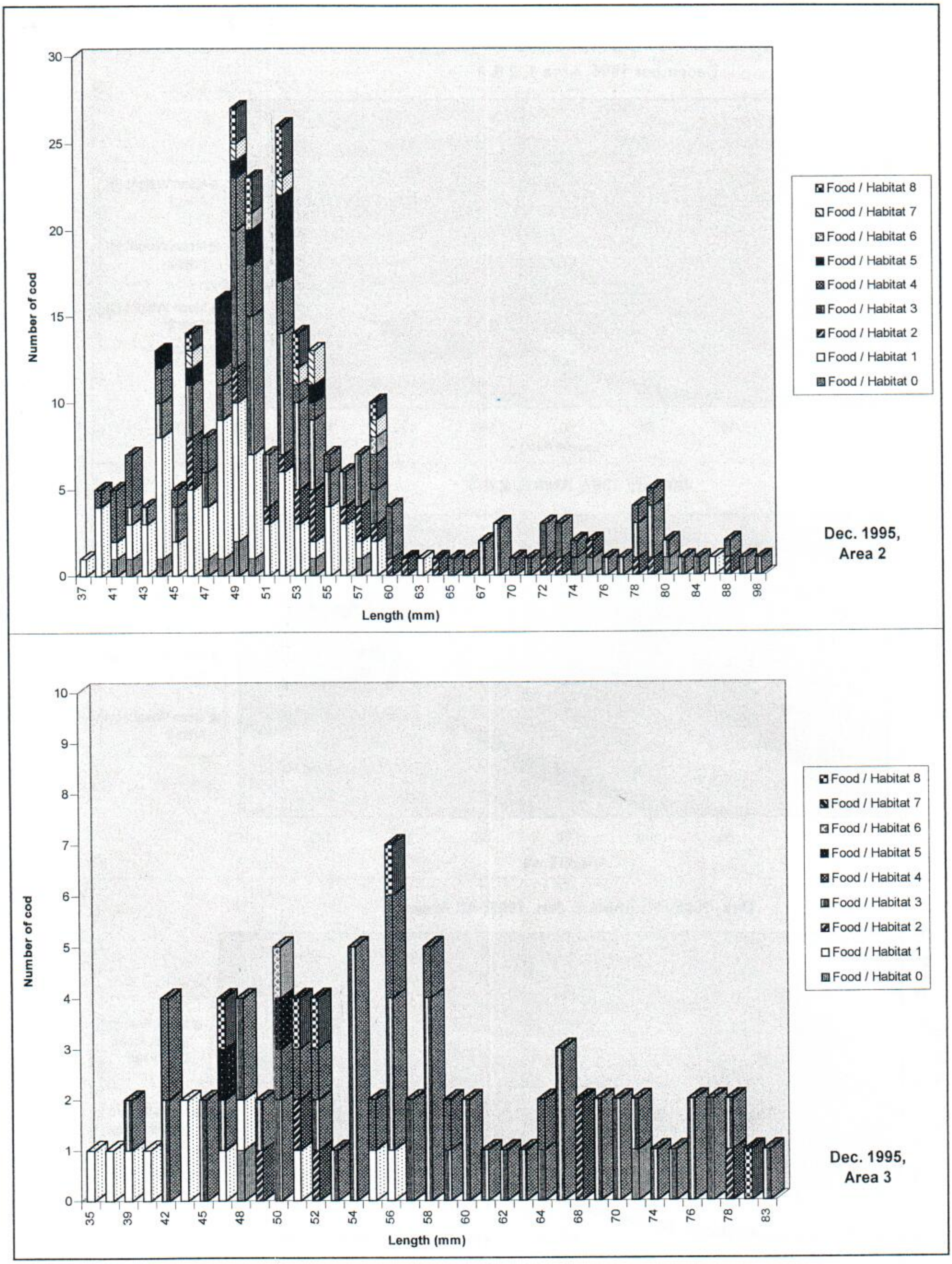

Figure 5. Number of juvenile cod subdivided by habitat specific food items (pelagic, demersal, intermediary) based on stomach content analyses. Dec. 1995. Explanation of labels: See Table 9.

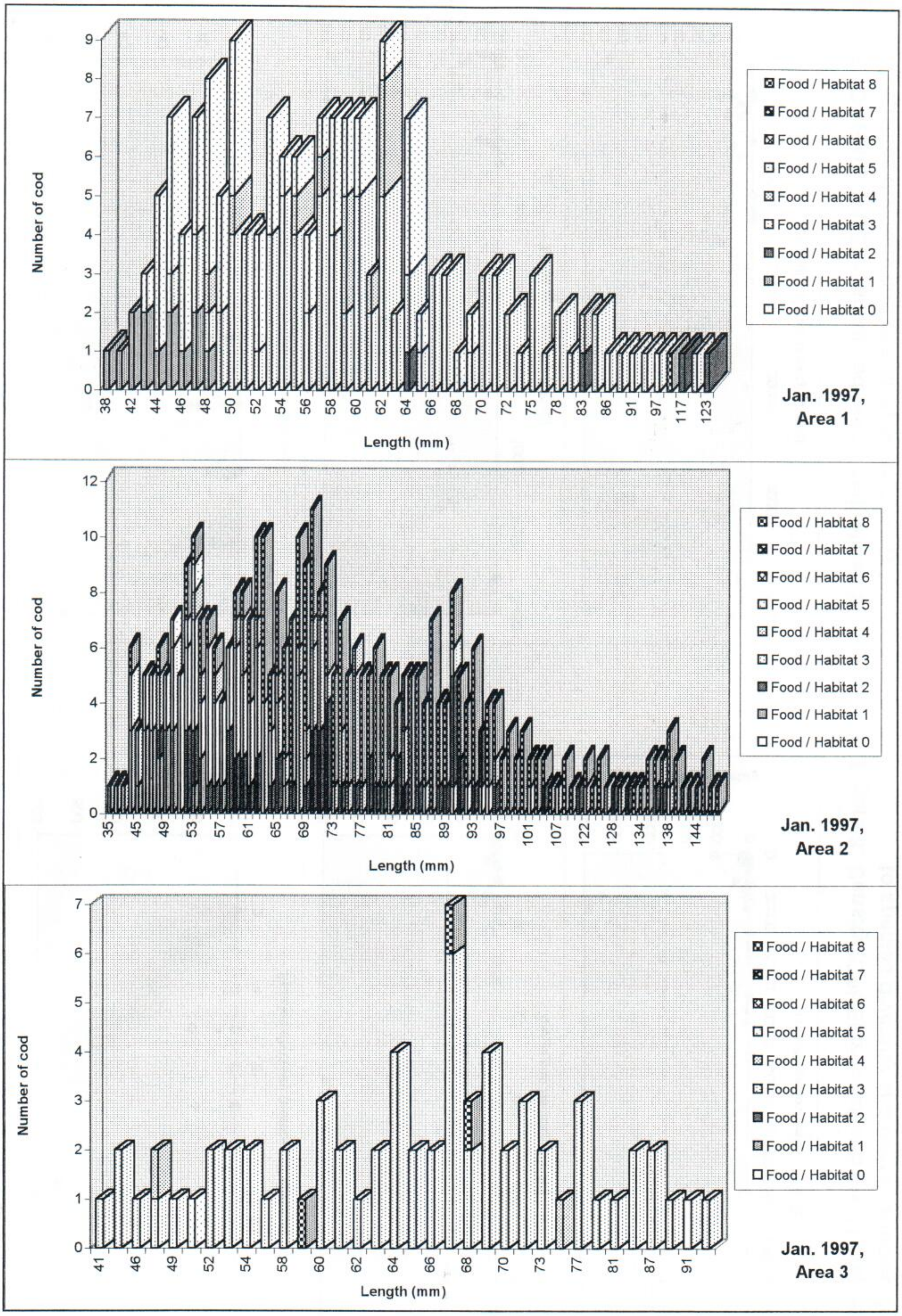

Figure 6. Number of juvenile cod subdivided by habitat specific food items (pelagic, demersal, intermediary) based on stomach content analyses. Jan. 1997. Explanation of labels: See Table 9.

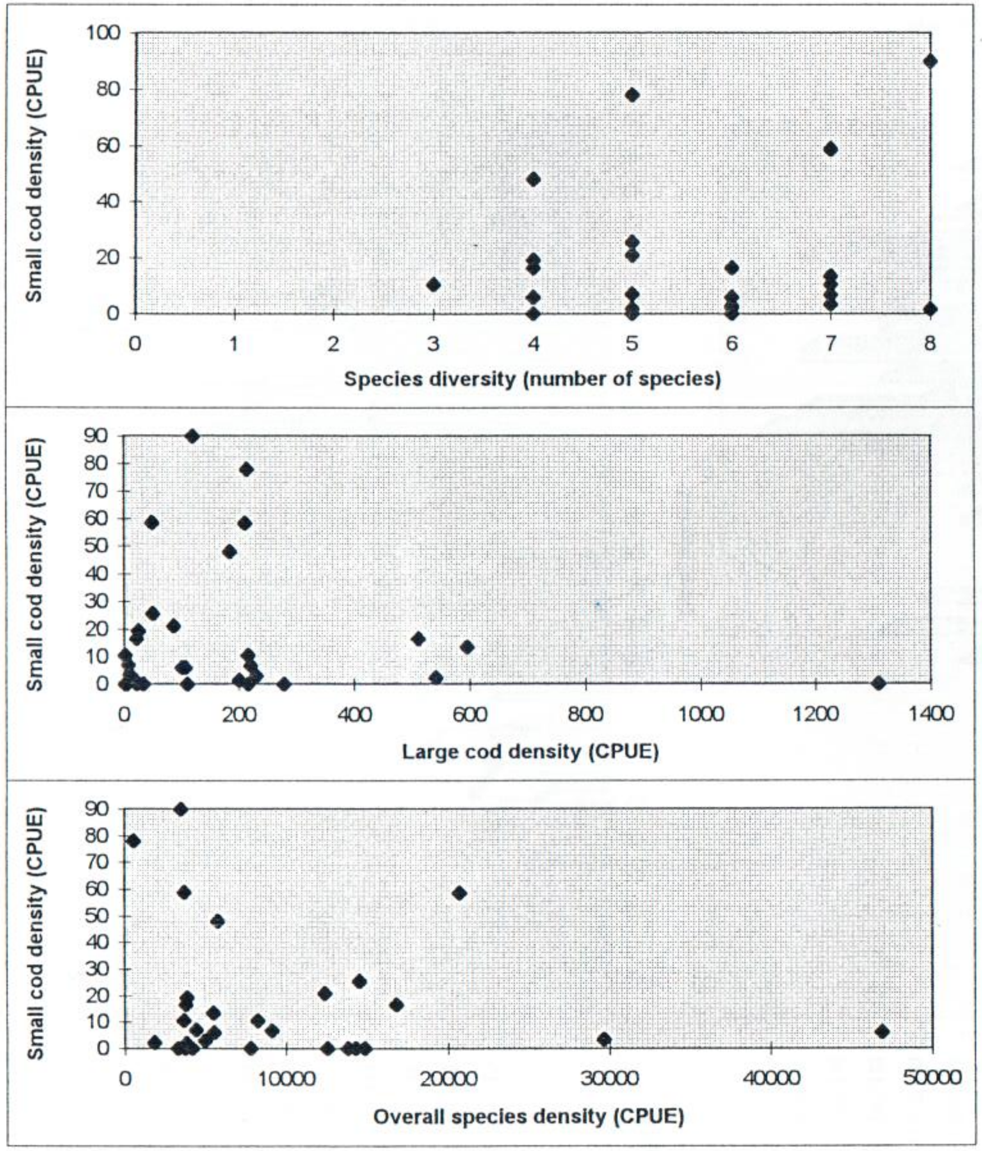

Figure 7. Density (CPUE) of small cod (=< 11 cm) related to species diversity and overall species density * for all species divided by activity. December 1995.
(* Cutling excluded)

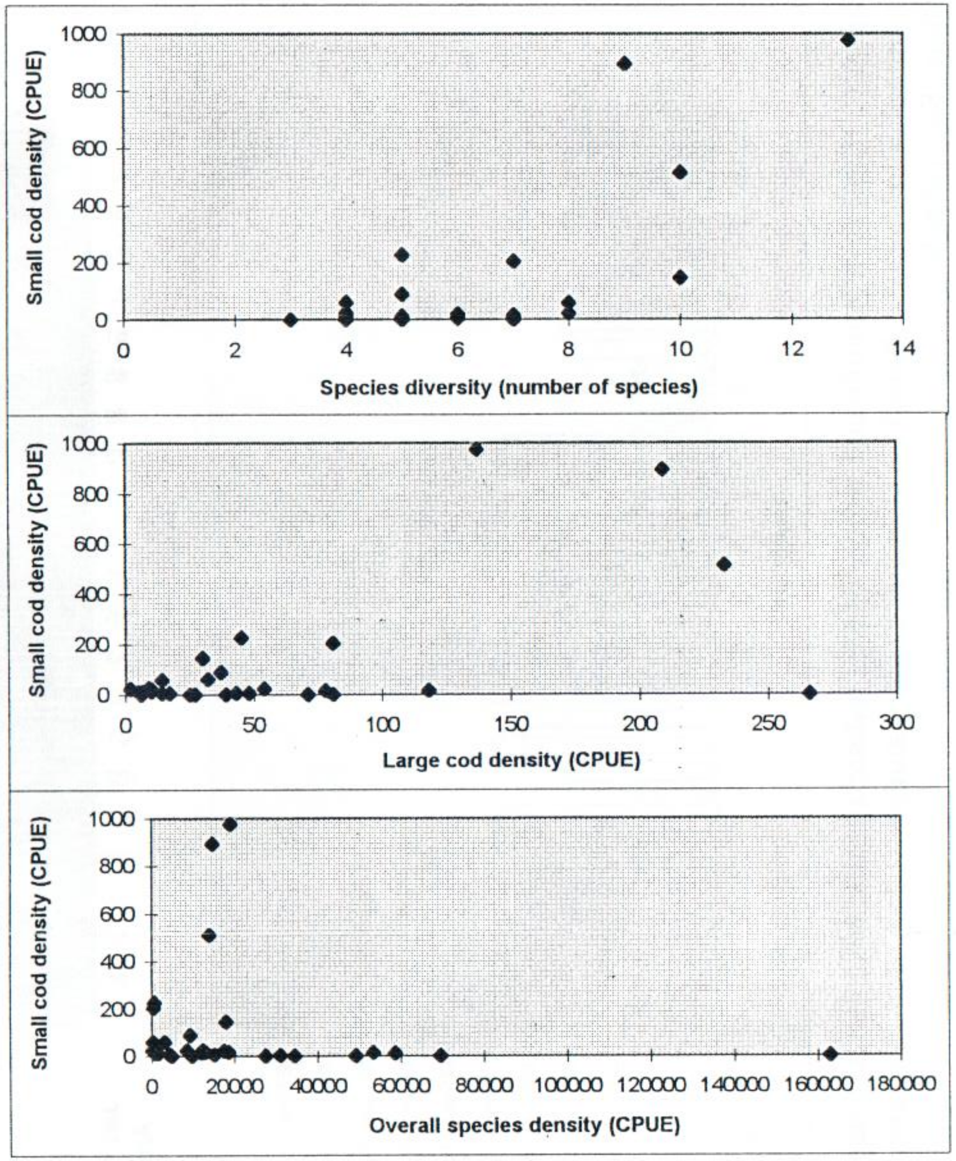

Figure 8. Density (CPUE) of small cod (=< 11 cm) related to species diversity and overall species density * for all species divided by activity. January 1997.
(* Cutling excluded)

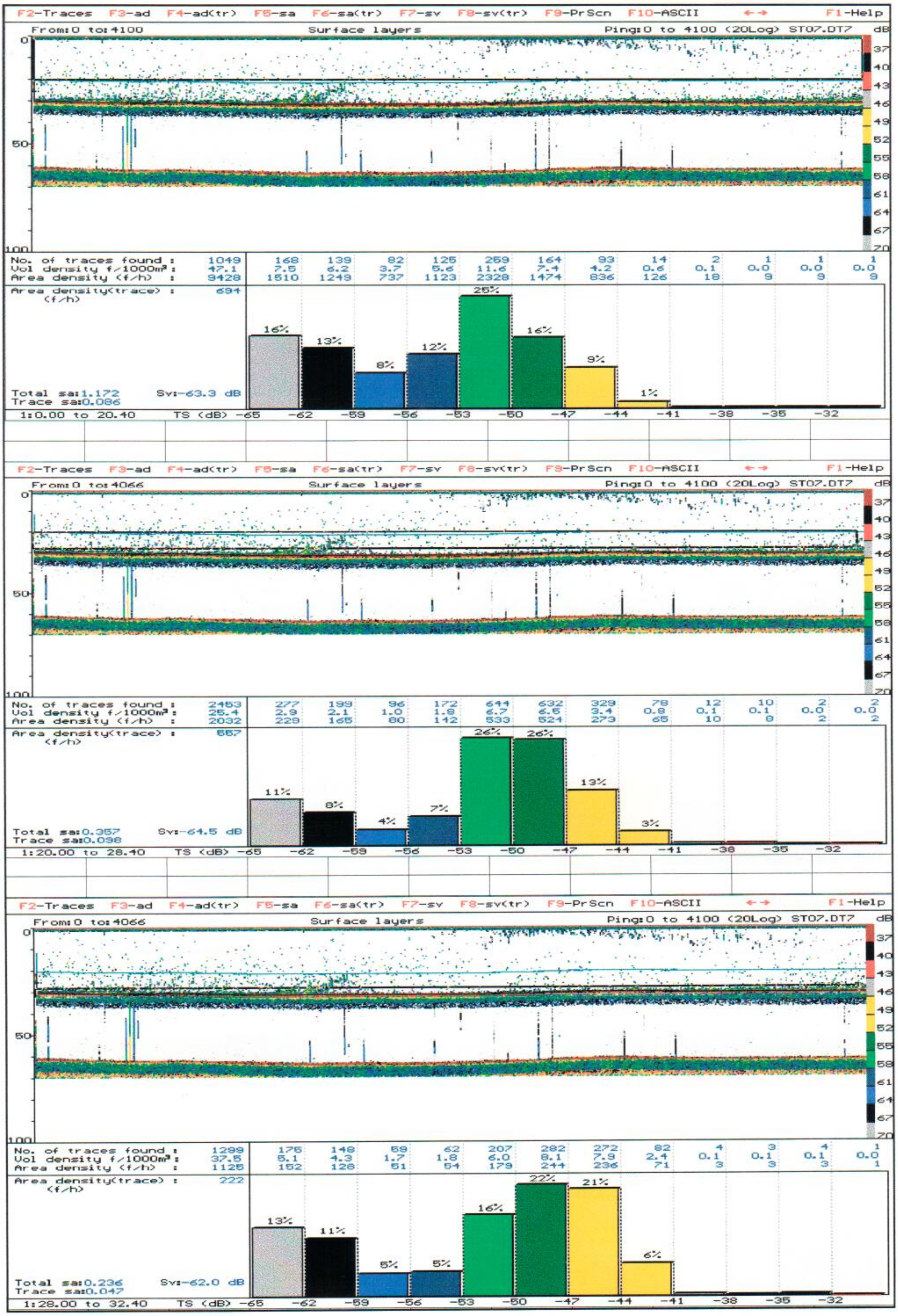

Figure 9. Density (Sv) and target strength (TS) distribution in different water layers. Not a pycnocline stratified locality. Depth 0 m is from where the hull mounted transducer is located, i.e. 6 m below sea surface. Activity 7.

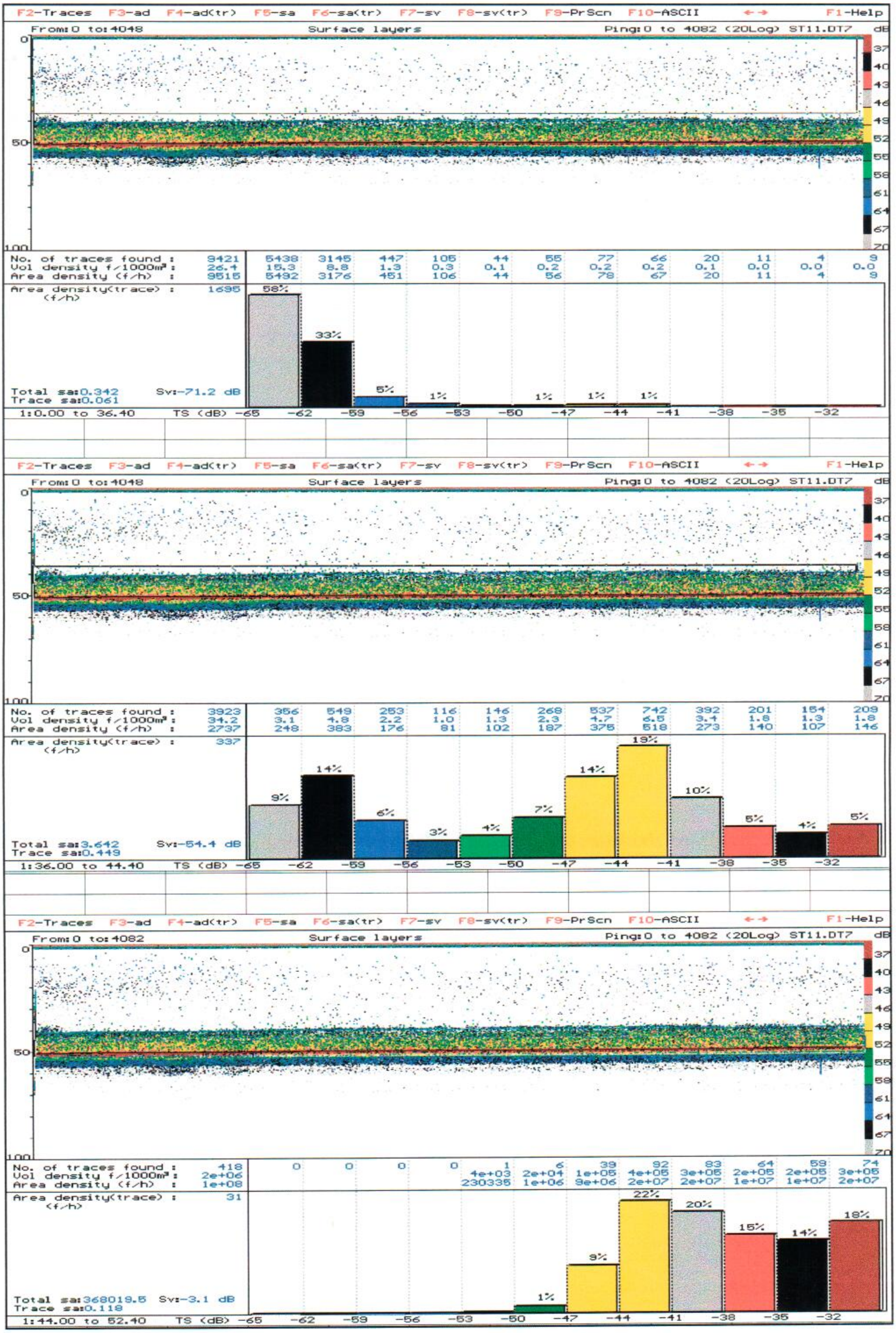

Figure 10. Density (Sv) and target strength (TS) distribution in different water layers. Pycnocline stratified locality. Depth 0 m is from where the hull mounted transducer is located, i.e. 6 m below sea surface. Activity 11.

```
                           Univariate Procedure

Variable=RES

                              Normal Probability Plot
            1.25+                                                   *+*+++*+
                 |                                          ********+
                 |                                   ***********
                 |                             ++******+
                 |         * *+*****+****
           -1.25++*++++++
                  +----+----+----+----+----+----+----+----+----+----+
                      -2        -1         0        +1        +2
```

```
                           Univariate Procedure

Variable=RES

            Stem Leaf                          #              Boxplot
               1 0022                          4                 |
               0 55666677999                  11                 |
               0 0001111111111122223333444    25              +--+--+
              -0 4333332221110                13              |     |
              -0 88888888877666666            17              +-----+
              -1 2                             1                 |
                 ----+----+----+----+----+
```

Figure 11. Analysis of variance structure of the GLM model residuals by the SAS Univariate procedure. Output from test of normality: schematic box plot, and a normal probability plot as a quantile-quantile plot of the residuals.