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ABUNDANCE ESTIMATION OF SCHOOLS USING A FISHERIES SONAR

by

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ABSTRACT

An attempt of abundance estimation of fish schooling close to surface using sonar was conducted in Eastern North Sea - Skagerrak in September 1990. The method is based on measurements of the school area by the Furuno CSH-70 sonar and purse seine capture of schools to establish a school-area to school-biomass relationship. In the actual region, the biomass of herring and mackerel was estimated to about 90 000 ton and 430 000 ton, respectively. The accuracy of the method is discussed and improvements suggested.

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INTRODUCTION

Conventional acoustic abundance estimation of fish schooling close to surface may be difficult due to vessel avoidance (Olsen 1987) and the upper blind zone of the echo sounder (Aglen 1989). Use of horizontal guided sonar can cope with these problems (Anon. 1974), but relationships to convert school target strength to school biomass have not been established (Hewitt et al. 1976). Misund (1988; 1990a) and Misund et al. (1990) have demonstrated that relationships exist between the geometric dimensions and biomass of schools. Based on acoustic dimensioning by sonar, this principle can be applied for abundance estimation of schooling fish.

In the North Sea, regular acoustic surveys are conducted to map the distribution and estimate the abundance of herring (Kirkegaard et al. 1990). There have been attempts of conventional acoustic surveys for mackerel also (Degnbol et al. 1988), but the classification of echo recordings was connected with great uncertainties. The mackerel is usually difficult to catch with standard sampling trawls, especially when it is schooling close to surface in summertime (Aglen and Misund 1990). There are also uncertainties connected to the target strength established for mackerel (MacLennan et al. 1989). The abundance of mackerel is therefore mainly estimated by indirect methods as egg surveys, catch data analysis and tagging experiments (Anon. 1990).

In 1990, a program was initiated to map the distribution of mackerel in the Norwegian ecomomic zone. Several surveys were carried out by hired, commercial purse seiners. On each survey recorded schools were counted from sonar recordings, and the species identification was conducted by purse seining or using hand lines.

In one of the surveys, an attempt was made to estimate the abundance of schooling fish using a fisheries sonar (Furuno CSH-70) to measure the area of recorded schools. The school biomass was estimated from a relationship between school area and biomass established by purse seine capture of sonar measured schools.

MATERIAL AND METHODS

The survey was carried out in the Skagerrak/Eastern North Sea area (Fig.1) by M/V "Endre Dyrøy" (799 GRT), well equipped with acoustic instruments for fish detection (Table 1) and a herring purse seine (735 x 167 m).

The upper 40 m of the water column was searched for schools during daytime by operating the Furuno CSH-70 sonar in a 180° mode with a 400 m search radius and a tilt angle of 5°. The gain functions of the sonar were given a setting (Table 2) that, according to the skipper's experience, was favourable for mackerel recording. A relative estimate of each school recorded was obtained by using the estimate function of the sonar when the schools were in the range interval og 100 m to 300 m away from the vessel. The estimate function gives a relative size from 0 to 100 of a recording within an octogonal area with cross-section equal to 1/4 of the search range choosen (Fig. 2). The relative estimate (a') is a function of the extent and target strength of the school. By assuming circular school shape and proportionality between school target strength and school area, an estimate of school area can be calculated by;

$$
\begin{aligned}
A'\ (m)^2 &= a' * s \\
&= 2(R_i * LW' * n * \tan(\varphi/2)) \\
LW\ (m) &= A'/2(R_i * n * \tan(\varphi/2)) - ct/2 \\
A\ (m)^2 &= \pi/4 * (LW)^2
\end{aligned}
$$

s	=	scaling factor (for search range = 400 m: 8850/100)
R_i	=	horisontal vessel-to-school distance (m)
LW	=	school diameter (m)
n	=	number of beams covered by the school projection
φ	=	horizontal beam-width of the sonar (6°)
c	=	speed of sound (m/s)
t	=	pulse-length (ms)

The classification of the recorded schools to species was mostly done acoustically by a qualitative judgement of the frequency response of the sonars or the dual frequency echo-sounder (Table 3). Species identification was also done by fishing with hand lines when the vessel was manoeuvred on top of recorded schools and by purse seining of selected schools.

For schools captured by purse seine, the relationship between school area and school biomass were investigated. The sonar picture was video taped during circling of these schools, and their area measured by a ruler on the screen by still picture playback as described by Misund (1990a). The biomass of whole schools caught was estimated from the volume occupied in the holding tanks, and control-measured during delivery.

The biomass of recorded schools was estimated using the area-to-biomass relationship established to convert the school area estimate to school biomass. The sailed distance, area searched, and total recorded school biomass were estimated for statistical squares of 30 x 30 nm (Fig. 1). By multiplying the total recorded biomass with a real-to-searched area proportion for each square, an estimate of the total biomass in these squares was obtained.

The horizontal beam-width of the Furuno CSH-70 transmitter is not explicitly stated as the operator manual claims it to be adjustable in the interval 5° to 10°. According to Misund (1990b), measurements of schools should be corrected for a horizontal beam-width that results in a range dependent proportion between the crosswise and lengthwise extent of the school projections. The measurements of crosswise extent for the schools selected for purse seine capture were therefore corrected for beam-widths in the actual interval, and the effects on the crosswise-to-lengthwise proportion studied (Table 4). Range independence was obtained at beam-widths of 5° and 6°, and in the following analyzis a horizontal beam-width of 6° is used.

RESULTS

Measurements on two herring schools (mean fish length 22 cm, Fig. 3) circled in Skagerrak confirmed the basic assumption of proportionality between the school area and the relative abundance estimate (Fig. 4), as there was a significant correlation between the school area and the Furuno estimate ($r=0.58$, $p<0.001$, $n=67$). The second assumption of circular school shape was acceptable for the circled herring schools (average crosswise-to-lengthwise proportion = 1.22, Table 4), but not for the mackerel schools (mean fish length 37 cm, Fig. 3) circled during purse seining (average crosswise-to-lengthwise proportion=1.92).

There was a clear relationship between the area and biomass of eight mackerel schools from 14 to 300 tons caught by purse seine (Fig. 5). The area of a 10 ton herring schools fits well to this relationship also. As indicated by the area of a 12 ton horse mackerel school (mean fish length 28.9 cm, Fig. 3), this species seems to organize schools with a smaller biomass per unit area than herring and mackerel (Fig. 5). The relationship between school area and school biomass for the herring and mackerel schools is expressed by;

$$\log(\text{Biomass}) = 1.329 * \log(\text{School area}) + 0.428 \qquad r=0.94$$

This relationship is used for the conversion of school area estimates to school biomass for the schools recorded during the sonar survey.

Mackerel schools were recorded along the coast of Southern Norway, in Skagerrak only a few herring schools were detected, while both herring, mackerel and horse mackerel schools were recorded in the Eastern North Sea. Most of the recorded schools were rather small (Fig. 6), and average school area was 300 m^2 and 220 m^2 for the herring and mackerel schools, respectively. This corresponds to average biomasses for the herring and mackerel schools of 7.5 tons and 5.5 tons, respectively. Average school biomass differed from one statistical square to another (Table 5). The average school area (565 m^2) of the few horse mackerel schools recorded was larger than that of herring and mackerel, but their average biomass was smaller (2.1 tons).

Based on the sonar recordings, the total abundance of herring was estimated to 30 000 tons in Skagerrak and 60 000 tons in the Eastern North Sea (Fig.7, Table 6). Only a small amount of mackerel seemed to be present in Skagerrak (Fig.7), but the total estimate for the Eastern North Sea was 430 000 tons (Table 5).

DISCUSSION

The school-area to school-biomass relationship established for mackerel fits well to a similar relationship reported by Misund (1988) on the basis of sonar measurements and subsequent purse seine capture of mackerel schools by M/V "Libas" in 1986 and a single observation by R/V "Fjordfangst" in 1987 (Fig. 5). These relationships indicate a biomass of 25 ton for a school of 1000 m^2, which is also comparable to the level of a relationship established by a similar method for North Sea herring (Misund 1990).

The area-to-biomass relationships estimated by purse seine capture of sonar measured schools give estimates about 5 times that of area-to-biomass relationships established by echo integration of sonar measured schools (Misund et al. 1990). This discrepancy may be the result of different sampling strategies, as the few schools singled out for purse seining may be larger and denser than average, while most schools recorded have been included in relationships established by echo integration. If this is the case, the abundance of herring and mackerel is severely overestimated. However, most sources of errors connected to the echo integration method tend to result in underestimated fish densities (Aglen 1989), especially of schools due to absorption (Toresen 1991).

A major uncertainty with the applied method is the estimation of school area. The assumption of circular schools is not met, at least for the mackerel schools. School shape is dependent of swimming depth, with more circular schools midwater and flattened discoides close to surface and bottom (Misund 1990b). Squire (1978) argues that circular school shape is rather uncommon in nature. Basing the estimation of school area to an assumtion of circular school shape is therefore not satisfactory. An alternative would be to use a relation between school area and the relative Furuno estimate directely. Unfortunately, this was not possible during this survey, as the comparisons between independently measured areas of some herring schools and the corresponding Furuno estimates were obtained at a shorter sonar range than used during the survey.

Despite intensive sampling and frequency response judgement of the recorded schools, allocation to species could be difficult. This is illustrated by the fact that a large school assumed to be mackerel turned out to be 12 ton horse mackerel when caught by the purse seine. In some of the areas covered, a significant amount of the schools was probably misjudged to be mackerel instead of horse mackerel. The abundance of herring is also underestimated, as herring schools close to bottom were frequently recorded by the echo sounder but not by the horizontal guided sonar.

A critical procedure is also the in situ classification of recorded targets, especially under difficult sonar conditions with much surface reverberation. In such situation, the vessel speed was reduced to enhance the probability of detecting and classify targets.

The potential of this method is as a supplement to conventional echo integration to record the abundance of fish schooling close to surface. The method may be improved by an algorithm for automatic detection and area measurements of the schools applied on a sonar with narrow horizontal beam-width (Misund 1991).

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Table 1. Acoustic instruments, M/V "Endre Dyrøy".

		kHz	Beamwidth (-3 dB)	PulseL(ms)
Sonar	Furuno CSH-70	180	5-10° x 6° a)	5 (400m)
	Simrad SU	24	8.5° x 9° a)	15 (1250m)
Echo	Skipper CS 119	200		
Sounder		50		
	Simrad EQ 50	49	8° x 18° b)	1.3

a): horizontal x vertical
b): alongship x athwartship

Table 2. Setting of the Furuno CSH-70.

Function	Interval	Choice
TVG NEAR	0 - 9	0
MEDIUM	0 - 9	5
FAR	0 - 9	5
Gain	0 - 9	7
AGC	0 - 9	2
HOR	0 - 9	0

TVG: Time varied gain
AGC: Automatic gain control
HOR: Horizontal beamwidth adjustment

Table 3. Criteria for qualitative frequency response judgement (colour scale: weak echo: grey or green; medium echo: yellow; strong echo: black or red).

Instrument	Frequency (kHz)	Mackerel	Horse mackerel	Herring
Simrad SU	24	grey	black	black
Furuno CSH-70	180	red (yellow)	red	red
Skipper CS 119	50	green	red (yellow)	red
	200	red	red	red

Table 4. Average crosswise/lengthwise (CW/LW) extent of the schools related to beam-width and distance (r_S: Spearman rank correlation coefficient for CW/LW and distance).

Beamwidth	Herring			Mackerel		
	CW/LW	r_S	N	CW/LW	r_S	N
5°	1.35	-0.10	68	2.00	0.16	81
6°	1.22	-0.14	68	1.92	0.15	81
8°	0.98	-0.25*	68	1.75	0.11	81
10°	0.73	-0.40*	68	1.62	0.04	81

* $p < 0.05$

Table 5. Biomass estimates for herring and mackerel in Skagerrak and Eastern North Sea, September 1990. (x: average school size; Σ: total estimate; RA: area of statistical square; SA: searched area.)

Square	Sailed distance (nm)	Searched area (nm2)	RA/SA	N	Herring Biomass (ton) x	Herring Biomass (ton) Σ	N	Mackerel Biomass (ton) x	Mackerel Biomass (ton) Σ
Skagerrak									
0916	28	9.07	50.00	2	21.0	2107	7	0.3	99
0917	80	25.92	34.23	15	7.4	3797			
0914	48	15.55	57.88	53	3.5	10860			
0910	20	6.48	138.89	-	-	-			
0913	52	16.851	53.41	14	11.0	8237	19	0.3	275
0909	67	21.712	41.46	18	7.1	5314			
Σ				102		30315	26		374
North Sea									
0802	33	10.69	42.10	1	0.2	10	111	1.7	8166
0801	50	16.20	55.56				119	3.5	23214
0817	20	6.48	48.23						
0925	13	4.21	213.76				40	1.6	13470
4177	32	10.34	87.04						
4167	14	4.54	198.24						
4176	37	11.99	75.06				3	0.9	219
4175	27	8.75	102.86						
0807	22	7.13	126.23	6	14.9	11296	18	3.0	6881
0806	30	9.72	92.59	10	5.6	5190	5	17.7	8215
0805	30	9.72	92.59				29	17.6	47277
0809	30	9.72	92.59	19	12.5	22055	75	12.9	89569
0852	30	9.72	92.59				31	15.1	43226
0851	35	11.34	79.37						
4173	35	11.34	79.37				5	15.3	6080
4174	15	4.86	185.19						
0810	35	11.34	79.37				188	9.4	139867
0812	25	8.10	111.11				53	1.0	5798
0811	30	9.72	92.59	4	0.4	174	39	2.5	8834
0859	30	9.72	92.59	14	1.9	1969	13	0.1	149
0854	30	9.72	92.59	18	15.2	25455			
0813	12	3.89	231.36						
0803	33	10.69	84.19				56	1.2	5763
0804	30	9.72	92.59	1	0.2	16	121	2.2	25194
Σ				73		66165	906		431922

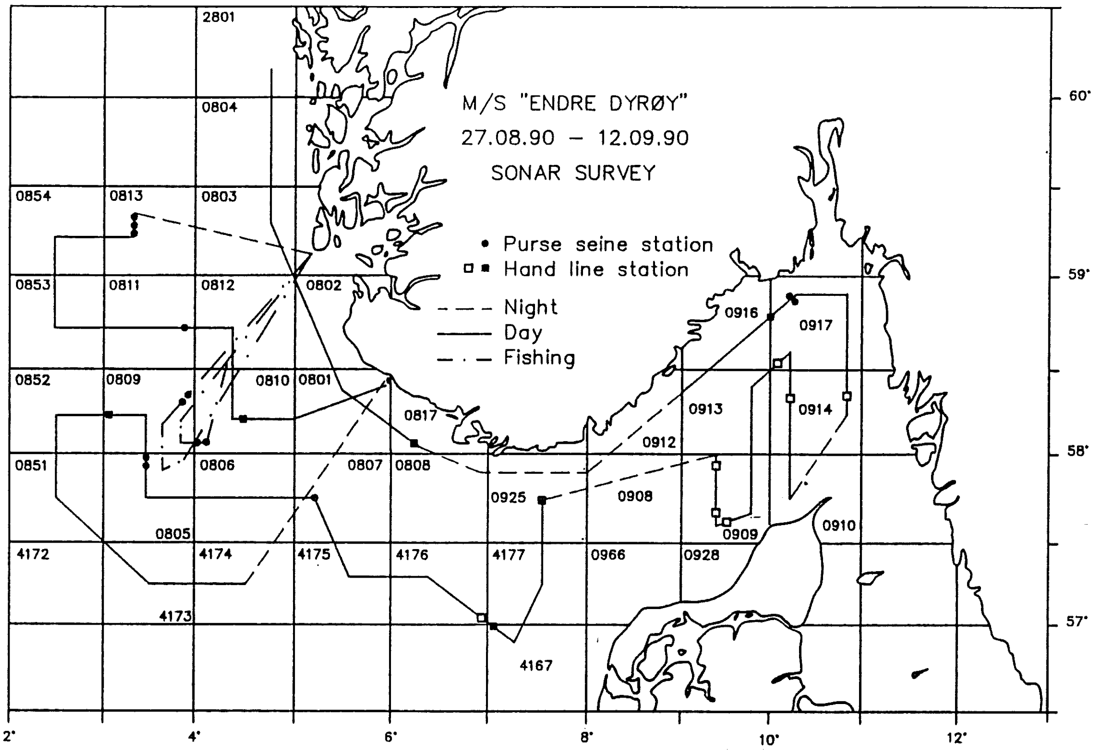

Figure 1. Transects, purse seine and hand line stations during the sonar survey 27/8 - 12/9 1991 (filled symbols: stations with catch, open symbols: no catch).

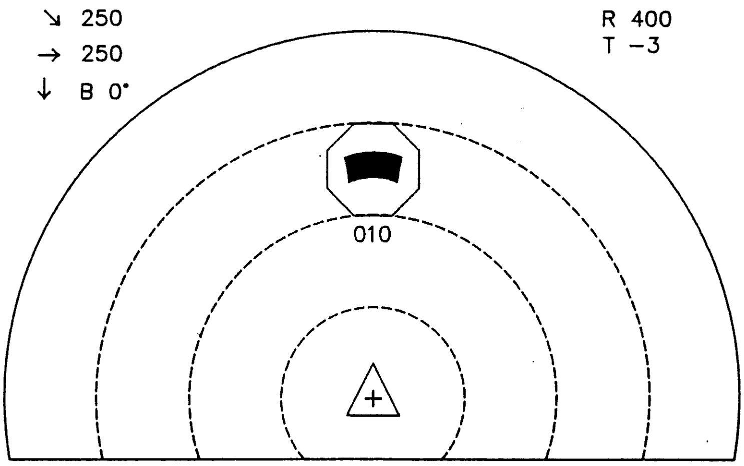

Figure 2. Estimate function of the Furuno CSH-70.

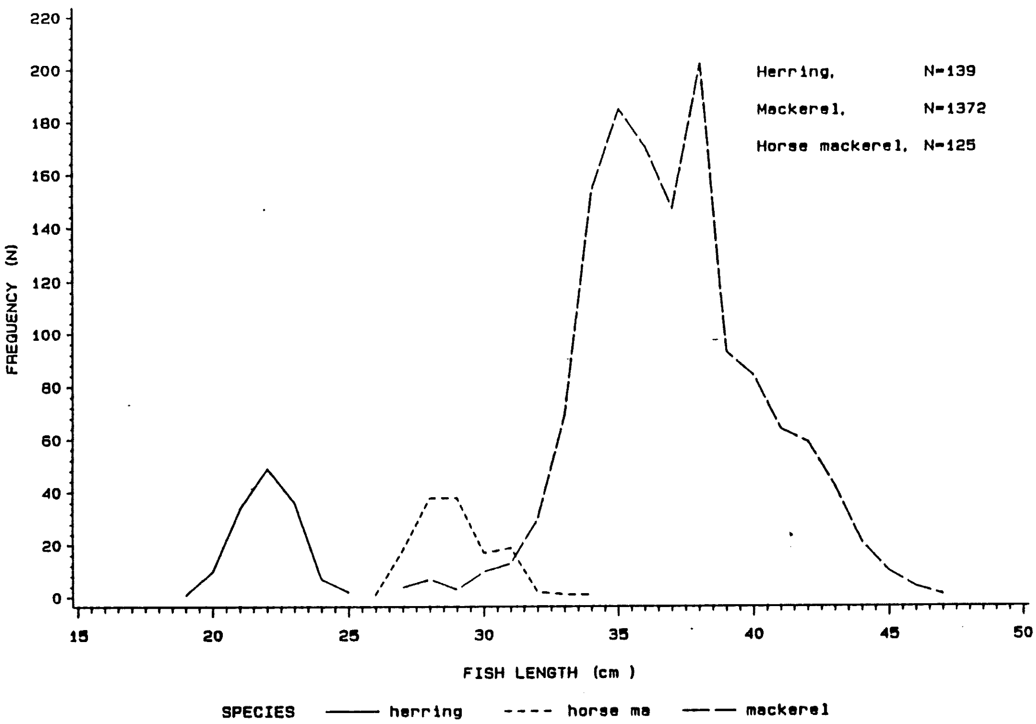

Figure 3. Fish length distribution of herring, mackerel and horse mackerel caught by purse seine or hand line.

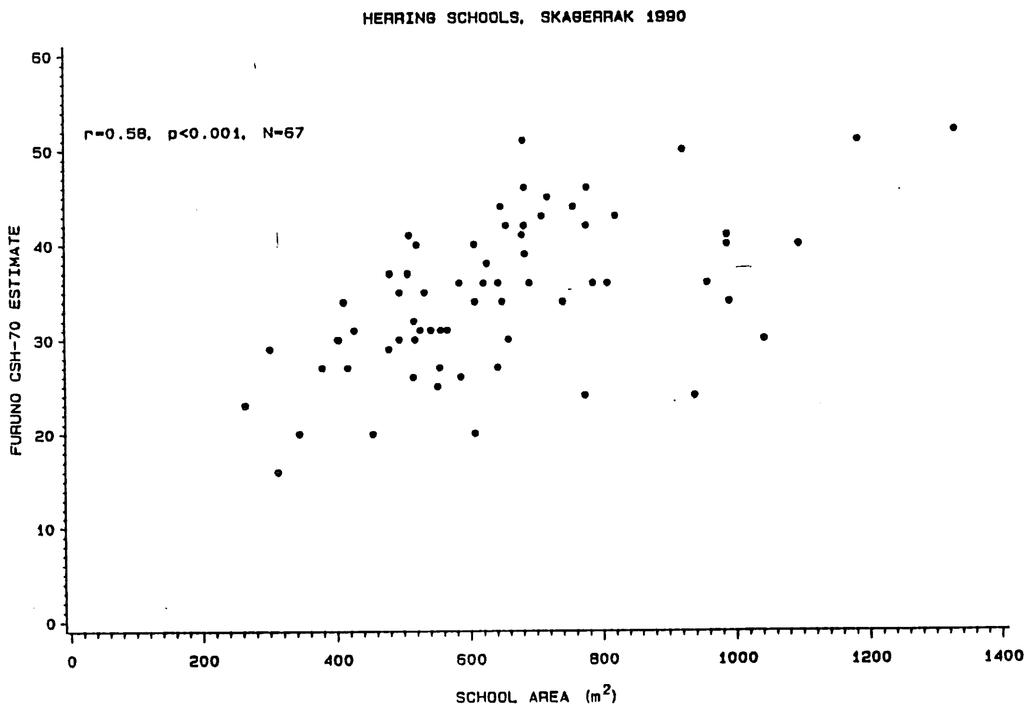

Figure 4. Relationship between the school area measured as described by Misund (1990a) and the Furuno-estimate for two herring schools circled during purse seining in Skagerrak.

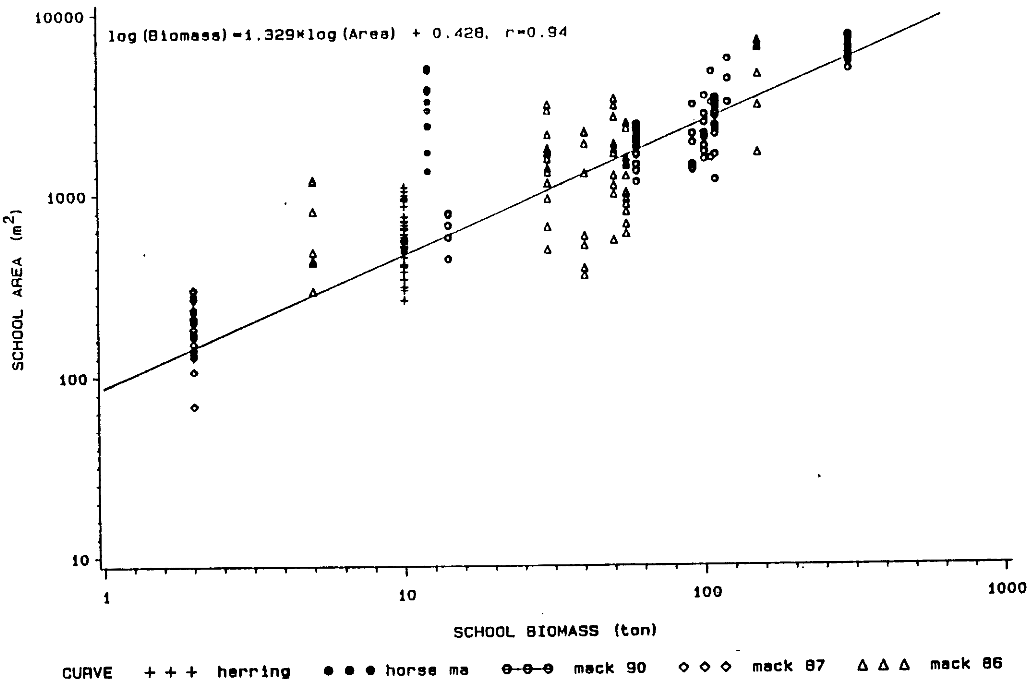

Figure 5. Relationship between the school area and biomass for mackerel schools caught by M/V "Endre Dyrøy", 1990. Data for a herring and a horse mackerel school are included, and measurements of mackerel schools conducted by M/V "Libas" in 1986 (Misund 1988) and R/V "Fjordfangst" in a Western Norway fjord in 1987 are also presented.

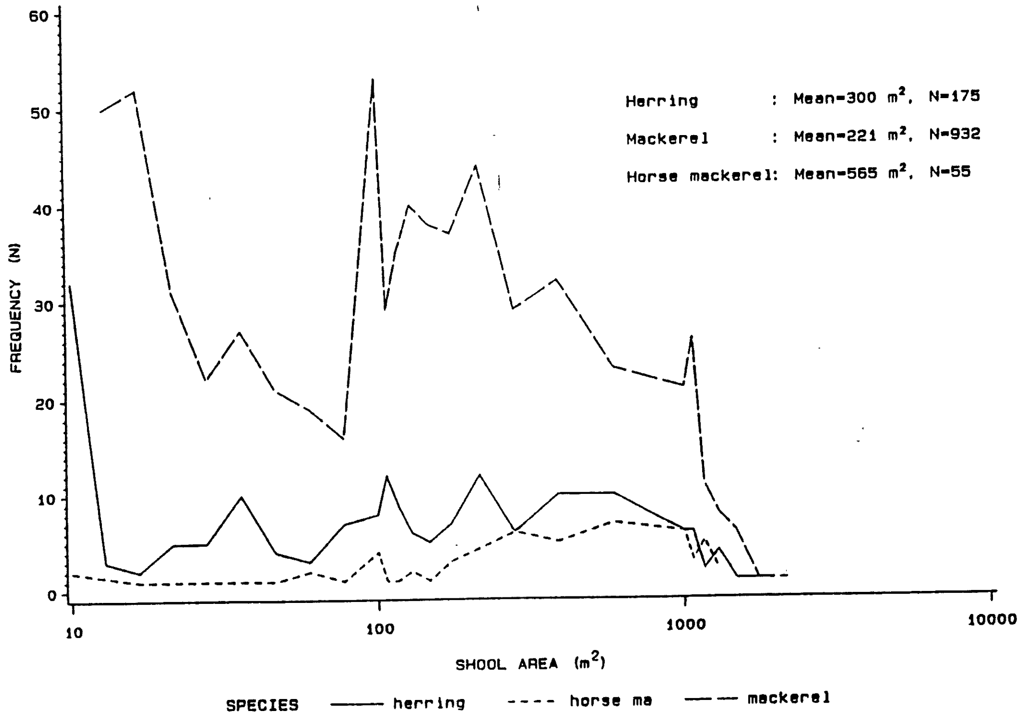

Figure 6. Distribution of recorded school size of herring, mackerel and horse mackerel.

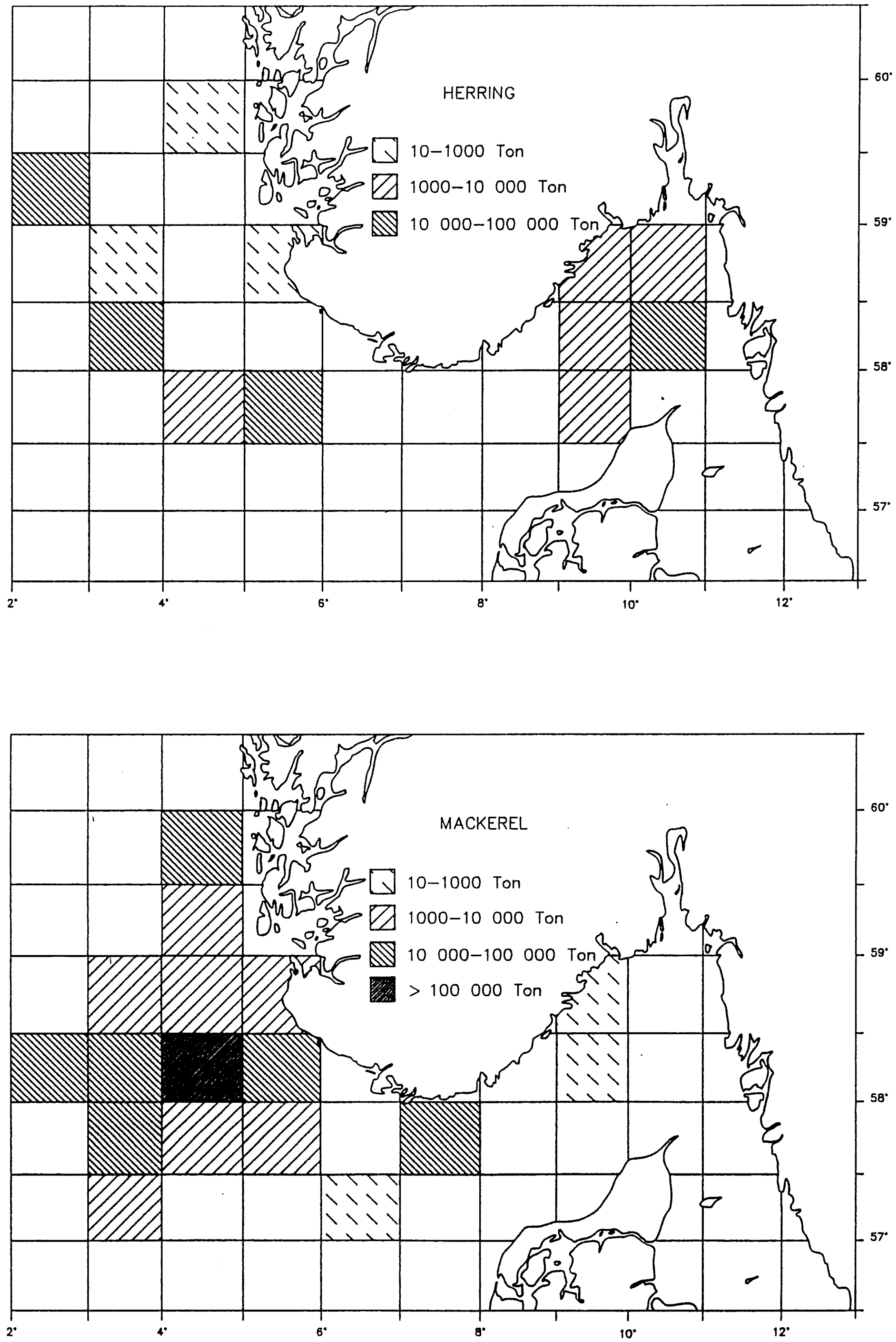

Figure 7. Abundance distribution of herring and mackerel as recorded by the Furuno sonar, september 1990.