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TEST EXPERIMENTS OF TARGET STRENGTH OF HERRING BY COMPARING DENSITY INDICES OBTAINED BY ACOUSTIC METHOD AND PURSE SEINE CATCHES

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ABSTRACT

The spawning stock of the Norwegian spring spawning herring has been assessed by acoustic methods using the target strength

TS = 20 logL - 71.9 dB (L = mean length of fish)

Comparable estimates of fish density were obtained from scattering layers of spent herring near the spawning grounds by using average area backscattering coefficient and purse seine catches. The results show that under the prevailing conditions the catch corresponded to fish density of some 4 dB below the TS-value used. The experiment indicates that the acoustic stock estimates obtained on the spawning grounds since 1988 should at least be raised by a factor of 2.0.

INTRODUCTION

Acoustic estimates of the spawning stock of the Norwegian spring spawning herring have been obtained in the wintering area (Ofoten-Tysfjord) in December-January and on the spawning grounds outside Møre in western Norway in February-March (Fig. 1), with contradictory results. The highest estimates are obtained in January, when the herring are starting their migration out of the wintering area, and the lowest ones are obtained on the spawning grounds in March, where the measurements are performed at night with the herring dispersed in layers of low density. The difference is considerable, the estimates on the spawning grounds giving stock numbers only about half of those obtained by the surveys in the fjords in January. The difference may be due to several factors, but the most important one seems to be variations in the target strength relationship of the herring. The target strength is usually treated as a specific

property for the species, but has a component that depends on the behaviour of the fish in the measuring situation. Lacking knowledge of the behaviour dependent component, one has customarily used only one target strength for herring, independently of measuring conditions. In order to check the acoustic fish density estimates on the spawning grounds, an experiment was carried out in March 1994 where the fish density estimated by an integrator survey was compared to density estimates obtained from purse seine catches. This paper describes the experiment and discusses the results.

METHOD

The number of herring (N) in area (A) (square nautical miles) is calculated by the formula

$$N = C \times s_A \times A$$

where s_A is the "integrator value", or area backscattering coefficient as explained by Knudsen (1990), and C is a factor dependent on the fish length/target strength relationship. The relation between fish length and target strength presently used for the Norwegian spring spawning herring is the one proposed by Foote (1987):

$$TS = 20 \log L + 71.9 \text{ dB}$$

which can be transformed to the C-value:

$$C = 10^6 \times 1.23 \times L^{-2}$$

where TS = the target strength and L = the length of the fish.

In February-March 1994 an acoustic survey of the herring spawning grounds was carried out with the research vessel "Michael Sars", and this C-value was used to convert the area backscattering coefficients to numbers of fish. In the first week of March the purse seiner "Inger Hildur" was chartered to catch herring in layers of fish where the density had been measured acoustically by the research vessel. This was performed by both vessels jointly seeking out areas where herring were present in layers of suitable size and density. After the direction for shooting the net had been decided, "Michael Sars" steamed ahead of the seiner, measuring the average density for each 0.1 nautical mile (one cable length). The seine could now be set with reasonably good precision in relation to the estimated fish density. Immediately after the net was shot, the research vessel also measured the average fish density in a circle around the seine. Four such sets were carried out and the area backscattering coefficients per 0.1 nautical mile relative to the position of the sets are illustrated in Figure 2. The area backscattering coefficients refer to the depth range 15 - 90 m. The net catches fish effectively down to about 100 m, but most of the herring caught was distributed between 15 and 50 m depth.

The herring caught in each set was kept in separate tanks on board the purse seiner and measured (in hectolitres), using the commercial measuring equipment at the factory where the herring was delivered. Since the net is not emptied completely by the pumping operation, 20 hectolitres have been added to each catch. The catches consisted of spent herring, and the length distributions are shown in Figure 3. The area of the seine is estimated as being the area of a circle with a circumference equal to the length of the seine (Table 1).

RESULTS

Four purse seine sets were made and the details of each set are given in Table 1. The acoustically obtained density estimates N_1 and N_2 refer, respectively, to the area backscattering coefficient from the first pass of the research vessel just before the set was made (s_{A1}), and to the average area backscattering coefficient obtained by sailing in a ring around the net just after the seine was set (s_{A2}). These figures are compared to the density estimate C obtained by dividing the catch in numbers by the area of the net. The "raising factor" (C/N) is converted to dB-units by calculating its logarithm (10 x log C/N).

Set no. 1 was carried out on a small school of herring and no estimate of fish density around the net was made in that case. Sets no. 1 and 4 were made at dusk when the herring shoals were in a state of dispersing, whereas sets no. 2 and 3 were made at night. The two night sets give rather similar raising factors, about 2.1 when using the ratio C/N_1 and about 2.9 when using the ratio C/N_2. The sets made at dusk show more variable raising factors: for set no. 1 it is 1.06, and for set no. 4 the raising factor is 1.28 when using C/N_1, but considerably higher (2.43), and at the level of the night sets, when using C/N_2.

DISCUSSION

The sets made at night, when the herring shoals are dispersed, are representative for most of the acoustic measurements made during the herring surveys on the spawning grounds. Although the density estimates based on catches are subject to uncertainties which may cause error in the estimates, for instance the effective catching area of the purse seine, and migration of fish in or out of the seine before it is fully pursed, the catch experiments show that the target strength value used in the herring survey during night time is too high, and the real value may be in an order of magnitude of 4 dB lower. This is in accordance with previous findings when comparing the acoustic stock measurements on the spawning ground to other stock estimates, like the acoustic stock estimates in the wintering area (Foote 1993, Dommasnes and Holst 1992, Røttingen et al. 1994), and the stock estimates based on tagging (Anon. 1994). The target strength value used for herring is based on target strength measurements in situ as well as measurements of tethered and caged clupeoids (Foote 1987).

An experiment similar to the present one was carried out in March 1982, on the same spawning grounds (Hagstrøm and Røttingen 1982), An echo integrator survey was made on a concentration of herring which was afterwards caught in a single set by a purse seiner. Although the result is not directly comparable to the present one, the test in 1982 indicates a TS-value 1.6 dB higher than the TS-value proposed by Foote (1987).

The target strength of a species is expected to vary, subject to the physiological condition and the behaviour of the fish (Olsen et al. 1983, Olsen 1987). The behaviour is assumed to be the dominating factor in the low target strength value observed at night in this experiment. The tilt angle of the herring is probably distributed in a more irregular manner during darkness than in daylight when the fish is schooling and thus may be orientated in a regular horizontal way. Another likely explanation may however be avoidance which causes the fish to dive when the research vessel is passing (Olsen et al. 1983). If this is the case, it means that the herring is more sensitive to boat disturbances during night than during the day.

Set no. 1 gave a small catch compared to the acoustically estimated density figure. This may be due to timing, i.e. that the fish was still schooling when the net was set at 21.27 local time. The set was however made on a small and narrow distribution, and parts of the encircled area may have been outside the main concentration of fish. Another point to be mentioned is that this set was made under rough weather conditions, which could influence the success of the set.

Set no. 4 was made at dusk, and the difference between the area backscattering coefficients s_{A1} and s_{A2} demonstrates the effects of the darkness on the tilt angle of the fish. s_{A2} was measured about 1 hour after s_{A1}. Prior to the set the herring was detected in shoals close to the bottom. When daylight decreased, the shoals ascended gradually and dispersed as they approached the sub-surface layer. The distribution was still lumpy when the net was set at 19.05, whereas the herring was mostly evenly dispersed when the s_{A2} measurement was obtained 1 hour later.

Due to a long period of bad weather, the catch experiment was terminated after these four sets. Although the sets are few, it is felt that the consistency of the results strongly supports the assumption that the previous herring surveys on the spawning grounds have underestimated the stock due to the use of a too high TS-value, and that the estimates should be raised at least by a factor of 2.

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Table 1. Details of the four purse seine sets.

Legend

Number	Thousands
Catch	Hectolitres (1 hectoliter herring equals 93 kg)
C	Density (thousands per nm^2) from purse seine catch
s_{A1}	Integrator value across pos. where the seine was set
N_1	Density (thousands per nm^2) calculated from M_1
s_{A2}	Mean integrator value in a ring around the seine
N_2	Density (thousands per nm^2) calculated from M_2

The purse seine

Length	365 fathoms
Depth	90 fathoms
Circumference	0,3650 nautical miles
Area	0,0106 square nautical miles

The sets	Set 1	Set 2	Set 3	Set 4	Mean
Date	06.mar	07.mar	07.mar	07.mar	
Time (local)	21:27	00:33	03:50	19:05	
Catch (hectolitres)	206	1474	783	492	
Mean length in catch(cm)	35,4	35,2	35,5	34,3	
Mean weight in catch(gram)	311,0	303,0	316,0	274,0	
C (thousands per nm2)	5811	42674	21736	15751	
s_{A1} (across position of set)	5556	14765	9643	11806	
N_1 (thousands per nm^2)	5468	14624	9406	12314	
Raising factor C/N_1	1,06	2,92	2,31	1,28	1,89
Raising factor dB	0,26	4,65	3,64	1,07	2,77
s_{A2} (ring around seine)		14974	7603	6208	
N_2 (thousands per nm^2)		14831	7416	6475	
Raising factor C/N_2		2,88	2,93	2,43	2,75
Raising factor dB		4,59	4,67	3,86	4,39

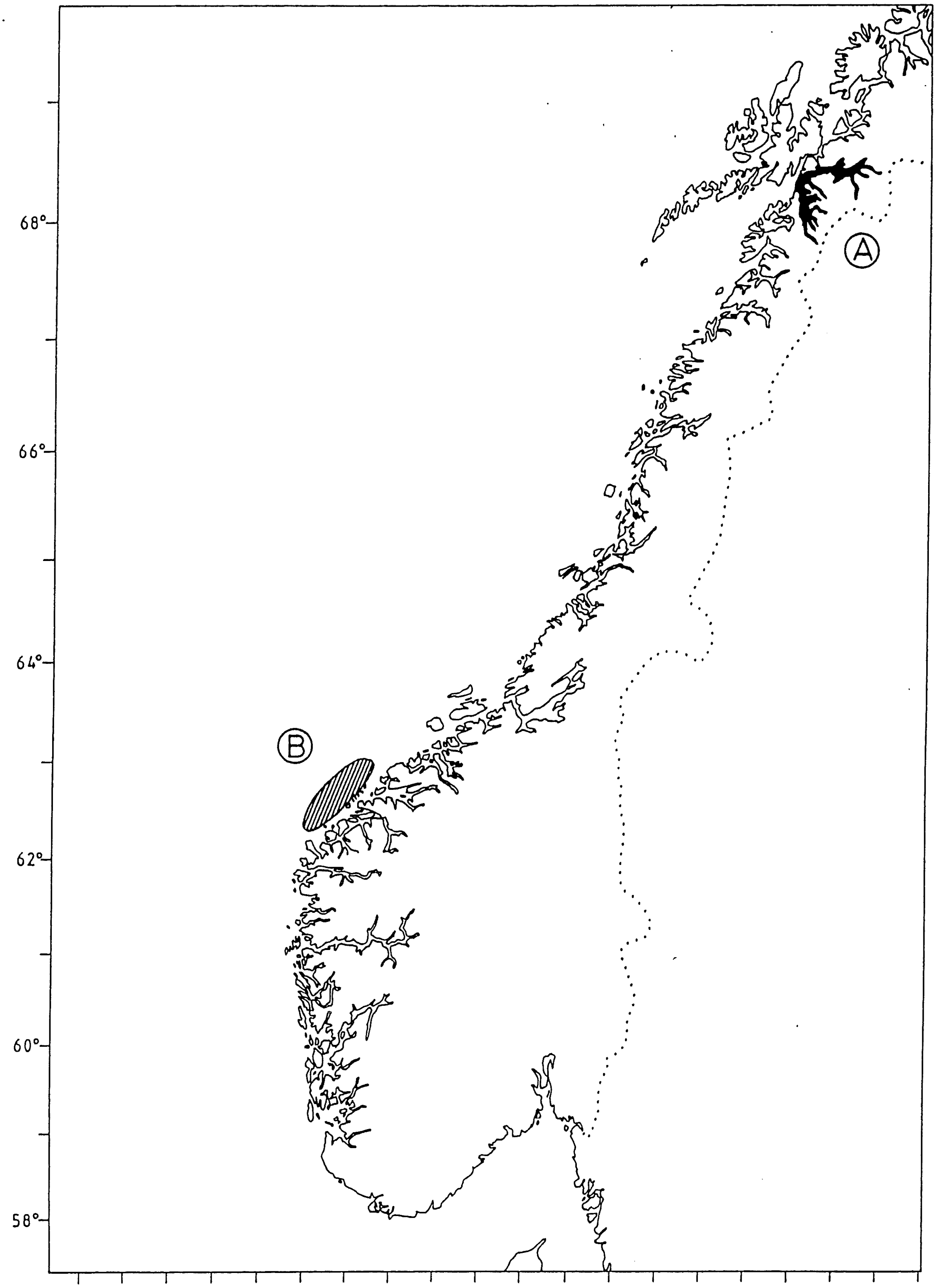

Figure 1. Areas where the spawning stock of the Norwegian spring-spawning herring has been measured acoustically: (A) The wintering area in Ofoten-Tysfjord, and (B) the spawning grounds outside Møre in western Norway.

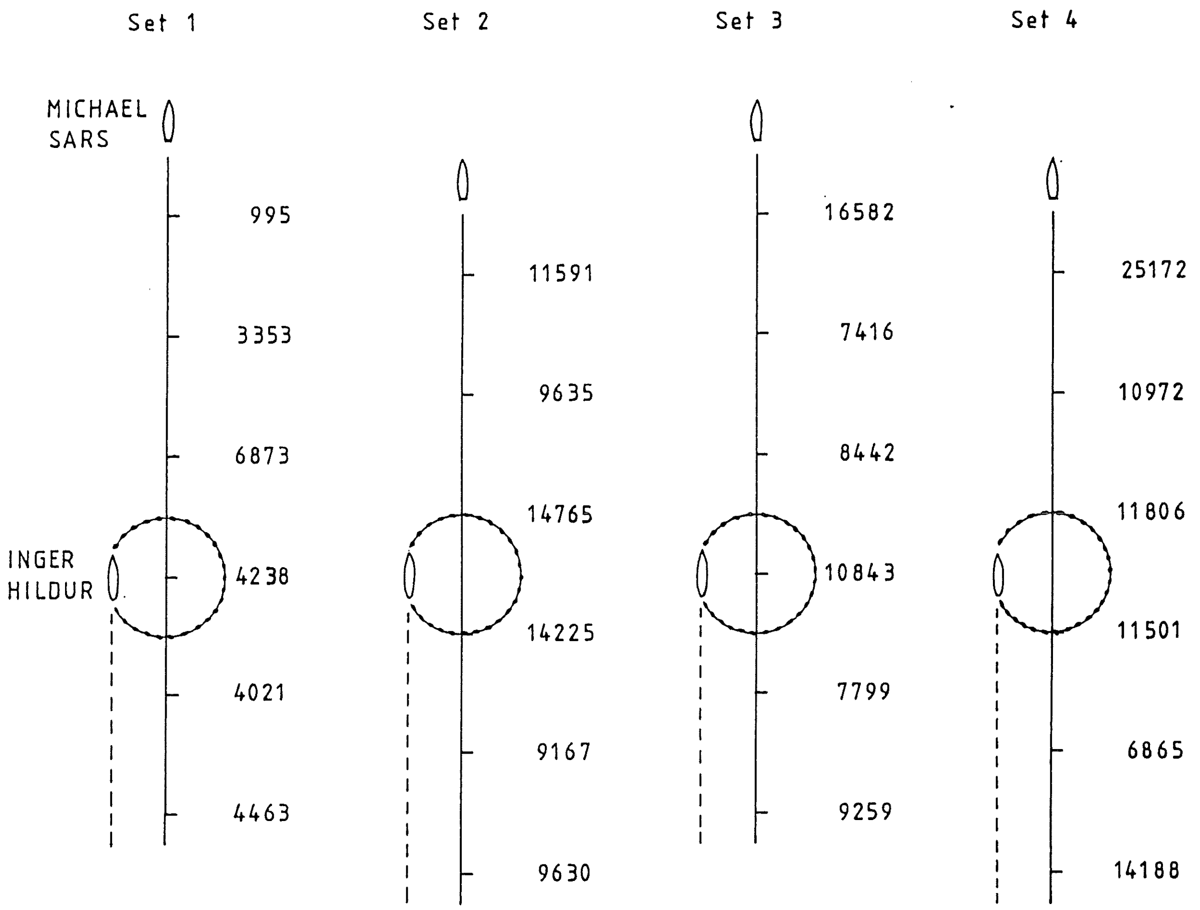

Figure 2. Area backscattering coefficients per cable length (0.1 nautical mile) and the relative positions of the purse seine sets.

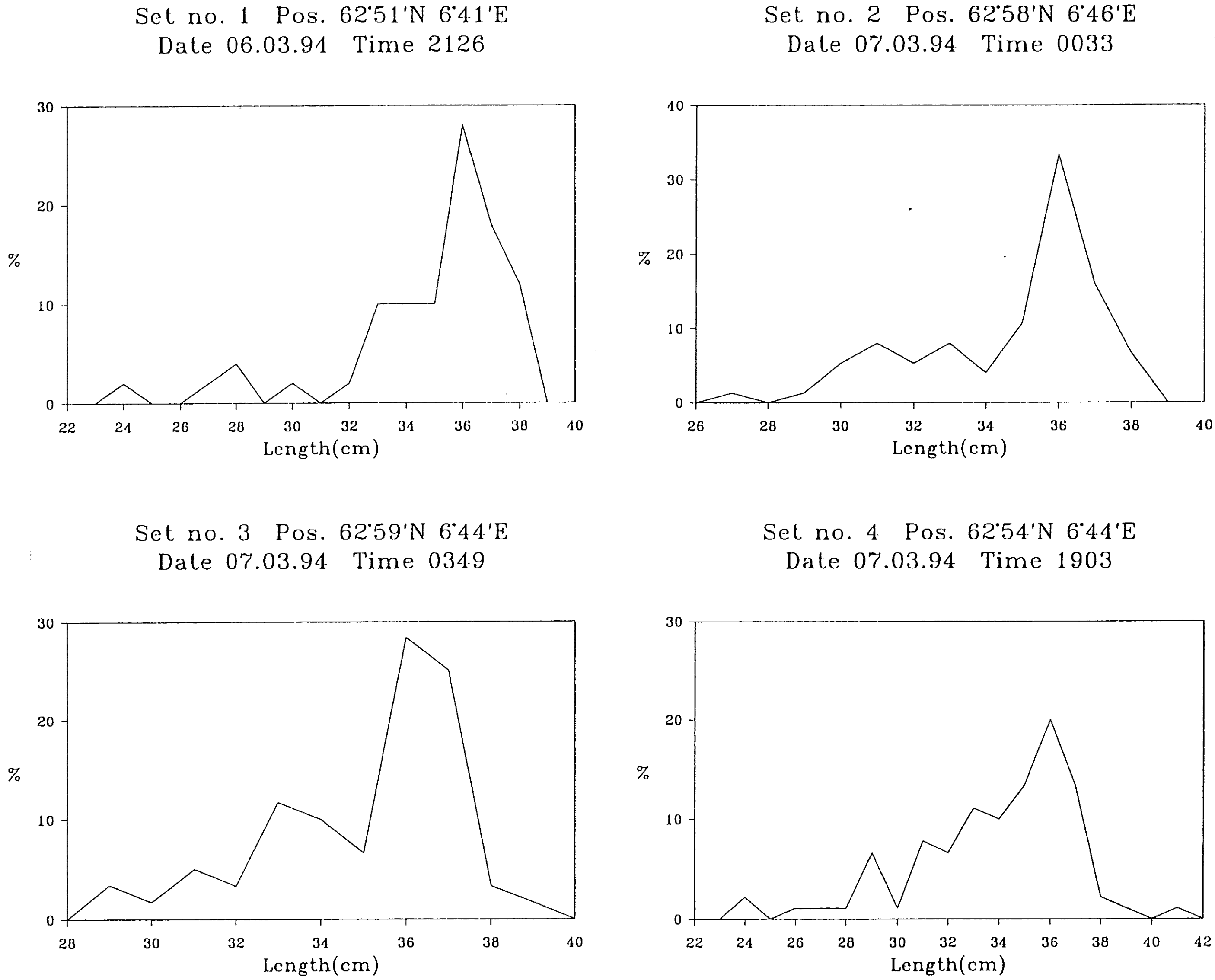

Figure 3. Length distributions of herring in the four purse seine sets.