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Observed avoidance behaviour in herring in relation to passage of an echo survey vessel

by

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INTRODUCTION

The extended use of echo sounders for fish finding ought perhaps to give no doubt about how well fish are registrated by an echo survey vessel. Typical patterns of behaviour in some fish species when reacting on noise stimuli as stimuli generated from an approaching vessel, would be to avoid the noise source. This could indicate that care shall have to be taken when echo sounders are intended to tell the truth about the fish density in an area. The approach of the vessel may have an effect of reducing fish density beneath the vessel and the change of space orientation may bias acoustic fish density estimates.

Conventional vertical echo sounding can give no information about the situation before the vessel approaches and the echo recordings are indeed difficult to analyse for the purpose of indicating avoidance behaviour of the fish. Careful analysis of single fish echo traces may in principle give some information about vertical movements of fish and distributions of echo target strength may tell something about average dorsal aspects of the fish, if good enough basic knowledge of target strength and aspects distributions are at hand (Foote, 1979).

Perhaps a better approach to obtaining information if avoidance behaviour takes place, would be to observe the fish density and behaviour in an undisturbed situation and then record if any changes occur when a vessel is passing.

In this paper are reported some experiments carried out with the intention to collect information of the possible importance of such behaviour phenomena in relation to quantitative fish abundance estimations methods as echo integration. The investigations are still continuing and the quantitative aspects are only briefly discussed.

Methods of observation.

In winter time, consentrations of herring (Clupea harugus L.) can be found in the fjords of Northern Norway. At night the consentrations form scattering layers in the upper water and such co ditions were assumed favourable for the intended behaviour studies The first experiments were carried out in February/March 1979 with the 100 feet research vessel R/V "Johan Ruud" running at various speeds over the fish consentrations.

Two different methods of observation were applied. By running the conventional ship echo sounder (Simard EK 120) with fast external trigging (8 pr. sec.) in connection with a 50 cm grafic recorder (EPC 3200), expanded display of single fish echo traces could be obtained. This method allows a detailed examination of single fish echo traces. The second method of observation was to make echo recordings by a stationary submerged transducer in the course line of the vessel. Information about fish density and vertical distribution could then be obtained before the vessel was approaching and during the passage. The transducer was either submerged to a position close above the fish consentrations, facing downwards, or beneath the consentrations facing towards the surface. In Fig. 1 is shown the experimental set up.

In order to reduce eventual disturbing movements of the transducer when the vessel was passing (and if touching the suspension system) only a small buoy of the balancing floats were floating right at the surface. By observing from an assisting boat, the vessel position in relation to a small flashlight buoy attached 10 m beside the transducer, exact logging of time of passage could be made on the corresponding echo recordings.

Observations.

The first experiments were carried out on consentrations of adult prespawning herring (25-30 cm). In a small fjord (Aasenfjorden) the herring at night time were distributed in a dense scattering layer reaching from about 10 m to 25 m depth. The water depth was 50-70 m.

In Fig. 2 is shown an echogram obtained from the submerged transducer facing upwards at 48 m depth. The upside down echogram is presenting a recorded sequence to be read from right to left. The sequence shows a situation with the research vessel approaching the submerged transducer at a speed of 9 knots and starts with the vessel at a distance of about 125 m.

During the moments of passage, the herring (which are seen consentrated in a well defined scattering layer) undertake a distinct and sudden downwards migration. Within the time period of 2-3 seconds before the bough is passing above the transducer, plus about 4-5 sec. after (passage of the propeller), the entire scattering layer has descended 7-8 m. This gives and average downwards migration within this time period of about 0.75 - 1 m/s.

In the top part of the echogram is seen the recordings of the hull and later on of the wake of the vessel. Because of the rather wide beam angle (27°, (- 3 dB)) the bough is appearing on the recording about 3 sec. before passage of the transducer position. After a period of a few minutes the disturbance in the scattering layer is gradually disappearing.

The very upper part of the undisturbed herring registrations recorded by the submerged transducer were found at a depth of 9-10 m. In the same nearby area and during the passage of the submerged transducer, the uppermost fish registrations on the echo sounder onboard the research vessels, were at a depth of 13-14 m. This indicates a downward migration of the herring of 3-5 m between consentrations recorded onboard the vessel during the run and the undisturbed fish consentrations.

In Fig. 3, Fig. 4 and Fig. 5 are shown registrations of concentrations of fat herring (20-23 cm) at night time obtained during similar experiments in Balsfjorden. In these experiments the submerged transducer was suspended in a normal downward facing position at 16 m depth (Fig. 3, Fig. 4) and at 10 m (Fig. 5). The herring are seen distributed in a disperced scattering layer from about 20-60 m depth. At the low end of the recordings ar marked the visually observed horizontal distances between the submerged transducer and the vessel during the run.

In all recordings can be observed a sudden descent of the herring in the moments of passage of the vessel. At the same time an apparent reduction in number of targets seems to take place, particularly in the recordings of Fig. 3 and Fig. 4. The recording of Fig. 5 were the fish are somewhat deeper, shows that the downward migration takes place throughout the scattering layer even at a depth of 50 m.

In Fig. 6 is shown an echogram obtained in the same experiments (transducer at 16 m depth), but recorded with an extremely fast recording paper speed (5 mm per sec.). The recording indicates that very little disturbance in the scattering layer takes place until the bough of the vessel has approached a distance of about 50 m. Again a general descent of the fish appears and also an apparently time limited reduction in numbers of fish within the area of the acoustic beam is observed.

Some additional runs were undertaken with the vessel passing the submerged transducer at varying horizontal distances. The descending reaction were observed still significant at a distance of 20-30 m, but were only weakly observable at a distance of 40-50 m. When the submerged transducer were tilted 45°, looking sideways down towards the area beneath the path of the vessel, a temporarily reduction in the numbers of targets could always be observed.

All the echo signals received during the experiments on fat herring consentrations were tape recorded (Simrad EM-system). The computation of these data are not completed. But there seems to be significant evidence for a conclusion that besides a reduction in the number of received fish echoes which appears during the passage of the vessel, their mean target strength are reduced as well.

In Fig. 7 are shown an echogram of expanded echo traces obtained on the echo sounder onboard the research vessel during a run on fat herring consentrations (speed 8 knots). The echo sounder was run with full depth compensating amplification (TVG: 40 log + 2 R).

The traces originate from fish being positioned in all parts of the acoustic beam when the vessel runs, but the longest traces are assumed belonging to fish having been positioned in the beam axes. A maximum observation beam angle of ≈ 16° have then been calculated by measuring the horizontal length of the longest echo traces in each depth interval and comparing this with recording paper speed and sailing speed of the vessel (beam angle of the transducer (-3 dB) = 9.5°).

The form of the echo trace will also depend on the tilt of the transducer. This tilt was measured by a diver using a specially designed under water spirit level meter. With normal trimming of the vessel, the tilt was 2,1° in ahead direction when the vessel was stopped, and increased to 2,7° at a vessel speed of 10 knots.

On basis of the maximum observation beam angle and the transducer tilt, an expected echo trace form of a fish with omnidirectional back scattering passing through the acoustic beam axes with no vertical movement, can be drawn as shown in Fig. 8 (8 knots). This ideal trace form has been used as a reference for later comparison of the obtained expanded echo traces.

Based on the following measurements for classification of the traces: horizontal trace length (l), vertical difference between points of beginning and end (d) and vertical difference between "curvation point" and point of beginning (h_1) or point of end (h_2), all traces in four sequences of recordings have been classified as originated from fish moving "up" (u), "down" (d) or swimming "horizontaly" (h). As a working routine only traces larger than 50% of the longest were measured (fish traces originating within 74% of beam cross section).

In Table 1 are listed the results. The analysed recording sequences are taken from runs with 4, 7.5, 8 and 10 knots within a tir periode of 2 hours in the middle of the night. Of all the 1122 traces analysed, 79 (7%) were classified as upwards moving fish, 182 (16%) were classified as fish staying horizontal and 861 (77%) were classified as fish moving downwards. The figures indicate little difference of behaviour between the different runs at various speeds, except that in the run at 4 knots there appears to be a reduced downward movement in the very deepest part of the fish consentrations. Fewer fish were apparently present close to the surface in the moments of recording in this run. (In a similar run at slow speed on adult herring, almost all fish seemed to disappear out of the beam area).

Discussion.

Both methods of observation have shown that herring under the present conditions reacted with a downward migration when the vessel was passing. It is not known to what extent this behaviour also gave a reduction in fish density in the echo sounder beam area beneath the vessel, but some reduction is strongly indicated.

It should be stressed that the observed behaviour shall of course not be looked upon as general, it could only be typical for herring in this season. However, from what is known in the fisheries for herring, the herring in the summer feeding season will often show a far more nervous behaviour to the presence of vessels (Olsen 1971). Similar behaviour of capelin have also been reported from fishermen. There are therefore reasons to believe that the observed phenomenon could be rather typical at least for related species.

The herring were observed to react at a depth of 50-60 m. Recordings of fish in deeper water (80-90 m) as shown on Fig.9 did apparently not show the same descending tendency. These fish were, however, identified by trawling as a mixture of cod (40-70 cm) and herring and traces from herring can not be clearly seperated.

The observation of a downward swimming in the order of 0,75 - 1 m/s implice a considerable downward tilt of the fish during the swimming. If these fish were swimming at an estimated maximum speed of about 2 m/s (4 knots or 6-8 bl/s), they would swim with an average downward tilt of 20-30°. Their individual downward orientation will probably show some variance (Beltestad, 1973).

The classification of echo trace formes is based primarely on the assumption that each fish during the movements of observation (1-3 sec.) is swimming at an approximately constant space orientation and secondly that fish echo targets have an omnidirectional back scattering. The first assumption may be looked upon as beeing reasonably probably, but the second is in most cases definately wrong and would at least be a great oversimplification. But to what extend may this bias the results?

In Fig. 10A are shown 5 dorsal aspect back scattering patterns of herring obtained on stunned fish (120 KHz, Foote & Nakken 1978/ Nakken & Olsen 1973). Although some deviations occurs the average picture of dorsal aspect back scattering in herring would be approximately like shown in Fig. 10B. If such a fish are recorded by a sailing vessel both the horizontal orientation and vertical tilt will influence the trace form. Fish moving within the direction of the sailing vessel will give trace forms which have a rising tendence as fish moving against the vessel will give traces which have a falling tendence. Sideways move in relation to the vessel will have less influence on the form of the trace because of the more inform back scattering in the transversal plane.

The expected behaviour in herring when scared by noise would be to turn away from the noise source and increase swimming speed (Hering 1968, Olsen 1969). When a noisy vessel is approaching at some angle above the fish, the well developed directional hearing ability will give the fish no problem to determine the direction towards the source and the fish would most probably turn away with a gradually increasing downward tilt.

When a fish is recorded within a beam angle of 16° this would imply a target strength variation of about 12 dB when crossing the beam, which is surprisingly much, unless the fish are moving "together" with the transducer some period of time. With the rather directional dorsal aspect back scattering pattern in herring this may only be possible if the fishes also are increasing the downward tilt during passage of the vessel.

In spite of a highly probable and indicated dominating horizontal orientation which will bais a trace form distribution with more formes with a rising tendency, more than 3 out of 4 of all traces which could be analyzed did show a falling tendence. Although the traces analysed are selected, a bias may only be probable due to a selection of traces originating from fish moving within a limited downward tilt. If the downward tilt is too high (>15-20°), the echo trace should be expected to be weak and irregular, and possibly not to be read.

More exact computation of the downward migration by utilization of trace angle distributions may be possible, but only when more precise evidence of the horizontal distribution of the fish during the moments of passing can be given.

All these details in the behaviour shall have to be considered when discussing an expected mean echo target strength of fish or for estimating echo integrator density coefficients. These apsects shall not be further dealt with in this paper. But it ought to be rather obvious that a considerable reducation in mean echo strength shall have to be expected compared to conditions when the fish behaviour are not significantly influenced.

Echo recordings like shown in Fig. 9, which apparently tell that many fish are present, may thus not tell the full truth. A considerable number of fish may be "hidden" in the beam due to their downward "flying" or the vessel may even have scared some of them out of the beam area.

Trace analysis could be one way of obtaining information if such a situation is present, more behaviour studies could be another.

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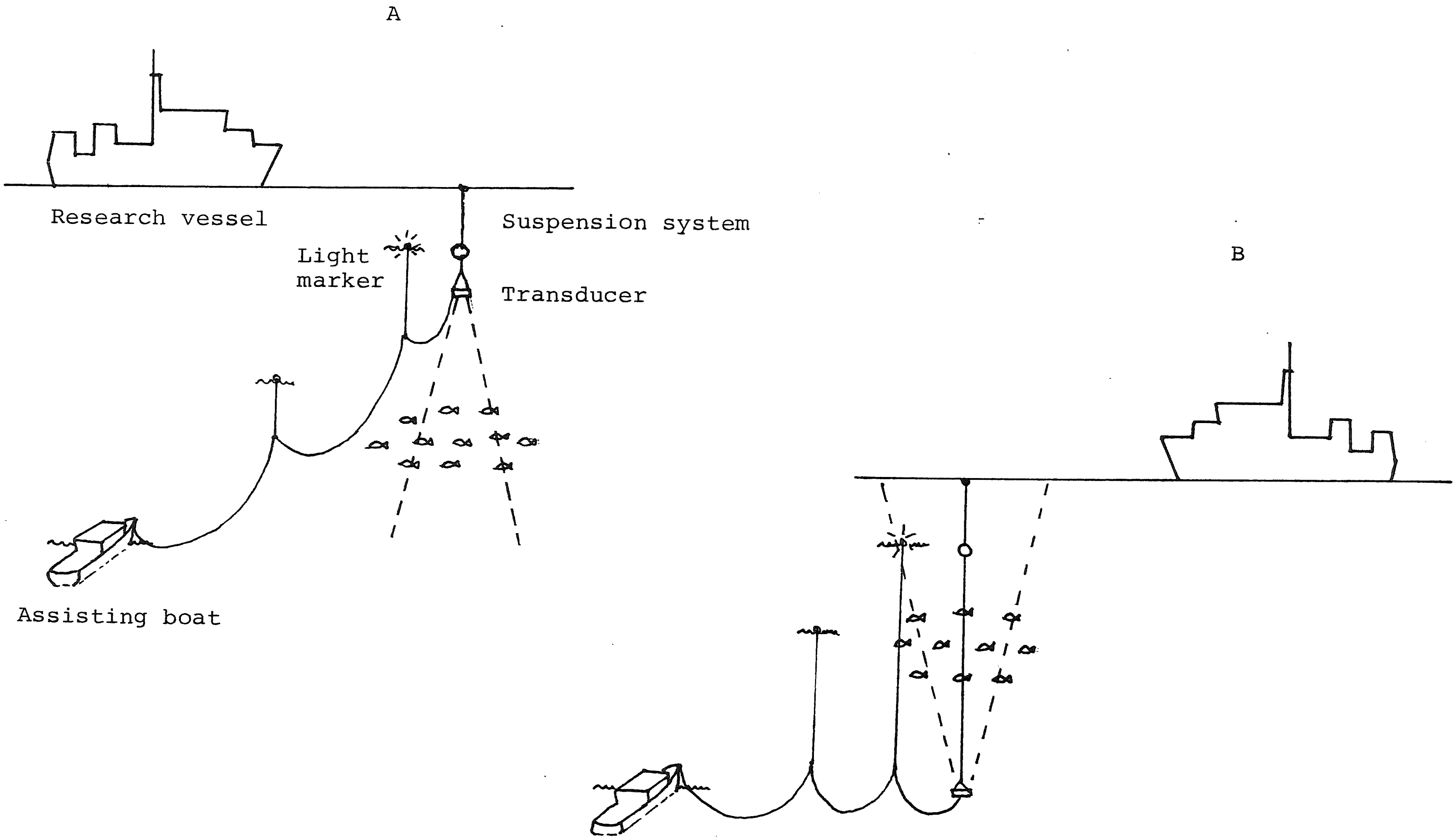

Fig. 1. Sketch of experimental set up.
A, run with the submerged transducer facing downwards.
B, run with the submerged transducer facing towards surface.

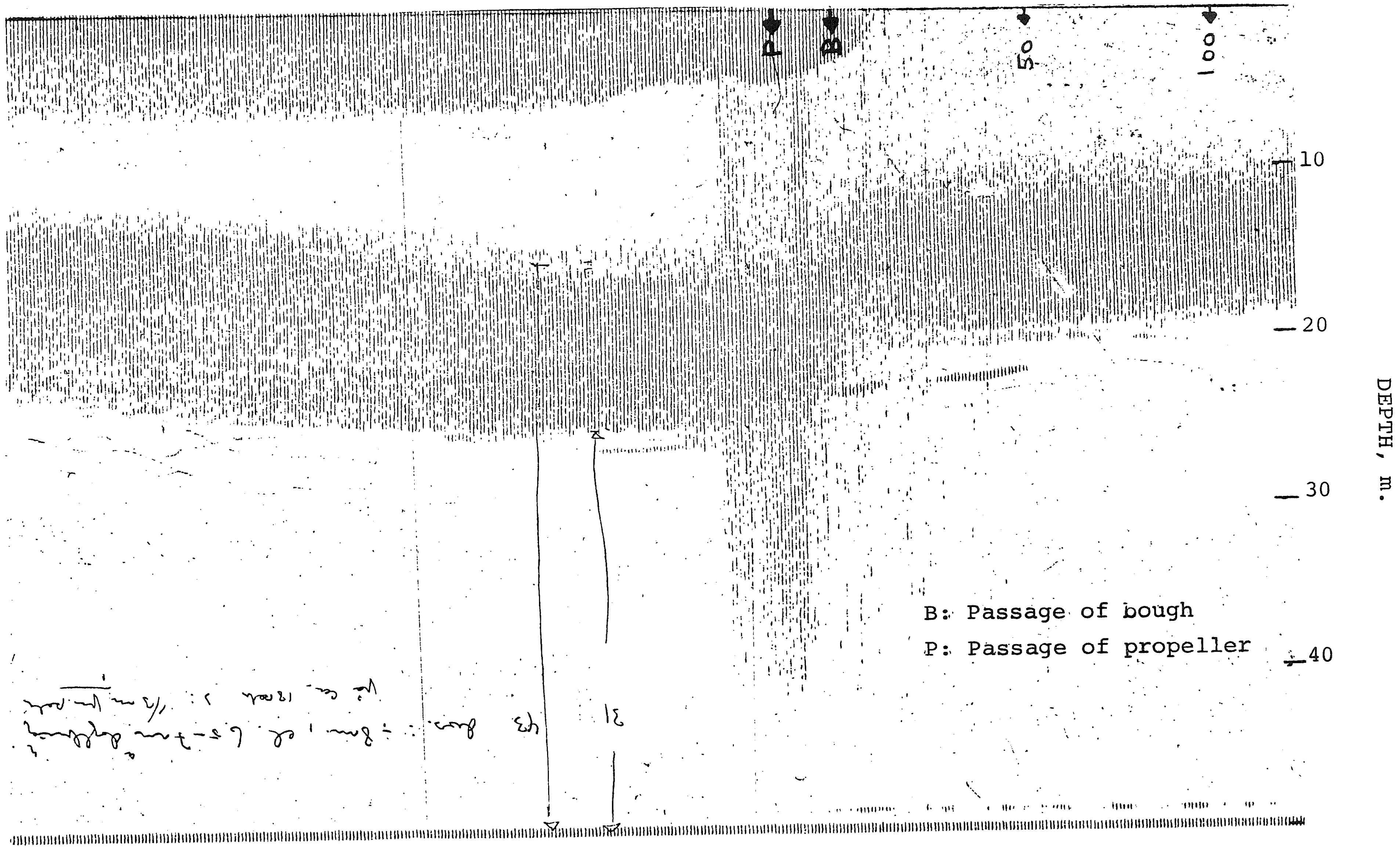

Fig. 2. Echo recording obtained by the submerged transducer at 48 m depth facing towards surface.

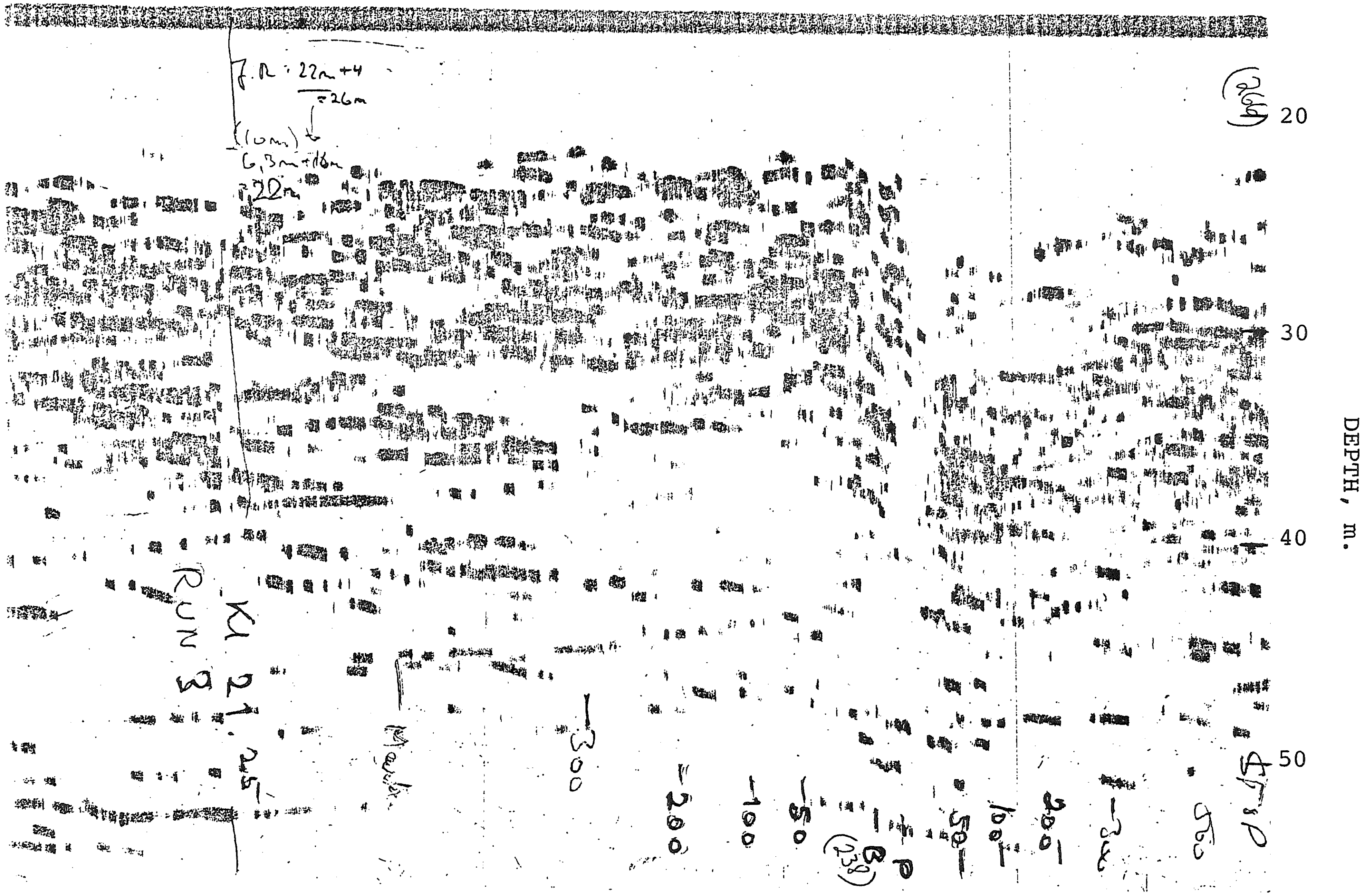

Fig. 3. Echo recording obtained by the submerged transducer at 16 m depth facing downwards.

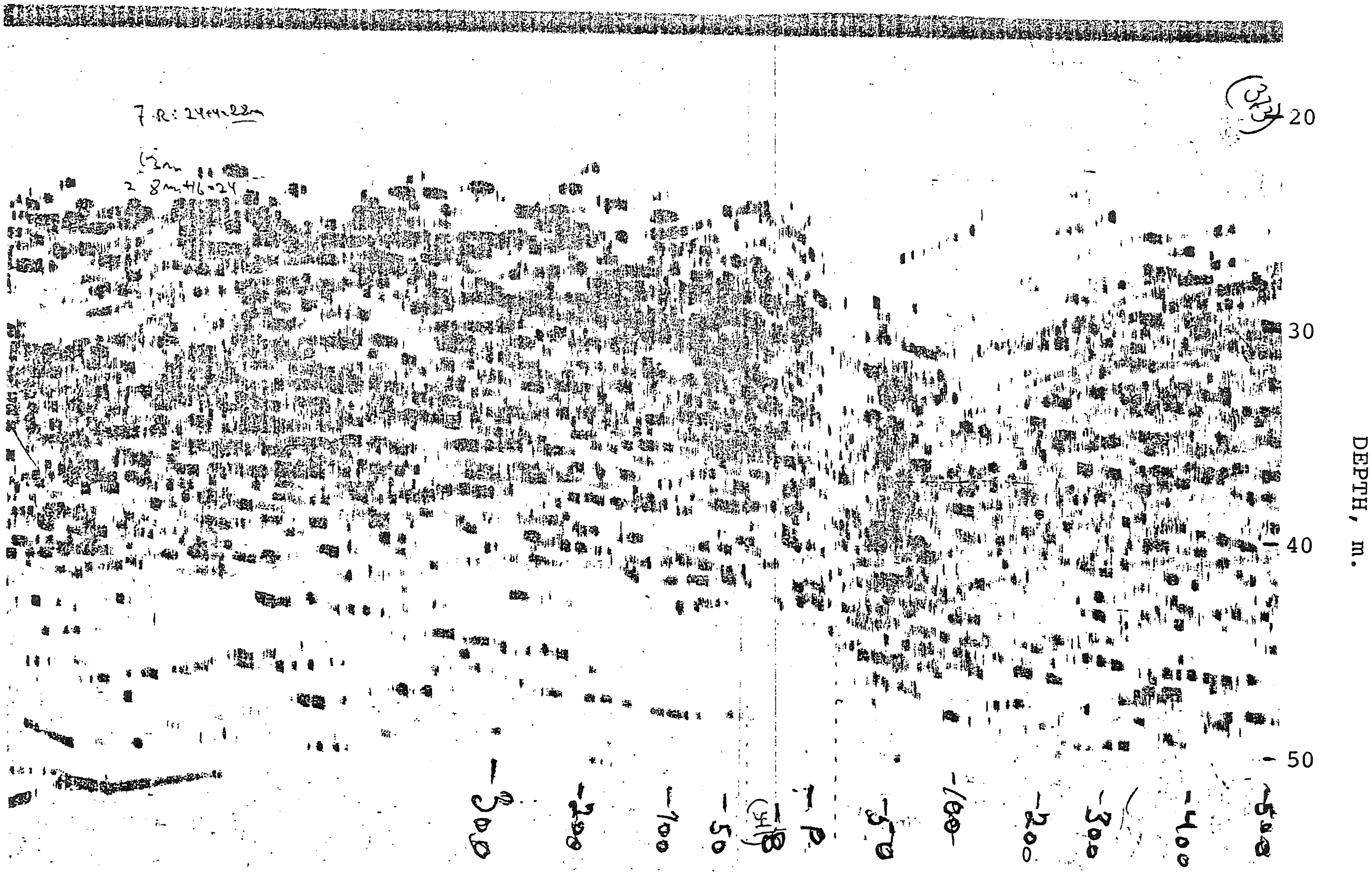

Fig. 4. Echo recording obtained by the submerged transducer at 16 m depth facing downwards.

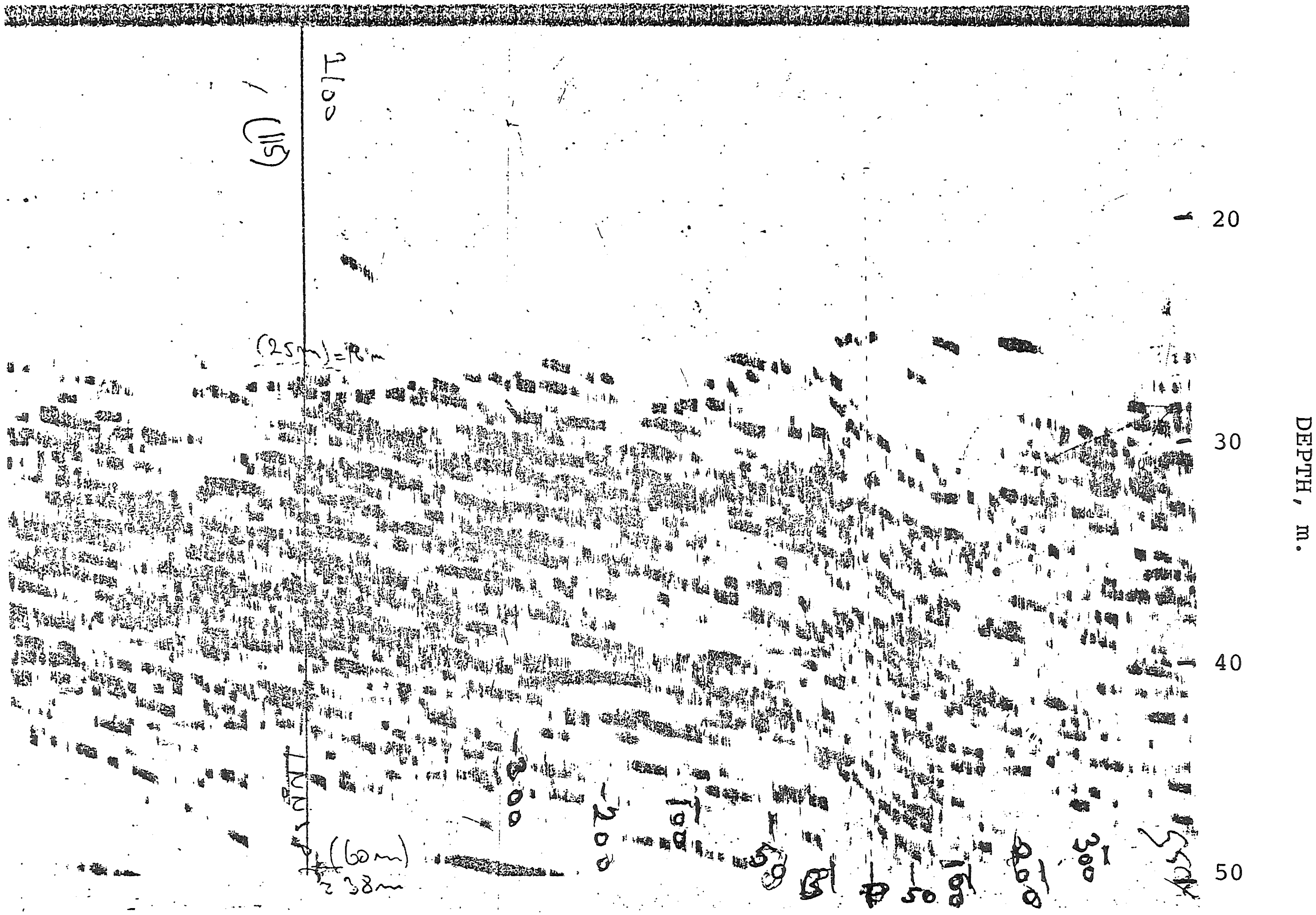

Fig. 5. Echo recording obtained by the submerged transducer at 10 m depth facing downwards.

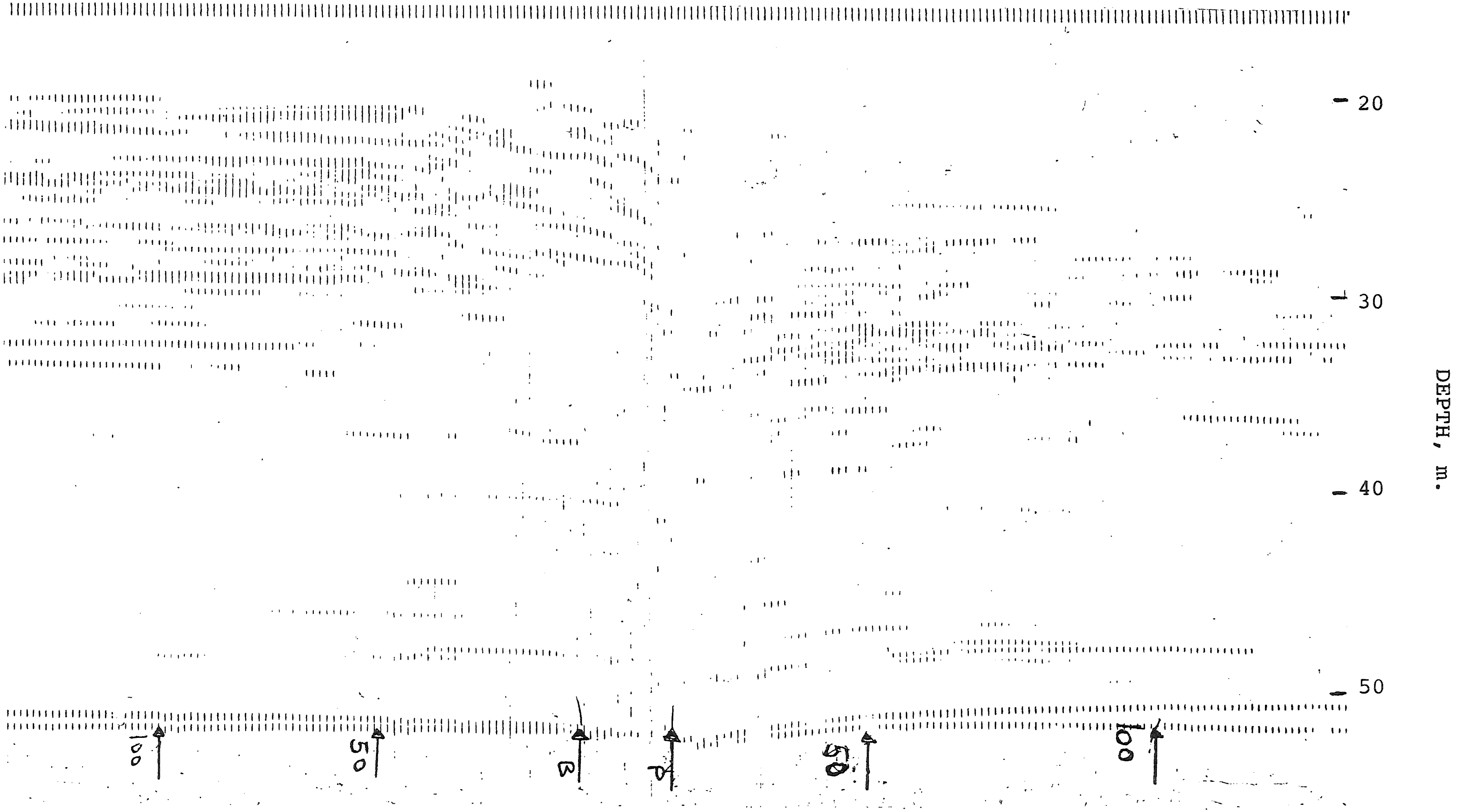

Fig. 6. Echo recording obtained by the submerged transducer at 16 m depth facing downwards. Extreme fast recording paper speed (5 mm pr. sec.).

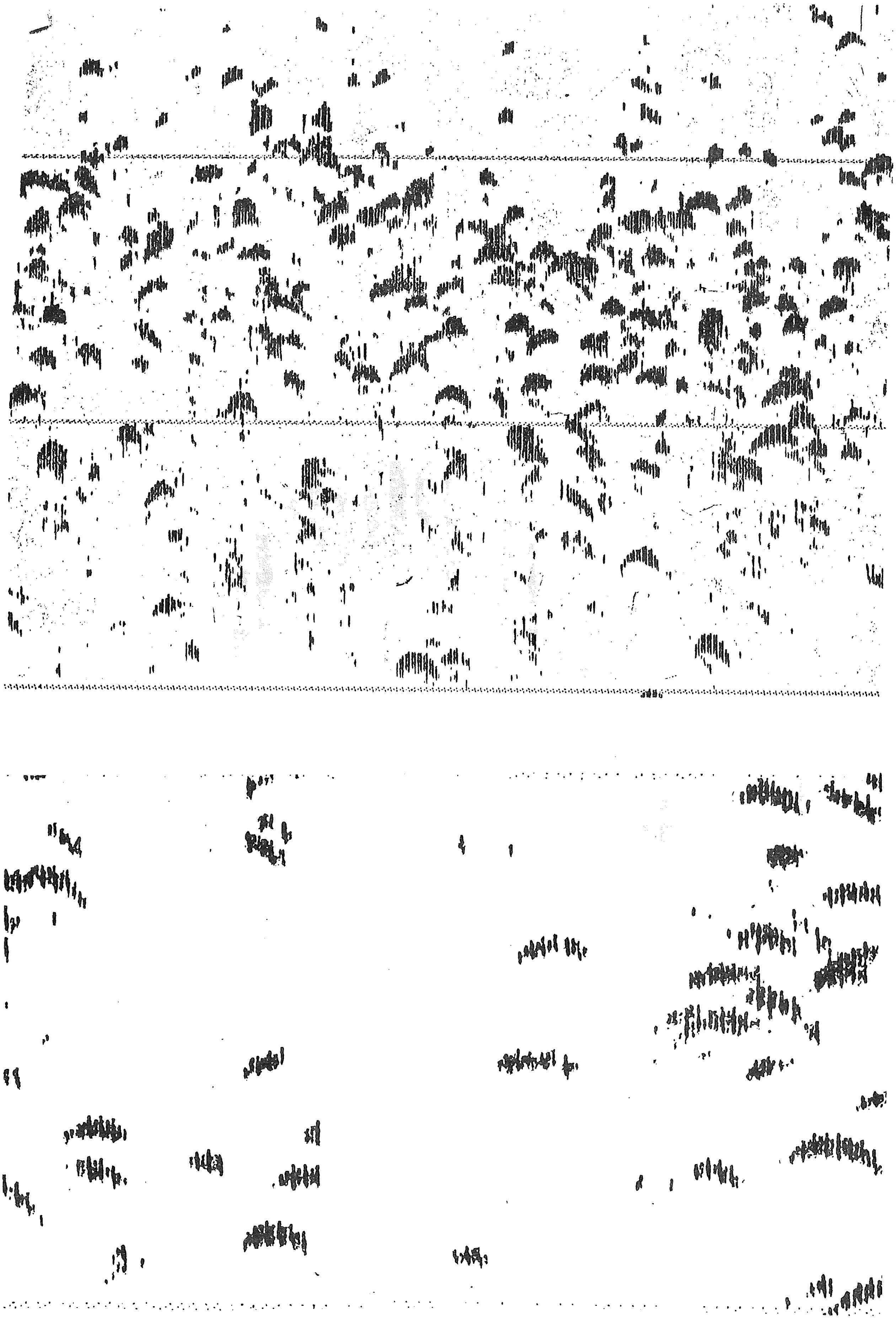

Fig. 7. Expanded scale echo recording obtained by the 120 KHz echo sounder onboard R/V "Johan Ruud" (A: original recording, B: x2 photografic magnified).

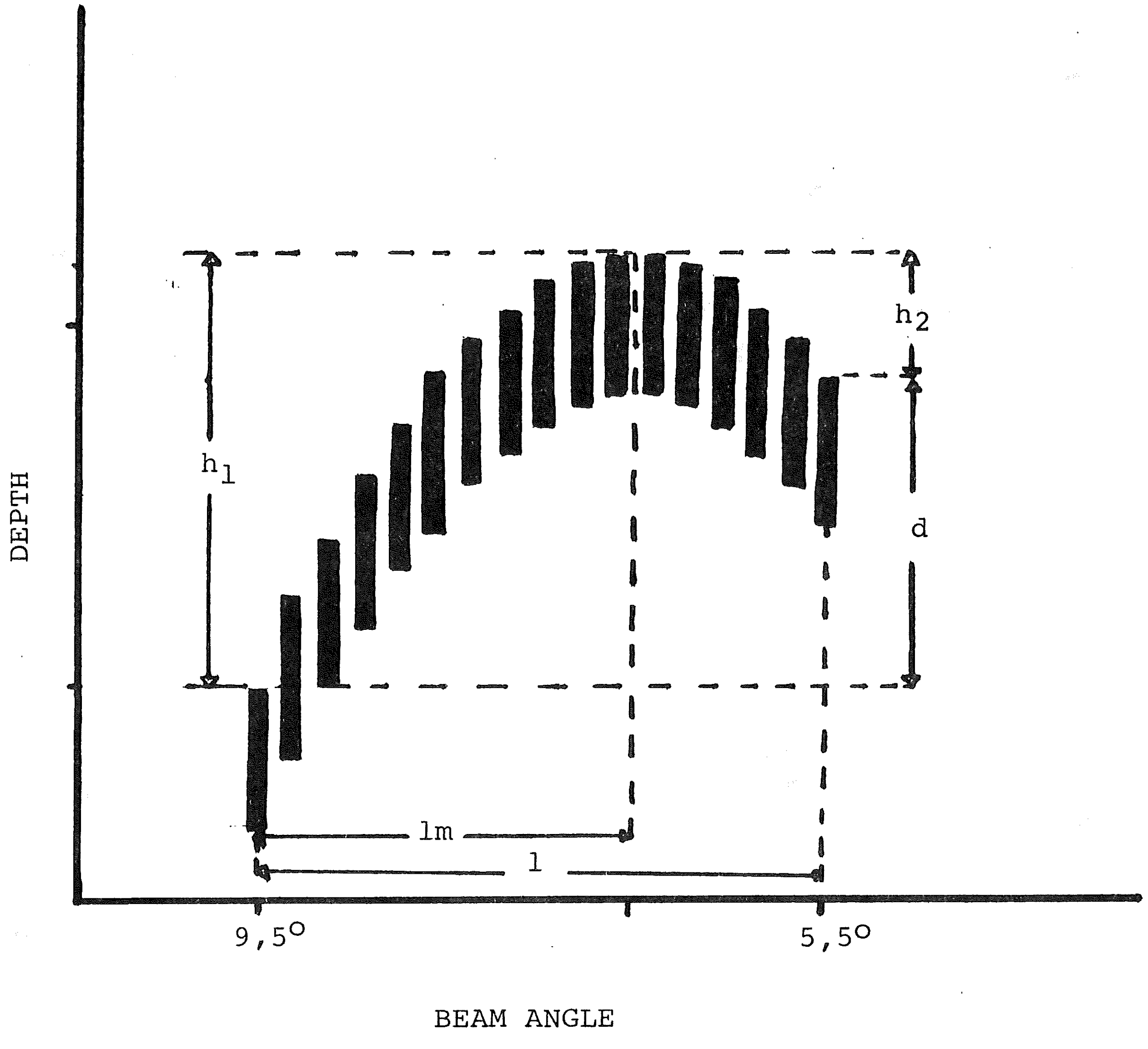

Fig. 8. Expected form of a fish echo trace recorded within beam angle of 16°, with an ahead transducer tilt of 2,5° (8 knots), passing through the beam axis with no vertical movement and with omnidirectional back scattering (echo sounder: 120 KHz, 0,1 ms pulslength).

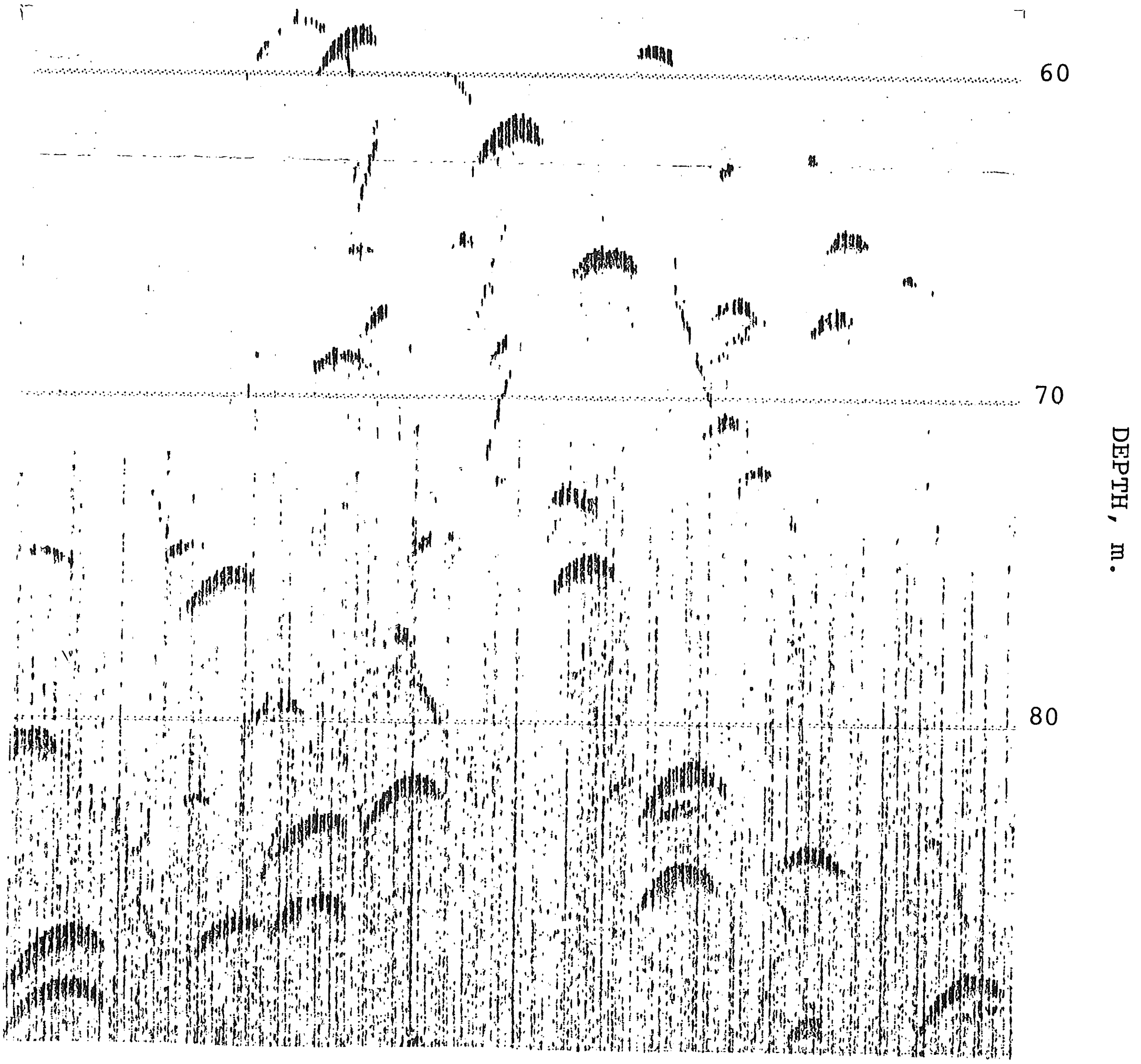

Fig. 9. Expanded scale echo recordings of fish (mixture of cod and herring) at 60-90 m depth.

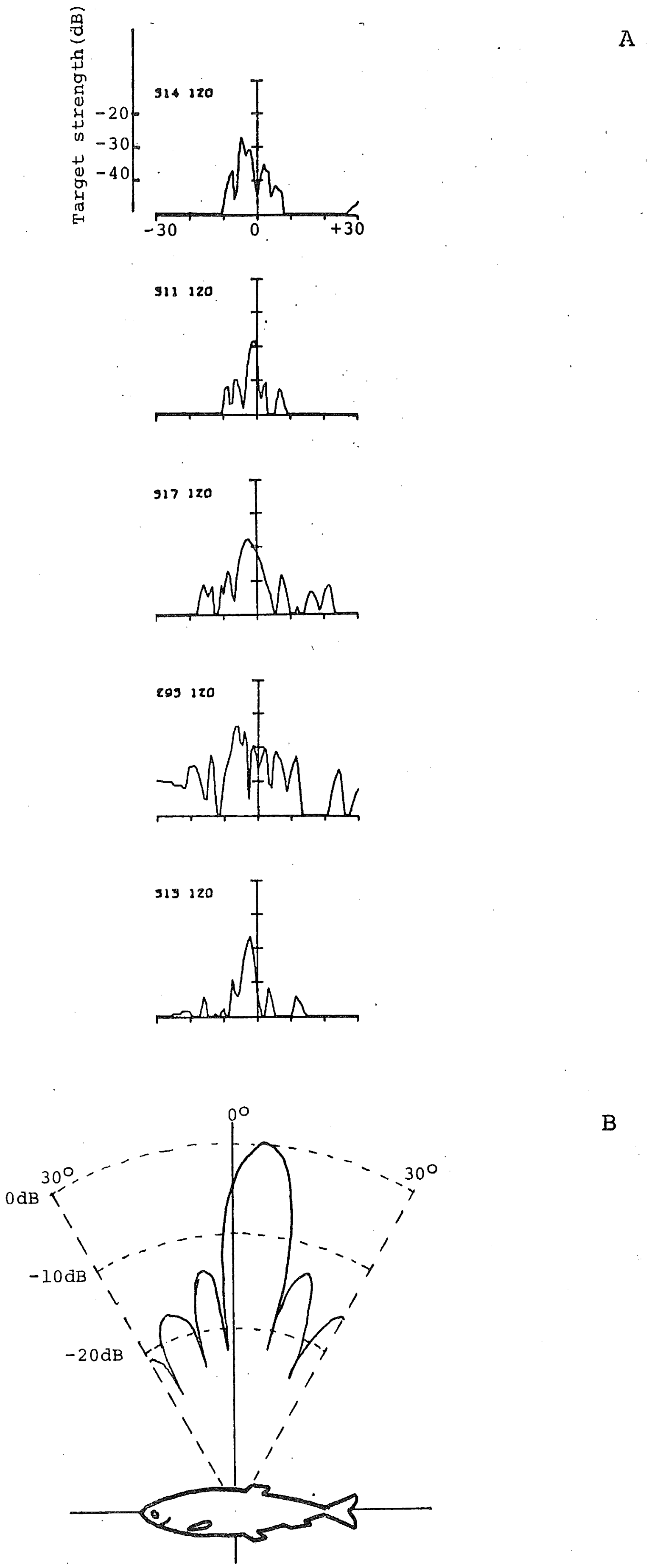

Fig. 10. Dorsal aspect target strength in herring as a function of tilt angle (120 KHz) (-degrees = "head down"). (Foote & Nakken 1978). (A: single fish diagrams, B: average directivity pattern).

Table 1. Classification of echo-traces obtained in runs at 4, 7,5, 8 and 10 knots (120 KHz). N is number of traces analysed, U is "upward" moving fish, H is "horizontally" moving fish, D is "downward" moving fish.

DEPTH INTERVAL	RUN AT 4 KNOTS				RUN AT 7,5 KNOTS				RUN AT 8 KNOTS				RUN AT 10 KNOTS			
	N	U	H	D	N	U	H	D	N	U	H	D	N	U	H	D
20 - 26	4		1	3	13	2	1	10	10	1	1	8	28	2	6	20
26 - 32	35		3	32	56	3	9	44	55	3	14	38	88	12	11	65
32 - 38	82	3	3	76	55	3	6	46	95	8	20	67	104	6	13	85
38 - 44	57	3	4	50	40	3	13	25	68	7	14	47	52	1	5	46
44 - 50	62	7	3	52	16	0	8	8	18	0	3	15	22	3	4	15
50 - 56	51	5	7	39	26	1	5	20	6	1	1	4	19	0	8	11
56 - 62	60	6	19	35												
	351	23	40	287	206	12	42	153	252	20	53	179	313	24	47	242