International Council for the Exploration of the Sea

CM 1998/J:18
Theme Session on Variation in the Pattern of Fish Aggregation: Measurement and Analysis at Different Spatial and Temporal Scales and Implications

Variation in acoustically measured abundance from repeated surveys of herring

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ABSTRACT

A large concentration of wintering herring was surveyed continuously with acoustics over 37 hours in a fjord in Northern Norway. 16 surveys of the same area were conducted. Total abundance and statistics were computed for each survey. Distribution graphs showed a clear diel variation, with deep daytime layers and more shallow night time distribution. Acoustically measured abundance at night was 50% of the daytime values. The results are discussed in terms of behaviour induced diel variation in acoustic backscattering, and potential influence on acoustic abundance measurements.

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INTRODUCTION

Norwegian spring spawning herring (*Clupea harengus*) winters in the Vestfjord region in northern Norway. During wintering the herring hibernate without feeding, developing gonads and avoiding predators while conserving energy. Still, the herring exhibits dynamic behaviour, characterised by extensive diurnal vertical migration. During the short winter day the herring stay deep, schooling, while at dusk they migrate towards the surface and the schooling structure disintegrates (Huse and Ona, 1996). Ship avoidance is pronounced at depths down to 100 m (Vabø et al., 1998).

Dynamics of vertical migrations of herring influences the estimated abundance levels. Fluctuations in levels of acoustic abundance caused by diurnal migrations of herring have been shown, qualitatively, by grouping results from the available data collected at the entrance region of Tysfjord (Huse et al. 1997). In the present investigation, we conducted a series of non-interrupted, multiple surveys, which enable us to quantify the magnitude of those fluctuations.

MATERIALS AND METHODS

The survey was conducted with R/V "Johan Hjort" in December 1997. A standard method for acoustic data collection was applied: a Simrad EK500 sounder at 38 kHz and the BEI echo-classification software (Foote et al., 1991). The acoustic abundance estimates and visualisations were obtained with the SV postprocessing software (Ostrowski, 1998)

The experiment was carried out in the inner part of Vestfjord (Figure 1). The surveying vessel circulated in a loop-pattern (Figure 2), closing a rectangular region with dimensions of 11-n.mi. across, and 2-n.mi. along the fjord. A time of the passage of a loop was approx. 2.5 hours. Period of the whole experiment exceeded 37 hours, and during that time a total of 16 coverages have been accomplished.

Computation of abundance was accomplished in the following way: (1) The data from the surveyed region were enclosed in a stratum, exclusive of regions along the coastlines (Figure 2). (2) Estimates of acoustic abundance for an individual coverage were obtained by multiplying that area by the average area fish density ρ_A from the data enclosed in the stratum. (3) Conversion from acoustic units was computed through the fundamental equation of echo integration,

$$\overline{\rho_A} = \frac{\overline{s_A}}{\sigma_b} \quad ,$$

where s_A is average area backscattering coefficient, σ_b is the average backscattering cross section. The value of this last quantity was derived from the standard equation for Norwegian spring-spawning herring (Foote, 1987) assuming root mean square length of the herring 32.04 cm.

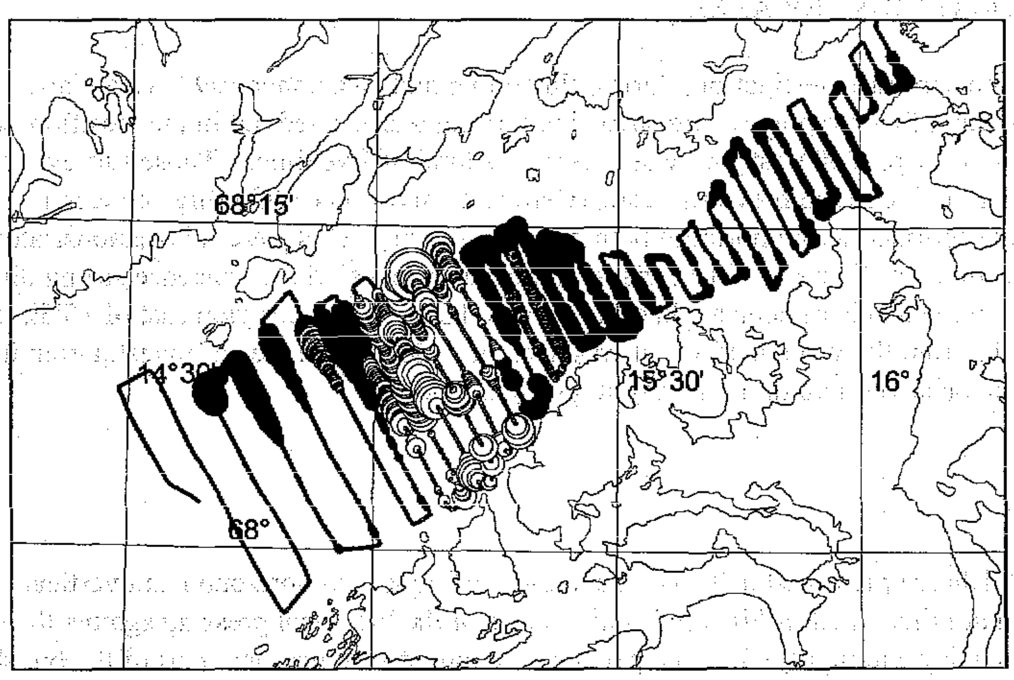

Fig. 1a Distribution of acoustic density of herring in Vestfjorden, 27-28 November 1997. Circle areas are proportional to s_A-values. The intensity of shading of the circles denote different lighting regimes effective for 68°N°15 E. These decrease from the back towards white color in the five steps, corresponding to different lighting regimes (nigh, astronomical twilight, nautical twilight, civil twilight, and day)

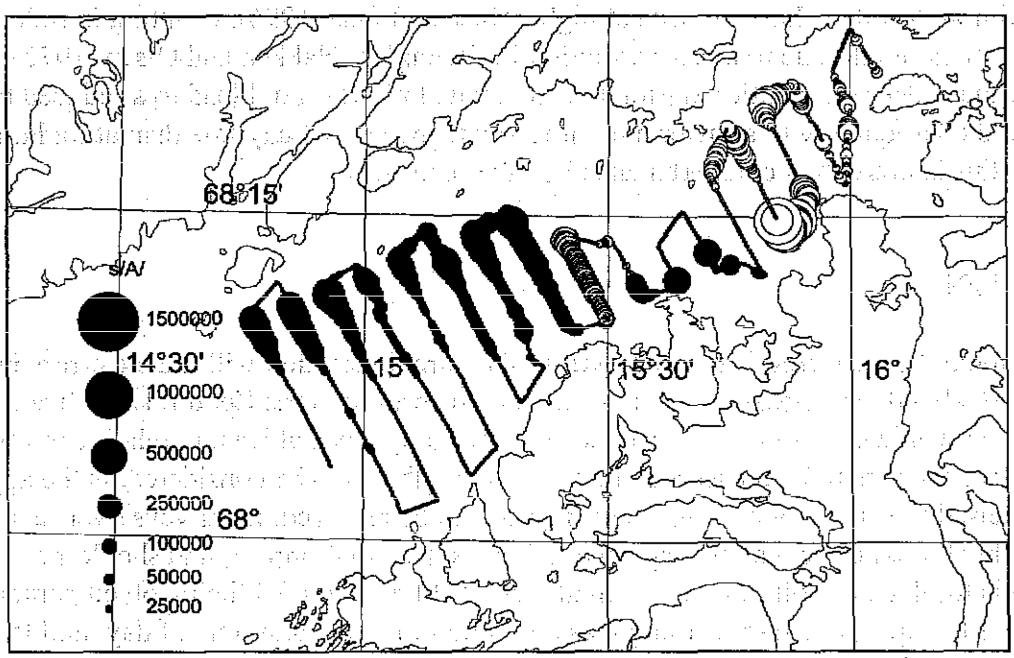

Fig. 1b Distribution of acoustic density of herring in 5 - 6 December 1997. Circle areas are proportional to s_A-values. The intensity of shading of the circles denote different lighting regimes effective for 68°N°15 E. These decrease from the back towards white color in the five steps, corresponding to different lighting regimes (nigh, astronomical twilight, nautical twilight, civil twilight, and day)

SELECTION OF SURVEY AREA

Preceding the current investigation, during November and December 1997, a standard acoustic survey of Norwegian spring spawning herring was carried out in the Vestfjorden region. The inner part of Vestfjord was surveyed a total of five times. Those surveys have revealed that, unlike in the previous years, (Ostrowski and Foote 1996) high concentrations of herring were confined to the northern boundary of the fjord. This pattern is demonstrated in the visualisations in Figure 1. These visualisations also revealed the existence strong diurnal differences in the levels of acoustic backscattering observed in the region east of 15°E. Based on the results from the visualizations, it was decided to locate the area of investigation in the region of the observed maximum of day-night fluctuations.

RESULTS

Numerical data are presented in Table 1, and diel differences in horizontal and vertical distribution are illustrated in Figures 2 and 3. Parts of the big shoal pressing against the slope remains deep day and night, while the pelagic component and the upper part of the big shoal show a clear diel vertical migration. The diel variation in abundance is shown in Figure 3. Daytime abundance is higher than at night, which is numerically corroborated by Table 1, where day is represented by surveys 3,4,5, and 12,13,14. There was a certain variation in abundance over the period, but comparing neighbouring surveys, the diel trend is clear. The mean number of herring in the five most typical night-time surveys (1,8,9,10,11) was 1.8 x 10^9, while the mean number for the most typical daytime surveys (4,5,12,13,14) was 3.6 x 10^9, in other words twice as much during the day as at night. The reason for this difference may be explained by ship avoidance at night (Vabø et al., 1998), but also by the energy saving swim-and-glide behaviour seen at night (Huse and Ona, 1996), resulting in reduced acoustic target strength due to a large variation in tilt angles (Nakken and Olsen, 1977). However, the deeper distribution during the day than at night should lead to a reduced target strength and consequently to a lower measured abundance in the daytime than at night. But obviously this is more than counterbalanced by the other factors.

DISCUSSION

The question to be answered is to what extent this diurnal variation will induce errors in acoustic fish abundance measurements in general. According to the Central Limit Theorem, this variation would even out in a survey lasting for many days, at least in relative terms. If absolute abundance is to be measured, the target strength has to be considered: is the applied function biased towards day or night? This remains to be resolved. In surveys over less than two days the diurnal effect can be expected to have substantial impact, and should be considered closely. The solution to this challenge could be to model the involved parameters: avoidance, tilt angles, and target strength as a function of depth and time of day, and let this model modulate the abundance measured.

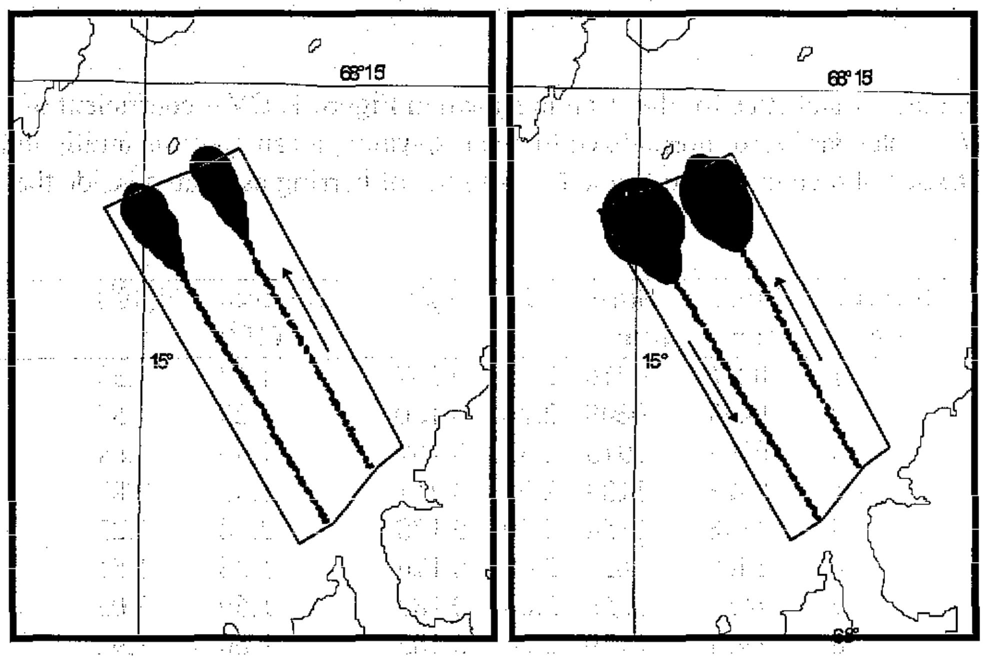

Fig 2 Comparison between nighttime and daytime distributions of herring obtained during repetitive surveys along two transects in Vestfjorden on December 10, 1997. The areas of the circles are proportional the area backscattering coefficient s_A. A polygon drawn around the surveyed area defines a stratum that was used for the computation of abundance shown in Table 1. The nighttime distribution, shown on the left figure, was obtained during survey 10, 0014-0217 UTC; the daytime distribution, shown on the right, represents the data collected during survey 14, 0959-1201 UTC.

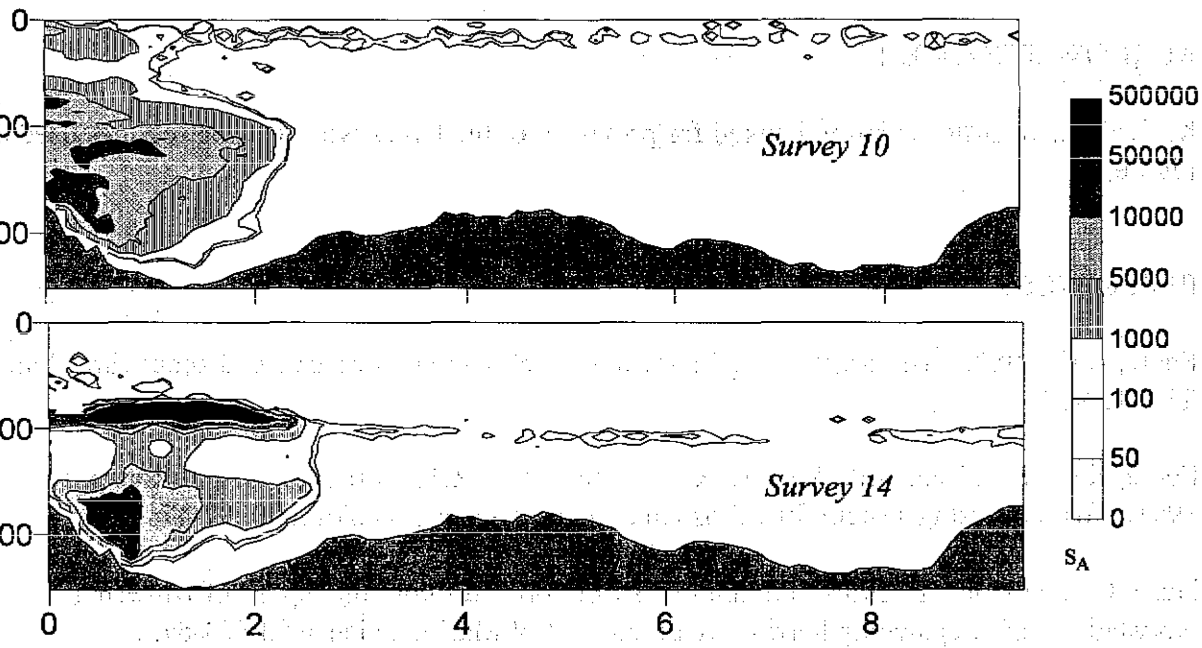

Fig. 3. Comparison of the vertical distributions of s_A-values obtained during nighttime (survey 10) and daytime (survey 14) transects across the fjord. Description along the horizontal axis denotes distance across the fjord expressed in nautical miles. Description along the vertical axis denotes depth in meters.

TABLE 1. Summary statistics for the stratum shown in Figure 1. CV – coefficient of variation, s_E/s_A – standard error normalized to mean s_A-value, mean s_A-value multiplied by the area of the stratum shown in Figure 1, and N – number of herring estimated inside the stratum.

Survey no.	Start time	Stop time	CV	s_E/s_A	s_A x area (10^6)	N(10^9)
1	0206	0410	2.35	0.167	1.12	1.35
2	0427	0649	2.24	0.160	1.29	1.55
3	0709	0913	2.32	0.167	1.36	1.64
4	0928	1133	2.96	0.211	2.35	2.83
5	1148	1354	2.49	0.178	2.68	3.22
6	1409	1621	2.48	0.176	1.26	1.51
7	1653	1856	2.64	0.187	1.69	2.03
8	1911	2129	2.60	0.185	1.60	1.92
9	2144	2358	2.50	0.176	1.45	1.74
10	0014	0222	2.17	0.154	1.47	1.76
11	0237	0446	1.92	0.140	1.85	2.22
12	0500	0724	2.23	0.159	3.00	3.60
13	0736	0947	2.35	0.167	2.99	3.59
14	0959	1209	2.32	0.164	3.91	4.70
15	1224	1441	2.25	0.159	1.47	1.77
16	1455	1711	2.27	0.162	1.12	1.34

ACKNOWLEDGEMENT

K. G. Foote of IMR is kindly thanked for provision of the tables with lighting regimes used in Figure 1.

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