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Hydroacoustic small scale investigations of pelagic fish stocks

by

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Abstract

Hydroacoustic investigations were carried out in two boxes with the dimension of 10 nm * 10 nm in the Arkona Basin (ICES subdiv. 24). Each box was covered three times during night and two times on daytime by four parallel transects of 10 nm length.
The measurements were aimed to study the variations in distribution and mean values of the area backscattering cross sections S_a. During the night surveys 23 trawl hauls were performed in order to determine the species composition and length distribution of fish targets.
The paper describes the catch results and the spatial distribution of S_a in the investigated area. Estimations of fish abundance in the two boxes were compared with the results of the International Hydroacoustic Survey in October 1992 in the same area.

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1. Methods

The pelagic fish shows a distinct day night behaviour. At day-time it forms solid shoals close to the ground. During the dusk the shoals disintegrate and at nighttime the fish is more or less even distributed in the whole pelagic region. Fig. 1.2 shows this behaviour in quality by means of echograms.

The investigations were carried out in two rectangular boxes, each of 10 x 10 nm^2. The boxes were consecutive surveyed by hydroacoustic as well as hydrographic measurements and by fishery. The position of the boxes was chosen in a previous hydroacoustic survey and selected according to the maximum fish density and the hydrographic conditions. Figure 4.1. shows the position of the boxes. Each box was covered 3 times at night and 2 times at day. Box A was investigated in the time from November 4 to 8 with a break of technical reasons from November 6 - 7. Box B was captured in the period from November 8 to 10.

Hydroacoustic: For the hydroacoustic measurements the echo-sounder system EK500 with a working frequency of 38 kHz was used. The transducer 38-22 was mounted in a towed body to reduce fish reaction caused by the ship noise. The transects within the boxes were parallel with a distance of about 2.5 nm. The averaging distance along the measuring course was adjusted to 0.1 nm.
The S_a-values were recorded on harddisk in 50 layers of 1 m length in the surface referenced mode and in 20 bottom refer-enced layers with the same length. The high resolution was necessary on one hand for an evaluation in detail, but also for the cleaning of the data from interferences of plankton and echoes from the bottom.

Hydrography: After each haul a hydrography station was carried out. With a storage probe the temperature, conductivity and the pressure was measured and the salinity and the density was cal-culated. Fig. 1.1 shows typical temperature profiles in this area. The depth of the thermocline showed a high variability in time and changed from 30 to 37 m.

Fishing: Fishing was done only at night due to working time regulations. The pelagic trawls were carried out with the trawling gear "Kabeljaubomber". For ground trawls the trawling gear "Aalhopser" was used. Both nets had 10 mm mesh size in the cod end. The trawling time was 30 minutes. Per hydroacousic transect there was made one haul to determine the species composition and length distribution of the targets.

2 Horizontal distribution of S_a values

The area backscattering cross section S_a was investigated on south-north transects. Figure 2.1 shows the distribution of total S_a-values along transect 1 in box A measured during night on

November 4th. The transect started on latitude 54° 44'N in the shallow part of the area and lasted until 54° 54'N in the deeper part of Arkona Basin. Results from the same transect measured next day are depicted in fig. 2.2. At daytime the fish was concentrated in single shoals. This behaviour leads to a higher degree of variation in S_a values than in the more even distributed night concentrations. The general trend was quite similar in the deeper region north of 54° 48'N. A stronger disagreement appears in shallow water areas especially near the 40 meter depth line.
The variations in S_a night distributions on the same transect in box A during the time period from November 4 - 7 are demonstrated in fig. 2.3. The averaging interval was chosen to 0.5 mile in order to show the trend without short fluctuations. The strong increasing in the later surveys was observed in the hole area of box A.
An overview on spatial distributions of S_a from different surveys in box A is given in fig. 2.4. The upper part shows the results of night surveys while in the lower part daytime investigations are depicted. The values are averaged over 2.5 nm on the transects and the mean S_a is indicated for each line and column.
In box B the situation was also characterised by a high degree of variation in the horizontal distribution of S_a.

3. Vertical fish distribution

By the determination of S_a as a measure of the fish density by the echointegrator, it is possible to analyse the effect of vertical migration in quantity. For the representation of vertical distribution the S_a-values of the several depth has been sorted by recording time and water depth and then averaged. The daytime data consist of the readings taken from 10-14 o'clock while the nighttime data were recorded between 22 o'clock and 02 o'clock. The transition periods found no consideration. The fig. 3.1, 3.2, 3.4 and 3.5 are showing the vertical daytime and nighttime distributions of S_a respectively of box A and box B. Note that the data of fig. 3.1, 3.2, 3.4 and 3.5. are related to the bottom (the maximum depth is on the left side) while the data of fig. 3.3 and 3.6 are related to the surface (the maximum depth is on the right side). From the upper figure it is evident, that during daytime the fish was concentrated below the thermocline close to the ground.
Between bottom and the lowest layer a death zone occurs. The fish is overlapped by the bottom echo and for that reason a separation from the bottom echo is not possible. The supposition is obvious that a big part of the biomass was included in the death zone. This fact leads to an error of measurement of course.
The fig. 3.3 and 3.6 are showing the differences between day and night S_a-values versus the water depth. Only close to the ground and at the occurrence of big schools in the pelagic region the S_a-values are higher at daytime than that at night.
The fig. 3.7 shows the night-day-ratio of the total S_a versus the depth. In the shallower areas the night values had a strong variation and were sometimes considerable higher, while in the

deeper areas the night-day-ratio is between 1 and 3. Therefore at daytime the biomass will be underestimated in shallow areas. In the deeper areas the correction of the day values seems to be possible.

4. Results of the trawl hauls

A total of 23 trawl hauls were made during the survey, 13 pelagic trawl stations and 10 stations with the bottom trawl. The positions of the trawl stations and the catch compositions of the main species herring and sprat are depicted in fig 4.1. The catch results per half an hour trawling time are summarised in table 4.1.
The water column was separated into two parts by a discontinuity of temperature which was found in depth of 30 to 37 meters. Both layers were investigated by pelagic or ground hauls. The catch ratio of the main species of box A is presented in table 4.2. The proportions were different in the separated layers but independent of depth. The variability of the proportions was low.
Table 4.3 shows the results of box B. In contrast to box A there was no herring in the upper layer. The results of the two layers differ in the proportions of the age group zero of sprat. Only low numbers were found in the hauls in the upper layer. In the layer below the discontinuity the proportion of sprat of age group zero increased with the catch in number of this age group.
Within the layers the proportions of the main species were independent of depth and the variability was also low.

5 Estimation of fish abundance

The calculations were made in two different depth layers separated by the mean depth of thermocline, one layer covered the upper 30 meters the other one the lower part from 30 meter depth to the bottom.
The estimation of abundance was based on the mean values of S_a and backscattering cross section of the targets in the whole box for each survey. The backscattering cross section of the "mean" fish in the stratum was calculated according to species compositions and length distributions from trawl hauls in the layer concerned using the TS-length relations:

$$TS = 20 \log L\,(cm) - 70.8\ dB \qquad \text{(Lassen \& Staehr, 1985)}$$
$$TS = 20 \log L\,(cm) - 67.5\ dB \qquad \text{(Foote, 1985).}$$

Trawl results were available only for night surveys. TS values and species compositions for the daytime surveys were supposed as the mean value from the previous and next night trawling.
The total number of fish in the two depth layers was allocated to the main species herring and sprat - both species divided in 0 group and 1+ group. Estimation results are summarised in table 5.1 and 5.2 for box A and B respectively.
The abundance of fish in the lower layer was rather similar in all

surveys while the abundance in the upper layer shows strong fluctuations and caused the great difference in fish abundance between box A and B. This situation is presented in fig. 5.1 and 5.2.
It may be of interest to compare these results with the abundance of fish determined during the International Hydroacoustic Survey in the Baltic in October 1992. On this survey in ICES square 3857 - this square includes the two boxes - a mean fish density of 3.65 millions fish per square mile was estimated. The mean value of fish density over all surveys in box A and B is 3.69 millions per square mile. Of course, the agreement of this numbers is a pure chance.

6. Conclusions

During the investigation a strong variability of day and night S_a-values was found. In the shallow areas the night values were generally considerable higher, while in the deeper areas the night-day-ratio was low. The results are doubtful if the daytime S_a-values in shallow water areas are used for the estimation of the biomass. Therefore hydroacoustic measurements at daytime in shallow water regions are not recommended. In the deeper areas the correction of the day values seems to be possible, but a constant factor can't be given.
The spatial distribution of the S_a-values shows a high degree of variation in time. Therefore a short survey time is necessary to get a synoptic picture of the real fish distribution.
The species composition and the density distribution is strong related to the depth. The thermocline forms a boundary for the living areas of different fish concentrations. Therefore a depth stratification is recommended to get better estimates of fish abundance.

7. References

Foote,K.G., Aglen,A. and Nakken,O. (1986). Measurement of fish target strength with a split-beam echosounder. - J. Acoustic. Soc. Am. 80(2): 612-621

Lassen,H. and Staehr,K.-J. (1985). Target strength of baltic herring and sprat measured in-situ. - ICES C.M. 1985/B:41

Box A	Pelagic Hauls							Ground Hauls					
Fish species\Haul-Nr.	23	24	27	29	30	32	34	25	26	28	31	33	total
Sprattus sprattus	1.6	16.6	31.9	28.6	41.8	30.0	53.6	86.5	63.8	74.5	75.5	44.6	549.0
Clupea harengus	10.7	42.8	56.2	99.2	98.4	155.2	17.9	1.3	3.3	0.5	6.7	4.5	496.7
Gadus morhua	0.9	2.5	2.9	2.9			2.9	7.5	4.7	16.2	12.0	12.0	64.5
Merlangius merlangus	0.1	0.7		2.1	0.3		1.2	1.8	8.0	1.1	8.2	3.3	26.8
Platichthys flesus								2.0	1.4		5.2	6.2	14.8
Pleuronectes plat.								8.3		1.2		3.4	12.9
Lota lota								1.5	1.9	1.1	5.2	0.8	10.5
Pomatoschistus minutus	+	0.2	+	0.1	0.1		0.3	0.5	3.0	2.0	1.9	0.5	8.6
Gasterosterus aculeatus	0.1		0.3	0.1	0.3		+	0.1	0.5	+			1.4
Psetta maximus								1.0		1.2	1.3		3.5
Stizostedion lucip.				0.2									0.2
Trachurus trachurus	+							0.1		+			0.1
Anguilla anguilla								0.5		1.2			1.7
Pollachius virens													0.0
Cyclopterus lumpus													0.0
Zoarces viviparus										+	0.5		0.5
Limanda limanda											0.2		0.2
Scomber scombrus													+
Solea solea									+				+
Osmerus eperlanus													+
Ammodytes spec.													+
total	13.4	62.8	91.3	133.2	140.9	185.2	75.9	111.1	86.6	99.0	116.7	75.3	1191.4

Box B	Pelagic Hauls						Ground Hauls						
Fish species\Haul-Nr.	35	37	38	40	43	45	36	39	41	42	44		total
Sprattus sprattus	87.8	22.0	152.1	146.1	36.4	5.0	80.6	48.8	5.6	61.9	109.6	755.9	1304.9
Clupea harengus	18.8	3.0	6.7	16.4	5.2	6.3	0.5	0.2	1.1	0.2	0.2	58.6	555.3
Gadus morhua		0.7		1.3			13.2	16.2	27.9	8.0	32.1	99.4	163.9
Merlangius merlangus	0.5	0.9	0.4	0.3	0.2	0.1	17.1	1.6	1.9	6.7	9.8	39.5	66.3
Platichthys flesus	0.5						3.4	5.8	13.8	8.4	6.5	38.4	53.2
Pleuronectes plat.		0.4					1.1	1.3			1.3	4.1	17.0
Lota lota							0.5	1.6	0.8	0.4	0.4	3.7	14.2
Pomatoschistus minutus	+				0.2	+	0.8	0.6	0.3	0.7	0.6	3.2	11.8
Gasterosterus aculeatus	+	1.5	7.6		+	+		0.1	+	0.4		9.6	11.0
Psetta maximus								0.5	2.2			2.7	6.2
Stizostedion lucip.	0.8	0.6	1.0	0.3					1.0	2.3		6.0	6.2
Trachurus trachurus	+	+					3.8	0.4		0.7	0.2	5.1	5.2
Anguilla anguilla								0.8	1.0			1.8	3.5
Pollachius virens						1.8						1.8	1.8
Cyclopterus lumpus		0.2			0.2		0.5					0.9	0.9
Zoarces viviparus										0.1		0.1	0.6
Limanda limanda											+	0.0	0.2
Scomber scombrus								0.1				0.1	0.1
Solea solea												+	+
Osmerus eperlanus											+	+	+
Ammodytes spec.												+	+
total	108.4	29.3	167.8	164.4	42.2	13.2	121.5	78.0	55.6	89.8	160.7	1030.9	2222.3

Table 4.1: Catch composition in kg / 0.5 hour for box A and box B

Night	Haul typ	Number	HE0	HE1	SP0	SP1
1	pelagic	2	24.0	25.0	14.0	27.5
2	pelagic	3	14.7	25.0	23.0	33.7
3	pelagic	2	7.0	19.5	30.0	42.0
Mean			15.1	23.4	22.4	34.0
Standard deviation			7.9	11.2	10.4	10.3
1	ground	2	0.0	0.0	18.5	58.5
2	ground	1	0.0	0.0	4.0	64.0
3	ground	2	1.0	0.5	2.5	69.0
Mean			0.4	0.2	9.2	63.8
Standard deviation			1.0	0.4	11.3	17.7

Table 4.2: Catch in proportion of the main species of box A

Night	Haul typ	Number	HE0	HE1	SP0	SP1
1	pelagic	3	0.3	1.3	34.7	48.3
2	pelagic	1	1.0	1.0	20.0	78.0
3	pelagic	2	3.5	5.5	35.5	50.0
Mean			1.5	2.7	32.5	53.8
Standard deviation			2.3	4.1	11.4	18.4
1	ground	1	0.0	0.0	2.0	78.0
2	ground	3	0.3	0.0	6.0	60.0
3	ground	1	0.0	0.0	2.0	78.0
Mean			0.2	0.0	4.4	69.2
Standard deviation			0.4	0.0	2.5	21.2

Table 4.3: Catch in proportion of the main species of box B

Layer		AN4	AD5	AN5	AN7	AD8
O-30m	Sa	236.8	51.6	425.7	466.0	132.0
	TS	2.3	2.22	2.13	2.18	2.18
	NHe0	26.9	4.5	36.9	16.3	4.2
	NHe1+	28.0	5.8	62.8	45.3	11.8
	NSp0	15.7	4.3	57.7	69.7	18.1
	NSp1+	30.8	7.1	84.6	97.6	25.4
30m-bot.	Sa	215.2	228.4	262.3	433.0	524.0
	TS	1.46	1.64	1.81	2.13	2.13
	NHe0	0.0	0.0	0.0	2.2	2.5
	NHe1+	0.0	0.0	0.0	1.1	1.2
	NSp0	29.7	15.7	7.3	5.5	6.2
	NSp1+	94.0	85.5	116.2	152.8	169.8

Tab 5.1 Estimated numbers (millions) of main species in different layers in box A

Layer		BN8	BD9	BN9	BD10	BN10
O-30m	Sa	638.9	328.8	585.8	120.8	756.5
	TS	1.22	1.38	1.54	1.55	1.56
	NHe0	1.6	1.5	3.8	1.7	16.9
	NHe1+	6.8	2.7	3.8	2.5	26.6
	NSp0	181.8	65.1	75.9	21.6	171.8
	NSp1+	253.1	150.3	295.9	49.7	241.9
30m-bot.	Sa	335.0	173.5	502.3	492.8	512.0
	TS	1.79	2.02	2.26	2.12	1.98
	NHe0	0.0	0.1	0.7	0.3	0.0
	NHe1+	0.0	0.0	0.0	0.0	0.0
	NSp0	3.7	3.4	13.4	9.3	5.2
	NSp1+	145.9	59.2	133.6	172.3	228.1

Tab 5.2 Estimated numbers (millions) of main species in different layers in box B

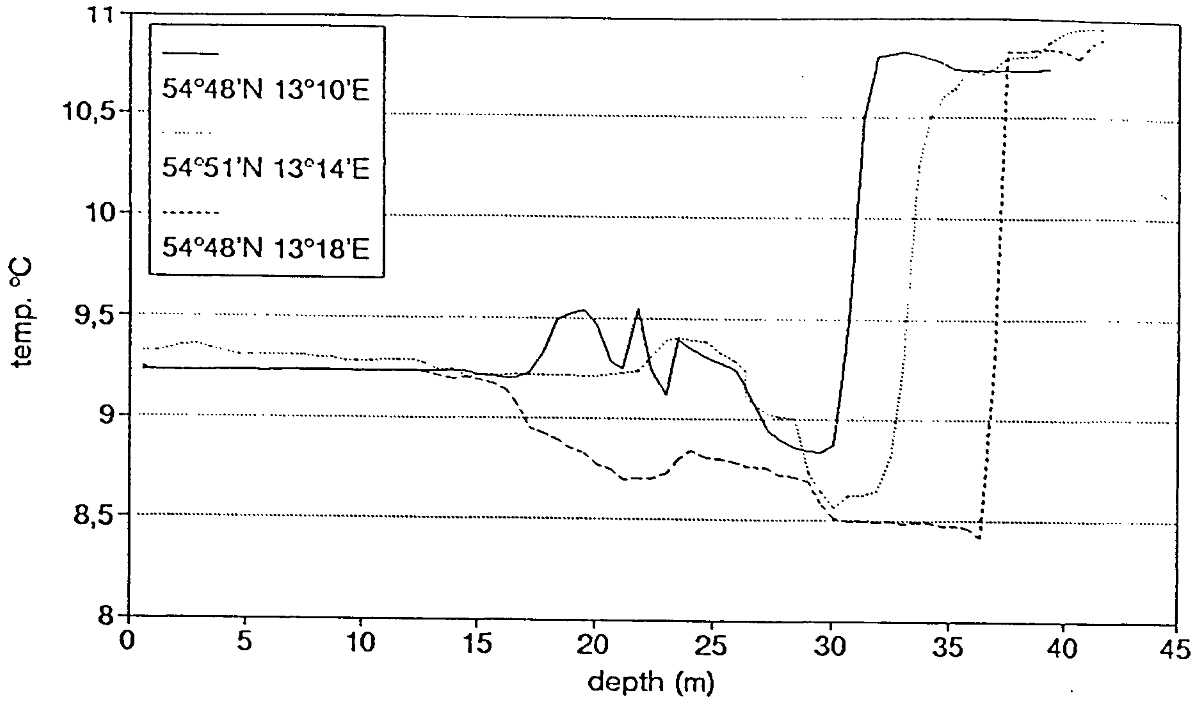
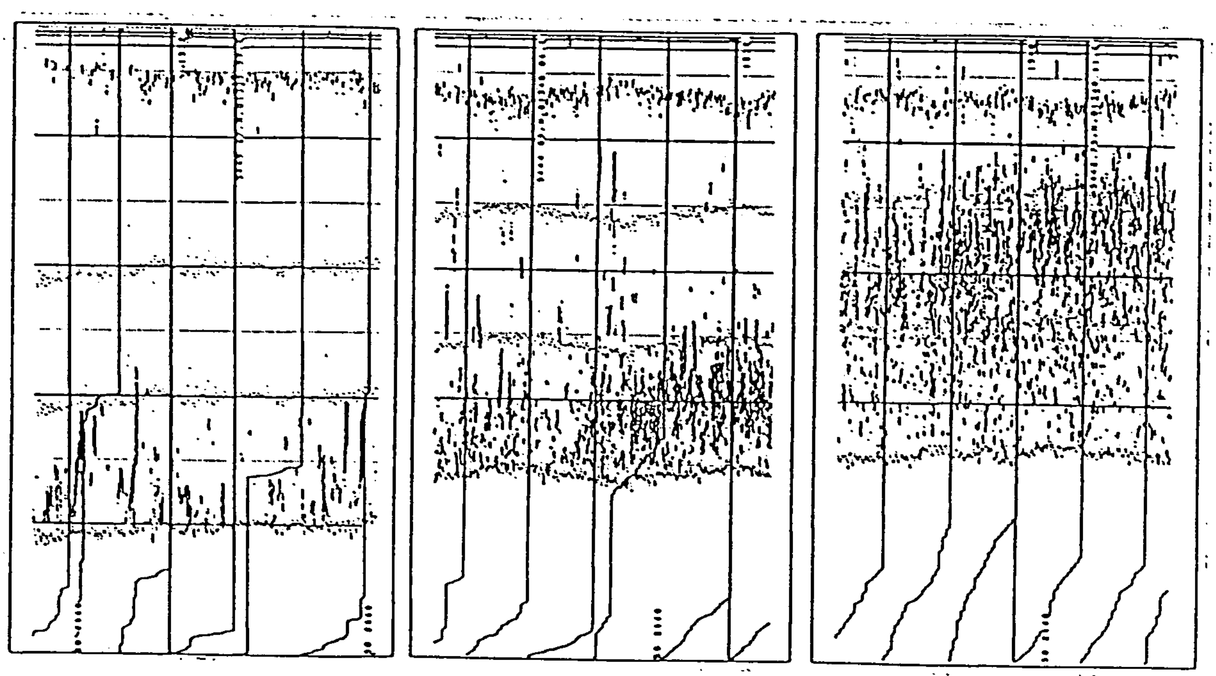


Fig. 1.1 Temperature profiles in box A on 5 November 1992



Day Dusk Night

Fig. 1.2 Typical echotraces of fish concentrations during the survey

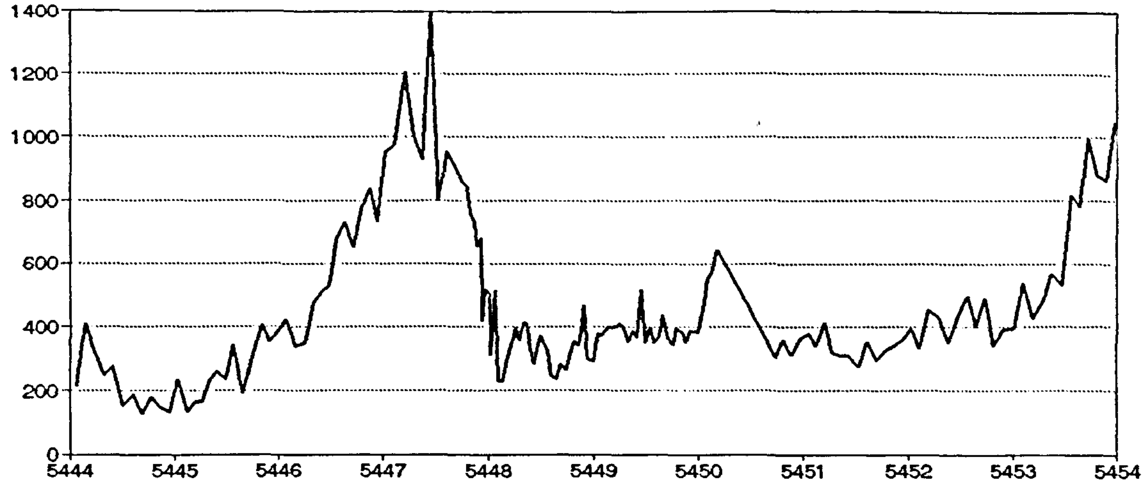


Fig. 2.1 Sa distribution on transect A1 during night survey

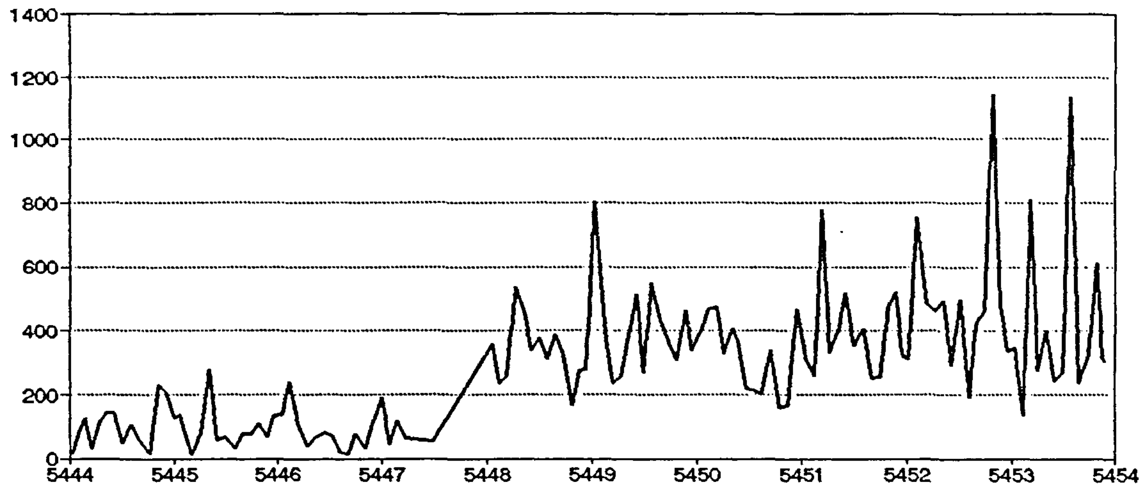


Fig. 2.2 Sa distribution on transect A1 during the next day survey

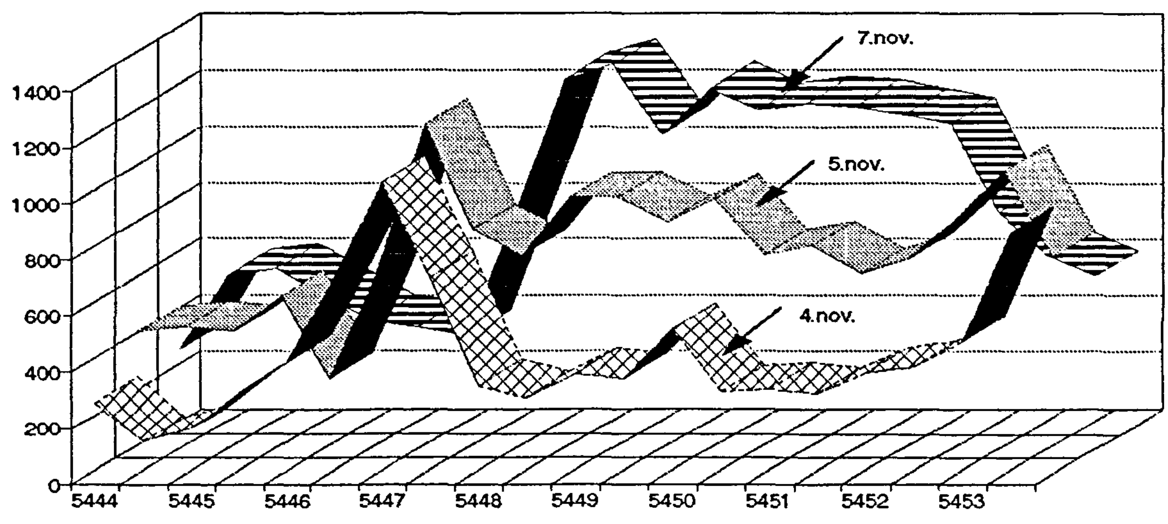
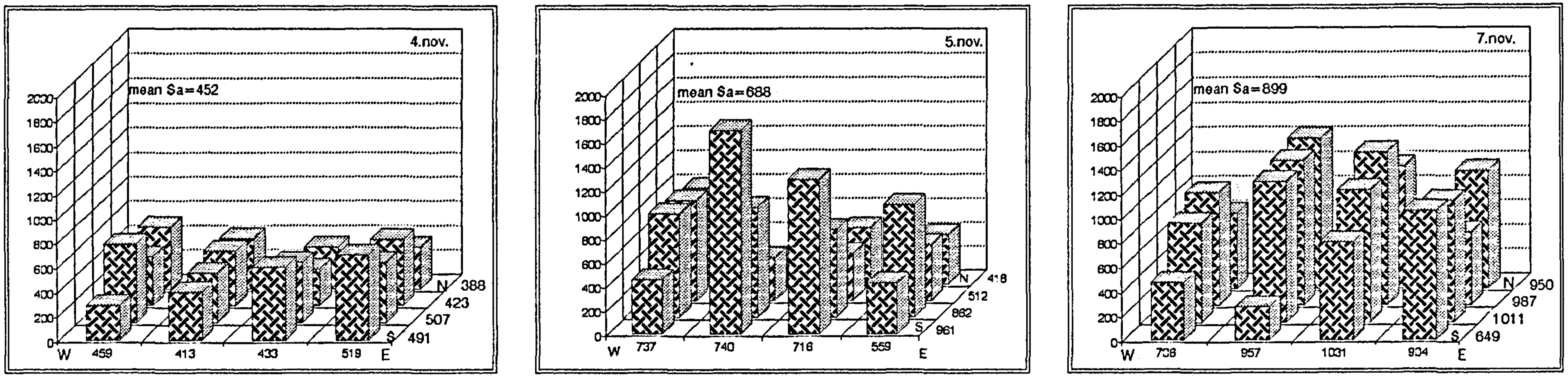
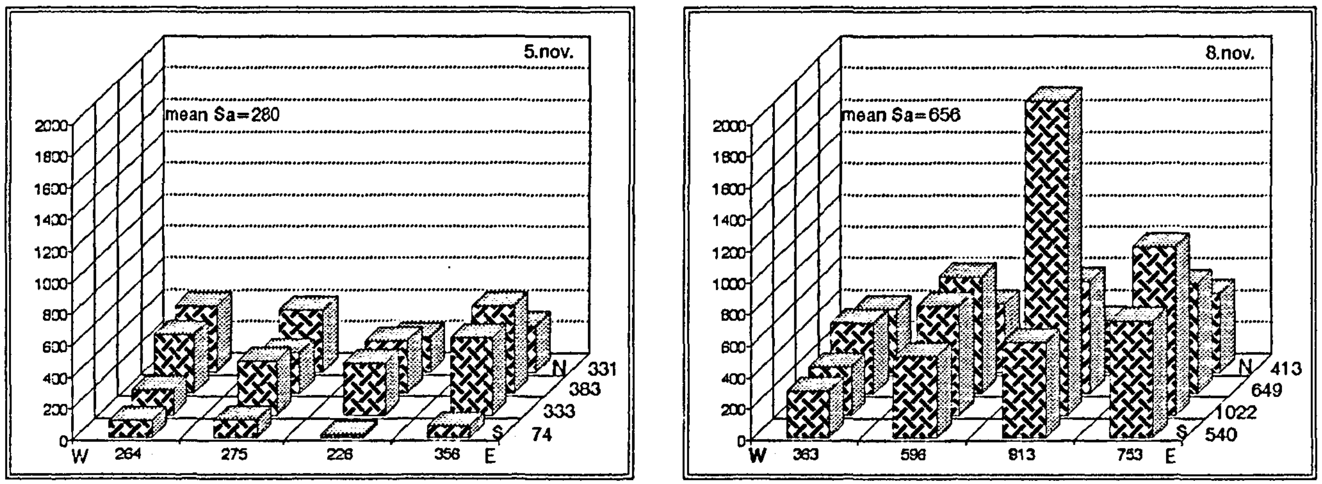


Fig 2.3 Variations in the Sa distribution of transect A1 during different night survey

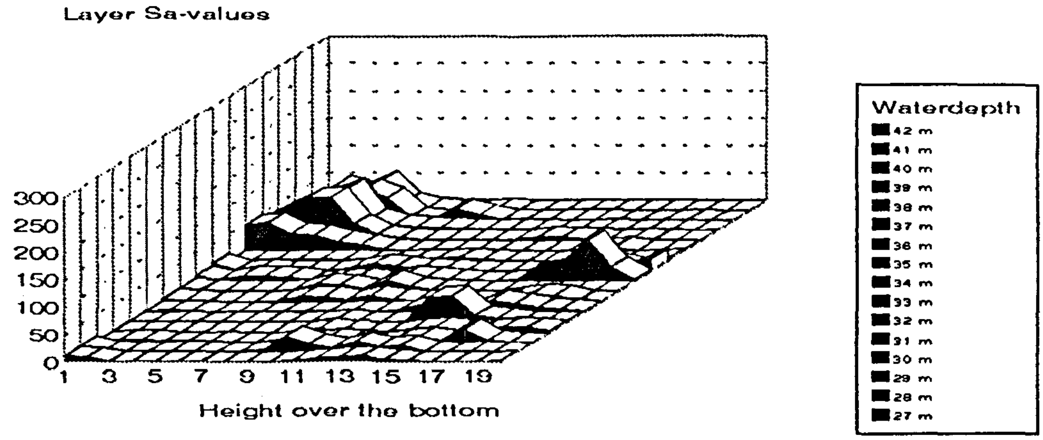


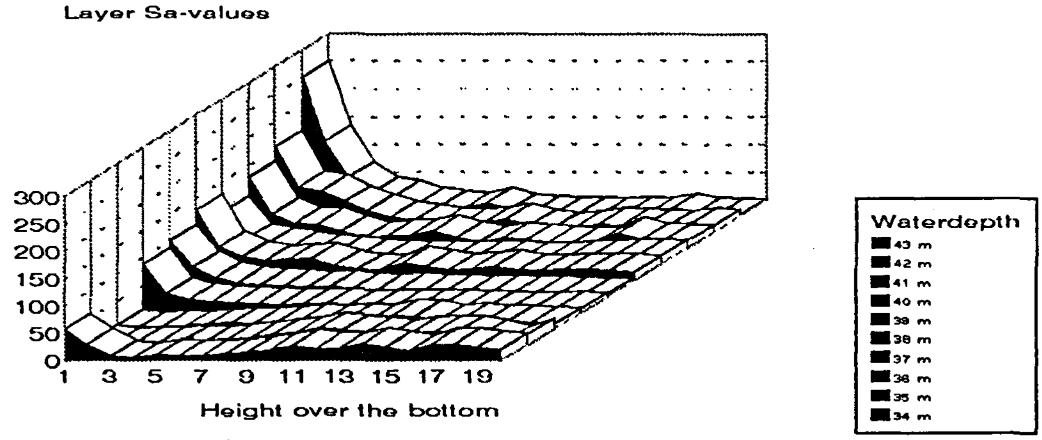
Sa distribution during night



Sa distribution during day

Fig. 2.4. Spatial distribution of Sa mean values in box A





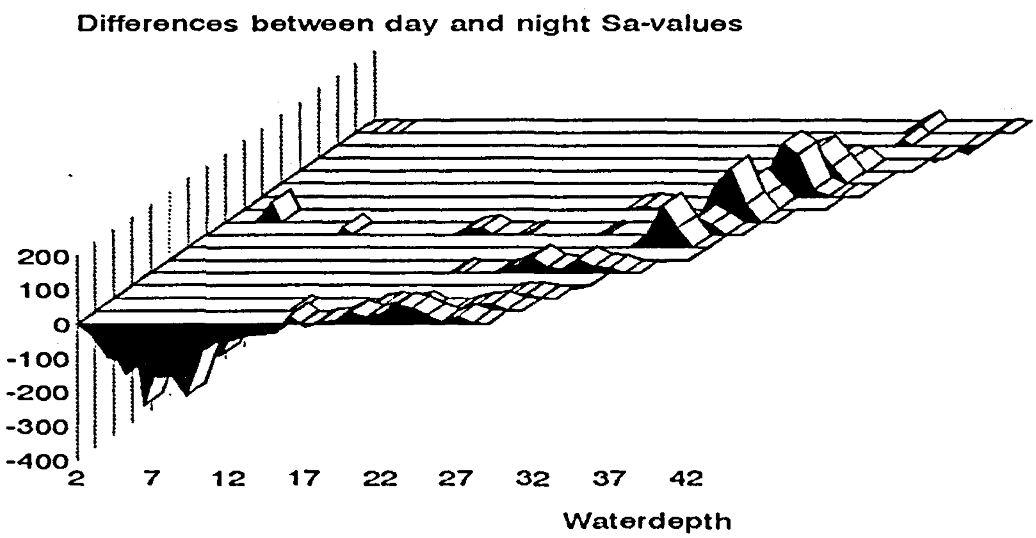
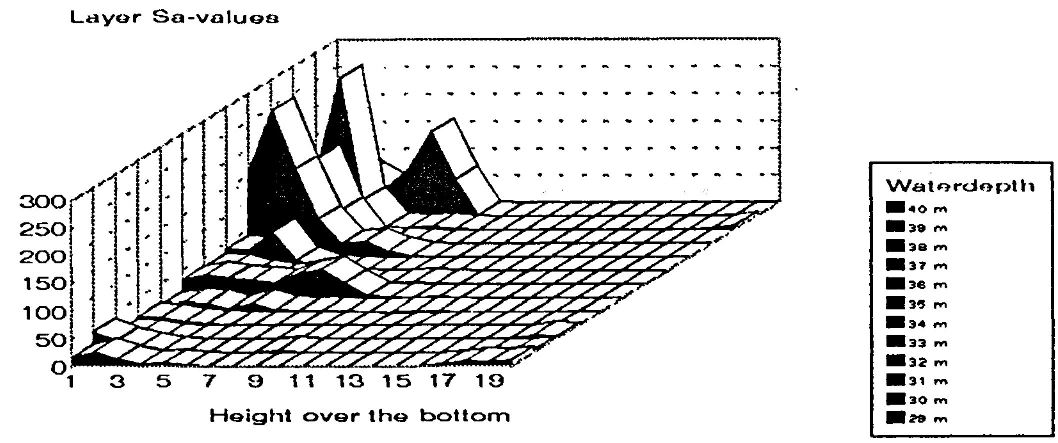
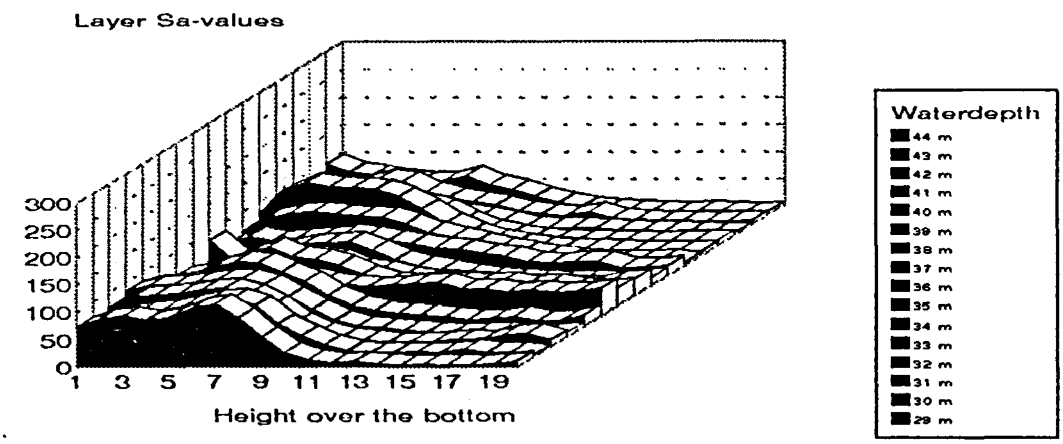


Fig. 3.1 and 3.2: Day and night Sa-values vs the height over the bottom of box A

Fig. 3.3: Differences between day and night Sa-values vs water depth of box A





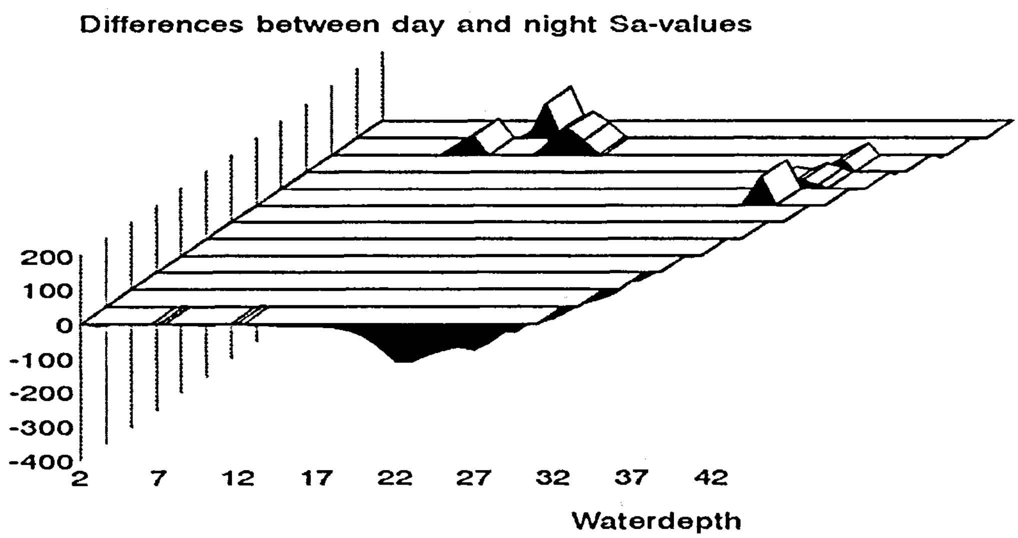


Fig. 3.4 and 3.5: Day and night Sa-values vs the height over the bottom of box B

Fig. 3.6: Differences between day and night Sa-values vs water depth of box B

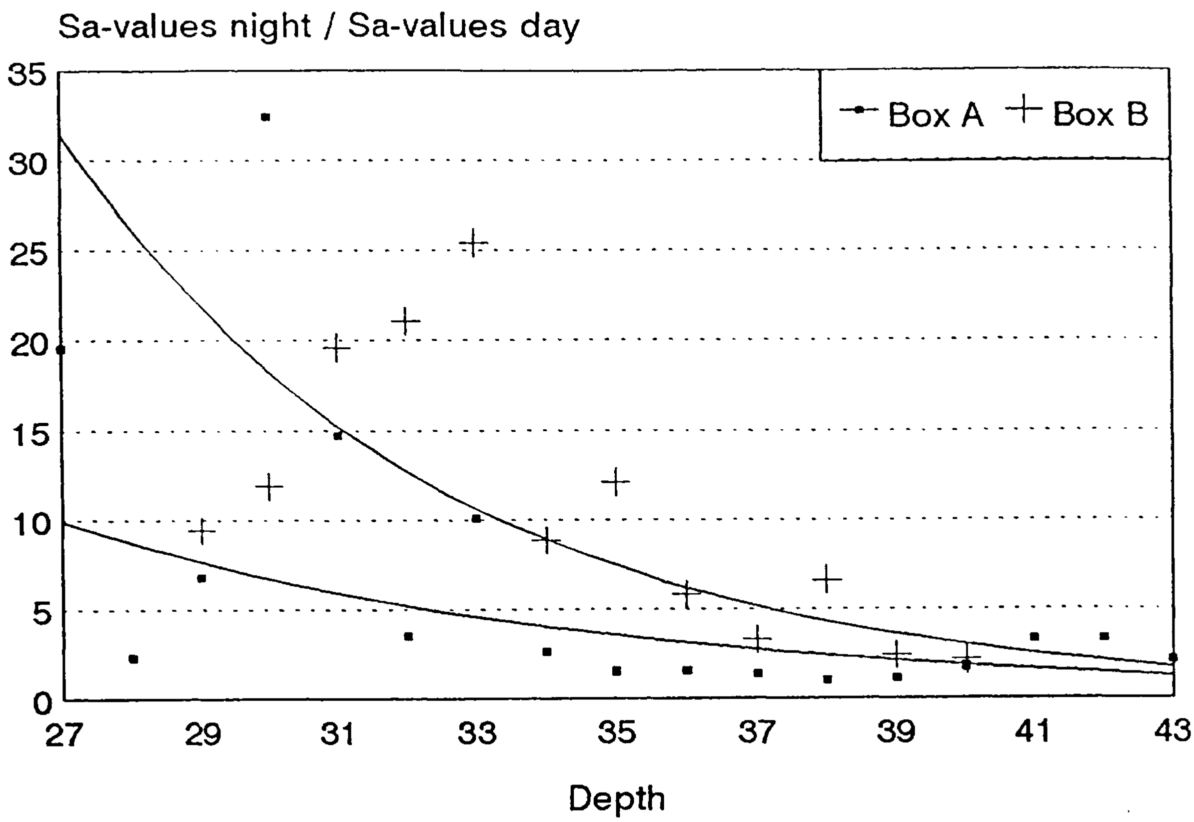


Fig. 3.7: Ratio of nighttime and daytime Sa-values vs waterdepth

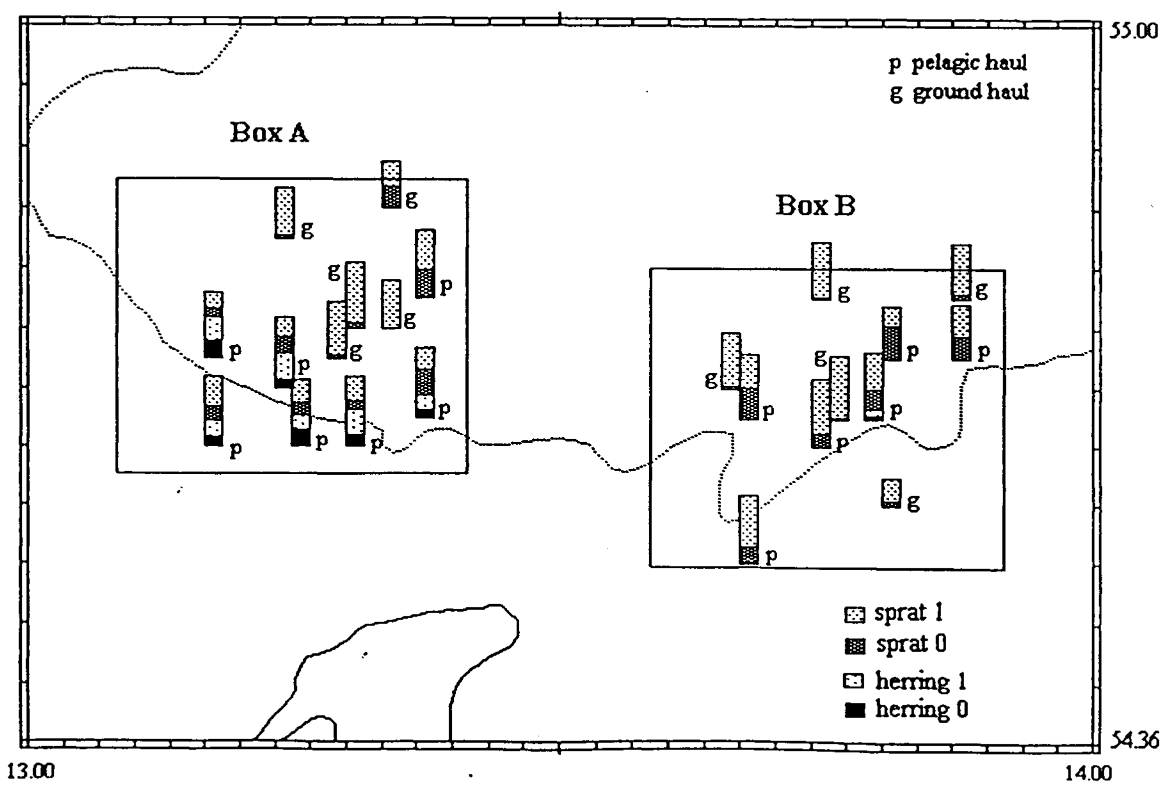


Figure 4.1: Catch composition of hauls

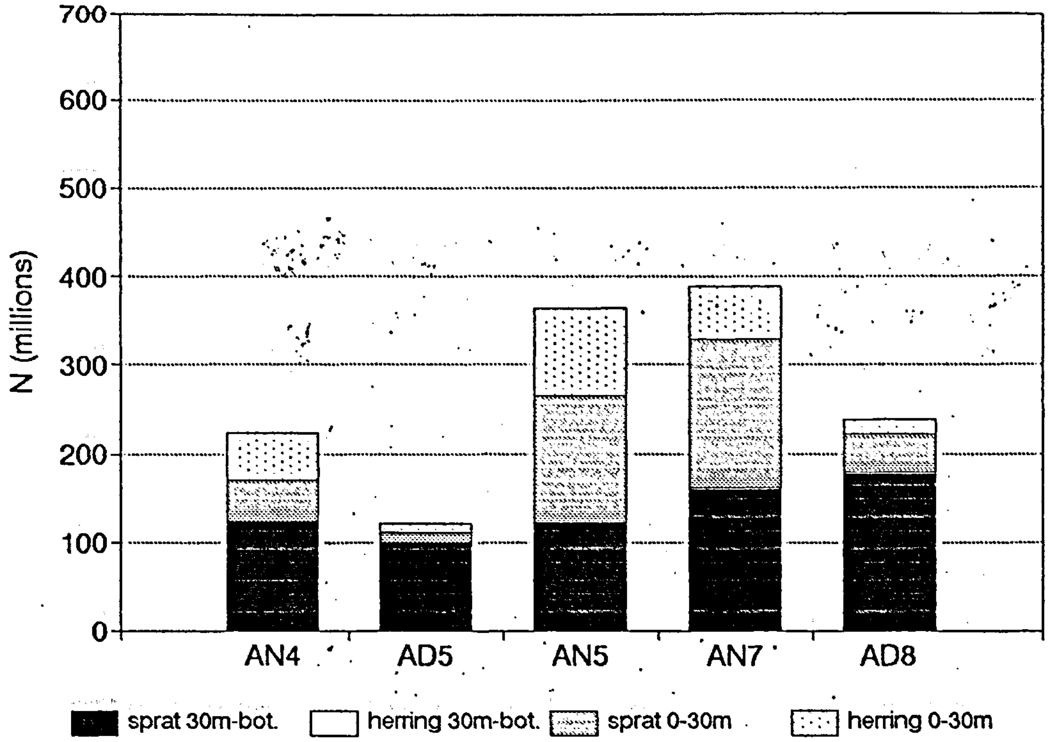


Fig.5.1 Estimated numbers of herring and sprat in box A

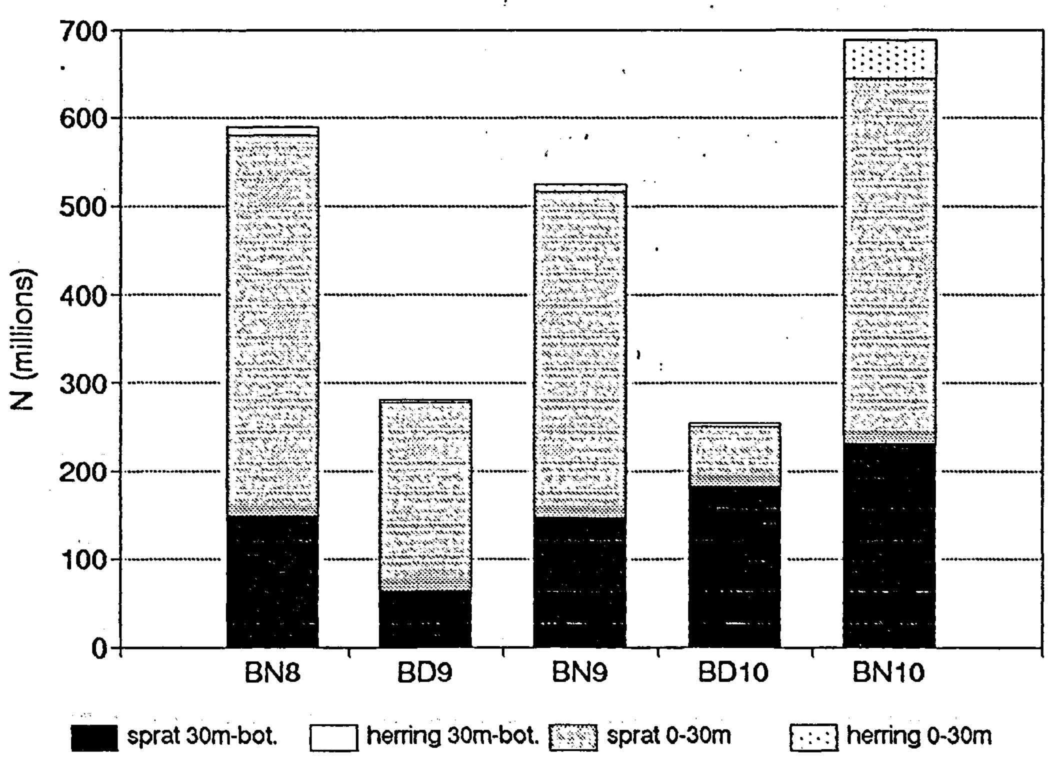


Fig.5.2 Estimated numbers of herring and sprat in box B