A Comparison between Two Sonic Measuring Systems for Demersal Fish[1]

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Two sonic methods for estimation of abundance of fish stocks, the echo integrator and the digital counter methods, were compared on single and schooling fish in the Lofoten area of Norway during March 1969. Good correlation was obtained between the two systems for both situations, but the slopes of the regressions of integrated values on the digital counter differed significantly between low and high density fish concentrations. This suggests that the two systems treated the echo information differently, but nevertheless maintained a linear relation between themselves over a wide range of counts.

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INTRODUCTION

Two main problems arise when acoustic instruments are used to estimate fish abundance. The first is to obtain reliable counts of the number of fish per unit volume detected by the echo sounder. Different systems have been developed for this purpose (Dragesund and Olsen, 1965; Dowd, 1967; Midttun and Nakken, 1968). The second is to determine the effective volume of water sampled uniquely by each sonic pulse (Cushing, 1968). For the latter purpose, it is necessary to know the target strength of the fish. Recently, Craig and Forbes (1969) have described a sonar for fish counting and derived an excellent method for determining the number of fish counted per unit volume.

The experiment reported here is confined to problems of the first kind and was carried out to compare two kinds of signal processing systems, the Digital Echo Counter (Dowd, 1967) and an Analog Echo Integrator (Dragesund and Olsen, 1965). The main questions to be answered were: is there a linear

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relation between systems when they are sampling signals from the same "isonified" volume, and can these signals be correlated with a count of echos obtained from echo-sounder paper recordings? The two systems were compared at different pulse lengths with reflections from various densities of spawning cod (*Gadus morhua* L.). The work was done on board the Norwegian Research Vessel *G. O. Sars*, in Lofoten, Norway, in early March 1969.

EQUIPMENT AND METHOD

The equipment was set up as in Fig. 1. A Simrad Model EK38 scientific echo sounder was used with a transmitted power of 1000 w and a measured source level of $+118$ db/μ bar at 1 m, emitted from the 15×30-cm transducer. The receiver has a time varied gain (T.V.G.) function and was set to compensate two-way transmission loss down to 230 m. The output of the receiver was injected into the three recording systems: the echo-sounder recorder, the echo integrator, the digital echo counter. The threshold for all three was set at -24 dbv to permit a direct comparison between the systems.

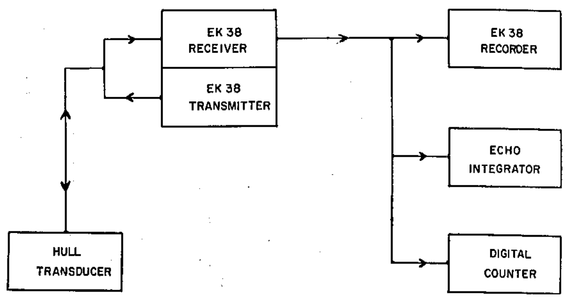

FIG. 1. A simplified block diagram of the system used on research vessel *G. O. Sars*. Arrows show direction of signal in the system.

The echo integrator (Dragesund and Olsen, 1965) accumulates the voltage from the received echos and resets automatically after each nautical mile or after full-scale deflection is reached. Also, it can be reset at any time by the operator. The sampling depth range is controlled from the transmitted pulse, gating for the desired layer to be sampled. If individual fish are recorded, the integrator reading is proportional to the number of recorded fish.

The echo-counting system (Dowd, 1967) records the number of echos from each transmission in digital form. The system uses a delayed pulse technique to sample a fixed distance from bottom irrespective of water depth. The resolution obtained depends on the pulse length, and separate counts can be obtained for individual fish if they are separated by more than 25 cm. In this experiment the echo counter was changed to sample the same layer as the integrator and converted from delayed pulse to transmit gate. The pulse lengths used were 0.3, 0.6, and 1.0 msec, nominal. Since the integrator was not changed to compensate for change in pulse lengths and the pulse-length gates in the counting system were changed to 0.6, 0.9, and 1.3 msec respectively, an increase in slope with an increase in pulse length was expected.

In Lofoten, the spawning cod are concentrated in a layer between 75 and 125 m below the surface and where the depth of water is approximately 150 m. During the night the cod occurred as well-separated fish, but aggregated in shoals during the day. In a sample obtained by purse seine the mean length was found to be 89 cm. The length of cod was generally between 65 and 105 cm. The sampling of echo information was carried out mostly during the night hours, and areas of different concentrations were selected. The ship speed was maintained at 5 knots. The counter and integrator were adjusted to record signals from the same depth range, 100–125 m. The readouts were taken at 10-min intervals. Echo-sounder paper counts for the depth range were taken whenever separation of echos permitted.

RESULTS

Figures 2A, B, and C show plots of integrator voltage versus echo count with fitted regression lines. The correlation coefficients are 0.84 (24 df), 0.94 (30 df), and 0.96 (30 df), for the pulse lengths of 0.3, 0.6, and 1.0 msec respectively. Since the integrator voltage is directly proportional to the pulse length and the counting system was adjusted to compensate for this change, an increase in slope with an increase in pulse length was expected and obtained. The slope for the three pulse lengths differed significantly as follows:

Pulse length (*msec*)	Slope	Difference between pulse lengths	*t*	df
0.3	.0044	0.3–0.6	3.7	52
0.6	.0070	0.3–1.0	5.7	53
1.0	.0085	0.6–1.0	2.7	53

Figure 2D shows the relation between the integrator and counter for high density daytime recording. The correlation coefficient between the two for the 0.3-msec pulse length was 0.99 (14 df). However, there was significant difference between the slopes for the day and night recordings (i.e., high and low densities) for 0.3-msec pulse lengths ($t = 4.1$, 37 df).

Figures 3A, B, and C show the relation between the actual paper counts and converted digital counts. Because individual counts cannot be resolved on paper for high fish densities, the comparison was possible only for night recordings.

To convert the digital instrument counts, C, into the estimated numbers of targets (fish), N, we proceeded as follows. If b_w is the beam width at the sampling depth and t_r is the transmission rate, if V is the ship's speed and T is the time of run, then the overlap factor between successive transmission is $(\frac{b_w t_r}{VT})$. The estimated number of targets seen by the counting system during the sample period is then

$$N = C\left(\frac{VT}{b_w t_r}\right).$$

With this formula, a conversion to the estimated numbers of fish was obtained and plotted against the paper counts (Fig. 3). Good correlation was obtained between the two methods with correlation coefficients of 0.96 (23 df), 0.98 (29 df), and 0.91 (30 df) for the pulse length of 0.3, 0.6, and 1.0 msec respectively.

DISCUSSION

The integrator readings and the echo counts for data of Fig. 2A–D could have been converted to the actual numbers of fish since the target strength of cod is known. This is unnecessary when comparing the two measuring

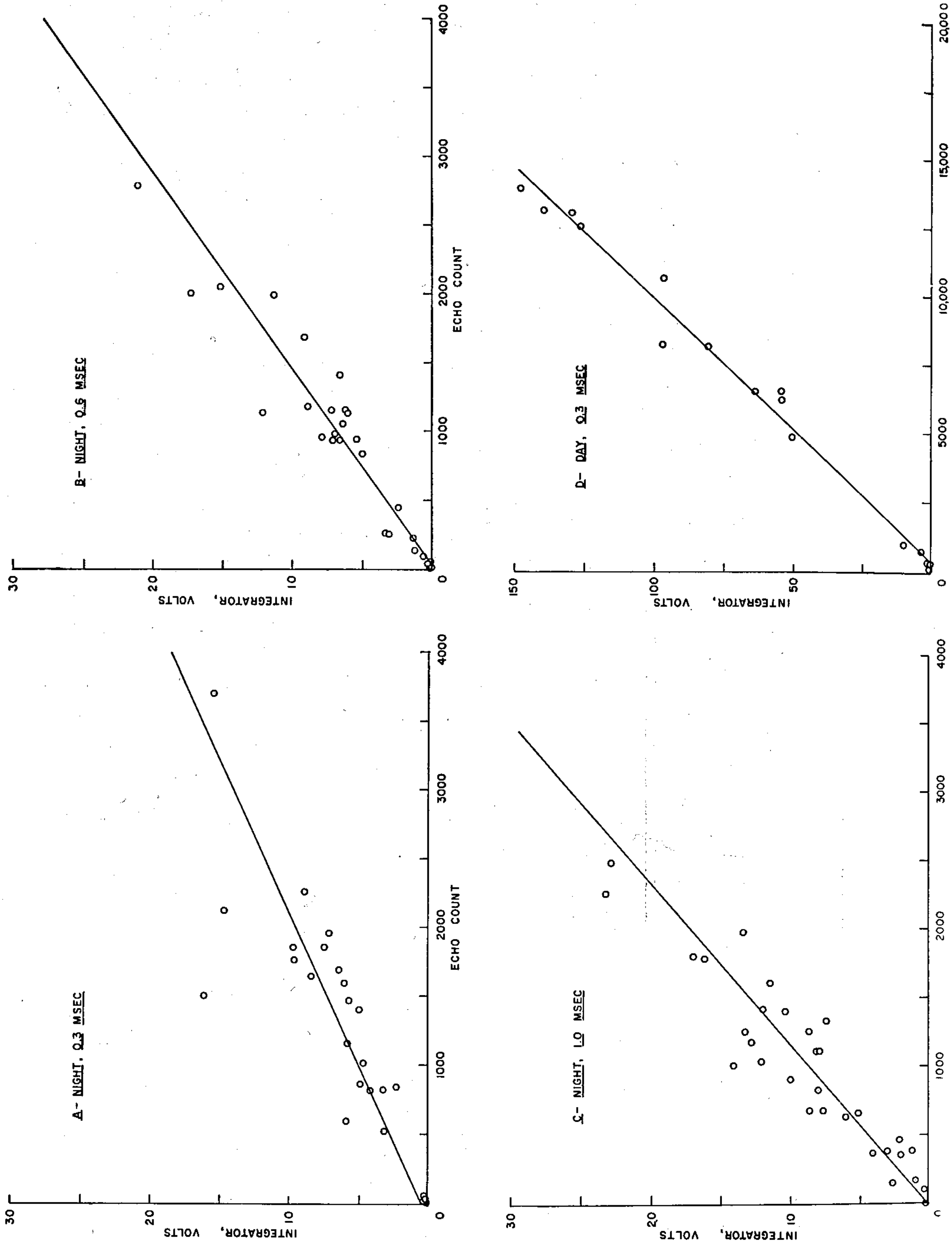

FIG. 2. Relation between integrator voltage and digital echo counts for: (A) 0.3 msec, (B) 0.6 msec, (C) 1.0 msec, night recording, and (D) 0.3 msec, day recording. The scale for D has been extended but maintains the same X–Y ratio as A, B, and C.

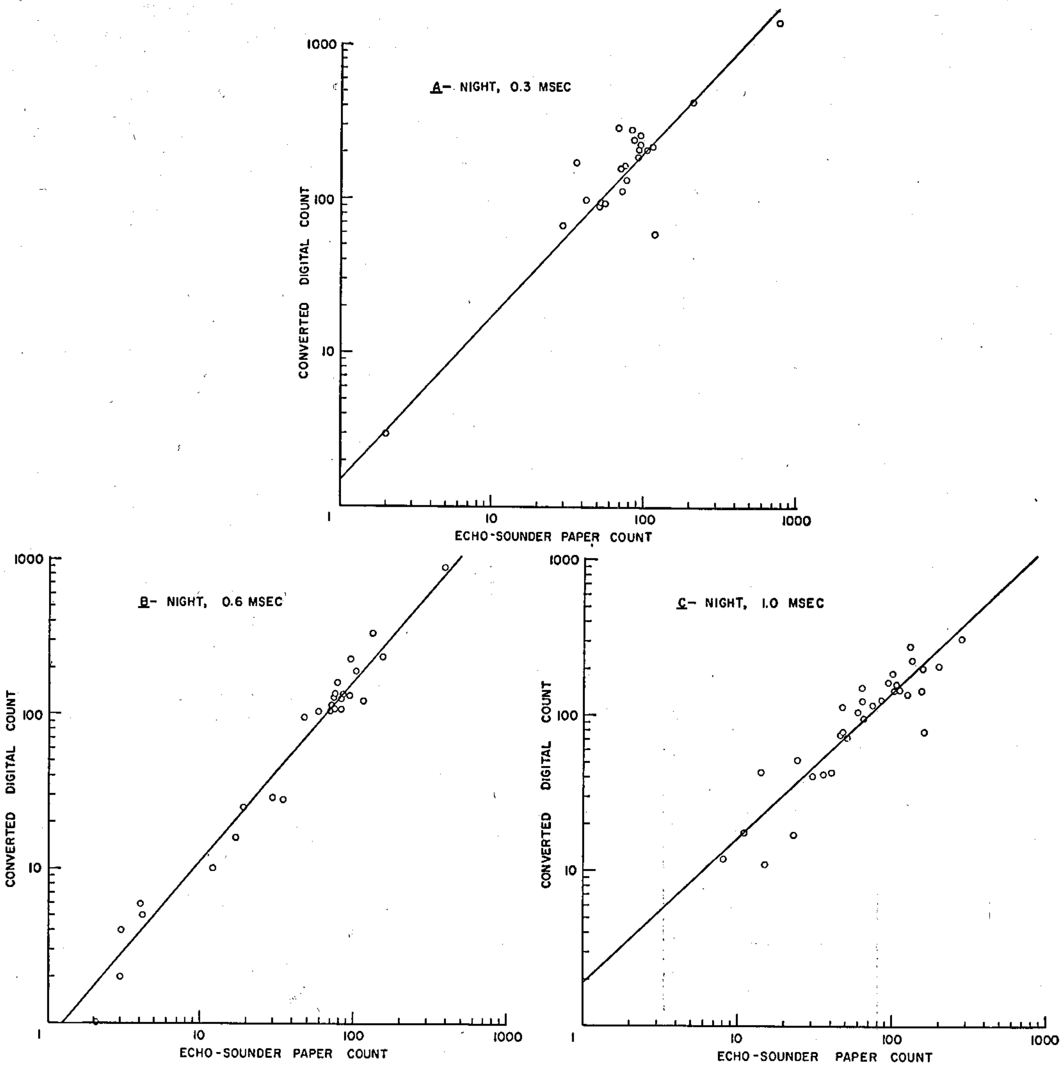

FIG. 3. Relation between converted digital echo count and echo-sounder recorder paper count for: (A) 0.3 msec, (B) 0.6 msec, and (C) 1.0 msec.

systems. At low fish densities, good agreement was found in all instances among the three systems. However, the relation between the number of counts and the integrator values was found to be significantly different between day and night. This implies that one or both of the recording systems are not linear with the actual numbers of fish. At night, when fish are recorded as singles, both units record values proportional to the actual numbers. But by day, when the fish are aggregated, the digital recorder accumulates lower numbers in relation to the integrator. However, the relation between the two systems is linear over a wide range of total counts, implying that the density of aggregation is reasonably constant and independent of school size. It also implies that neither system has a linear response to changes in the total actual numbers of fish during schooling. Further experiments should be conducted on the aggregation behaviour of fish for stock estimation, including integration, counting, and fishing, to attempt to obtain a better knowledge of the relation between sonic measurements and the actual numbers of fish is schools.

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