SHORT COMMUNICATION

SARSIA

AN INTERSHIP SCHOOL-COUNTING EXPERIMENT USING SONAR IN THE NORWEGIAN SEA

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During their spring and summer migrations in the Norwegian Sea, Norwegian spring-spawning herring may be surveyed by vessels from several nations. Because the herring may occur in schools close to the surface, horizontal guided sonar may be useful for mapping their geographic distribution and estimating their abundance. To be able to compare the sonar recordings of schools obtained by different sonar systems on different vessels, an intership school counting experiment is necessary. Such an experiment, which is the first of its kind, was conducted in the Norwegian Sea in June 1995. Vessels from the Faroe Islands, Iceland, Norway and Russia lined up at intership distances of one nautical mile, and headed in the same direction at a speed of about 4 m s^{-1} over a total distance of 30 nautical miles. The number of schools recorded from 50-300 m to the side of the individual vessels was quite similar, but the correlations between the number of schools recorded by the different vessels declined the smaller the sampling distance unit. The implications of the results for cooperative sonar surveys are discussed.

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INTRODUCTION

When the geographical distribution and migration routes of Norwegian spring spawning herring in the Norwegian Sea were being mapped during the fifties and sixties, the use of horizontal guided sonar was a central method (DEVOLD 1963; JAKOBSSON 1963; ØSTVEDT 1965). At that time the sonar was used qualitatively to detect schools of herring, but trained sonar operators made a certain quantitative assessment by classifying the school size in categories ranging from 'fly-shit', 'raisins', 'grapes' to 'elephant droppings'. With the disappearance of the herring stock from the Norwegian Sea in the late sixties (DRAGESUND & al. 1980), sonar became less important in fisheries investigations in the North Eastern Atlantic.

The herring in the Norwegian Sea is once again abundant, and horizontal guided sonar is a relevant method of recording herring schools. The sonar method has been improved by the introduction of a high-resolution multibeam instrument (MISUND & al. 1985) connected to a computer-based system for automatic detection and measurement of school size (MISUND & al. 1994). This system has been used since 1993 during annual surveys to map the distribution of herring in the Norwegian Sea (MISUND & al. 1996).

Several countries share an interest in the fish resources of the Norwegian Sea and therefore conduct annual fisheries investigations in the area. Since 1995 cooperative surveys have been conducted by the Faroe Islands, Iceland, Norway and Russia on the herring stock in the Norwegian Sea in the summer (ANON. 1995; 1996). To be able to compare and make distribution charts based on sonar recordings from different research vessels equipped with different sonars, it was decided to carry out an intership school-counting experiment by sonar in the Norwegian Sea in summer 1995 (ANON. 1995). The setup for the experiment was planned according to the standard procedure for intership calibration of echo-integration systems (FOOTE & al. 1987). However, this is the first experiment of its kind to compare horizontal guided sonars.

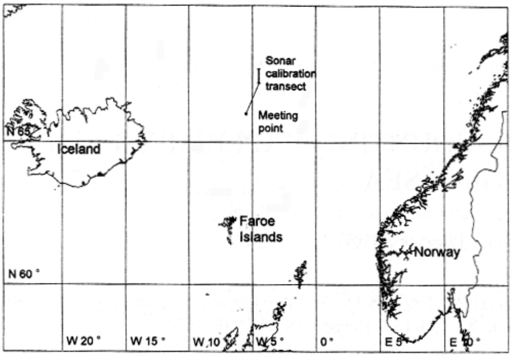
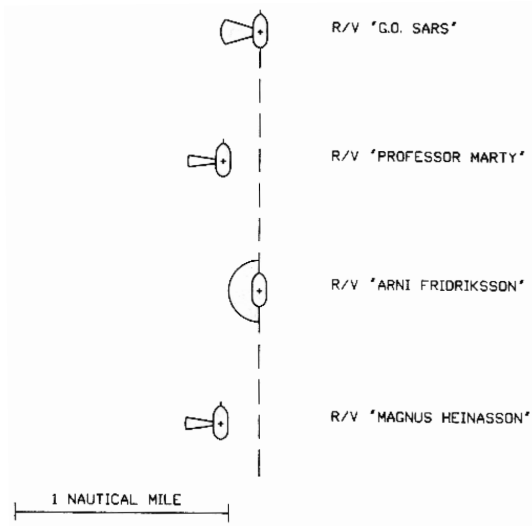


Figure 1. Position of sonar calibration experiment.



Figur 2. Sailing order of the research vessels during the sonar calibration experiment.

MATERIAL AND METHODS

To conduct the sonar calibration, four fisheries research vessels from different countries (Table 1), R/V *Professor Marty* from Russia, R/V *Arni Fridriksson* from Iceland, R/V *Magnus Heinasson* from the Faroe Islands and R/V *G.O. Sars* from Norway gathered at position 66° N 5°30' W at 1400 UTC on 17 June 1995. This position was chosen because R/V *Magnus Heinasson* had made recordings of substantial amounts of herring in the area about one week earlier. However, there were few schools in the area when the vessels arrived, and it was therefore decided that the vessels should sail side by side in a north-easterly direction in order to search for a more suitable area. An easterly gale during the evening of 17 June also prevented a calibration exercise. The wind decreased to strong breeze (about 10 m s^{-1}) during the night. On the morning of 18 June the vessels approached an area with purse seine fishing at 67° N 4°30' W. It was decided to start the sonar calibration at 67°05' N 4°30' W (Fig. 1) at about 0645 UTC, and to sail north at a speed of about 4.5 m s^{-1} (8 knots). The vessels lined up in the following order: R/V *G.O. Sars*, R/V *Professor Marty*, R/V *Arni Fridriksson* and R/V *Magnus Heinasson*. To avoid sailing in the propeller wakes of the vessels in front, the vessels sailed one nautical mile apart and slightly to the side of each other (Fig. 2). R/V *Professor Marty* had R/V *G.O. Sars* at 10° bearing starboard, R/V *Arni Fridriksson* had R/V *Professor Marty* at 10°bearing port, and R/V *Magnus Heinasson* had R/V *Arni Fridriksson* at 10° bearing starboard. The intership calibration exercise ended at 67°35' N 4°30' W at about 1100 UTC. The wind was about 8 m s^{-1} from the east during the exercise, and wave height was about 3-4 m.

On all the vessels the sonars were turned 90° to port and tilted to -10° to avoid surface reverberation or air plumes caused by breaking waves. During the exercise, all schools within 50-300 m of the side of the vessels were recorded. On board R/V *Professor Marty*, R/V *Arni Fridriksson* and R/V *Magnus Heinasson* this was done manually by trained operators, while schools were counted both manually and automatically by the computer-based sonar system on board R/V *G.O. Sars* (Misund & al. 1994). On the Faroese, Norwegian and Russian vessels, the number of schools was counted for

Table 1. Acoustic characteristics of the sonar systems used during the intership sonar calibration experiment in the Norwegian Sea, June 1995.

Vessel	Sonar	Frequency (kHz)	Horizontal beam (-3 dB)	Vertical beam (-3 dB)	Pulse length (ms)	Display
Professor Marty	Sargan	135	14°	5-10°	1	Paper
Arni Fridriksson	Kaijo Denkij	24	360° sector scan, 12° on 15 reception beams	12°	15	CRT
Magnus Heinasson	Simrad SU	15	14°	11°	6	Paper
G.O. Sars	Simrad SA950	95	45° sector scan, 1.7° on 33 reception beams	10°	0.3	CRT and Paper

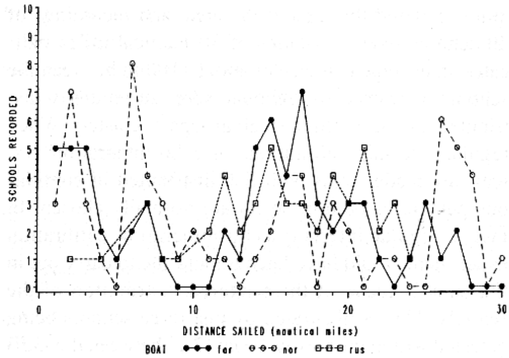


Figure 3. Number of schools recorded per nautical mile of the sonar calibration transect by the Faroese (far), Norwegian (nor) and Russian (rus) vessels.

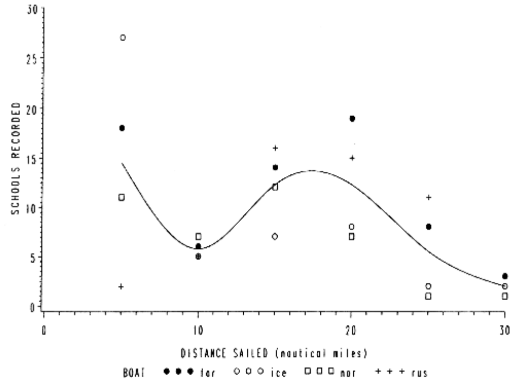


Figure 4. Number of schools recorded per five nautical miles of the sonar calibration transect by the Faroese (far), Icelandic (ice), Norwegian (nor) and Russian (rus) vessel.

each nautical mile, while on the Icelandic vessel the number of schools counted was summed for intervals of five nautical miles.

The four vessels were equipped with different sonar systems (Table 1). In order to achieve high resolution and thereby improve the probability of manual school detection, the systems were operated at a range setting of 300 m or the nearest setting above 300 m. The 300 m limit was also chosen because sound absorption, which increases drastically at higher frequencies, reduces the probability of detection of small schools beyond that range by the rather high-frequency sonars on board the Norwegian and Russian vessels (Table 1). The sonars were operated using settings optimal for recording schools under the sea conditions during the transect. The school detection system connected to the Simrad SA950 on board R/V *G.O. Sars* sonar was set to a detection threshold at colour value 15 (recordings are presented on a pixel-based sonar display by colours with values ranging from 0 - 63, according to intensity), a lengthwise school extent of 5 m, and a minimum number of four detection pings.

The calibration transect appeared to be in the most suitable area for purse seine fishing by Norwegian and Icelandic vessels. Three Norwegian vessels with herring catches alongside were passed during the transect, and about 20 Icelandic vessels heading east crossed the transect at about 67°15' N to 67°20' N. The calibration transect was thus probably in the best possible location for recording herring schools in the area on that date.

RESULTS

During the 30 nautical mile long calibration transect, 68 schools were counted manually by both the Faroese and Norwegian vessels. The Russian and Icelandic vessels counted 49 and 51 schools, respectively. The average number of schools counted manually per nautical mile was not significantly different among the Faroese, Norwegian and Russian vessels (Kruskal-Wallis test, $p > 0.05$), and there was no significant difference in the average number of schools counted per five nautical miles by the four vessels (Kruskal-Wallis test, $p > 0.05$). The school detection system connected to the Simrad SA950 sonar onboard R/V *G.O. Sars* recorded only 39 schools. This indicates that the detection criteria on the computer-based detection system on-board R/V *G.O. Sars* had been set too strictly to record a further 29 small schools that were clearly present on the paper record of the sonar.

When comparing the recordings on a one nautical mile basis, there were substantial differences among the Faroese, Norwegian and Russian vessels (Fig. 3), and there was no significant correlation between the numbers of schools recorded by the Norwegian and the Russian or Faroese vessels (Table 2). However, there was a significant correlation between the numbers of schools detected by the Russian and Faroese vessels. When the recordings on a five nautical mile basis were compared, there were still substantial differences in the number of schools recorded by the different vessels (Fig. 4), and no significant correlation between the numbers of schools recorded by the different vessels (Table 2). However, the modal pattern in the number of schools recorded between mile 10 and 25 seemed to be similar in the recordings of all the vessels.

During the calibration transect, only three schools were recorded by the 38 kHz Simrad EK500 echo sounder on board R/V *G.O. Sars*, and similarly, few schools were recorded by the echo sounders of the other vessels. Because of the small number of recordings, a comparison of the sonar and echo sounder recordings within and among the vessels was impossible.

DISCUSSION

The total number of schools counted manually differed among the four vessels, but there was no significant difference in the average number of schools counted per distance unit. We therefore conclude that the probability of detection of herring schools did not differ among the vessels and sonar systems that participated in this exercise. This implies that sonar recordings of herring schools during surveys in the Norwegian Sea in summer by the four vessels participating in this experiment should be given equal weight when recordings from the vessels are combined in order to assess the summertime distribution and abundance of the herring stock in the Norwegian Sea.

If properly conducted over a sufficient distance, intership calibrations of echo-integration systems usually offer strong intership regressions of the area backscattering coefficients obtained over a distance of 30 nautical miles (MacLennan & Simmonds 1992; Røttingen 1978). This was not the case with the number of schools recorded by the four vessels that participated in our school-counting experiment. There were both differences in the number of schools detected by the different vessels and a lack of intership correlation at small sampling distance units. However, the intership correlations improved when five nautical miles were taken as the sampling distance unit, but even then, none of the correlations were significant.

However, a direct comparison between our school-counting experiment by sonar and regular echo-integration system calibration experiments is not relevant. This is because the fish distribution recorded during the school-counting experiment was fundamentally different from that normally encountered during intership calibration of echo-integration systems. In our experiment the herring were found in distinct schools of various sizes in the upper water column. The schools were quite scattered throughout the area, and recordings of 50 schools over a distance of 30 nautical miles indicates an average distance of about 1100 m between the schools. However, the schools were not regularly distributed, but occurred in small groups or clusters. When regular intership calibrations of echo integration systems are made, areas with fish distributed in continuous pelagic or bottom layers are normally chosen. In fact, a regular intership echo-integration calibration experiment would have been impossible to carry out in this area because of the scattered distribution of the schools. This is illustrated by just three schools being detected within the narrow beam (7.1° between the -3dB points) of the vertically directed echo sounder of R/V *G.O. Sars* in the course of the whole calibration transect.

The scattered distribution of the herring schools indicate that intership correlations between the number of schools detected over small sampling distances have little value. This is evident from the lack of intership correlation between the number of schools detected per nautical mile. The intership correlations improved when the recordings were summed within sampling distances of five nautical miles. A calibration transect of 30 nautical miles provides only six data points when the number of schools per five nautical miles are used. None of the six intership correlations were thus significant. A longer calibration transect that produced more five nautical mile data points would thus have been preferable.

The volumes sampled by the various sonar systems differed substantially because of the differences of up to 4° in vertical opening angle (Table 1). A sonar with a 10° vertical beam width and tilted to -10° will cover a depth of 4-14 m at a range of 50 m and 25-80 m at 300 m range. Similarly, a sonar with a 14° vertical beam width will cover a depth of 3-15 m at 50 m range and 16-92 m at 300 m range. However, the herring schools recorded during this exercise seemed to have been dis-

Table 2. Correlation coefficients (r) for the number of schools recorded per unit of distance sailed during the calibration transect (ns: $p > 0.05$, s: $p < 0.05$, n: number of observations).

	One nautical mile recordings			Five nautical mile recording		
	r	p	n	r	p	n
G.O. Sars vs *Professor Marty*	-0.20	ns	30	0.28	ns	6
G.O. Sars vs *Arni Fridriksson*				0.65	ns	6
G.O. Sars vs *Magnus Heinasson*	0.28	ns	30	0.70	ns	6
Professor Marty vs *Arni Fridriksson*				-0.26	ns	6
Professor Marty vs *Magnus Heinasson*	0.37	s	30	0.47	ns	6
Arni Fridriksson vs *Magnus Heinasson*				0.67	ns	6

tributed within a rather narrow range of depths near the surface. Therefore, the depths occupied by the herring schools were probably sampled about equally effectively by the four sonar systems employed in this exercise.

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