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On the possibility of estimating year-class strength by measuring echo-abundance of 0-group fish

By

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INTRODUCTION

The most commonly used method of estimating relative year-class strength in marine fishes is that of comparing the frequency distribution of the different year-classes in the exploited stocks. For a number of reasons it would be very desireable to determine the year-class strength at an earlier stage, and the first question that arises in this connection is then: at what stage or age in the life history of a fish is the strength of a year-class decided ?

It is generally accepted that the natural mortality may be extremely high in the very early stages of life, but little is known about the magnitude of the early mortality rate, its variability, and the exact time of levelling off. Various authors have suggested that there are critical periods during early life when mass mortality may occur. For instance Rollefsen (1930) suggests that in the case of the Arctic cod mechanical damage of eggs by wave action may have a serious effect. Hjort (1914, 1926) mentions mass mortality caused by lack of suitable food immediately after the time of yolk absorption and/or drift of larvae to unfavourable localities.

The hypothesis of critical periods has been discussed by Marr (1956), who concluded that although catastrophic mortalities restricted in time will always remain as a possibility, evidence points towards survival at a constant rate or at a constantly increasing rate, rather than towards the existence of critical periods.

In the case of post-larval fish fry, however, a number of workers have presented evidence of a proportional relationship between the abundance of 0-group fish of a particular year-class and the subsequent abundance of the same year-class at older ages (se for example Russel (1935), Knudsen (1954), Saville (1956)), and as a working hypothesis for the present investigations we shall assume that such a relation does exist.

During late summer and fall post-larval fish fry of many species are pelagically distributed off the Norwegian coast and in the Barents Sea, and in this paper we shall discuss the possibilities of estimating their distribution and abundance by a combination of echo surveying and fishing experiments with pelagic trawl and purse seine.

The success of such investigations depends on the fulfillment of the following requirements:

1. A fairly complete and accurate mapping of the vertical and horizontal distribution of the sound scatterers (echo-abundance).
2. Easy and reliable identification of the sound scatterers.
3. Exact measurement of the echo signals received.
4. Knowledge of the relationship between the amount of scatterers and the strength of the echo signals, and how this relationship is influenced by depth, species, size, density and behaviour of the fish.

SOUND SCATTERING BY 0-GROUP FISH AND THEIR IDENTIFICATION

When the echo sounder was applied in oceanographic research, the existence of scattering layers was detected over broad reaches of the oceans e.g. Hersey and Moore(1948),Johnson (1948),Tucker(1951),Parrish and Craig (1951). Observations made by different investigators in the same part of the ocean sometimes did not conform, but later investigations showed that these differences were mainly due to differences in echo sounding equipment, especially the operating frequency.

Hersey and Backus (1962) distinguishes between "scattering groups" and "scattering layers", and by their definition the scattering groups are discontinous in the horizontal plane with horizontal dimensions less than, or only a few times larger than their vertical extension. These aggregations are generally of high scattering cross-section and are usually attributed to schooloing fishes.

Those scatterers which are more or less continuously distributed in the horizontal plane, their horizontal extension being many times their vertical range, are called scattering layers. Commonly these layers appear on the record of an echo sounder as a uniform band of numerous relative weak echo traces.

The question has often arisen if density discontinuities themselves may give echoes to be recorded as a scattering layer. In the North Sea this problem was carefully investigated by Weston (1958) who demonstrated that the sharp density gradient at the level of a scattering layer was not the scattering agent. There is little doubt that the scattering layers are of biological origin, and planktonic animals including fish larvae are regarded as the probable source of these layers.

The sound scatterers referred to in the present paper are generally distributed in the top layers of water and compose scattering layers as well as scattering groups according to Hersey's and Backus's terminology. Their vertical extension may reach 50-100 m during the daytime, but at night they usually come closer to the surface. They are then distributed in typical layers, whereas during the day they cluster together in schools, (Fig. 1) i.e. scattering groups as defined by Hersey and Backus.

During the nineteen fifties scattering layers in surface water were frequently recorded in the Barents Sea and some success was made in identifying the cause of the sound scatterers by U.W.-photography (Midttun and Sætersdal 1959). However, no systematic routine program of identification was developed until 1959. For this purpose mainly midwater trawls have been used and proven successful to obtain samples from the depth strata where recordings were made.

Several attempts have been made to correlate the vertical distribution of sound scatterers recorded with the vertical distribution of marine animals as determined by capture methods (Cushing 1963). In many types of gear, however, and especially in towed gears (i.e. trawls, plankton nets etc.), the catch composition is greatly affected by mesh selection and differential ability of avoidance. Consequently, one cannot be certain that the catches obtained with such gears give representative samples of the organisms responsible for the observed scattering.

Various other approaches of identification have been tried, for example in Scotland with U.W.-photography technique (Craig and Priestly 1963). A further application of this technique has been developed by Soviet investigators (Fedorov, Truskanov and Yudanov 1963) who have recently reported successful attempts of combining results from U.W.-photography experiments with echo survey data for the purpose of estimating the abundance of adult Atlanto-Scandian herring. Similarly, during the last few years U.W.-photography experiments have also been carried out at this laboratory, but as yet, the methods and equipment applied do not seem to be sufficiently well developed for routine use.

DISTRIBUTION OF LARVAE IN RELATION TO THE CURRENT SYSTEM

The spawning of herring in Norwegian waters has in the last decade occurred from the end of February to the middle of March, and mass hatching of larvae is completed approximately three weeks later. The following weeks the distribution of the larvae is determined by the current running along the entire coast of Northern Norway. During the period 1957 to 1964 the major spawning grounds of the herring were located between Møre and Lofoten,

In the northernmost part of this area the main spawning of the Arctic cod also takes place, but the spawning time (March to April) is somewhat later than that of the herring. When the herring larvae pass the Lofoten area they are therefore mixed with cod-larvae, and the pattern of the drift is nearly the same for the two species.

In most years the main spawning of the Artic haddock takes place south of the Lofoten area, probably south of 65^{o}N (Sætersdal 1952), and the spawning time overlap with that of the cod. The haddock larvae are also distributed in the surface layers and consequently, the drift pattern of the haddock larvae is in general similar to that of the cod and herring (see for instance Wiborg, 1960).

During the further drift of the larvae in the areas north of Lofoten, including the Barents Sea and the eastern part of the Norwegian Sea, the distribution is largely determined by the current system in these areas, a general outline of which is shown in Fig.2 (modified from Tantsura 1959).

From the shelf west of the Lofoten islands the larvae are transported by the coastal current that flows northwards and the different species are gradually becoming mixed. Passing the banks off Troms the drift becomes more influenced by the Atlantic current, which in this area is intensively mixed with coastal waters (Ljøen 1962). Before reaching the entrance to the Barents Sea the water masses divide into several branches, one proceeding towards north, forming the Spitsbergen current. Off Torsvåg (70^{o}30'N), where a large shelf is located, two eastgoing branches separate form the Spitsbergen current. One of these flows along the coast of West Finnmark (The North Cape Current), the other one proceeds into the northern part of the Barents Sea. The North Cape Current again splits into two branches, one entering along the southern and the northern slopes of the Goose Bank, the other passing near the Murmansk coast.

Considering this current system the most likely extreme borders of dissemination of larvae hatched during the same year, and being passively transported by currents, would be the western shore of Spitsbergen (Hornsund Bank), the south western ares of the Central Bank, the Novaya Zemlya shelf, the southern slope of the Goose Bank, Kanin Nos and the inlet to the White Sea.

This distribution is confirmed by the observations made during the last few years, which indicate that from August to October fish fry of various species are abundant in the surface layers of the north and east going currents (Dragesund and Hognestad 1959,1962,Olsen 1960). By the end of the autumn the fry are aggregated along the frontiers between the cold and warm water masses covering the area from Spitsbergen to Bear Island and further to the east and south over the central and southeastern part of the Barents Sea (Fig.3). A concentration also takes place along the coast especially at the entrances of the fjords, whereas in the central region between the coast and Bear Island the larvae are less numerous. In late autumn the O-group of cod, haddock, and to some extent also herring and capelin, descend and settle near the bottom, and the occurance of fish fry in the surface layers during the winter months are more rare.

THE RELATION BETWEEN ECHO SIGNALS AND SCATTERING AGENTS

The echo signal received from an individual target is in the receiver transformed into an electric pulse of varying voltage (V_t), the energy of which is given by:

$$E= \int_{t_1}^{t_2} V_t \, dt. \qquad (1)$$

When the duration of the pulse is $t_2 - t_1$.

When a target passes through the beam of an echo sounder, echoes from the same target may be received for several successive transmissions, and the total energy of all signal pulses derived from the same target is:

$$S_E = b \, \bar{E} \qquad (2)$$

where b is the number of individual echoes received, and $\bar{E}$ is the mean energy of the pulses.

The strength and duration of the individual echoes are affected by the size of the target, and the target strength for fish of the same species is found to be a function of the size of the fish (Midttun & Hoff 1961, Richardson et.al. 1959).

Scatterers distributed at a constant depth

Let us now consider the simple case that fish of the same kind and size being sparsely and ~~energy~~ evenly distributed in a layer of constant depth, so that there is no overlapping of echoes from individual fish. We shall further assume that echoes from no other type of target are received.

When a ship with an echo sounder has covered a unit distance, one nautical mile, say, a number of n fish has passed through the beam, and the energy of the sum of all signals received is n times that received from one single fish. Thus, the sum of all signal voltages received is directly proportional to the abundance of fish present.

When fish are more densely concentrated echoes from two or more fish may be received at about the same time, i.e. their individual echoes overlap more or less completely and, eventually, when the density further increases a continuous layer or a school is formed. In the case that all fish within the beam were situated exactly at the same distance from the transducer, and only the direct reflections from each fish were received, the combined signal strength produced would still be directly proportional to the number of fish (n) within the beam.

This condition, however, is never experienced in practice, as a layer or a school will always have a range of vertical as well as horizontal distribution. The echo signals received are therefore produced both by direct reflections of the transmitted sound pulses and by such derived from multiple scattering of the sound. On the other hand the strength of the signal received from such a school is also affected by interference and by the fact that part of the transmitted sound energy is absorbed by the school itself.

Richardson et.al. (1959) has used a square-root approximation to describe the relation between the amount of signals received and catch. Shishkova (1963) introduces a term refering to the affect of multiple scattering, absorption etc.

THE EFFECT OF VARIATIONS IN DEPTH DISTRIBUTION

The absorption of sound energy by sea water is relatively low for medium and low frequencies, and within the limited depth range in question, i.e. usually less than 100 m, the effect of the sea water absorption may be completely neglected.

Because of the geometrical spread of the sound energy the echo signals received from an individual target is reduced proportionally to the 4th power of the depth of the target:

$$E_d \propto d^{-4} \qquad (3)$$

This reduction may conveniently be adjusted for in the receiver amplifier. Thus, if the amplifier is so arranged that the amplification, starting at a certain level when a sound pulse is transmitted, increases proportionally to the 4th power of time, the signal voltage produced by the receiver is adjusted for the effect of the geometrical spread of the sound energy.

Provided that the shape of the main sound beam does not depart much from that of an ideal cone, the area of a horizontal cross section of the beam increases proportionally to the square of the depth. With constant fish density the number of fish covered by the beam also increases with depth. At low densities, when mainly separate individual fish echoes are received, the net effect of depth is consequently a variation in signal voltage proportionally to the square of the depth. This variation may conveniently be corrected for by automaticly increasing the receiver amplification with the second power of time. However, as fish density increases and a square-root relationship between signal strength and number of fish becomes more applicable such a procedure will give an underestimate of the abundance of sound scatterers. In such a case an increase in amplification with the 3rd power of time will possibly yield less biased results.

Another method which may be used for comparing the amount of echo signals received from different depth levels is to estimate the corresponding sum of signal voltages in a chosen standard depth. When the vertical range of distribution is small compared with the mean depth of the concentration, the error introduced by assuming all fish in the school or layer situated at one depth (e.g. the mean) will be small, particularly when there is little or no vertical gradient in density within the school. However, in the case of a large vertical range and/or considerable vertical density gradients the effect might become highly significant. In this case integration of signal voltages within several different depth intervals would become necessary.

INVESTIGATIONS IN THE BARENTS SEA FROM 17. AUGUST TO 6. OCTOBER 1963

In order to obtain a more precise and unbiased numerical estimate of the amount of echo signals received an electronic echo-integrator was developed at our laboratory to work in conjunction with the research sonar equipment onboard the R/V "G.O.Sars". This instrument is summing all signal voltages generated by the echo sounder received within a set time interval (i.e. depth range). For each transmission any new signal voltages from the same depth range is added to the previous ones, and the result is displayed on a special paper recorder (a more detailed description of the echo-integrator is given in appendix I). The integrator is reset to zero for each nautical mile sailed, and presently we are using a duo-channel system, which allows integration over two different depth ranges at the same time, or over two different signal amplitude levels (Fig.4).

This set-up was first used during a cruise in the Barents Sea in August to October 1963, and its technical performance proved to be successful. Figures 5 and 6 show the areas covered and the grid of lines surveyed. On the maps are plotted the sum of signal voltages per five nautical miles and iso-lines for equal levels of echo-abundance are drawn as adjusted to a standard cruising speed of 10 knots.

From 17. August to 11. September (Fig.5) the main concentrations were found between latitudes 71°N and 75°N, and longitudes 28°E and 33°E; whereas the survey from 15. September to 6. October indicated that a displacement towards east had occurred, the main concentration being than between longitudes 33°E and 37°E.

Numerous fishing experiments with midwater trawls were carried out and the catches obtained indicated that the sound scattering agents in these areas were mainly O-group herring, cod and haddock mixed with some invertebrates (Table in appendix II). During the first survey (17. August to 11. September) a separate area of dense sound scatterers was located west of Novaya Zemlya (between longitudes 45°E and 31°E). These were identified as being mainly fry pf polar cod, capelin and various other cold water fishes.

When surveying the Bear Island area in August the echo-integrator was not yet properly adjusted, and consequently integrator readings from this area are only available from the second survey. It is noted that during this second survey fairly high readings were obtained west of Bear Island, but unfortunately time did not permit an extension of the survey further to the north. However, considering the current system it is likely that this concentration was the southernmost part of 0-group fish being transported northwards by the Spitsbergen current.

Regarding the distribution along the Norwegian coast the usual aggregations of especially 0-group herring at the entrances of the fjords is noted. Similarly the scarsity of sound scatterers on the banks off northern Norway (between latitudes 71°N and 72°N and longitudes 15°E and 25°E) is also in conformity with the distribution observed in previous years (see Fig.3).

The experience from these surveys showed that whenever the pelagic trawl was used at the exact depth where sound scatterers were recorded, catches of fish fry and/or invertebrates were made. This suggest that pelagic trawl is quite suitable for the purpose of identifying and sampling of sound scatterers, at least up to the size of 0-group fish. However, more experiments are needed in order to assess whether the catches taken with pelagic trawl are really representative as regard species and size composition.

From the Table in appendix II it appears that the cod predominated over haddock and herring in the central part of the Barents Sea, whereas along the Norwegian coast the herring were most abundant. The same was also the case west of Bear Island. In the area west of Novaya Zemlya the polar cod predominated over the capelin and the various other cold water species.

CONCLUDING REMARKS

Provided that the design and performance of the technical and electronic equipment are adequate, we might assume that precise measurements of what we suggest to call echo-abundance is feasible. The problem of mapping the echo-abundance distribution of an area with sufficient accuracy is then mainly a matter of research vessel time.

To establish the biological significance or meaning of the echo-abundance, however, is a much more difficult problem to solve. Ideally, the echo-abundance may be regarded as an index of total biomass of sound scattering agents in an area, but this index is affected by a large number of factors. Some of these are inherited with the equipment and methods used, (i.e. frequency, power and technical quality and performance of the equipment, operational skill, and how complete the area is surveyed) and may be accounted and adjusted for. Others are variable and to a large extent unknown. Thus, variations in size and species composition of the sound scatterers, and above all, their density and local distribution will greatly affect the sum of signal voltages received.

Nevertheless, the problems encountered do not seem to be unsolvable. Identification is possible by fishing experiments with midwater gears (pelagic trawls, purse seine) and perhaps also with the aid of U.W.-photography and -T.V.

Quantitative fishing is probably reliable only under certain conditions with a small meshed purse seine, but the samples taken with the more easily handled pelagic trawl, may give unbiased information regarding size and species composition. This question, however, needs further investigation.

Knowing the size and species composition and the target strength for each species, their relative contribution to the observed sound scattering, i.e. the echo-abundance, may be estimated. In this connection it should be noted that precently insufficient knowledge excists on the target strength of the various kinds of fish fry and its variation with size.

Remain then the effects of density variations etc. on the relation between the observed sound scattering and the abundance of scatterers. One approach is to develop theoretical models, the parameters of which might be determined experimentally. Such models would necessarily need to contain several variables, and to be rather complex, especially in cases when various degrees of schooling occur. We therefore suggest to avoid variability in schooling as far as possible by surveying the denser areas during night time when the fish fry are more evenly distributed in continuous layers.

For this type of distribution, we suggest to establish directly, by fishing experiments with purse seine, an empirical relationship between echo-abundance and fish fry present in an area. In September and October 1963 the first experiments in this regard were made, the records of which are given in Table 1. When plotting the respective integrator readings against the square root of the numbers caught, five points are obtained which fit fairly well to a straight line. Thus, the observations made so far seem to indicate that this approach is feasible, and further experiments are planned.

SUMMARY

This paper attempts to discuss the possiblity of estimating the distribution and abundance of 0-group fish by a combination of echo surveying and fishing experiments with pelagic trawl and purse seine.

The existence of scattering layers, their origin, and the identification of sound scatterers are discussed with special reference to observations made in recent years off Northern Norway and in the Barents Sea. The scattering layers observed in late summer and fall in this area consist mainly of 0-group fish of which herring, cod and haddock are the most important.

The transport of the larvae from the spawning places in relation to the current systems are described. The observations indicate that during August to October fish fry are abundant in the surface layers of the north and east going currents, and by the end of autumn the fry are aggregated along the frontiers between the cold and warm water masses covering the area from Spitsbergen to Bear Island and further to the east and south over the central and southeastern part of the Barents Sea.

The relation between echo signals received from scattering agents distributed at a constant depth is discussed as well as the effect of variations in depth distribution. Special attention is payed on experiments measuring signal strength received from targets uniformly distributed in a layer or school of wide horizontal distribution.

The needs of theoretical as well as empirical approaches to obtain more precise and unbiased numerical estimates of the amount of echo signals received in relation to the abundance of sound scatterers (echo-abundance), are stressed.

The first results of mapping the echo-abundance distribution are presented. For this propose an electrónic echo-integrator was developed to measure exactly the signal voltages received.

Some preliminary data on the relationship between echo-abundance and the catch of fish fry with purse seine are also given.

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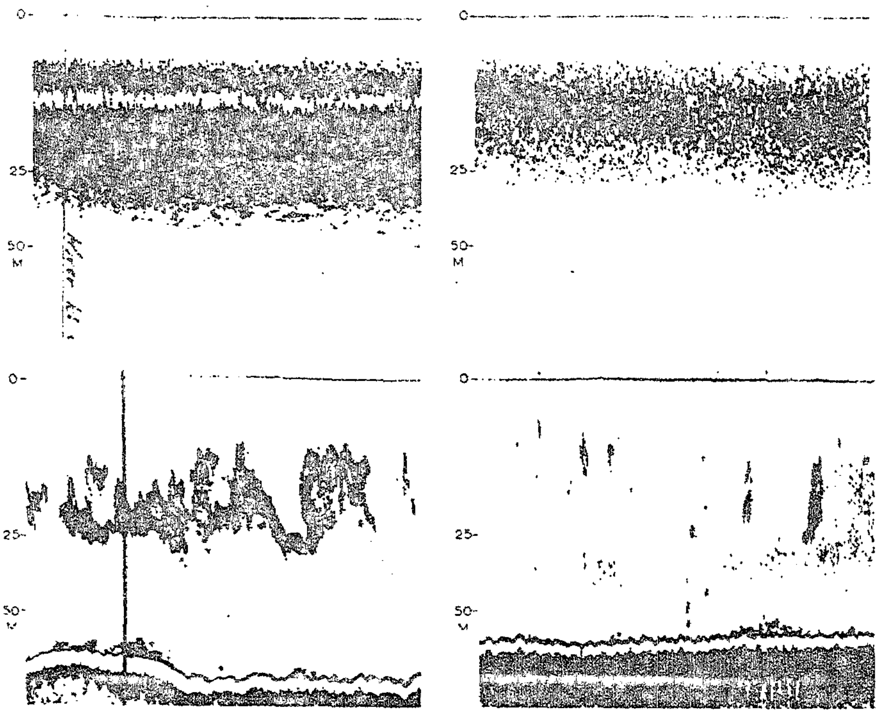

Fig. 1. Sound scatterers identified as O-group herring at night (above)and during daytime (below).

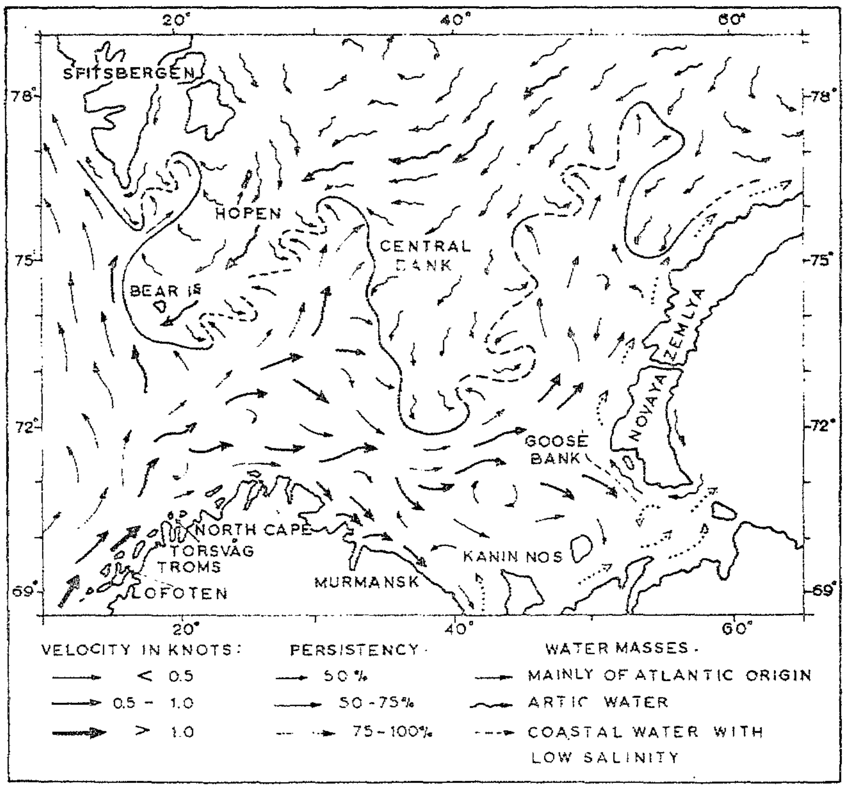

Fig. 2. The general current systems off Northern Norway and in the Barents Sea (modified from Tantsura 1959).

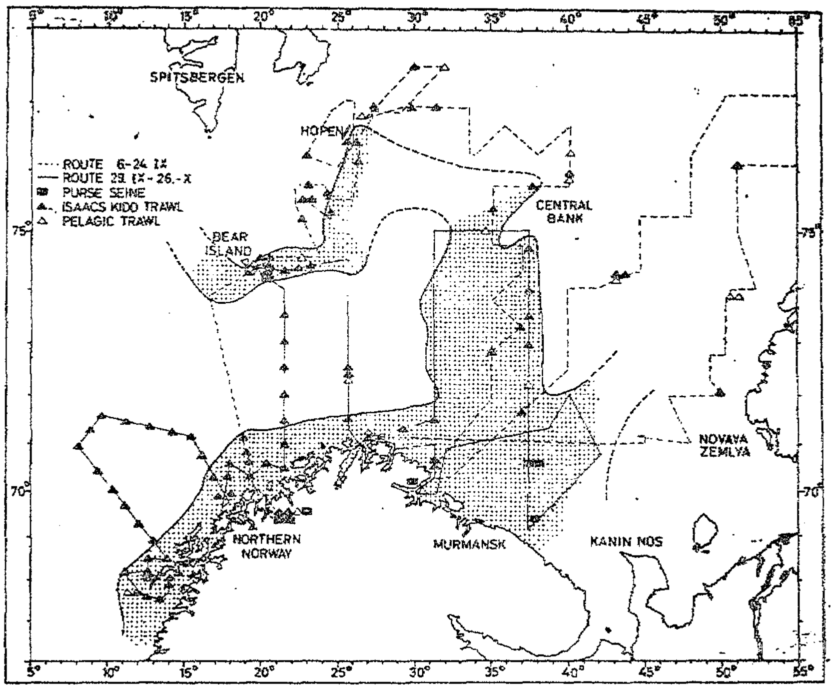

Fig. 3. Map showing the distribution of 0-group herring (mainly) in late September and October 1960.

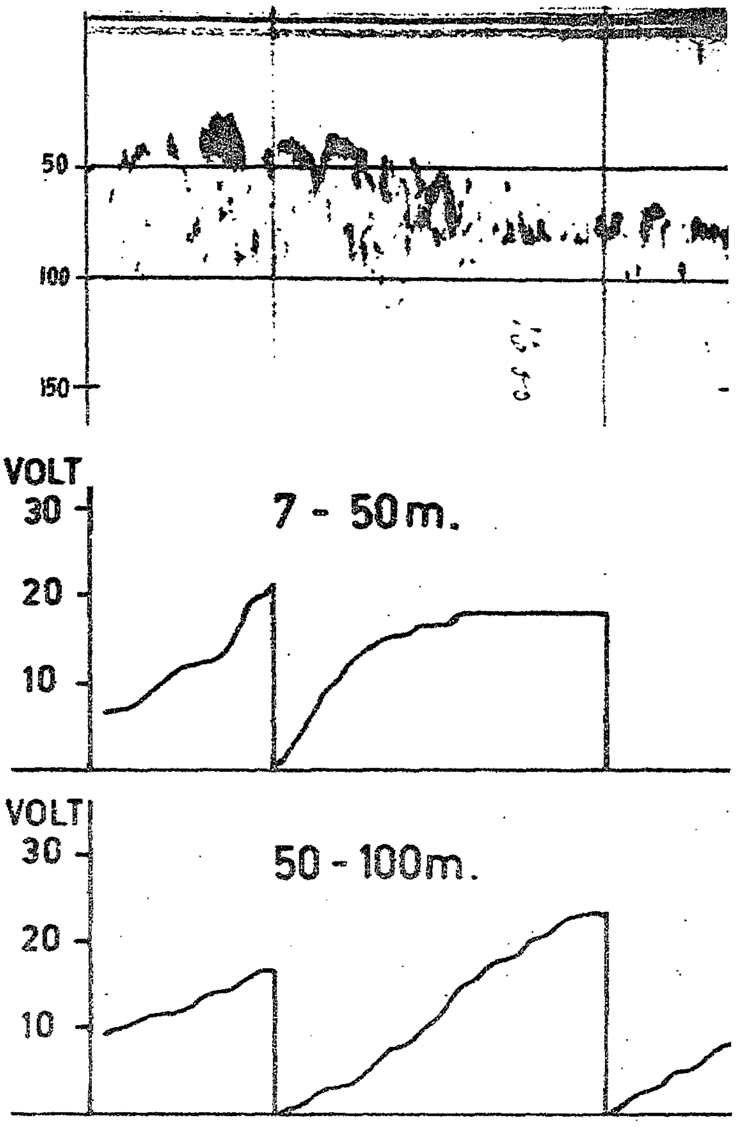

Fig. 4. Echo sounder recordings of a fish fry layer (top) and the corresponding signal voltages from 7 - 50 m (middle) and 50 - 100 m (bottom) depth.

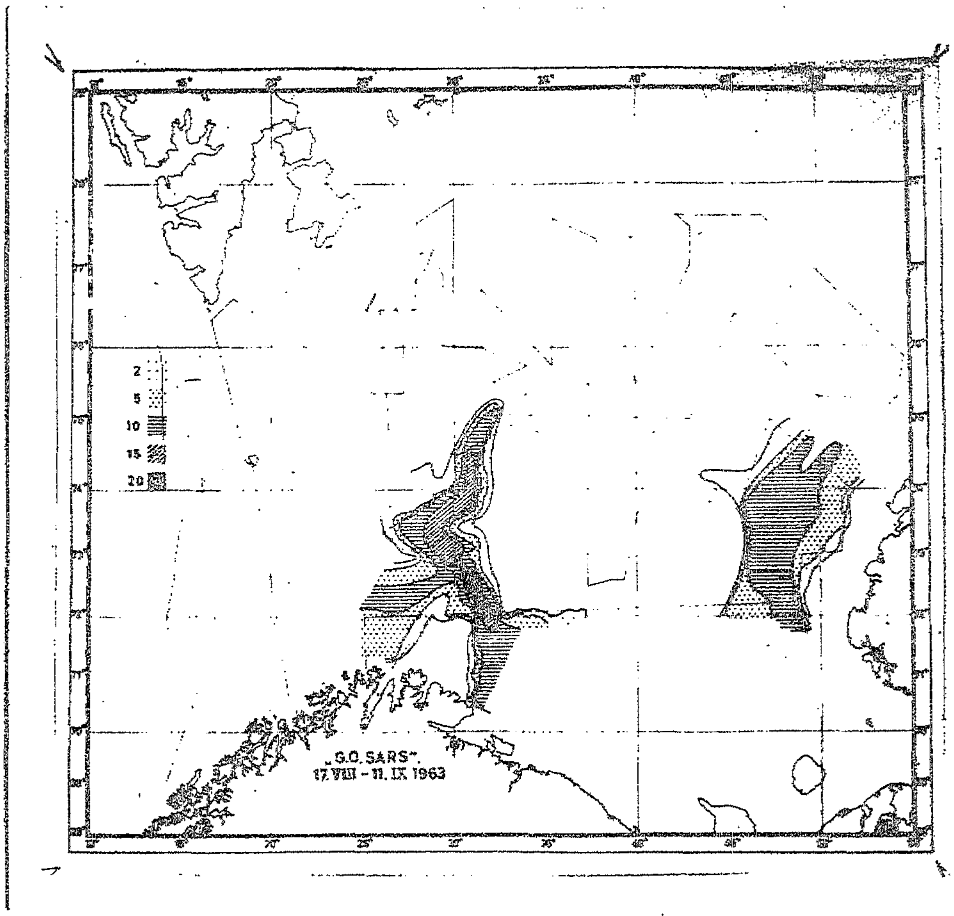

Fig. 5. Echo-abundance distribution as determined by the echo-integrator during the survey from 17. August to 11. September 1963. Equal levels of abundance are indicated by isolines.

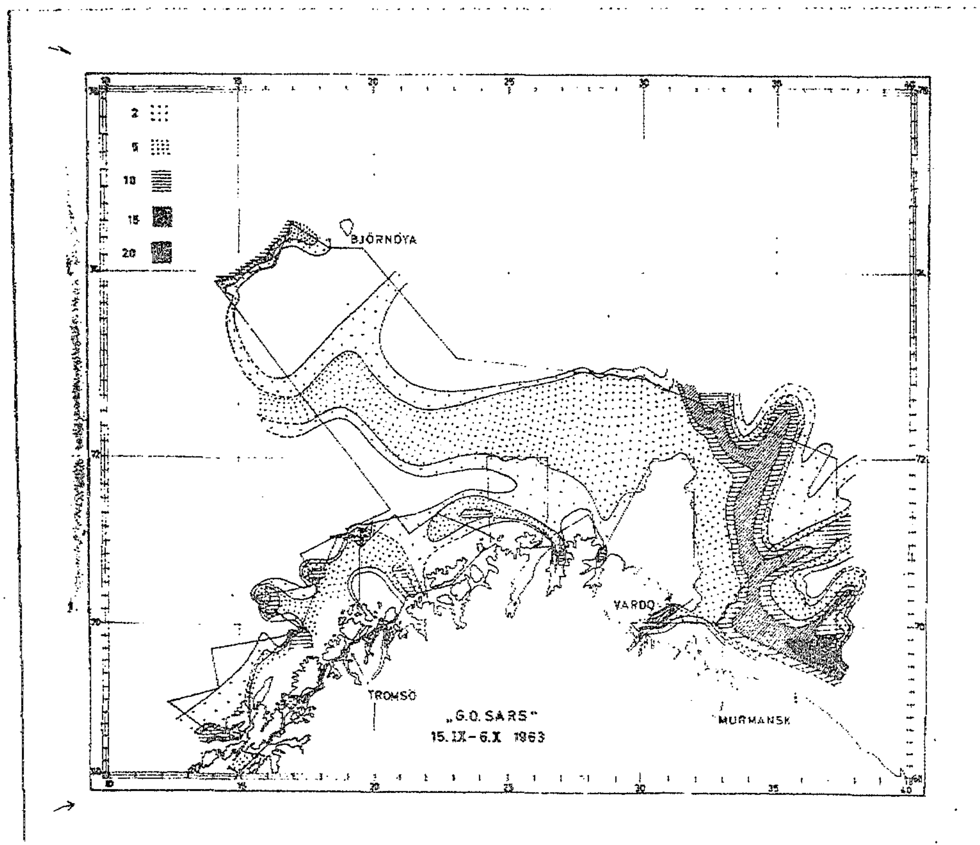

Fig. 6. Echo-abundance distribution as determined during the survey from 15. September to 6. October 1963.

Table 1. Comparison between purse seine catch and echo-abundance index

Locality Position	Date Hour	Catch in numbers		Vertical range of echo trace in m	Echo-abundance index (30 kc/s)	
		Herring	Others		11-34 m	Total range
Ullsfjord $N69^{\circ}58'E20^{\circ}10'$	27.9.63 1940-2100	600	-	10-120 m	8.0	69.0
Ullsfjord $N69^{\circ}58'E20^{\circ}06'$	28.9.63 0200-0300	500	9 1 of scypho-medusae	10-120 m	7.5	68.5
Ullsfjord $N69^{\circ}43'E19^{\circ}43'$	30.9.63 1912-2000	8520	-	10- 80 m	35.5	128.8
Lyngenfjord $N69^{\circ}50'E20^{\circ}25'$	1.10.63 0255-0400	5322	-	10- 60 m	26.0	-
Hadselfjord $N68^{\circ}28'E14^{\circ}30'$	4.10.63 0213-0330	13424	-	10- 25 m	28.9	28.9

APPENDIX I

Short description of the echo-integrator set up

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A block diagram of the complete installation is shown in Fig.1, and the principle of operation is as follows:

The signals received during a predetermined time interval following each transmission of the echo-sounder (i.e. echoes from a certain depth range) are fed to an integrator unit (4) which accumulates the signal voltages received, and the output voltage of the integrator at any one moment is displayed by a separate paper recorder (5).

This is accomplished by feeding the signals through a gated amplifier (2), here called a signal selector, which is opened by a gate pulse produced by a pulse generator (9). The duration of this pulse, which may easily be varied, determines the time interval during which signals are fed to the integrator.

In case we do not want the integration to start at the time of transmission (i.e. from the surface), we have to delay the start of the pulse generator for a suitable period of time. This is arranged by a waveform generator (8), which provides a negative trigger pulse to the pulse generator.

At the moment the negative pulse has reached a certain level, the pulse generator starts and generates a gate pulse. This trigger level is selected in the pulse generator and enables us to regulate the delay time between the moment the waveform generator is triggered and the moment the pulse generator excites the gate pulse.

Suppose we wish to integrate signal voltages between 75 meters and 150 meters ($t_2 - t_1$) and at the same time to add the sum of these voltages over one nautical mile.

At the moment the stylus of the echo-sounder recorder passes the zero position (t_0) a contact in the recorder is closed and both the start pulse to the transmitter (6) and the start pulse to the waveform generator (8) are generated. After a certain time period, at the moment the stylus passes the 75 m position (t_1), the pulse generator starts, and provides a gate pulse to the signal selector (2). The signal selector, which was blocked prior to the time t_1, will now feed signals from the echo-sounder amplifier (1) via a signal rectifier (3) to the integrator (4).

Again, after a certain time period, at the moment the stylus passes the 150 m position (t_2), the gate pulse ends, and the signal selector will remain blocked until the stylus passes the 75 m position after the next transmission.

The stylus of the integrator-recorder is attached to a galvanometer instrument, indicating at any one moment the output voltage (of the integrator).

This voltage will remain unchanged unless new signals are received, until it is reset to zero at the end of each nautical mile, through a relay, connected to the ship's log. The final value of the curveline at each reset provides then a measure of the amount of echo signals received.

In order to adjust the pulse generator easily and exactly to the desired depth range, a part of the gate pulse is tapped and fed to a pulse deformer (10). This pulse deformer now feeds two short positive pulses to the stylus of the echo-sounder recorder, the first pulse marking the beginning and the second the end of the gate pulse.

The various makes and types of units used are given in the text of the block diagram, except for the signal selector, the signal rectifier and the pulse deformer, which were specially designed for the purpose.

APPENDIX FIGURE

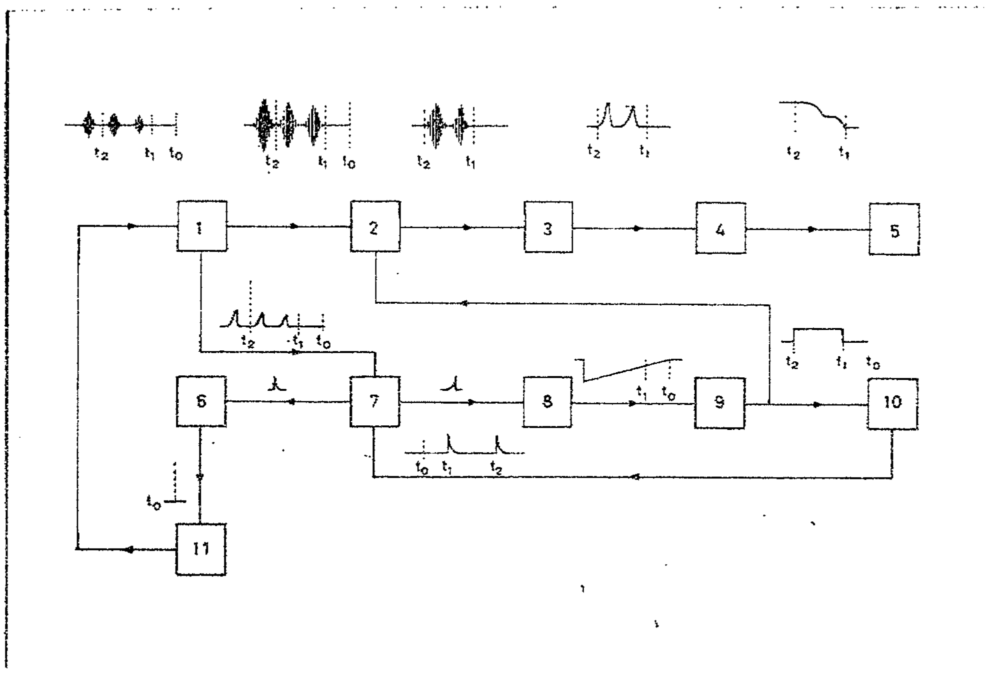

Fig. 1. Block diagram of echo-integrator set-up:
1. Amplifier (Simrad) 2. Signal selector (gated amplifier)
3. Signal rectifier 4. Integrator (Tektronix, type O) 5. Integrator recorder (Sanborn, type 322) 6. Transmitter (Simrad) 7. Echo-sounder recorder (Simrad) 8. Waveform generator (Tektronix, type 162)
9. Pulse generator (Tektronix, type 161) 10. Pulse deformer
11. Transducer (Simrad).

Appendix II

Table "G. O. Sars" 17. August to 4. October 1963. Records of fishing experiments for identification of echo traces

St.No. Position	Date Hour	Gear	Dist. towed	Catch in numbers				Evertebrates	No. of fish per n. mile	Echo-abund. index		Remarks
				Herring	Cod	Haddock	Other fish			38 kc/s	30kc/s	
49 N71°30'E20°30'	17. 8.63 1730	I.K.M.T.	1.5	-	-	2	-	-	1.3	1	-	Integrator out of function
50 N72°00'E20°20'	17. 8.63 2110	I.K.M.T.	1.0	-	6	-	-	-	6.0	1	-	Integrator out of function
51 N73°00'E19°52'	18. 8.63 0320	I.K.M.T.	1.0	-	-	-	-	-	-	1	-	Integrator out of function
52 N73°30'E19°37'	18. 8.63 0650	I.K.M.T.	1.0	-	1	-	5 redfish 3 long rough dab	-	9.0	1	-	Integrator out of function
54 N75°53'E27°15'	20. 8.63 0413	I.K.M.T.	1.2	-	-	-	4 long rough dab 1 Leptagonus decagonus	0.5 l of euphausiids	4.2	0	-	Integrator out of function
55 N76°00'E31°30'	21. 8.63 0222	I.K.M.T.	1.2	-	-	-	-	20 specimens of diff. medusae, ca. 200 euphausiids, 50 amphipods	-	0	7.4	
57 N76°10'E53°40'	24. 8.63 0945	I.K.M.T.	0.8	-	-	-	7 polar cod 2 long rough dab	Some Clione	11.3	1	-	
58 N76°03'E54°10'	24. 8.63 1053	I.K.M.T.	-	-	-	-	ca.100 polar cod	Some amphipods	ca.100	1	-	
59 N75°18'E52°20'	24. 8.63 2007	I.K.M.T.	-	-	-	-	ca. 50 polar cod 1 sea scorpion	-	ca. 50	1	-	
60 N75°05'E32°27'	26. 8.63 1845	I.K.M.T.	1.0	-	-	-	4 long rough dab 1 sea scorpion	Some Clione, ctenophores and amphipods	5.0	1	-	
61 N75°09'E32°25'	26. 8.63 2050	P.T.	3.0	-	752	59	100 capelin	4 cephalopods, some Clione, 1 scyhpomedusa	304.0	1	-	
62 N74°31'E31°46'	28. 8.63 0722	P.T.	1.2	-	1	2	9 long rough dab 3 Liparis sp. 2 Lumpenus sp. 1 Leptagonus decagonus	Some Clione, ctenophores	15.0	1	-	
63 N74°16'E31°13'	28. 8.63 1230	I.K.M.T.	0.6	-	7	-	-	-	11.7	2	-	

Table (continued).

64 N74°05'E31°13'	28. 8.63 1339	P.T.	2.0	-	887	21	2 capelin	-	455.0	2	-	
65 N73°00'E31°13'	28. 8.63 2205	I.K.M.T.	1.0	-	76	1	14 redfish	-	91.0	2	-	
66 N72°04'E31°13'	29. 8.63 0636	I.K.M.T.	1.0	-	-	-	-	-	-	1	48.8	Echo-trace at 100 m, trawl did not catch representative
67 N70°49'E31°13'	30. 8.63 -	I.K.M.T.	1.1	15	51	2	-	Some euphausiids	61.8	2	9.4	
68 N70°59'E30°28'	30. 8.63 0430	I.K.M.T.	0.7	-	1	-	-	Some scyphomedusae	1.4	2	10.9	
70 N72°02'E33°20'	3. 9.63 0203	I.K.M.T.	1.0	-	3	-	-	Some euphausiids	3.0	1	10.7	
71 N72°03'E35°35'	3. 9.63 0610	I.K.M.T.	1.0	-	-	-	-	-	-	0	-	
72 N72°04'E40°20'	3. 9.63 1553	P.T.	2.1	-	-	-	712 polar cod	Some euphausiids	339.0	0	-	
73 N72°05'E46°40'	4. 9.63 0406	I.K.M.T.	1.0	-	-	-	7 capelin 5 long rough dab 3 Lumpenus sp. 1 Liparis sp.	-	16.0	1	-	
74 N72°05'E47°25'	4. 9.63 0610	I.K.M.T.	1.0	-	-	-	15 polar cod 3 long rough dab 2 Liparis sp. 1 capelin	Some Clione	21.0	1	15.4	Integrator reading 5 n.m. before station
75 N72°05'E48°50'	4. 9.63 0900	I.K.M.T.	1.0	-	-	-	6 Gymnocanthus tricuspis 3 capelin 2 polar cod 2 Lumpenus sp. 1 Liparis sp.	Some Clione	14.0	2	-	Integrator out of function
76 N73°00'E49°15'	4. 9.63 1417	I.K.M.T.	0.8	-	-	-	12 polar cod 3 Artediellus uncinatus europeus 2 Gymnocanthus tricuspis	Some Clione	2.1	1	8.8	
77 N73°00'E51°20'	4. 9.63 1755	I.K.M.T.	1.0	3	-	-	3 Gymnocanthus tricuspis 2 Artediellus uncinatus europeus	Some Clione	5.0	1	4.5	

Table (continued).

78 N73°30'E51°32'	4. 9.63 2100	I.K.M.T.	1.0	-	-	-	15 polar cod 9 Gymnocanthus tricuspis 1 Artediellus uncinatus europeus 1 capelin 1 Lumpenus sp.	Some scyphomedusae	27.0	1	4.3	
79 N74°20'E50°15'	5. 9.63 0325	I.K.M.T.	2.0	-	-	-	108 polar cod 6 Artediellus uncinatus europeus 2 Gymnocanthus tricuspis	Some Clione	58.0	2	11.6	
80 N74°40'E48°52'	5. 9.63 0655	I.K.M.T.	0.5	-	-	-	52 polar cod	Some ctenophores and Clione	104.0	1	15.4	
81 N74°08'E46°20'	5. 9.63 1515	I.K.M.T.	1.0	-	-	-	61 polar cod 1 Artediellus uncinatus europeus	Some Clione	62.0	1	7.1	
82 N73°38'E45°40'	5. 9.63 1838	I.K.M.T.	0.7	-	-	-	46 polar cod 23 Leptagonus decagonus 1 long rough dab	Some Clione	100.0	1	13.1	Trawl depth 43-44 m
83 N73°38'E45°40'	5. 9.63 1904	I.K.M.T.	2.1	-	-	-	23 polar cod 12 Leptagonus decagonus	Some Clione and euphausiids, 1 Sagitta sp. 1 ctenophore	16.7	1	13.1	Trawl depth 55-65 m
84 N74°46'E41°05'	6. 9.63 0525	I.K.M.T.	1.3	1	-	-	1 polar cod 1 Leptagonus decagonus	Some euphausiids and Clione	2.3	1	-	
85 N74°38'E37°20'	7. 9.63 1445	P.T.	0.8	-	-	-	23 Lumpenus sp. 16 long rough dab 1 polar cod 1 Leptagonus decagonus 1 Artediellus uncinatus europeus 1 Anarhichas latifrons	Some euphausiids and Clione	52.5	1	-	

Table (continued).

86 N74°37'E31°15'	8. 9.63 0931	P.T.	3.0	-	720	7	3 Leptagonus decagonus 2 long rough dab	Some Clione	244.0	1	4.4	
87 N74°32'E30°50'	8. 9.63 1110	I.K.M.T.	1.3	-	-	-	-	-	-	1	21.0	Trawl did not catch
88 N74°30'E30°00'	8. 9.63 1522	P.T.	1.9	-	1240	7	1 Leptagonus decagonus 1 long rough dab	-	657.4	1	29.6	
89 N74°53'E26°30'	10. 9.63 0914	I.K.M.T.	1.1	-	-	-	14 long rough dab	-	12.7	1	3.5	
90 N73°48'E28°40'	10. 9.63 2330	I.K.M.T.	1.0	18	33	-	-	10 euphausiids	51.0	1	16.3	
91 N73°36'E27°27'	11. 9.63 0202	I.K.M.T.	1.0	8	11	-	-	Some euphausiids	19.0	1	10.7	
92 N73°29'E26°47'	11. 9.63 0340	I.K.M.T.	0.6	-	-	-	-	Some scyphomedusae	-	1	16.0	Trawl did not catch
93 N73°19'E26°10'	11. 9.63 0620	I.K.M.T.	1.0	-	-	-	-	Some scyphomedusae	-	2	3.6	
94 N72°56'E28°30'	11. 9.63 1148	P.T.	2.8	-	1200	18	-	-	435.0	1	10.4	
96 N71°50'E28°20'	12. 9.63 0003	I.K.M.T.	0.9	-	10	-	-	-	11.1	1	7.9	
97 N71°20'E24°16'	16. 9.63 2223	I.K.M.T.	0.9	-	-	-	-	Some euphausiids	-	1	8.8	
98 N72°00'E24°12'	17. 9.63 0324	I.K.M.T.	0.8	-	-	-	-	-	-	1	3.8	Trawl towed above top of echo-trace
99 N71°56'E26°34'	17. 9.63 0930	P.T.	1.1	-	220	4	-	2 scyphomedusae	204.0	1	9.0	
100 N70°51'E27°02'	17.9.63 2230	I.K.M.T.	1.2	10	-	-	-	Some euphausiids and scyphomedusae	8.3	2	-	Echo integrator out of function
101 N70°51'E27°02'	18. 9.63 0150	I.K.M.T.	0.6	4	-	-	-	Some euphausiids and scyphomedusae	6.7	2	-	Trawl towed at greater depth than previous trawl
102 N70°51'E27°02'	18. 9.63 0217	I.K.M.T.	1.2	2	1	-	-	Some euphausiids and scyphomedusae	2.5	2	-	Trawl towed at greater depth than previous trawl

Table (continued).

103 N70°53'E28°35'	18. 9.63 1145	P.T.	5.3	239	1	1	-	A few scypho-medusae	45.5	1	2.0	
104 N71°40'E29°55'	18. 9.63 1940	I.K.M.T.	-	-	16	-	-	1 cephalopod	16.0	1	9.0	
105 N70°02'E30°39'	20. 9.63 0438	P.T.	1.6	3564	175	78	8 blue whiting	3 cephalopods, some scyphomedusae	2391.0	3	21.7	
106 N70°45'E34°26'	20. 9.63 1950	I.K.M.T.	0.5	3	36	-	-	1 scyphomedusa	78.0	1	-	Echo integrator out of function
107 N70°53'E35°13'	20. 9.63 2300	P.T.	2.0	76	800	3	4 blue whiting	-	442.0	1	14.8	
108 N69°50'E36°50'	21. 9.63 0840	P.T.	1.5	-	196	3	-	Some Scyphomedusae	132.7	1	32.5	
109 N70°30'E37°20'	21. 9.63 1950	I.K.M.T.	0.6	1	12	-	-	-	21.7	2	15.8	
111 N72°42'E31°30'	23. 9.63 0512	P.T.	1.7	-	-	3	-	-	1.8	1	30.2	Trawl towed above most dense echo-trace
112 N74°18'E17°47'	24. 9.63 1835	P.T.	1.0	126	4	-	A few long rough dab	-	130.0	3	11.4	
113 N73°22'E16°50'	24. 9.63 2220	P.T.	1.0	-	20	7	1 Triglops pingeli	Some euphausiids	28.0	1	11.1	
116 N69°42'E19°44'	30. 9.63 2122	P.T.	1.0	240	12	11	-	2 litres of euphausiids, 8 scyphomedusae	263.0	2	14.4	
117 N70°44'E17°37'	2.10.63 1033	P.T.	1.5	-	-	-	-	-	-	1	11.8	Likely trawl did not catch representative
118 N70°11'E16°15'	2.10.63 1955	I.K.M.T.	2.0	1	-	-	69 Myctophum glaciale 1 blue whiting	Some euphausiids and 1 scyphomedusa 1 cephalopod	35.5	0	16.3	
119 N68°32'E14°00'	3.10.63 1955	I.K.M.T.	2.6	1	1	-	-	1 scyphomedusa	0.8	1	4.5	
120 N69°55'E17°10'	4.10.63 1908	P.T.	2.1	448	-	-	-	-	213.3	1	19.3	