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ACOUSTIC IDENTIFICATION OF 0-GROUP COD IN THE BALTIC SEA

by

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ABSTRACT

Combined acoustic, oceanographic and trawl surveys have been conducted during 1993 and 1994 to determine the distribution for young of the year (YOY) Baltic cod in the Bornholm Basin (ICES Subdivision 25, Baltic Sea). During these cruises acoustic signals were obtained at some sites which were analysed to see wether they were indicative of the presence of YOY cod. Sampling was performed at these sites with 'GOV' and 'IYGPT' trawls resulting in the catch of YOY cod. Concurrent with trawl sampling, vertical profiles were taken for salinity, temperature and oxygen. Current velocities were performed (ADCP). The methodology of acoustic for describing the vertical and horizontal distribution of juvenile cod is discussed based on the limited data on YOY cod obtained during the R/V Dana survey September/October 1994 in the Bornholm Basin and adjoining waters. Further, the utility of existing TS-functions are discussed related to YOY cod. On that basis design of future investigations are proposed.

Key Words: Acoustic target identification, YOY Baltic Cod, CTD, ADCP, ICES Subdivision 25.

* Authorship equal.

Introduction

Several combined hydroacoustic and trawl surveys have been carried out by R/V Dana in the Bornholm Basin and adjoining waters related to the AIR Program "Mechanisms influencing long term trends in reproductive success and recruitment of Baltic cod: implications for fisheries management" (AIR2-CT94-1226). Two pilot surveys were performed in August 1993 (DS0793) and August 1994 (DS0894) with the purposes of localizing young of the year (YOY) cod and get a fishery independent spawning stock biomass estimate, respectively. A later survey was carried out in October 1994 to continue the search for the YOY cod. To localize different stages and size groups of YOY cod (eggs, larvae, 0- and 1-group juveniles) and measure environmental parameters of their habitats a variety of equipment and several catch gears have been used during these surveys which include hydroacoustic equipment, ADCP, CTD, Particle Counter, BONGO, small meshed pelagic ringtrawl (MIK), small meshed pelagic young fish trawl (IYGPT) and large demersal and pelagic trawls with small mesh sizes (GOV, EXPO). A major purpose of the AIR2 project is to localize and map the pelagic and horizontal distribution of juvenile 0-group Baltic cod and estimate their relative densities. The present work aims to contribute to the establishment of an acoustic identification catalogue with acoustic patterns of small cod in the central Baltic Sea and to develop methods to distinguish different acoustic patterns for YOY cod related to physical and biological conditions. Based on 38 kHz acoustic split beam measurements of single fish echo reflections, which are related to catch in concurrent performed trawl fishery to detect acoustic patterns and distribution patterns of juvenile 0-group cod, the present preliminary results will be the first limited material in this catalogue. Further investigations based on combined acoustic and trawl surveys with both R/V Dana and R/V Havfisken using both 38 kHz and 120 kHz split beam echosounders are performed in 1995 to supplement with more extensive information to this catalogue and hopefully to establish an empirical TS algorithm of small YOY cod based on 120 kHz single fish echo reflections.

Materials and methods

Data were collected during the R/V Dana survey DS1094 from 27 September to 6 October 1994 where the Bornholm Basin and adjacent waters was surveyed with a combination of hydroacoustic measurements and demersal and pelagic trawl sampling.

Hydroacoustic data were obtained along parallel transects covering the basin with an intertransect distance of 10 nm and on the cruise route off the basin. Hanö Bay, Södra Midsjö Bank and the area between Rönne Bank and Oder Bank were only covered with one transect each. A 38 kHz Simrad scientific split beam echosounder system connected to an EchoAnn echoanalyzer (Degnbol et al. 1990) was used for data collection. The basic settings were high power, pulselength 1 ms and receiver bandwidth 1 kHz. The hull mounted transducer was of the type 38-29/25. The system was calibrated using the standard copper sphere technique (Foote et al. 1986, Degnbol et al. 1990). The SL + VR of the system was 132.5 dB.

Species and size composition were sampled by trawling with a standard GOV bottom trawl (mesh size in codend 16 mm stretched) and a mid-water IYGPT trawl (mesh size in codend 16 mm stretched). The main log information of trawl stations are given on Tab. 1, together with CTD and ADCP data. Species composition and abundance of station 41 and 43 are given on Tab. 2 and size distribution of cod, herring and sprat are showed on Figs. 1 to 4.

The length distribution of cod, herring and sprat were calculated to TS distributions using the estimated empirical TS function for Gadoids and Clupeoids used in the Baltic (Götze et al. 1994):

Gadoids (Based on large cod):	TS=20 log L (cm) - 67.5 dB	(Foote et al. 1986)
Clupeoids:	TS=20 log L (cm) - 70.8 dB	(Lassen & Staehr, 1985)

The resulting TS values are showed on Figs. 1 to 4.

The single target values from the 38 kHz split beam echo sounder system were sampled during trawling on stno. 41 and 43, starting just before shooting the first trawl, and ending just after the second trawl was on deck. The recorded single target values were pooled by dB size groups for the two stations, respectively, and the calculated TS frequency distributions are given on Fig. 5.

Vertical profiles of temperature, salinity and oxygen from station 41 and 43 were recorded by a CTD probe and showed on Fig. 6.

Results

During the Dana surveys DS0793, DS0894 and DS1094 covering the whole central Bornholm basin, the basin edges and surrounding waters, significant numbers of small, juvenile, 0-group cod have been found only on two localities during the DS1094 survey in the area between Oder Bank and Rönne Bank (st. 41 and 43; Tabs. 1 & 2). These two stations covers a shallow water area, i.e. 10-20 m bottom depth (st. 43 and surrounding areas), and a more deep area with bottom depths from 35-40 m (around st. 41), respectively. (Tabs. 1 & 2). Both areas are characterized by slow water currents below 0.3 knot at all depths coming from shifting directions and low salinities below 7-8 ‰ in the whole water column. The water temperature on both stations are about 12-13°C in all vertical layers except for the near bottom water layer on station 41 where the temperature drops down to about 6°C. At this site the near bottom oxygen saturation is also lower (app. 60%) compared to the oxygen saturation in all other layers in the rest of the area being at a level between 80-90 % saturation.

The catch in the GOV trawl on st. 41 is by weight dominated by cod, while cod and flounder are dominating in the GOV catch on st. 43. The IYGPT trawl catch on st. 41 is by weight dominated by sprat, while cod, flounder and herring are dominating in the IYGPT catch on st. 43. Largest occurrences of small cod (TTL<=12 cm) are in the GOV catches on both stations, however, the GOV catches do not contain cod smaller than 6 cm, while cod down to 3-5 cm length occur in the IYGPT catch.

Trawling with the demersal GOV trawl is performed on bottom, however, the fishing and catch of the trawl during shooting and during heaving is not known, which makes pelagic catches of this trawl very possible. The IYGPT trawl is hauled in a pelagic zig-zag movement covering the whole water column, i.e. from surface to bottom to surface again. This means that the vertical distribution of the single fish species and size groups on the stations is not known based on the present trawl catches, in general. The echograms (Fig. 7) show that large herring or/and sprat shoals occur in the pelagic layers of the water columns on the trawl stations. These shoals give high, thin and very distinct signals. However single fish echoes of small cod can not visually be identified among the residual signals. (Fig. 7).

Other abundant fish species in the catches are flatfish such as flounder, turbot and plaice, and also sculpins. These species are closely connected to the seabed environment and is, thus, not believed to have significant vertical distribution above the 1 m offset layer from the bottom used in the acoustic measurements. These species are, therefore, not believed to be included in the obtained echo signals and gives no acoustic noise in the analysed single fish echo reflections.

The length distributions in the trawl catches of the three most abundant fish species in the pelagic water layers in the area (cod, sprat and herring) are compared to calculated TS values for the observed length groups. The calculations are based on existing empirical estimated TS functions, which are species and size specific (see the materials and methods section). Small cod have, where they occur in significant numbers, ie. in the GOV catches, a tendency to have a bimodal TS distribution (and length frequency) within the TS interval -50 dB to -45 dB with modes around -46 dB and -48 - -49 dB, respectively (Figs. 1-4). Within that interval there is an overlap in the TS distribution for small cod (5-15 cm in TTL corresponding to calculated TS values between -50 dB and -45 dB) and sprat (5-16 cm in TTL corresponding to calculated TS values between -52 to -47 dB). In general, the calculated TS mode spectrum for small cod are observed to overlap with the calculated spectrum for especially larger sprat observed in the catches. Also the length distributions and the TS value distributions for the smaller size groups of the caught herring overlap with the distributions of the larger size groups of the small cod and with sprat (in the TS value interval -47 dB to -44 dB) based on the results from the GOV trawl catches on both stations and in the IYGPT catch on st. 43. Further, very small herring caught in the IYGPT trawl on st. 41 have overlapping TS values with the smallest group of the small cod in the TS interval around -51 dB. Figs. 1-4.

Regarding the observed TS value distribution from the 38 kHz split beam echosounder it appears from Fig. 5 that the highest number of single fish echo reflections on the deeper st. 41 originates from the 23-29 m depth layer. This can be related to the pelagic localization of the thermocline and the more modest halocline at the depth around 29-30 m (Fig. 6). In the 23-29 m water layer and, thus, in the resulting TS distribution pattern for the whole st. 41 the observed single target TS value distribution have several modes. The major number of single fish reflections on st. 41 is observed within the TS value interval between -59 dB to -52 dB. A bimodal TS distribution pattern is (also) observed on the more shallow water st. 43. On both stations there exist a major TS mode around -58 dB to -53 dB with dispersions between -64 dB to -50 dB. This mode can not directly be explained based on the calculated TS values for small cod, small herring and sprat occurring in the trawl catches on both stations, which have higher calculated TS values in the interval around -52 dB to -45 dB (Figs. 1-4). However, other modes in the observed TS value distribution on both stations covers this TS value interval. At st. 43 the largest mode is observed around -44 dB with a dispersion between -48 dB and -40 dB while a more modest mode in the same TS value interval appears on st. 41. Based on the used TS function TS values up to around -32 dB have been calculated for the large cod in the trawl catches. However, the observed TS values on especially st. 41 succeeds this level where TS values up to -26 dB is observed. Even though the calculated single fish TS values represents a convoluted TS distribution of about 5-6 dB the observed extreme TS values about -26 dB can not be explained based on the species and size composition found in the trawl catches. Possibly, these values represents very large cod that have either avoided or escaped from the trawls or have stayed in not covered (hauled) water layers by the large GOV trawl.

Discussion

Based on the found overlaps in the calculated TS value distributions of single target reflections between small cod, sprat and small herring it is not possible to isolate and identify specific acoustic patterns for small cod from those of sprat and small herring occurring in the trawl catches. Thus, further analyses on the acoustic signals with respect to geometric angles between single target reflections identified to species and size group with special emphasis on small cod gives no meaning based on the existing limited material.

The calculated TS values around -50 dB to -45 dB for the small cod and small herring and sprat are very high, and lower values for these size groups are expected. The unexpected high values might be due to a major methodological problem by using an empirical TS algorithm estimated for large cod, i.e. the present used TS value distribution for all cod size groups are based on a TS algorithm that is established on the basis of empirical estimates for only larger cod with an 38 kHz split beam echosounder. The reason for using this function in the present work is that no empirical estimated TS algorithm for small size groups of cod in the Baltic Sea exist. The used TS function based on a relatively long wavelength from an 38 kHz echosounder is useful for larger cod as the wavelength/swimbladder-size relationship (= λ /L) is high (>> 1) for these size groups. However, this is not the case for small cod where the λ /L relationship is around 1 or even lower than 1 when estimated with a 38 kHz split beam echosounder with relatively long wavelengths (3-4 cm in sea water). First of all, when λ/L lays in the range around 1 resonance may occur giving too large TS values for small cod. Further, in the λ /L area around 1 and lower values, completely different physical characteristics exist for the echo reflection from an air bubble in water (i.e. the swimbladder) compared to higher λ /L-values, as the relationship between the acoustic cross section area and the physical (target) cross section area are different when λ /L >>1 compared to when λ /L<= 1. For that reason, lower TS values for the smaller cod are expected. Possibly, the TS values for small cod could be in the interval between -64 dB to -52 dB, which is the TS value interval where major modes between -58 dB to -53 dB with dispersions between -64 dB and -50 dB actually occurred for the single target reflections on both st. 41 and st. 43.

Another problem related to the present exact calculated TS values for single fish targets is, that they represent a convoluted mean TS value which varies within an range (dispersion) of maybe 5-6 dB dependent of the swimbladder directivity and fish behaviour of the actual measured single target. The calculated TS value per length group represents, thus, a convoluted mean over a TS distribution, and this value has not been empirical estimated for small cod in the Baltic Sea. Even for larger size groups of cod this mean value and its range (dispersion around the mean) is not thoroughly empirical measured. As the TS value, and thus the mean TS and range, is dependent of fish behaviour and swimbladder directivity, species and size specific differences are very likely.

To measure an useful empirical TS algorithm for small cod it is necessary to measure echo reflections from single fish targets within a broad target size range (length groups), within a broad range of target swimbladder directivities, and within a broad target behavioral range with an high frequency split beam echosounder, e.g. with an 120 kHz split beam echosounder, in the natural environment of small cod in the Baltic Sea. Thus, future investigations should first of all concentrate on estimating an useful TS algorithm for small cod size groups. To do so, it is necessary, when performing combined acoustic and trawl surveys, to get abundant trawl catches of small cod with no or only limited occurrences of other fish species and size groups with overlapping TS value distributions and, concurrently, it is necessary to sample acoustic data on single target reflections from an high frequency echosounder to ensure that the λ /L relationship for small cod are relatively high.

Investigations on the coming Dana cruises in the Baltic Sea related to the AIR2 program will based on previous experience concentrate on acoustic measurements with an 120 kHz split beam echo sounder to establish an useful TS algorithm for small cod and try, based on repeated selective trawl fishery on stations with relatively high abundances of small cod, to identify differences in the vertical distribution patterns of small cod, small herring and sprat (as the most important pelagic species) in different vertical water layers.

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Table 1. Main logg information of R/V DANA survey 10, September/October 1994, in the Bornholm Basin and adjoining waters.
A: Hanö Bay, B: Södre Mitsjö Bank, C: Between Rönne Bank and Oder Bank.

		Duration	Locality	Latitude	Longitude	Date	UTC	Dept m	Depth m	ADCP component Current		
Stno.:	Gear	minuts		pos.- N	pos.- E	YYMMDD	HHMM	Middwater	Near bott.	N / S	E / W	Knob
1	iygpt	12	A	5554.4	1432.4	940930	1352	20	64	23.5	68.5	1.41
2	iygpt	33	A	5550.6	1434.9	940930	511	20	40	11.6	-15.7	0.38
3	iygpt	15	A	5548.2	1438.2	940930	814	20	50	-3.2	-3.4	0.09
4	iygpt	15	A	5542.9	1442.9	940930	1145	10	16	-19.2	-11.3	0.43
22	iygpt	30	B	5540.9	1657.9	941003	35	10	20	-1.5	-10.3	0.20
23	iygpt	28	B	5542.4	1707.2	941003	600	10	22	0.2	5.3	0.10
24	iygpt	31	B	5543.0	1725.1	941003	924	10	18	4.8	12.9	0.27
25	iygpt	28	B	5544.6	1736.6	941003	1151	20	38	5.6	15.3	0.32
41	iygpt	29	C	5437.8	1434.2	941005	1018	10	28	-9.5	-5.1	0.21
41	gov	30	C	5437.8	1434.4	941005	1146	10	28	-8.7	-10.6	0.27
42	gov	30	C	5432.3	1427.8	941005	1545	2	6	-10	5	0.22
42	iygpt	30	C	5432.4	1424.1	941005	1705	2	6	-5.2	3.5	0.12
43	iygpt	31	C	5430.7	1419.6	941005	1946	2	6	-10.4	5.8	0.23
43	gov	31	C	5430.8	1419.2	941005	2101	2	6	-11.3	8.9	0.28

		ADCP components bottom			Temperature °C		Salinity		Oxygen saturation		Cod<=12
Stno.:	Gear	N / S	E / W	Knob	Midwater	Bottom	Midwate	Bottom	Middwate	Bottom	numbers
1	iygpt	3.6	35.1	0.69	10	9	31	32	60	60	0
2	iygpt	10.1	-9.1	0.26	11	9	32	32	95	88	0
3	iygpt	18	-10.7	0.41	13	11	29	33	-	60	0
4	iygpt	-21.6	-9.5	0.46	12	10	7	7	93	85	0
22	iygpt	0.6	-13.3	0.26	11	11	7	7	90	90	0
23	iygpt	2.6	-0.2	0.05	12	12	7	7	90	90	3
24	iygpt	5.9	11.3	0.25	11	11	7	7	90	90	0
25	iygpt	4.2	2.1	0.09	12	12	7	7	90	90	0
41	iygpt	-9.9	10.1	0.27	13	6	7	8	90	60	26
41	gov	-9.2	4.2	0.20	13	6	7	8	90	60	306
42	gov	-2.9	-6.2	0.13	12	12	8	8	90	80	38
42	iygpt	-1.6	-5.3	0.11	12	12	8	8	90	80	0
43	iygpt	0.8	-1.5	0.03	12	12	8	8	90	90	37
43	gov	-0.2	1.4	0.03	12	12	8	8	90	90	117

Table 2. Catch per species in weight and numbers in GOV and IYGPT trawl hauls on stations no. 41 and 43.

Stat-no	41	41	43	43
gear	iygpt	gov	iygpt	gov
CW-cod (kg)	< 0.50	284.49	18.38	64.42
CNo-cod	26	715	81	351
CW-herring (kg)	5.24	10.40	12.80	4.50
CNo-herring	951	278	108	110
CW-sprat (kg)	124.30	3.40	3.32	0.74
CNo-sprat	33935	96	818	113
CW-flounder (kg)	-	8.60	28.40	147.30
CNo-flounder	-	21	153	486
CW-plaice (kg)	-	6.30	0.60	3.10
CNo-plaice	-	26	4	22
CW-turbot (kg)	-	7.40	3.30	17.20
CNo-turbot	-	9	14	61
CW-whiting (kg)	-	0.16	-	-
CNo-whiting	-	2	-	-
CW-sculpin (kg)	-	33.40	3.10	10.20
CNo-sculpin	-	?	?	86
CW-gobies (kg)	-	0.01	0.72	5.68
CNo-gobies	-	?	1086	19454
CW-eel	-	-	0.08	-
CNo-eel	-	-	2	-

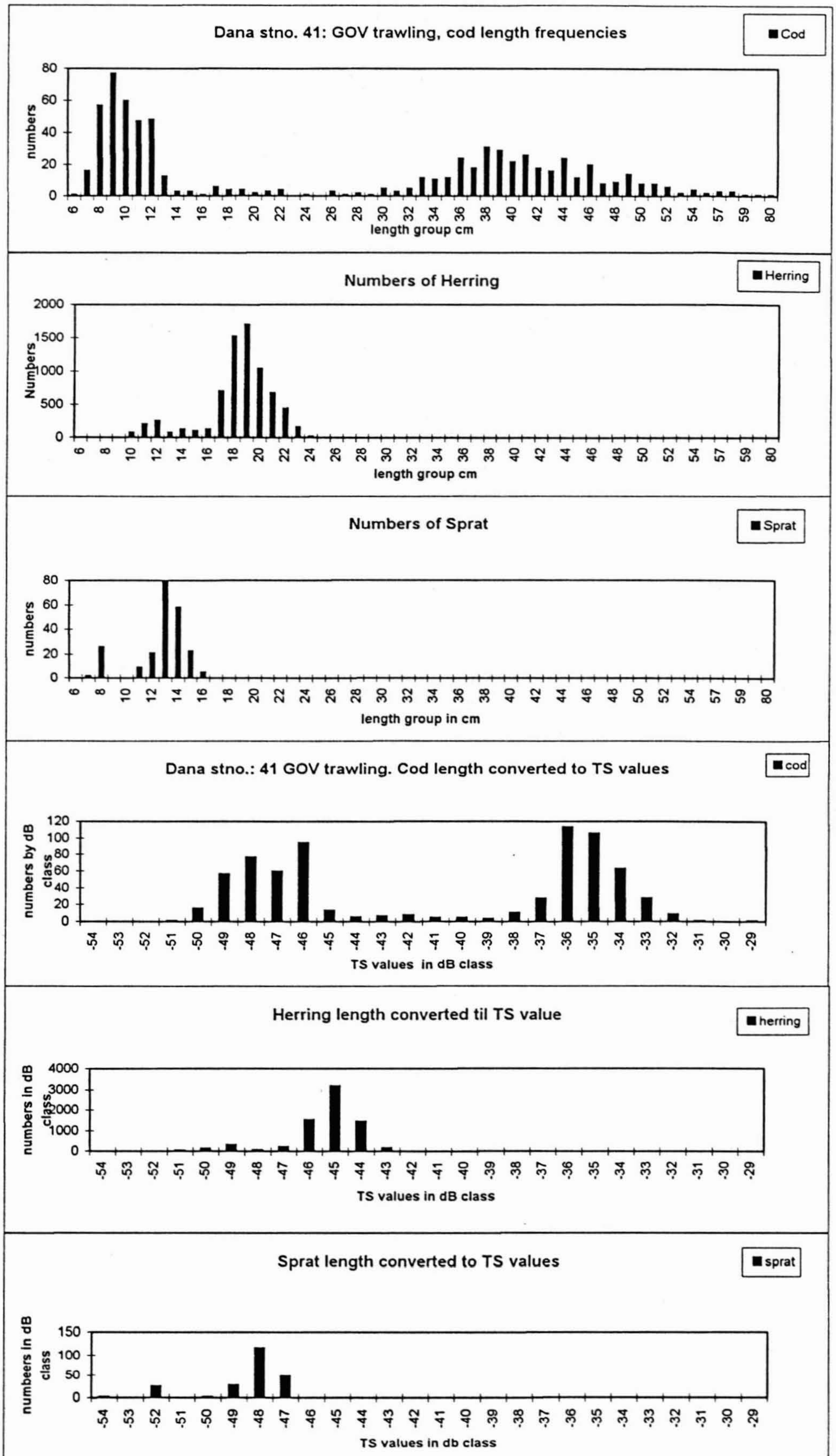


Figure 1. Length frequencies of major species in catch and converted length distribution in catch to species specific distribution of TS-values.

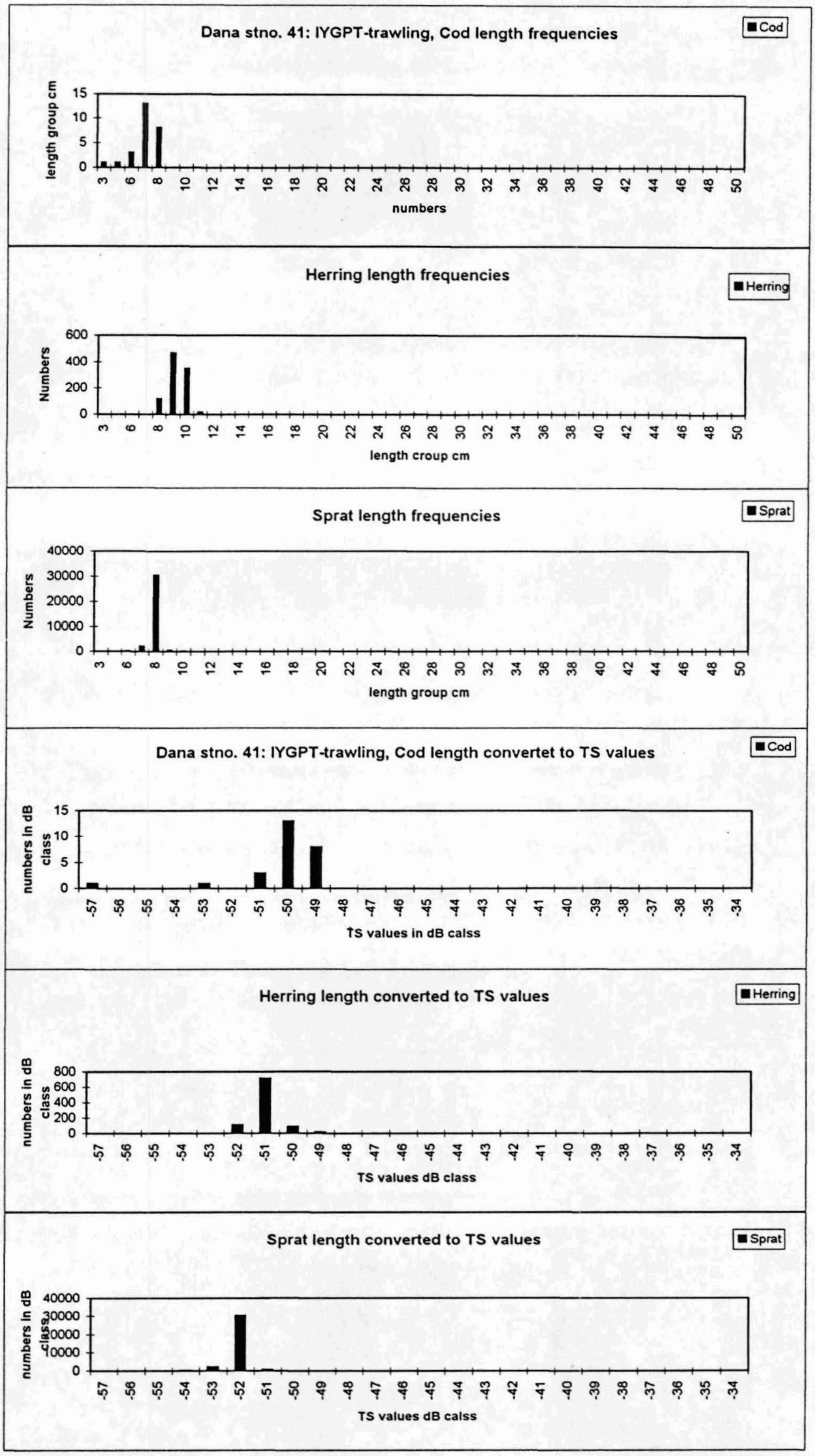


Figure 2. Length frequencies of major species in catch and converted length distribution in catch to species specific distribution of TS-values.

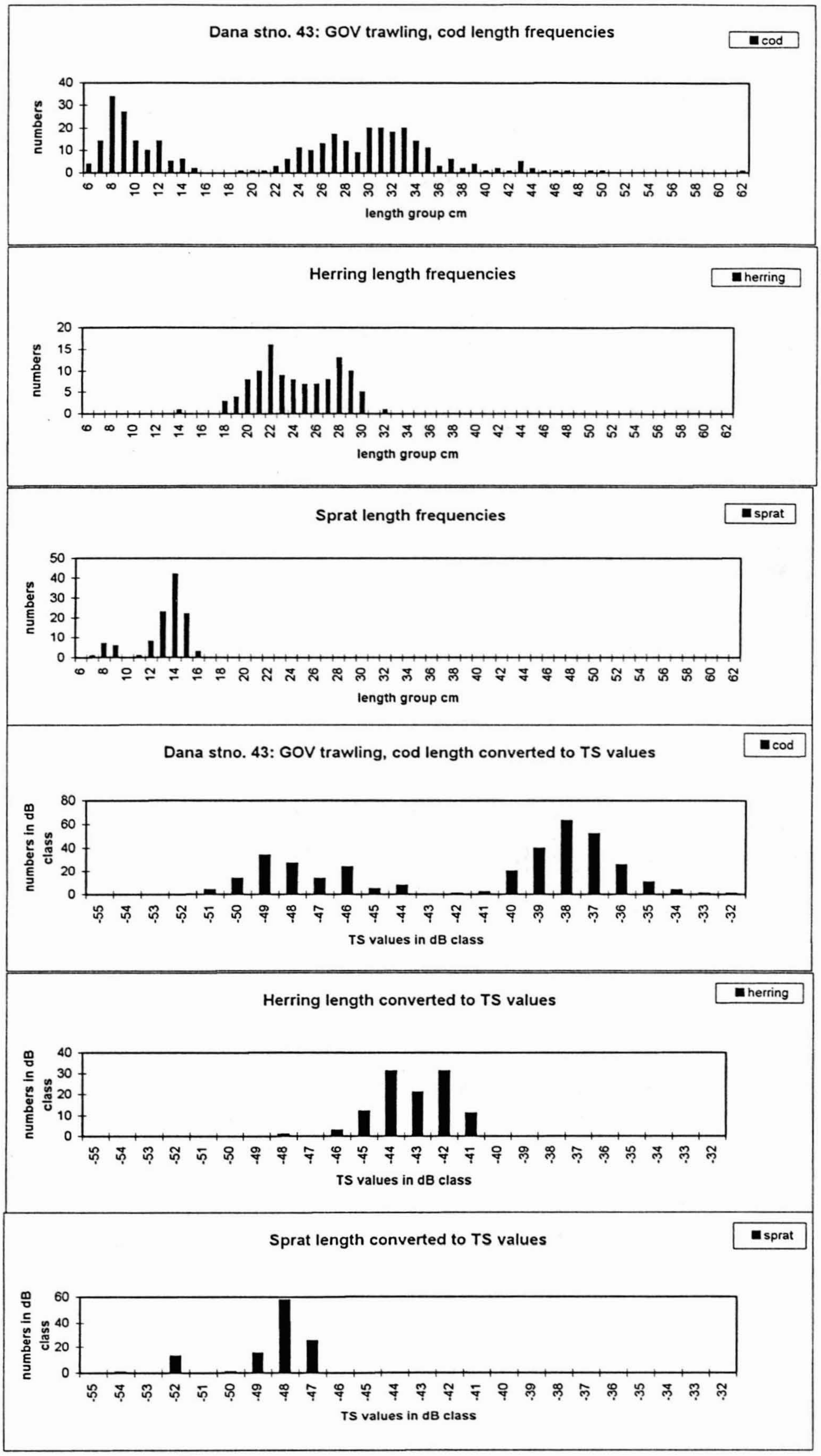


Figure 3. Length frequencies of major species in catch and converted length distribution in catch to species specific distribution of TS values.

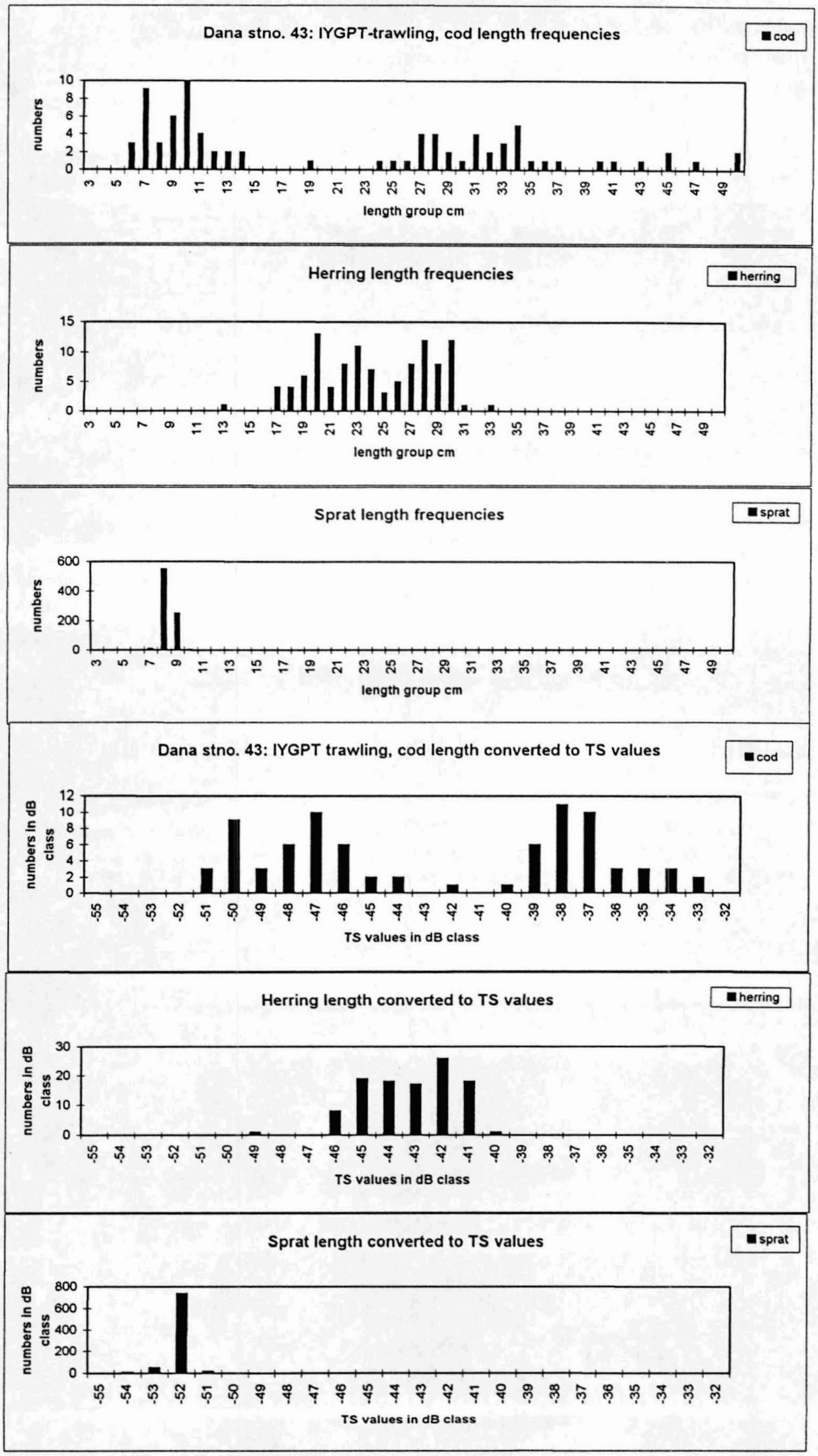


Figure 4. Length frequencies of major species in catch and converted length distribution in catch to species specific distribution of TS values.

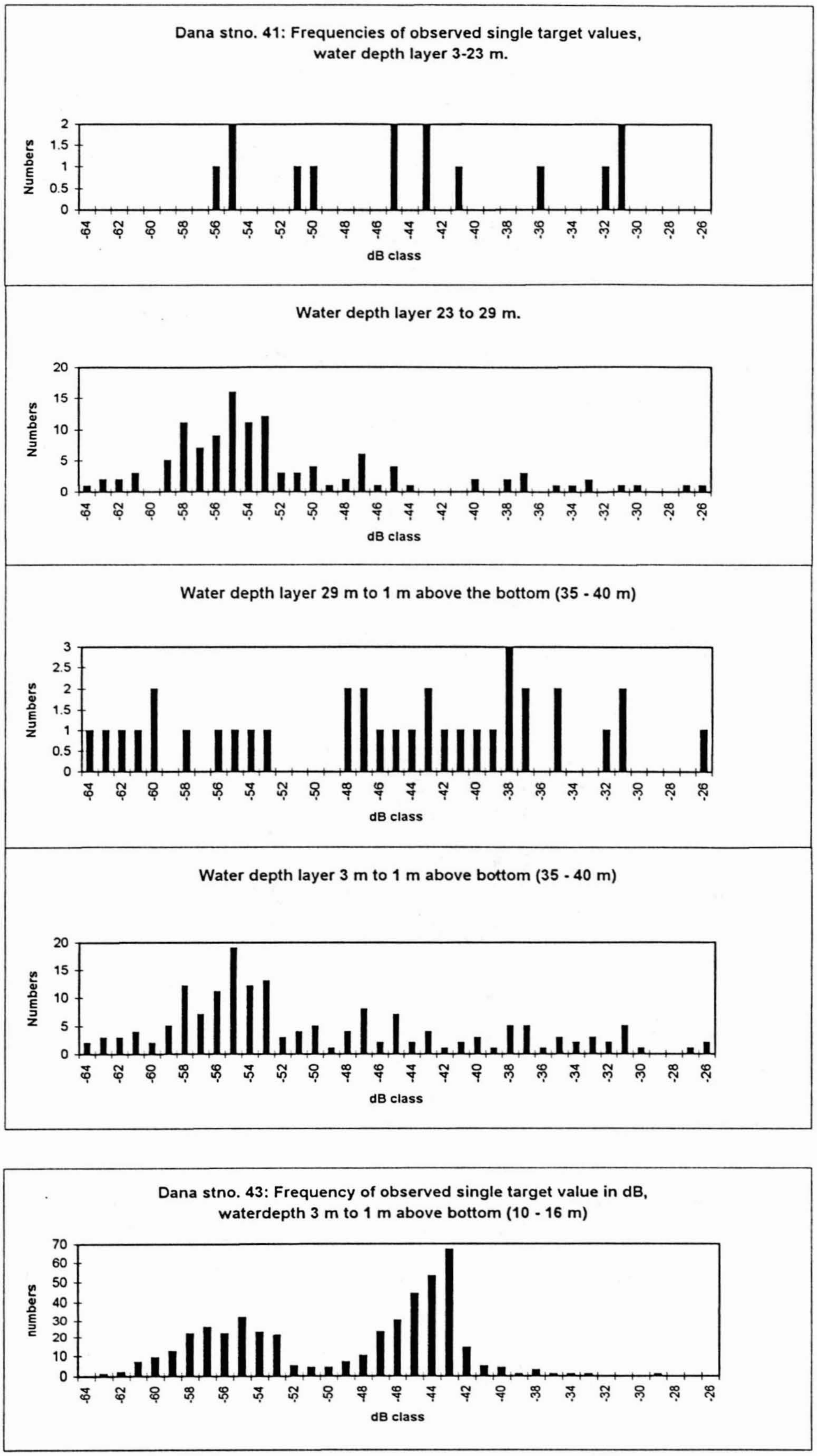
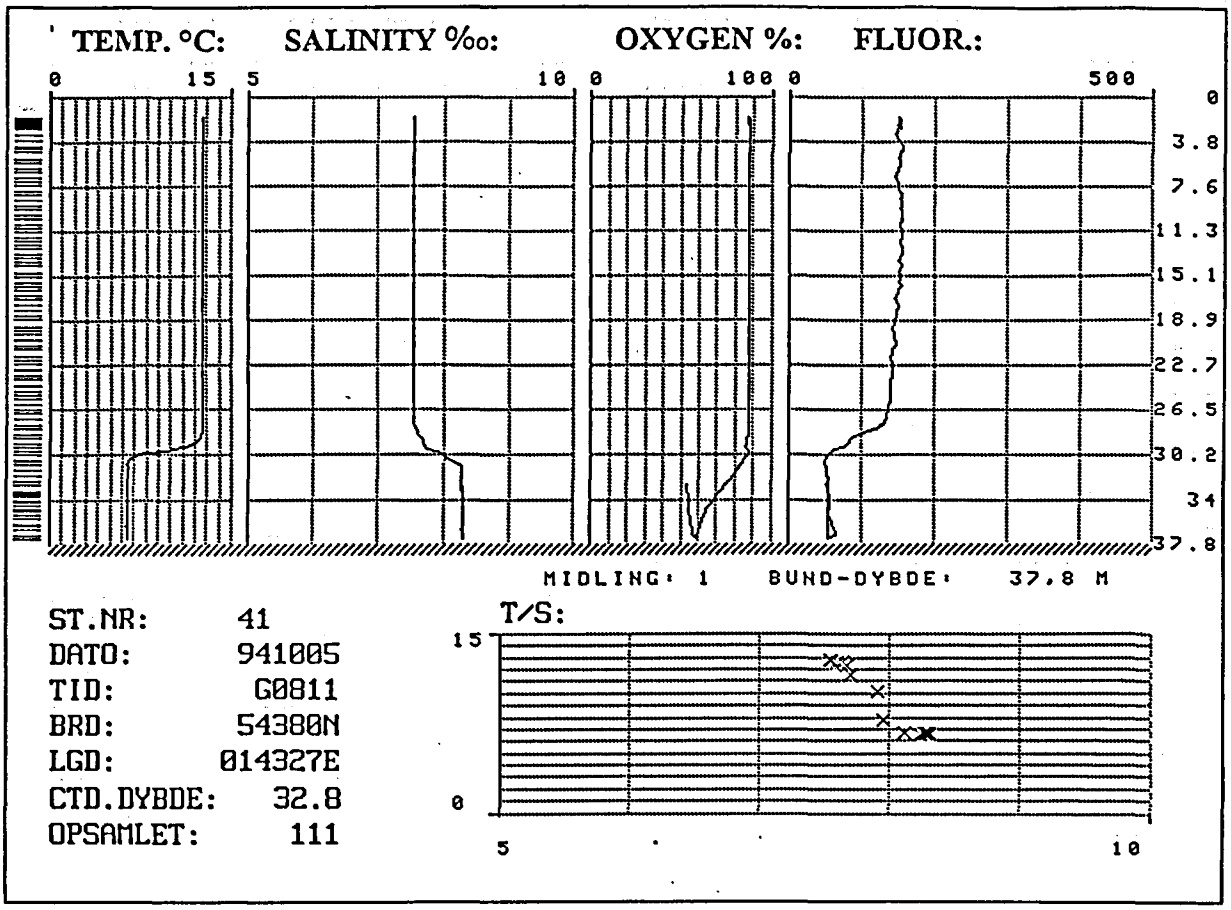


Figure 5. Observed single target values (38 kHz split beam) from R/V DANA survey in Bornholm Basin and adjoining waters, September/october 1994.



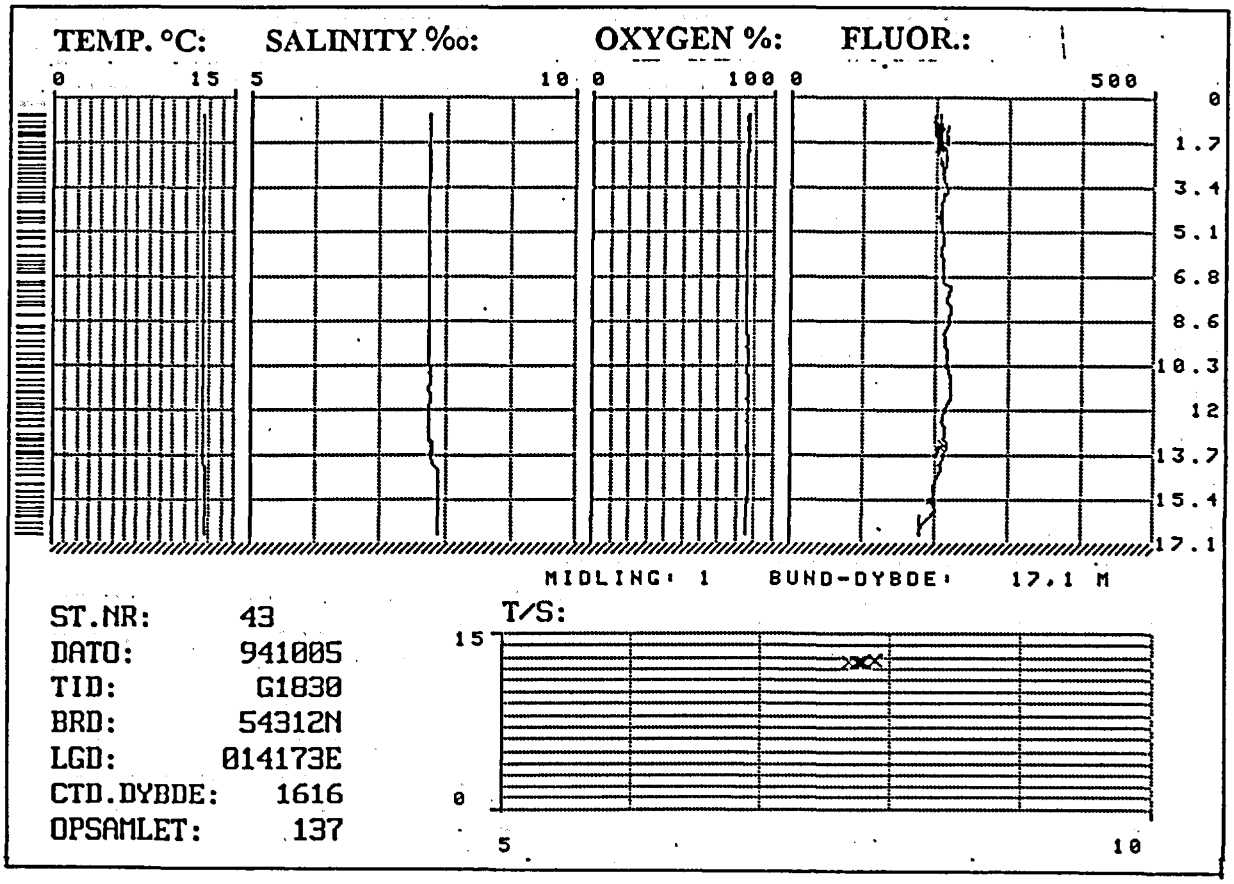
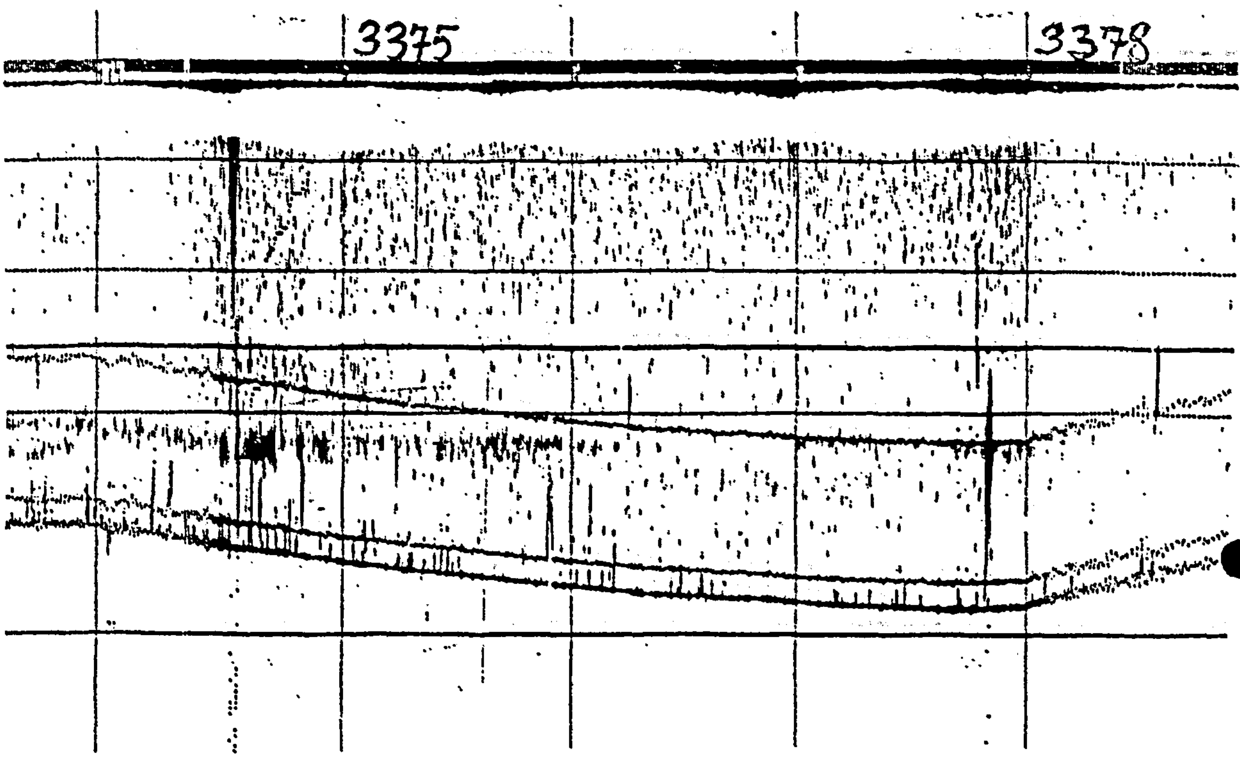


Figure 6. CTD profiles of temperature, salinity, oxygen and fluourescence from R/V DANA survey 10, September/October 1994 on stno.: 41 and 43.

A)



B)

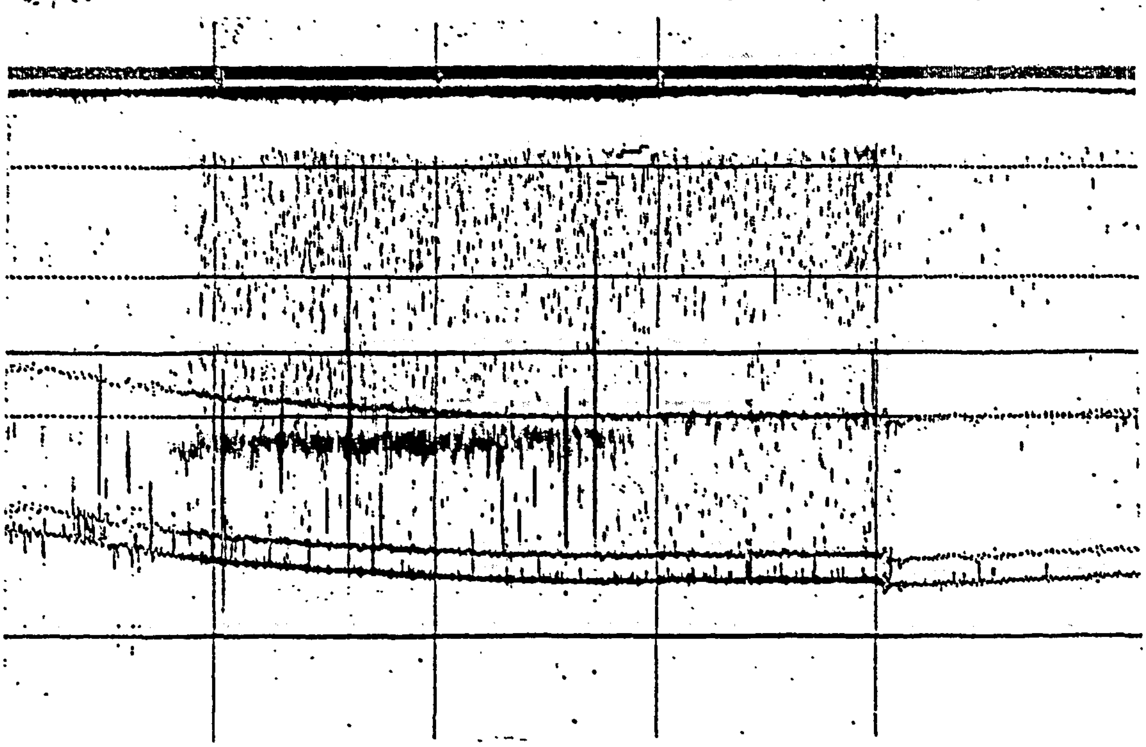
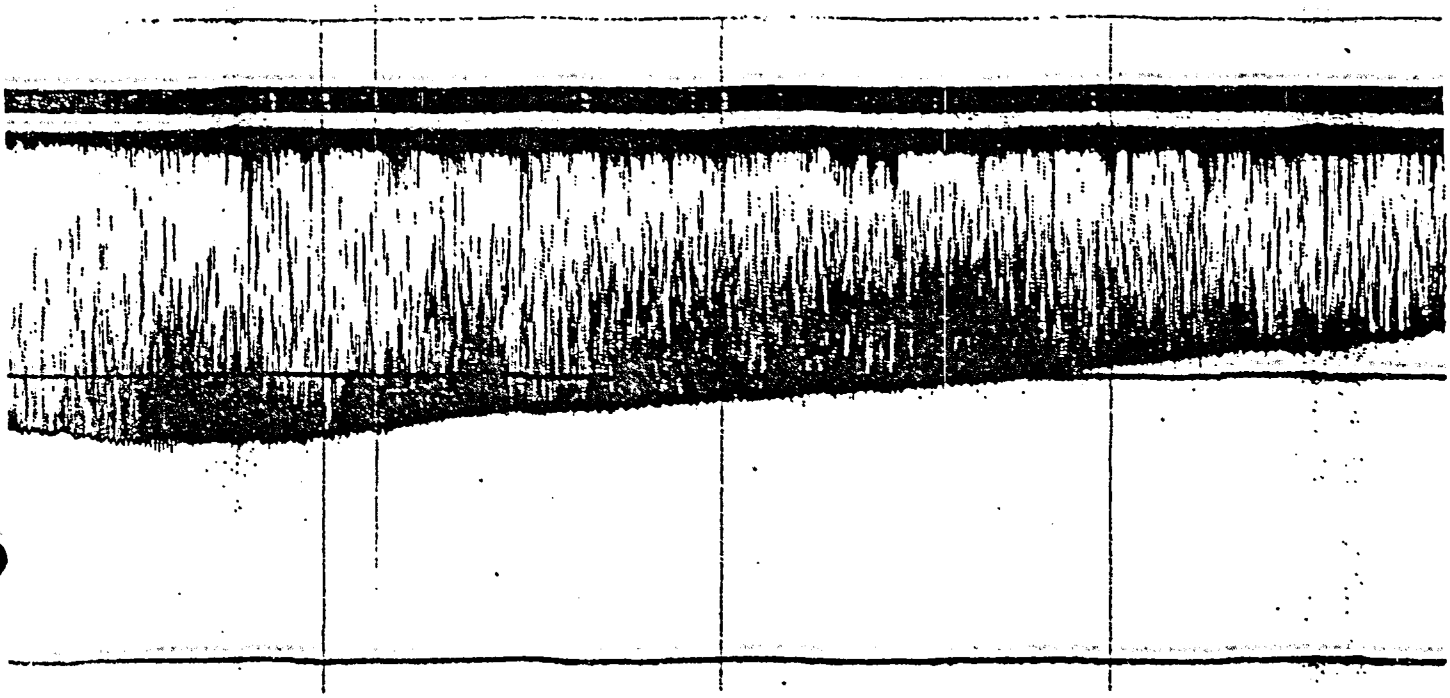


Figure 7. Echograms from SIMRAD 38 kHz split beam echosounder from GOV and IYGPT trawl stations 41 and 43. A) St. 41, GOV trawling; B) St. 41, IYGPT trawling; C) St. 43, GOV trawling; D) St. 43, IYGPT trawling.

C)



D)

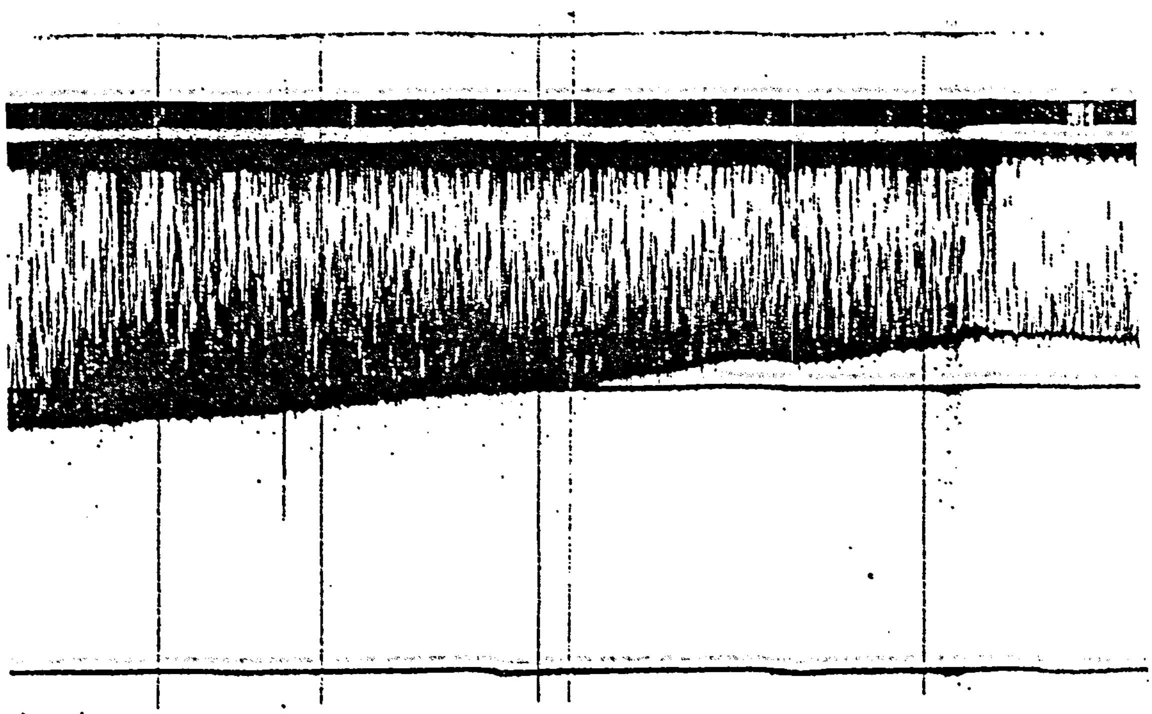


Figure 7. (Continued).